LIFE CYCLE INVENTORY OF PACKAGING OPTIONS FOR SHIPMENT OF RETAIL MAIL-ORDER SOFT GOODS

FINAL PEER-REVIEWED REPORT

Prepared For

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY (DEQ)
And
U.S. EPA ENVIRONMENTALLY PREFERABLE PURCHASING PROGRAM

By

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FOREWORD

This document constitutes a life cycle inventory (LCI) of packaging used to ship non-breakable items in e-commerce or catalog sales. As direct marketing and Internet sales have grown, so has the quantity of materials used to package and transport these goods. In Oregon, per-capita generation of all non-hazardous solid wastes has risen more than 20% in the last ten years. Packaging represents a significant portion of waste generation. The Oregon DEQ, Metro, and U.S. EPA have co-sponsored this study in order to evaluate the solid wastes, as well as energy, materials, and atmospheric and waterborne emissions associated with the production, use, and disposal of these packaging materials. This study demonstrates that within the realm of shipping non-breakable items in catalog or e-commerce sales, there are a wide variety of packaging choices that directly impact the quantity of solid waste generated, amounts and types of energy and raw materials used, and amounts and types of atmospheric and waterborne emissions.

Most life cycle inventories (in North America at least) are privately funded and many are never published. It is easy to misinterpret the results of an LCI, and care must be taken when reading and applying results of any LCI report. This report is no exception.

The contents of this report (and its appendices) are highly technical and should be read in that context. The findings and conclusions of this report are strictly those of Franklin Associates, which acted as an independent contractor. Neither the methodology nor the findings of the report represent official policy of the U.S. EPA, State of Oregon, or Metro. Readers should interpret the results of this study with care and with full awareness of the limitations in data, study methodology and the context in which the report was done as described in the report itself.

While life cycle assessment can be a powerful tool for improving knowledge and understanding environmental considerations, there are limits to the applications of any specific LCI. This report is a Life Cycle Inventory only; it *inventories* inputs (energy, materials) and outputs (solid waste, atmospheric and waterborne emissions) but makes no claims regarding the *impacts* of these inputs and outputs. The LCI provides no methodology for comparing the environmental impacts of the different packaging options, such as a comparison of greenhouse gases and eco-toxicity.

There are many popular questions that this report does <u>not</u> attempt to address. This report does not compare recycling vs. disposal. It makes no judgments or conclusions regarding individual products or manufacturers. It does not evaluate the impacts or benefits of manufacturers switching to or away from "green energy" or raw materials derived from "sustainable" or "environmentally protective" agriculture and forestry practices. It does not evaluate the sustainability of renewable versus nonrenewable material use, issues of social equity, the relative benefits of purchasing products made domestically vs. abroad or the fate of improperly discarded plastics in the marine environment.

While the study does compare some all-paper and all-plastic packaging options (and many paper/plastic blends), it does not constitute a comparison of "paper vs. plastic" that can be generalized to other packaging systems. This study does not attempt to evaluate the age-old debate of paper vs. plastic grocery retail bags. Its evaluation of corrugated boxes is limited to the use of boxes to ship soft (non-breakable) items in e-commerce/catalog sales; the study does not discuss the many other (and larger) uses of corrugated (such as packaging of fragile/breakable items, agricultural packaging, and business-to-business packaging). While the study compares several different types of void fills, it is on a per-pound basis and then, as with boxes, in the context of e-commerce/catalog shipments of non-breakable items. The study does not evaluate these different void fills in the context of the amounts of packaging needed to protect fragile, breakable items. Readers should be aware of the limitations of the scope of this report and avoid generalizing the results to other uses of packaging.

Environmental concerns are just one of several criteria that factor into decisions about what type of packaging to use. Cost, functionality, and availability are other important criteria. The State of Oregon, Metro, and U.S. EPA do not endorse any particular brand or manufacturer of packaging; decisions as to what materials to use, how to use them, and where to buy them are the responsibility of the user.

June 9, 2004

PREFACE

The report that follows is a Life Cycle Inventory (LCI) of two types of packaging – corrugated boxes with dunnage and shipping bags – for shipping retail mail-order soft goods. Funding for this project was provided by the Oregon Department of Environmental Quality (DEQ) and Metro, the regional government of the Portland metropolitan area. The US EPA contributed additional funding for the critical review and public appendices. The project also included development of a model that can be used to develop environmental profiles for additional packaging configurations composed of the materials analyzed in this report.

At Franklin Associates, the project was managed by Beverly J. Sauer, who served as primary life cycle analyst in developing the interactive user model, analyzing results, and responding to peer review comments. James Littlefield and Melissa Huff assisted with development of report appendices and modeling. Melissa Huff also provided quality assurance review of the report and public appendices under the peer review project. William E. Franklin provided overall project oversight as Principal in Charge.

Franklin Associates gratefully acknowledges significant contributions to this project by David Allaway of Oregon DEQ and Scott Kopacek of Pack Edge Development. Their efforts added significantly to the quality of the report. Together DEQ and Pack Edge developed the data on weights and compositions of the packaging systems. David Allaway also provided detailed writeups on data development for the report appendices, and, with assistance from Abby Boudouris of DEQ and Steve Apotheker of Metro, review of drafts of the appendices and report. Derek Smith of Norm Thompson Outfitters and Nancy Himmilfarb of Williams-Sonoma graciously contributed data to this study, as did many manufacturers of packaging materials. The project was peer reviewed by an expert panel consisting of Mary Ann Curran, U.S. EPA, National Risk Management Research Laboratory (serving as review chair), Dr. Greg Keoleian of the University of Michigan Center for Sustainable Systems, and Dr. Joyce Cooper of the University of Washington Department of Mechanical Engineering. The revisions made in response to the peer review panel's insightful comments added greatly to the quality and credibility of this final report.

This study was conducted for DEQ by Franklin Associates as an independent contractor. The findings and conclusions presented in this report are strictly those of Franklin Associates. Franklin Associates makes no statements nor supports any conclusions other than those presented in this report.

April 26, 2004

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EXECUTIVE SUMMARY
FOR
ENERGY AND ENVIRONMENTAL RESULTS FOR PACKAGING OPTIONS FOR SHIPMENT OF RETAIL MAIL-ORDER SOFT GOODS

INTRODUCTION

A life cycle inventory (LCI) quantifies the energy use and environmental emissions associated with the life cycle of specific products. This study examines the environmental profiles of various packaging options used to ship mail-order soft goods to residential customers. Soft goods include clothing (e.g., sweaters), linens, and the like. The two main types of packaging considered in the analysis are corrugated boxes with various types of dunnage, and shipping bags. Dunnage materials included in this study are inflated air packets, expanded polystyrene (EPS) foam loose fill, cornstarch foam loose fill, molded pulp loose fill, kraft paper, newsprint, and shredded postconsumer office paper and corrugated. Shipping bags evaluated in this study include unpadded and padded bags made from several different paper grades and plastic resins.

The results presented in this report comprise a full LCI, beginning with extraction of raw materials from the earth and continuing through packaging production, use, and disposal. Results are broken out into several life cycle stages, including production of packaging (all steps from raw material extraction through packaging manufacture), transportation of finished packaging items to the mail order distribution center or order fulfillment center, transportation of the packaged soft goods to the consumer, and disposal of the packaging discarded after diversion for reuse and/or recycling.

Companies that sell mail-order soft goods typically can exert some control over the types of materials and level of postconsumer content in the packaging that they buy but have much less influence on what their customers do with that packaging once they receive it. To reflect this fact, this study uses a methodology that models postconsumer content as coming in free of the environmental burdens associated with raw material extraction and virgin material production. This is the maximum possible reduction in energy use and emissions for packaging production that can be assigned to postconsumer recycled content. Thus, no additional reductions in packaging production burdens can be given for increases in recycling/reuse at end of life. This choice of methodology is appropriate since the study is intended to provide information that companies can use to guide their purchasing decisions, not to evaluate the effects of various end-of-life options used by consumers to manage packaging, since consumers' postconsumer packaging management choices are beyond the control of the mail-order company.

Purpose of the Study

The purpose of this study is to evaluate the energy, solid wastes, and atmospheric and waterborne emissions associated with various packaging options for the delivery of mail-order soft goods. This study is intended not as an analysis of the effects of end-of life options such as recycling vs. disposal of postconsumer wastes in the hands of consumers, which are largely beyond the control of the mail-order company, but rather as an analysis of *purchasing options* that reflects the environmental profiles associated with different materials, postconsumer recycled contents, and package weights and volumes. DEQ's primary interest in this topic is to identify best practices that meet the criteria of being readily adoptable by users of packaging (such as businesses) on a voluntary basis, while incurring lower environmental burdens, based on a consideration of multiple (as opposed to single) environmental criteria.

Systems Studied

Two general types of packaging systems for mail-order soft goods are analyzed in this study: corrugated boxes with various types of dunnage and shipping bags composed of paper and/or plastic. Most specific packaging systems consist of more than one material. For most components two levels of recycled content are analyzed. Table ES-1 shows the compositions by material and by weight of the various packaging options that are analyzed in each of these categories.

Functional Unit

In order to insure a valid basis for comparison for the packaging systems studied, a common functional unit is essential. For this study, the functional unit for each system is the packaging required to deliver 10,000 representative packages of soft goods items to customers. The dimensions and weight of the representative packaged item were determined by Oregon Department of Environmental Quality (DEQ) staff, based on data provided by a large Oregon-based mail-order company. The dimensions and weights of each packaging configuration required to ship the representative item were determined by DEQ staff based on data provided by several mail-order companies, packaging vendors, and a packaging study and other analysis conducted by Pack Edge Development, a packaging engineering firm also under contract to DEQ. The material composition of each packaging configuration was determined by DEQ staff and Franklin Associates staff, with assistance from Pack Edge Development. The development of these data are described in detail in the report appendices.

It is assumed that all packaging options in this study provide equivalent protection for the packaged product, so it is not necessary to take into account different rates of product damage, returns, and replacement shipments for the various packaging options.

Table ES-1

DEFINITION OF INDIVIDUAL PACKAGING COMPONENTS MODELED IN THE STUDY
(Study models corrugated boxes used in combination with various dunnage options.)

		Postconsumer Recycled Content	Pounds/ Package	Thou Lb/ 10,000 Packages
CORRUGATED BOX				
Option 1	industry average linerboard	28%	0.95	9.49
	industry average medium	59%	0.44	4.41
	overall box	38%	1.39	13.90
Option 2	recycled linerboard	71%	0.95	9.49
	recycled medium	100%	0.44	4.41
	overall box	80%	1.39	13.90
DUNNAGE (used with corrugated box)				
Inflated Polyethylene Air Packets				
Option 1	LDPE	0%	0.084	0.84
Option 2	LDPE	30%	0.084	0.84
Polystyrene Foam Loose Fill				
Option 1	EPS	0%	0.048	0.48
Option 2	EPS	30%	0.048	0.48
Starch-based Loose Fill				
	cornstarch	0%	0.086	0.86
Molded Pulp Loose Fill				
	newspaper	100% (1)	0.38	3.79
Kraft Paper (Crumpled)				
Option 1	unbleached kraft	0%	0.18	1.84
Option 2	unbleached kraft	50%	0.18	1.84
Newsprint (Crumpled)				
Option 1	newsprint	10%	0.17	1.68
Option 2	newsprint	50%	0.17	1.68
Shredded Postconsumer Paper(board)				
Option 1	corrugated	100% (1)	0.32	3.18
Option 2	office paper (2)	100% (1)	0.15	1.48

(1) 100% postconsumer material; postconsumer content of postconsumer material may be less than 100%.
(2) 83.6% printing-writing, 16.4% newspaper

Table ES-1 (cont.)

DEFINITION OF INDIVIDUAL PACKAGING COMPONENTS MODELED IN THE STUDY

SHIPPING BAGS		Postconsumer Recycled Content	Pounds/ Package	Thou Lb/ 10,000 Packages
Unpadded Kraft				
Option 1	bleached kraft	0%	0.14	1.41
Option 2	bleached kraft	30%	0.14	1.41
Kraft with Paper Padding				
Option 1	bleached kraft outer	0%	0.10	0.95
	unbleached kraft inner	0%	0.090	0.90
	shredded newspaper pad	100% (1)	0.19	1.92
			0.38	3.77
Option 2	bleached kraft outer	30%	0.10	0.95
	unbleached kraft inner	30%	0.090	0.90
	shredded newspaper pad	100% (1)	0.19	1.92
			0.38	3.77
Kraft with Bubble Wrap				
Option 1	bleached kraft bag	0%	0.086	0.86
	LDPE film (50% of bubble)	0%	0.024	0.24
	LLDPE film (50% of bubble)	0%	0.024	0.24
			0.13	1.33
Option 2	bleached kraft bag	30%	0.086	0.86
	LDPE film (50% of bubble)	30%	0.024	0.24
	LLDPE film (50% of bubble)	30%	0.024	0.24
			0.13	1.33
Unpadded Film Bag				
Option 1	LLDPE	0%	0.067	0.67
Option 2	LLDPE	30%	0.067	0.67
Film Bag with Bubble Wrap				
Option 1	LLDPE bag	0%	0.063	0.63
	LDPE film (50% of bubble)	0%	0.035	0.35
	LLDPE film (50% of bubble)	0%	0.035	0.35
			0.13	1.33
Option 2	LLDPE bag	30%	0.063	0.63
	LDPE film (50% of bubble)	30%	0.035	0.35
	LLDPE film (50% of bubble)	30%	0.035	0.35
			0.13	1.33

(1) 100% postconsumer material; postconsumer content of postconsumer material may be less than 100%.

Scope and Boundaries

The LCI results presented in this chapter include the following:

- Manufacture of all packaging material components, beginning with the extraction of raw materials from the ground and continuing through all subsequent processing and transportation steps up to manufacture into packaging materials. Data were not available for the fabrication of shipping bags from their component materials; thus, the burdens for shipping bags are understated by an unknown amount. Based on data for the fabrication of corrugated boxes, it is expected that fabrication data might account for five to ten percent of the total energy required to produce a package.
- Glues, adhesives, printing inks, and other inputs accounting for less than one percent of the weight of product were not included. Starch-based adhesive for corrugated box manufacture, which accounts for more than one percent of the box weight, was included.
- Other system components not included in the study, in order to keep the scope of the study focused and manageable within practical budget and time constraints, include capital equipment, space conditioning, support personnel requirements, a proprietary plasticizer used in the production of cornstarch loose fill, and certain process emissions for which data were not available. (See Chapter 1 and the Appendices for additional details.)
- Transportation of finished packaging items from the manufacturer to the order fulfillment center or distribution center is included. The representative order fulfillment center is assumed to be located in Western Oregon. DEQ provided region-specific data for the transportation of packaging items from the packaging producers to the order fulfillment center, as well as some data on transportation of input materials such as resins to packaging producers. Transportation data for all other steps are from Franklin Associates' US Life Cycle Inventory database.
- Transportation of packaged products from the order fulfillment center to a representative customer located at the population center of the United States, in central Missouri, is included. The environmental burdens for this step reported in the LCI reflect only those burdens allocated to the package itself, based on the total transportation burdens and the packaging's percentage of the total weight of the product with packaging.
- Disposal of packaging, adjusted to account for diversion for reuse and recycling, is included.
- The results shown for each packaging system include the burdens for extraction, processing, delivery, and combustion of all process and transportation fuels used.
- This analysis is not an impact assessment. It does not attempt to determine the fate of emissions, or the relative risk to humans or to the environment due to emissions from the systems. In addition, no judgments are made as to the merit of obtaining natural resources from various sources.

LCI RESULTS

Energy, solid waste, and emissions results are summarized in this chapter for the packaging systems broken out into the following categories:

- Cradle-to-production results for packaging materials.
- Transportation of packaging materials from the producer to the order fulfillment center.
- Transportation of packaged product to the mail-order customer.
- Disposal of packaging materials at end of life (after diversion for reuse and recycling).

Energy results are shown by life cycle stage in Figure ES-1. Solid waste results (total solid waste, solid waste credit for recycled content, and net solid waste) are shown in Figures ES-2, ES-3, and ES-4. A summary of greenhouse gas (GHG) emissions is presented in Figure ES-5.

Data development and assumptions for production, transportation, and disposal of individual packaging components are described in Chapter 2 and the report appendices.

The LCI results presented in this report were developed by multiplying the 1,000-pound modules presented in Chapter 2 by the appropriate weighting factors to represent the packaging systems defined in Table ES-1. Modules for material production, transportation, and disposal are then combined to model scenarios with different material combinations and recycled contents for the delivery of 10,000 packages to residential customers. Development of data for delivery of packaged product and allocation of delivery burdens to the packaging is described in Chapter 3 and in the report appendices.

Energy Results

Energy results shown in Figure ES-1 include process energy, transportation energy, and energy of material resource. Process energy includes totals for all processes required to produce the packaging materials, from acquisition of raw materials through manufacture into packaging materials. Transportation energy is the energy used to move material from location to location during its journey from raw material to product. Energy of material resource is not an expended energy but the energy value of fuel resources withdrawn from the planet's finite fossil reserves and used as material inputs for materials such as plastic resins. Use of fuel resources as a material input is a depletion of fuel resources just as the combustion of fuels for energy is. In this study, energy of material resource is reported for the plastic film components of the packaging systems. Natural gas and petroleum are the primary material feedstocks for resin production. No energy of material resource is assigned to wood used as a material input for paper(board) packaging components because wood's primary use in the United States is as a material input, not as a fuel resource. Wood combusted for energy (such as bark and black liquor burned for fuel in virgin pulp and paper mills) is counted as process energy.

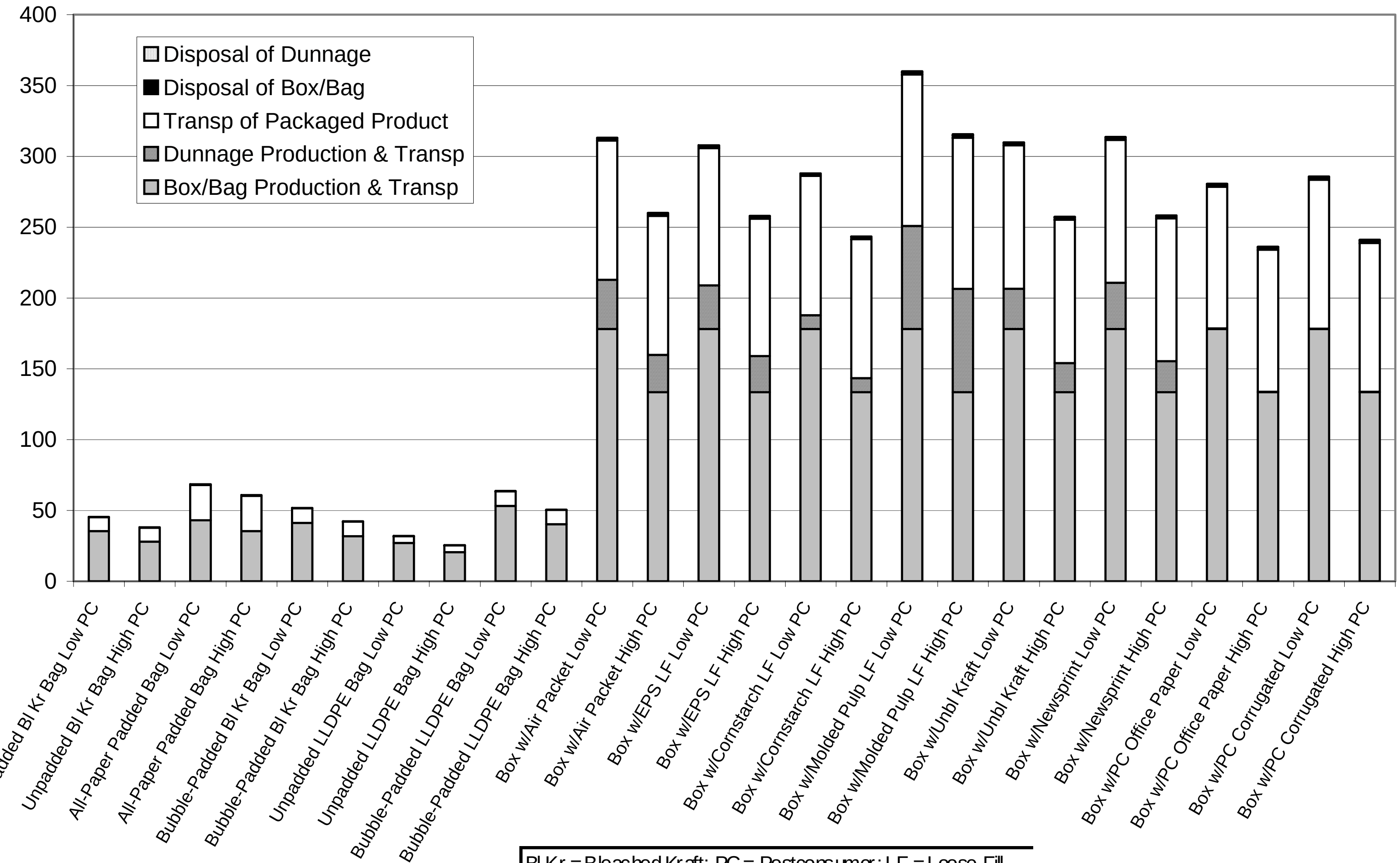
Figure ES-1 shows that total energy requirements for all five shipping bag systems are significantly lower than for the eight corrugated box and dunnage systems defined in Table ES-1. The two main reasons for this are (1) lesser quantities of materials are used in shipping bags, and (2) the more compact size of a product packaged in a shipping bag allows for more energy-efficient shipping.

The energy figures show that material production and transportation to customer are the dominant contributors to total energy for all systems. As seen in Table ES-1, the weight of materials used to package a product in a corrugated box with dunnage is much higher than the weight of materials required to package the same product in a shipping bag. The lightest weight of a box plus dunnage is almost four times the weight of the heaviest shipping bag. (In the case of molded pulp loose fill, the dunnage alone is equivalent to the weight of the heaviest shipping bag.) The weight of each material used in the packaging configuration is multiplied by the energy per pound. Even though the energy per pound of corrugated box is not as high as some other packaging materials, the much greater weight of boxes results in higher energy requirements for the box and dunnage systems.

Transportation to the customer is the other main contributor to total energy. The transportation energy for delivery of packaged product shown in the figures is the energy allocated to the packaging based on its weight percentage of the product with packaging. Boxed products take up a large volume relative to their weight. An analysis of the weights and volumes of mail-order soft goods packaged in boxes and bags (described in detail in the report appendices) indicated that delivery vehicles typically fill by volume rather than by weight. Volume-limited transportation is less efficient than weight-limited transportation, as a greater number of truckloads are required to haul a given weight of cargo. The volume factor has a significant impact on the transportation results in this study, where the representative packaged product is being shipped over 2,000 miles, from the Pacific Northwest to the Midwest.

Energy for transportation to customer is lower for bags compared to boxes, for two main reasons. First, bagged product occupies less volume relative to its weight, so more packaged products can fit in a delivery vehicle load. Second, the weight of a shipping bag is less than the weight of box with dunnage used to ship the same product, so a lower percentage of the transportation burdens for the packaged product is allocated to the bag.

Figure ES-1. Total Energy Requirements for 10,000 Packages (million Btu/10,000 packages)



Bl Kr = Bleached Kraft; PC = Postconsumer; LF = Loose Fill

In Figure ES-1, the results for lower and higher recycled content options for each package are shown next to each other. The figure shows that increasing the recycled content of packaging materials affects only the energy for material production; thus, the results for the lower recycled content option are very similar to those for the corresponding higher recycled content option, but with a lower energy contribution from packaging material production. The energy associated with end-of-life disposal or recycling of packaging is insignificant compared to the energy requirements for producing the packaging and shipment to consumers.

More detailed presentation and discussion of energy results, including energy use by category, energy profiles by fuel source, and energy credit for waste-to-energy combustion of a portion of postconsumer packaging disposed to municipal solid waste can be found in Chapter 3.

Solid Waste

Total solid waste shown in Figures ES-2 includes process wastes, fuel-related wastes, and postconsumer wastes. Process wastes are the solid wastes generated by the various processes from raw material acquisition through material manufacture. Fuel-related wastes are the wastes from the production and combustion of fuels used for process energy and transportation energy. Postconsumer wastes are the wastes discarded by the end users of the product after diversion for reuse and recycling, i.e., the boxes, dunnage, and shipping bags that are discarded by the soft goods mail-order residential customer. As with the energy results, the bag systems create significantly less solid waste than the box/dunnage systems.

This study assumes that some percentage of the packaging materials studied are reused or recycled once they have been used to deliver the product to the residential customer. (Material-specific reuse and recycling rates described in Appendix E range from 10 to 55 percent and are based on assumptions and two national studies conducted by Franklin Associates.) In some communities with comprehensive residential recycling programs, the actual recovery rates for some materials may be higher. However, the numbers used in this study are intended to reflect national averages. Because of the allocation method used in this study (discussed in detail in Chapter 1 starting on page 1-16), changes to the end-of-life reuse/recovery rates impact only solid waste-related burdens. In this study, other benefits of recycling, such as reduced manufacturing energy use and emissions, have already been reflected to the maximum extent in the modeling of packaging systems with postconsumer recycled content.

Figure ES-2. Total Solid Waste for 10,000 Packages
(pounds of waste/10,000 packages)

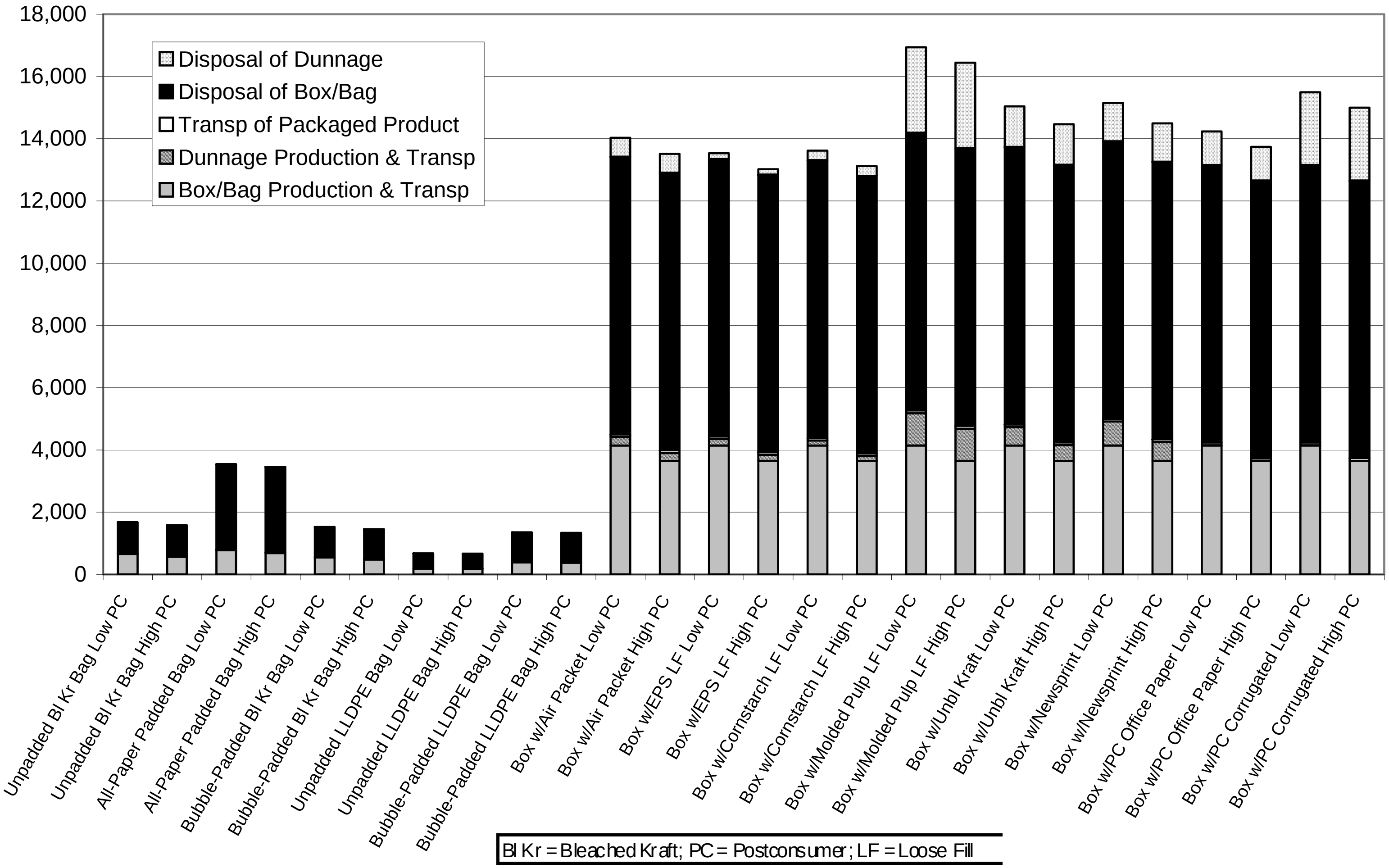


Figure ES-2 shows total solid waste by weight for the packaging systems, broken out by life cycle stage. Postconsumer solid waste from the disposal of packaging components (after diversion for reuse and recycling) is the dominant contributor to the total weight of solid waste for all packaging options, followed by solid waste from the production of materials (primarily fuel-related solid wastes). Solid waste from the transport of packaged product consists only of fuel-related solid wastes and is so small relative to other life cycle stages that it does not show up on Figure ES-2. As with energy results, total solid wastes for the box and dunnage systems is significantly higher than for the shipping bag systems, again largely due to the greater weight of the box and dunnage systems.

For box systems, the box itself contributes the majority of postconsumer solid waste. The weight of postconsumer dunnage varies considerably, based on the weight of dunnage used and its diversion rate for reuse and recycling. The only dunnage options modeled with significant reuse or recycling in this analysis are EPS and cornstarch foam loose fill. (For this study, it was assumed that molded pulp loose fill, while technically as reusable as other types of loose fill, is not likely to be reused because of its significantly different appearance from EPS and starch-based foam loose fill. The reader can adapt the 1,000-pound material disposal modules in Chapter 2 to model other diversion rates for individual packaging materials. The adapted modules can then be multiplied by the appropriate weighting factors in Table 3-1 to obtain results for their use for delivery of 10,000 packaged items.)

More detailed presentation and discussion of solid waste results, including solid waste by volume, can be found in Chapter 3. Detailed assumptions are provided in Appendix E. (The Appendices are a separate document.)

In order to provide the recycled content of the packaging options considered, postconsumer solid waste must be recovered from other product systems manufactured from these materials. The quantities of material diverted from landfill to provide recycled content for the packaging systems studied are shown in Figure ES-3. The heavier the package and the higher its recycled content, the more postconsumer material it uses. For example, Figure ES-3 shows that 10,000 high (80 percent) recycled content corrugated boxes utilize over 11,000 pounds of postconsumer material that might otherwise have been landfilled. Under the methodology used in this study, the solid waste credit shown in Figure ES-3 is assigned to the initial system that produced the postconsumer material used in the packaging.

Figure ES-4 shows the net solid waste burden that must be managed as a result of using postconsumer recycled content in the packaging systems, i.e., how using postconsumer material produced by the initial system (thus diverting it from solid waste) offsets later packaging disposal burdens assigned to the packaging systems utilizing the postconsumer recycled content. The net solid waste is calculated as the total solid waste from production, transportation, shipment, and disposal of the package (from Figure ES-2) minus the solid waste credit associated with the diversion of postconsumer material from a preceding product system to provide the recycled content of the package (from

Figure ES-3). Figure ES-4 shows that the net solid waste for high recycled content box and dunnage options are much more comparable to the bag options, while the lower recycled content box and dunnage options are still significantly higher in net solid waste compared to shipping bags. This is because the higher recycled content box (80 percent postconsumer content) uses more than twice as much postconsumer material compared to the lower (average) recycled content box with 38 percent postconsumer content.

Environmental Emissions

Atmospheric and waterborne emissions for each system include emissions from processes and those associated with the production and combustion of fuels. Chapters 2 and 3 present detailed tables showing emission results for 45 different atmospheric emissions and 41 different waterborne emissions for the various packaging options, reported by life cycle stage. A full list of atmospheric emissions can be found in Tables 2-6, 2-7, 3-6, and 3-7. The list of waterborne emissions is shown in Tables 2-8, 2-9, 3-8, and 3-9.

After diversion for reuse and recycling, the majority of postconsumer packaging components enter the managed municipal solid waste stream. It is recognized that a small portion of postconsumer packaging components may end up being burned in consumers' fireplaces or yards, or disposed directly to land in the form of litter or illegal dumping; however, these types of disposal are not included in this analysis due to the lack of data available to quantify packaging wastes disposed in these ways and to characterize the resultant environmental burdens. A portion of packaging components discarded to municipal solid waste are burned in municipal solid waste incinerators. This analysis does not include emissions from combustion of these wastes, as no data are available on combustion emissions for individual materials burned with mixed municipal solid waste. Similarly, data on the rate of decomposition and emissions resulting from decomposition of individual packaging materials in landfills is limited and also varies depending on landfill characteristics (moisture, pH, temperature, etc.). Therefore, this analysis does not include emissions from landfilling these packaging wastes. As a result, the carbon dioxide and methane emissions, as well as other products of decomposition and incomplete combustion, reported in this analysis are understated by an unknown amount.

It is not practical to attempt to discuss all the atmospheric emission categories listed in the full LCI; therefore, this summary focuses on the high priority atmospheric issue of greenhouse gas (GHG) emissions. A short discussion of other atmospheric and waterborne emissions follows at the end of this section.

Figure ES-3. Postconsumer Solid Waste Diverted from Disposal to Provide Recycled Content for 10,000 Packages (pounds of postconsumer content/10,000 packages)

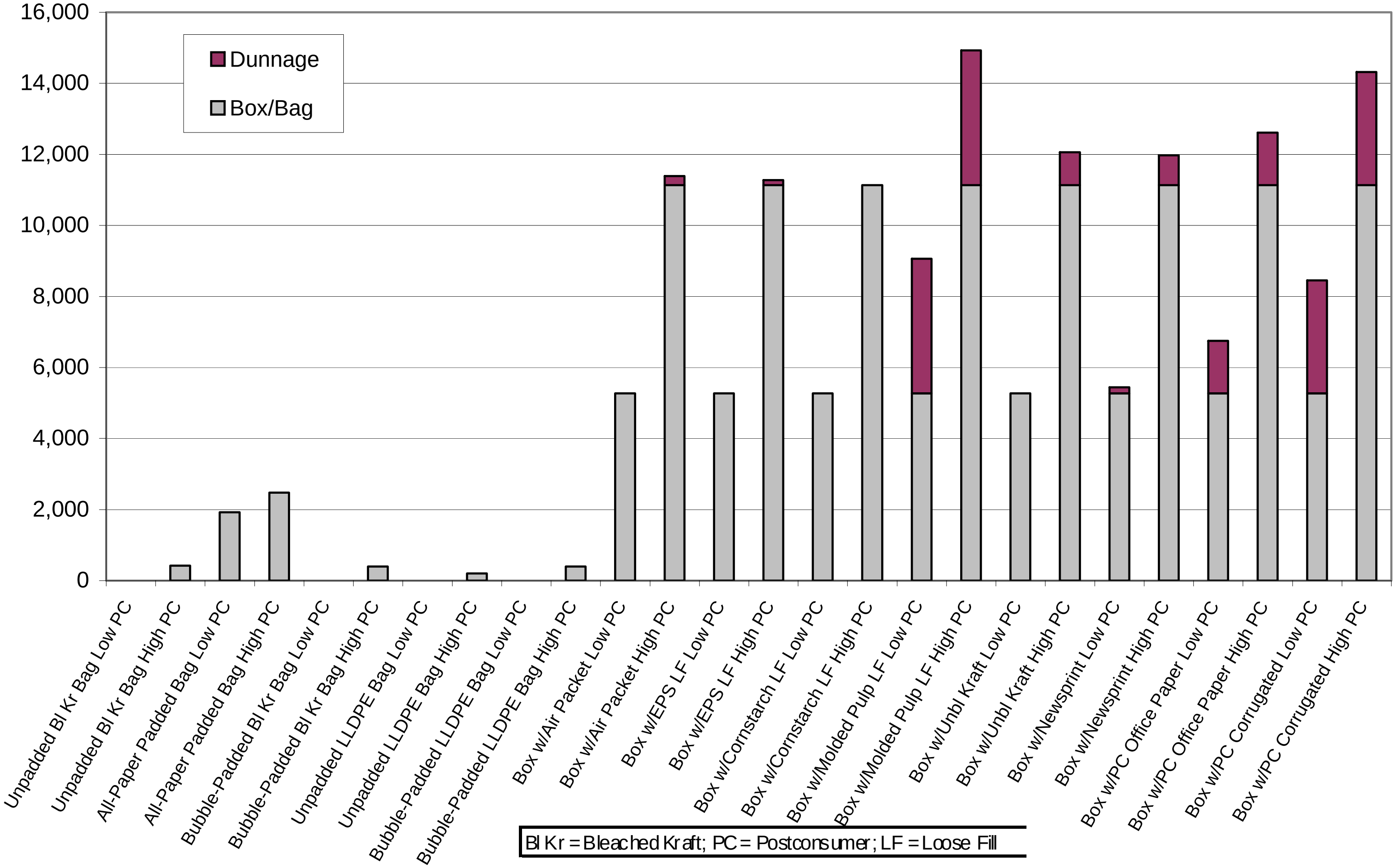
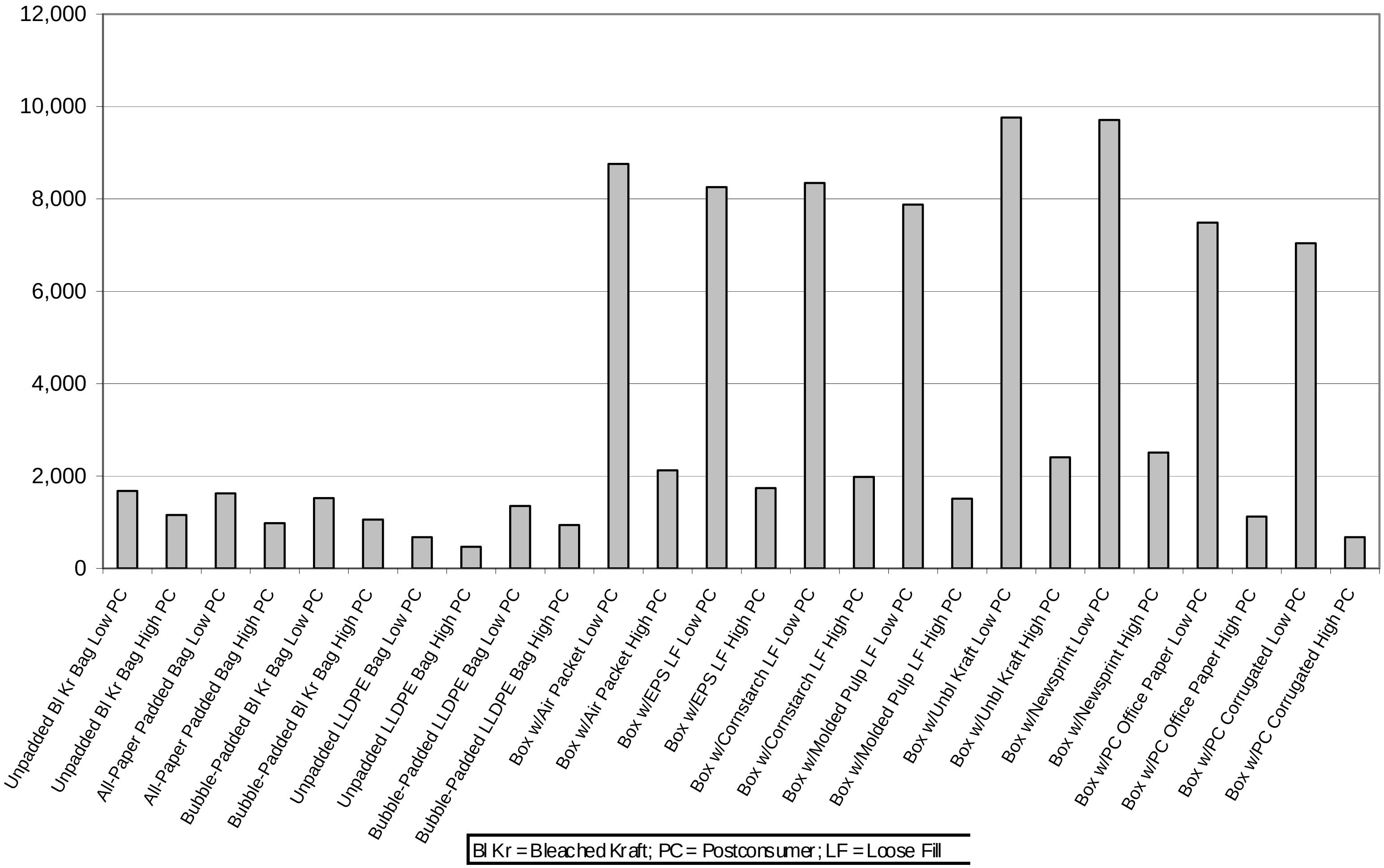


Figure ES-4. Net Total Solid Waste for 10,000 Packages
(pounds of waste/10,000 packages)



The primary three atmospheric emissions reported in this analysis that contribute to global warming are fossil fuel-derived carbon dioxide, methane, and nitrous oxide. (Non-fossil carbon dioxide emissions, such as those from the burning of wood and wood wastes at integrated pulp and paper mills, are considered part of the natural carbon cycle and are not considered a net contributor to global warming.)

The GHG totals shown in Figure ES-5 were calculated by multiplying emissions of carbon dioxide, methane, and nitrous oxide for each packaging system by their global warming potentials. (The global warming potential represents the relative global warming contribution of a pound of a particular GHG compared to a pound of carbon dioxide.)

GHG results are significantly lower for shipping bag systems compared to box and dunnage systems for the same reasons discussed previously in this chapter: the greater weight of corrugated box systems and the greater transportation requirements. For volume-limited transportation of packaged product, GHG emissions per 10,000 packages shipped are higher for bulkier packages (e.g., boxes) compared to packages that can be shipped more compactly (e.g., bags) with more efficient use of vehicle cargo space. In addition, the higher weight of box and dunnage packaging means that a greater percentage of the transportation burdens for the product with packaging are allocated to the package.

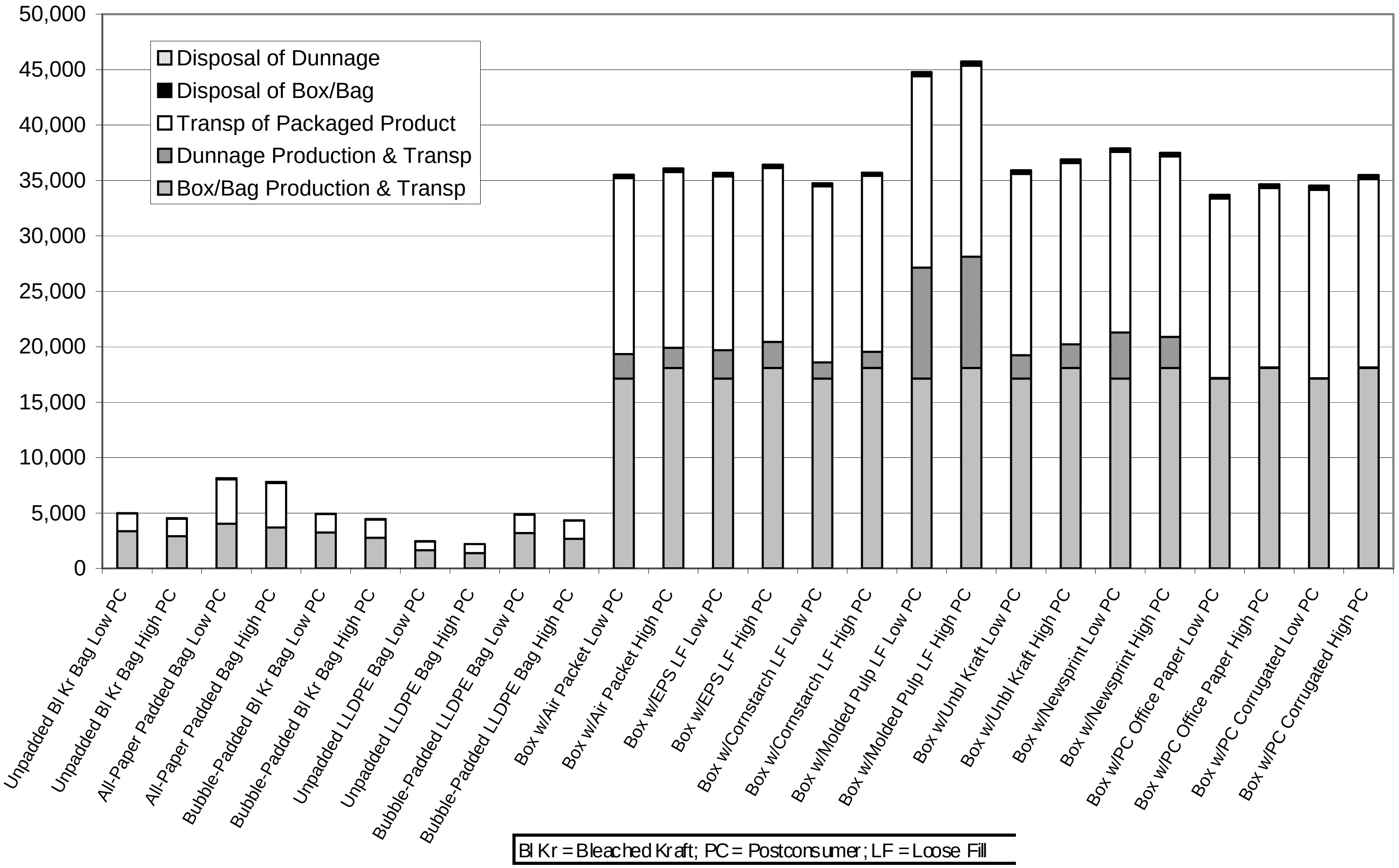
This report evaluates a total of 45 different atmospheric emissions (of which greenhouse gases are only three) and 41 different waterborne emissions. A full discussion of these emissions is not practical; however, a summary comparison is.

For each of the over 80 different atmospheric and waterborne emissions, the range of individual emissions for all box options was compared to the range of corresponding individual emissions for all bag options. In most cases, there was little or no overlap between the range of burdens for box options and the range of burdens for bag options. While most individual emissions for shipping bags are lower in magnitude than the corresponding emissions for box and dunnage systems, it is not appropriate to attempt to draw overall comparative conclusions about emissions results, as this analysis makes no attempt to evaluate the potential impacts of individual emissions on human health and the environment, other than the global warming potential of GHG emissions.

OBSERVATIONS AND CONCLUSIONS

The main conclusion that can be drawn from this analysis regarding packaging options for shipping mail-order soft goods to residential customers is that the weight of the packaging is the most critical factor influencing the environmental burdens. Burdens for material production, transportation, and disposal all relate directly to the weight of material that is required. In this analysis, heavy packaging components with a relatively low environmental profile per pound have higher overall environmental burdens than packaging options that are made of materials with higher per-pound burdens but that have lower weights used in packaging.

Figure ES-5. Total Greenhouse Gas Emissions for 10,000 Packages (pounds CO2 equivalents/10,000 packages)



The weight of the lightest box and dunnage combination evaluated (box with EPS dunnage) is almost four times the weight of the heaviest shipping bag option (all-paper padded bag). The weight of the heaviest box and dunnage combination (box with molded pulp dunnage) is 26 times the weight of the lightest shipping bag (LLDPE film).

In comparison, Chapter 2 shows that the most energy-intensive shipping bag material (virgin LDPE film) requires four times as much energy **per pound** to produce (cradle-to-production) as the least energy-intensive box (80% PC box). Making the same "highest profile bag material" to "lowest profile box" comparisons for solid waste and GHG, the cradle-to-production solid waste **per pound** of bleached virgin kraft is nearly twice as high as solid waste per pound of 80% PC box, and cradle-to-production GHG **per pound** of virgin LDPE film is twice as high as GHG per pound for the average box.

Since total burdens are based on weight of material multiplied by its environmental profile per pound, this means that any box system that is more than four times as heavy as a shipping bag will require more cradle-to-production energy than the shipping bag. Similarly, any box system that is more than twice as heavy as a shipping bag will produce more cradle-to-production solid waste and GHG emissions. (Although energy and greenhouse gas results generally correlate well, the total energy includes energy of material resource, that is, the energy content of fuel resources used as material inputs to plastic products. This represents an energy content that does not result in combustion emissions; thus, the difference in comparative factors for energy and greenhouse gases.)

Solid waste burdens for the production, transportation, shipment, and disposal of packages are offset by the amount of postconsumer material that is diverted from landfill to provide recycled content for the package. For heavier package components with high recycled content such as corrugated boxes, this has a significant effect on net solid waste results.

Packaging weight is also the basis for determining the packaging's share of environmental burdens for transportation of packaged product to the customer. In this study, transportation to customer accounted for a significant portion of the overall life cycle burdens; however, this is affected not only by the packaging weight but also by the package volume, mode of transportation, and the transportation distance (over 2,000 miles in this study).

Transportation of mail-order soft goods to customers is volume-limited; as a result, more cargo space and more vehicle loads are required to transport bulky packages compared to compact packages, resulting in higher transportation burdens for bulky packages regardless of their weight. Transportation to customer would be less dominant in the results if transportation of packaged goods was weight-limited or if shorter transportation distances were analyzed.

LIMITATIONS

It is important to recognize that the results and conclusions presented in this analysis apply to a specific set of packaging options for shipping a soft good product of a certain weight and dimensions. The packaging options defined represent typical shipping practices and do not necessarily represent the minimum amount of packaging that can be used to ship the product. For example, it may be possible to use smaller or lighter boxes or shipping bags or to ship product in boxes without any dunnage. Also, it is very important to recognize that not all the packaging options defined in this study are suitable for many types of items, including items that are fragile, bendable, rigid and bulky, or that have sharp edges, corners, or protrusions.

The general conclusions made in this study regarding the relationship of packaging weight and environmental profile per pound of material are valid for any application. However, general conclusions about the relative overall environmental performance of corrugated boxes compared to shipping bags in this analysis do not necessarily apply to all packaging applications. Comparisons between packaging systems should only be made based on analyses of specific applications in which the sizes, weights, and compositions of each system are clearly identified and modeled on an equivalent use basis.

CHAPTER 1

STUDY APPROACH AND METHODOLOGY

INTRODUCTION

The life cycle inventory presented in this study quantifies the total energy requirements, energy sources, atmospheric pollutants, waterborne pollutants, and solid waste resulting from the production, use, and disposal of packaging used for retail mail-order soft goods in the U.S. The methodology used for goal and scope definition and inventory analysis in this study is consistent with the methodology for Life Cycle Inventory (LCI)[1] as described by the Society of Environmental Toxicology and Chemistry (SETAC) and in the ISO 14000 Standard documents.

This analysis is not an impact assessment. It does not attempt to determine the fate of emissions, or the relative risk to humans or to the environment due to emissions from the systems. In addition, no judgments are made as to the merit of obtaining natural resources from various sources.

A life cycle inventory quantifies the energy consumption and environmental emissions (i.e., atmospheric emissions, waterborne wastes, and solid wastes) for a given product based upon the study boundaries established. The unique feature of this type of analysis is its focus on the entire life cycle of a product, from raw material acquisition to final disposition, rather than on a single manufacturing step or environmental emission. Figure 1-1 illustrates the general approach used in an LCI analysis.

The information from this type of analysis can be used as the basis for further study of the potential improvement of resource use and environmental emissions associated with a given product. It can also pinpoint areas in the life cycle of a product or process where changes would be most beneficial in terms of reduced energy use or environmental emissions.

GOALS OF THE STUDY

The principal goal of this study is to evaluate the energy, solid wastes, and atmospheric and waterborne emissions associated with the production, use, and disposal of various packaging options for the delivery of mail-order soft goods in the U.S., in order to develop a better understanding of the key factors affecting their environmental profiles.

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1 SETAC. 1991. **A Technical Framework for Life-Cycle Assessment.** Workshop report from the Smugglers Notch, Vermont, USA, workshop held August 18-23, 1990.

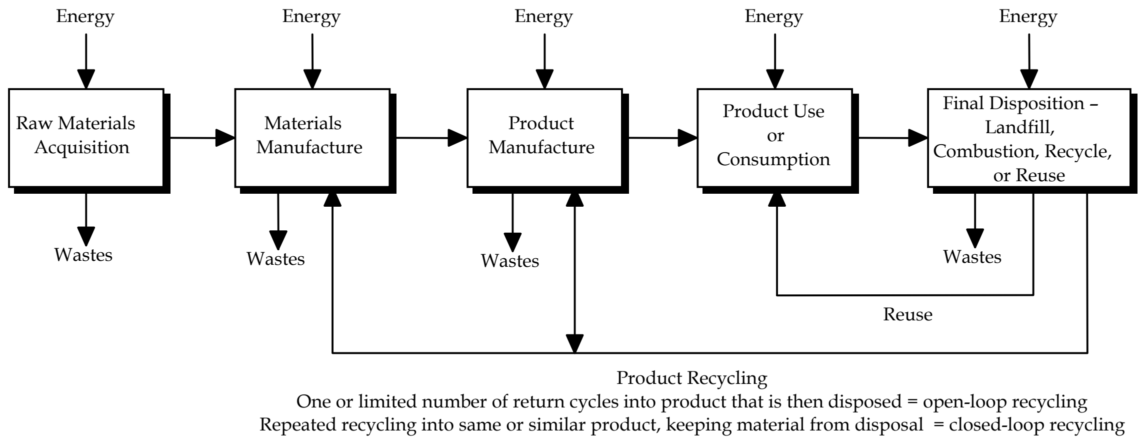

Figure 1-1. General materials flow for "cradle-to-grave" analysis of a product

STUDY SCOPE

Functional Unit

In order to provide a basis for comparison of different products, a common reference unit must be defined. The reference unit for an LCI is described in detail in the standards ISO 14040 and 14041. The reference unit is based upon the function of the products, so that comparisons of different products are made on a uniform basis of providing consumer utility. This common basis, or functional unit, is used to normalize the inputs and outputs of the LCI.

For the packaging studied in this LCI, the functional unit is the packaging required to deliver 10,000 packages of mail-order soft goods to customers. A detailed description of the representative item packaged, the locations of the order fulfillment center and customer, and the shipping distance are provided in the Functional Unit section of Chapter 3.

System Boundaries

Beginning with acquisition of initial raw materials from the earth, this study examines the sequence of processing steps for the production, use, and disposal of packaging used for retail mail-order soft goods in the U.S. Materials that comprise less than one percent by weight of the packaging products are considered negligible and are not included in this study.

Description of Data Categories

Key elements of the LCI methodology include the resource inventory (raw materials and energy), emissions inventory (atmospheric, waterborne, and solid waste), and disposal practices.

Figure 1-2 illustrates the basic approach to data development for each major process in an LCI analysis. This approach provides the essential building blocks of data used to construct a complete resource and environmental emissions inventory profile for the entire life cycle of a product. Using this approach, each individual process included in the study is examined as a closed system, or “black box”, by fully accounting for all resource inputs and process outputs associated with that particular process. Resource inputs accounted for in the LCI include raw materials and energy use, while process outputs accounted for include products manufactured and environmental emissions to land, air, and water.

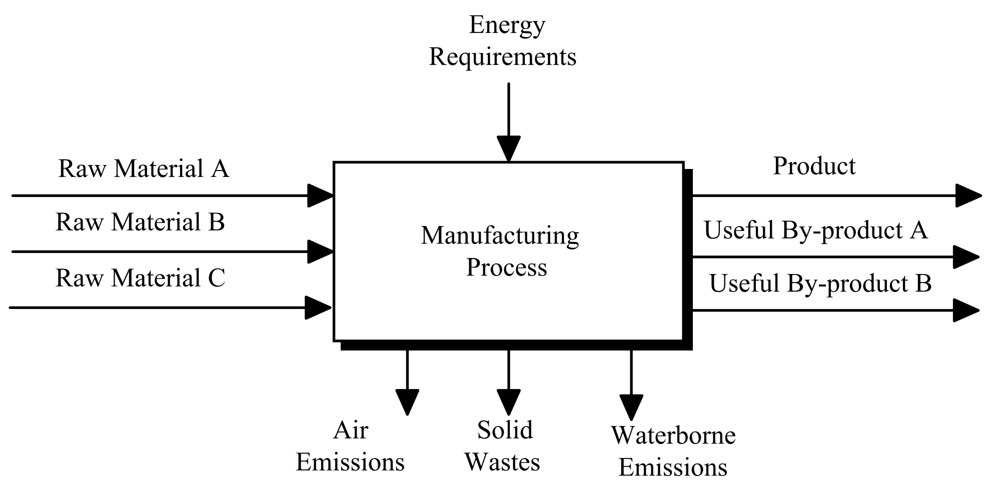

Figure 1-2. "Black box" concept for developing LCI data.

Material Requirements. Once the LCI study boundaries have been defined and the individual processes identified, a material balance is performed for each individual process. This analysis identifies and quantifies the input raw materials required per standard unit of output, such as 1,000 pounds, for each individual process included in the LCI. The purpose of the material balance is to determine the appropriate weighting factors used in calculating the total energy requirements and environmental emissions associated with the packaging systems. Energy requirements and environmental emissions are determined and expressed in terms of the standard unit of output.

Once the detailed material balance has been established for a standard unit of output for each process included in the LCI, a comprehensive material balance for the entire life cycle of the packaging system is constructed. This analysis determines the quantity of materials required from each process to produce and dispose of the required quantity of each packaging system component and is typically illustrated as a flow chart. Data must be gathered for each process shown in the flow diagram, and the weight relationships of inputs and outputs for the various processes must be developed.

Energy Requirements. The average energy requirements for each industrial process are first quantified in terms of fuel or electricity units such as cubic feet of natural gas, gallons of diesel fuel, or kilowatt-hours (kWh) of electricity. Transportation requirements are developed in the conventional units of ton-miles by each transport mode (e.g. truck, rail, barge, etc.). Statistical data for the average efficiency of each transportation mode are used to convert from ton-miles to fuel consumption. The data for these conversions are presented in the fuels appendix, a separate document.

Once the fuel consumption for each industrial process and transportation step is quantified, the fuel units are converted to British thermal units (Btu) using conversion factors. These conversion factors have been developed to account for the energy required to extract, transport, and process the fuels and to account for the energy content of the fuels. The energy to extract, transport, and process fuels into a usable form is referred to in this report as "precombustion energy" (precombustion energy is also commonly referred to in the life cycle literature as "upstream energy"). For electricity, precombustion energy calculations include adjustments for the average efficiency of conversion of fuel to electricity and for transmission losses in power lines.

The LCI methodology assigns raw materials that are derived from fossil fuels with their fuel-energy equivalent. Therefore, the total energy requirement for coal, natural gas, or petroleum-based raw materials includes the fuel energy of the material (called energy of material resource or inherent energy). No fuel-energy equivalent is assigned to combustible materials, such as wood, that are not major fuel sources in the United States. For example, in an LCI of paperboard, the calorific value of the wood fiber that is used to make the paperboard would not be included in the energy analysis.

The Btu values for fuels and electricity consumed in each industrial process are summed and categorized into an energy profile according to the six major energy sources listed below:

- Natural gas
- Petroleum
- Coal
- Hydropower
- Nuclear
- Wood-derived

Also included in the systems energy profile are the Btu values for all transportation steps and all fossil fuel-derived raw materials. An additional electricity generation category "Other" includes the portion of electricity generated from sources such as wind and solar power.

Environmental Emissions. Environmental emissions include air pollutants, solid wastes, and waterborne wastes. Through various data sources identified later in this chapter, every effort is made to obtain actual industry data. Emission standards are often used as a guide when operating data are not available.

It is not uncommon for data provided by some individual plants to be more complete than that submitted by others. Other factors, such as the measuring and reporting methods used, also affect the quality of air and waterborne emissions data. This makes comparison of the air and waterborne emissions between the systems more difficult. Comparisons of LCA databases have shown that airborne and waterborne pollutant emissions for a particular material production inventory can easily vary by 200%. Energy and solid waste values are generally more agreeable between databases. The best use of the detailed air and waterborne emissions data at this point in time is for internal improvement. A close look at the reason for certain air or waterborne pollutants within each system may identify areas where process or material changes could reduce emissions.

Substances may be reported in speciated or unspeciated form, depending on the compositional information available. General categories such as “Acid” and “Metal Ion” are used to report unspeciated data. Emissions are reported only in the most descriptive single category applicable; speciated data are not reported again in the broadly applicable unspeciated category. For example, emissions reported as “HCl” are not additionally reported under the category “Acid,” nor are emissions reported as “Chromium” additionally reported under “Metal Ion.”

The scope of this analysis is to identify what wastes are generated through a cradle-to-grave analysis of the systems being examined. No attempt has been made to determine the relative environmental effects of these pollutants.

Atmospheric Emissions. These emissions include carbon dioxide and all other substances classified as air pollutants. Emissions are reported as pounds of pollutant per unit of product output. The amounts reported represent actual discharges into the atmosphere after existing emission control devices. The emissions associated with the combustion of fuel for process or transportation energy as well as the process emissions are included in the analysis. Some of the most commonly reported atmospheric emissions are particulates, nitrogen oxides, hydrocarbons, sulfur oxides, and carbon monoxide.

The following are Franklin Associates' definitions of some of the major atmospheric pollutants:

Nitrogen oxides (NOx): Compounds of nitrogen and oxygen produced by the burning of fossil fuels, or any other combustion process taking place in air. The two most important oxides in this category are nitrogen oxide (NO) and nitrogen dioxide (NO_2). Nitrous oxide (N_2O), however, is reported separately.

Sulfur oxides (SOx): Compounds of sulfur and oxygen, such as sulfur dioxide (SO_2) and sulfur trioxide (SO_3).

Hydrocarbons: A subcategory of organic compounds which contain only hydrogen and carbon. These compounds may exist in either the gaseous, liquid, or solid phase, and have a molecular structure that varies from the simple to the very heavy and very complex. The category Non-Methane Hydrocarbons is sometimes used when methane is reported separately.

Other organics: Compounds containing carbon combined with hydrogen and other elements such as oxygen, nitrogen, sulfur, or others. Compounds containing only carbon and hydrogen are classified as hydrocarbons and are not included in this category.

Particulate matter (Particulates): Small solid particles or liquid droplets suspended in the atmospheric, ranging in size from 0.005 to 500 microns.

Particulates are usually characterized as primary or secondary. Primary particulates, usually 0.1 to 20 microns in size, are those injected directly into the atmosphere by chemical or physical processes. Secondary particulates are produced as a result of chemical reactions that take place in the atmosphere. In our reports, particulates refer only to primary particulates.

Particulates reported by Franklin Associates are not categorized by size range and are sometimes called total suspended particulates (TSP). The category PM-10 refers to all particulates less than 10 microns in (aerodynamic) diameter. This classification is sometimes used when health effects are being considered, since the human nasal passages will filter and reject particles larger than 10 microns. PM 2.5 (less than 2.5 microns in diameter) is now considered the size range of most concern for human health effects.

Waterborne Wastes. As with atmospheric emissions, waterborne wastes include all substances classified as pollutants. Waterborne wastes are reported as pounds of pollutant per unit of product output. The values reported are the average quantity of pollutants still present in the wastewater stream after wastewater treatment and represent discharges into receiving waters. Some of the most commonly reported waterborne wastes are biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, dissolved solids, iron, chromium, acid, and ammonia.

Solid Wastes. This category includes solid wastes generated from all sources that are landfilled or disposed in some other way. This also includes materials that are burned to ash at combustion facilities. It does not include materials that are recycled or coproducts. When a product is evaluated on an environmental basis, attention is often focused on postconsumer wastes. Industrial wastes generated during the manufacture of the product are sometimes overlooked. Industrial solid wastes include wastewater treatment sludges, solids collected in air pollution control devices, trim or waste materials from manufacturing operations that are not recycled, fuel combustion residues such as the ash generated by burning coal or wood, and mineral extraction wastes. Waste materials that are left on-site or diverted from landfill and returned to the land without treatment (e.g., overburden returned to mine site, cornstalks returned to the field or forest residues left in the forest to decompose) are not reported as wastes.

Inclusion of Inputs and Outputs

Franklin Associates commonly uses a mass basis to decide if materials should be included in an analysis; however, it is recognized that use of mass exclusion criteria could result in oversight of minor constituents that are highly toxic. Before the decision is made to exclude a material from the study based on its mass, the analyst evaluates the likelihood of significant energy, solid waste, or emissions burdens associated with the material. Any material less than one percent of the mass in the system is generally considered negligible if its contributions are estimated to be negligible, based on the information available to the analyst. In some cases materials that have small mass but potentially significant burdens may have to be excluded from the study because of the unavailability of LCI data, particularly for proprietary or chemically complex substances; in such cases, the exclusions are specifically noted in the study limitations.

Data Quality Requirements

Standards for data procurement and quality are described in ISO Standards 14040-14043. Franklin Associates' methods in this area have been in place for many years, and the ISO Standards are in part drawn from our experience in developing these methods.

The accuracy of the study is only as good as the quality of input data. The development of methodology for the collection of data is essential to obtaining quality data. Careful adherence to that methodology determines not only data quality but also objectivity. However, methods for quantifying and communicating data quality, including data uncertainty, are being established. Franklin Associates is pursuing a data quality and data uncertainty methodology at this time. Documentation of the methodology for data collection is currently the most widely used method for communicating data quality. The use of single values for individual data points that may actually have wide ranges (such as process energy requirements or component weights) is done to make the calculation process manageable.

Data necessary for conducting this analysis are separated into two categories: process-related data and fuel-related data.

Process Data

Methodology for Collection/Verification. The process of gathering data is an iterative one. The data-gathering process for each system begins with a literature search to identify raw materials and processes necessary to produce the final product. The search is then extended to identify the raw materials and processes used to produce these raw materials. In this way, a flow diagram is systematically constructed to represent the production pathway of each system.

Each process identified during the construction of the flow diagram is then researched to identify potential industry sources for data. Each source for process data is contacted and worksheets are provided to assist in gathering the necessary process data for their product. Each worksheet is accompanied by a description of the process boundaries.

Upon receipt of the completed worksheets, the data are evaluated for completeness and reviewed for any material inputs that are additions or changes to the flow diagram. In this way, the flow diagram is revised to represent current industrial practices. Data suppliers are contacted again to discuss the data, process technology, waste treatment, identify coproducts, and any assumptions necessary to understand the data and boundaries.

After each data set has been completed and verified, the data sets for each process are aggregated together into a single set of data for that process. The method of aggregation for each process is determined on a case-by-case basis. For example, if more than one process technology is involved, market shares for these processes are used to create a weighted average. In this way, a representative set of data can be estimated from a limited number of data sources. Process technologies and assumptions are then documented and returned with the aggregated data to each data supplier for their review. The data and documentation may also be provided to other industry and academic experts for comment. This provides an opportunity for experts on each process to review the completed data for accuracy, reasonableness of assumptions, and representativeness.

Confidentiality. The data requested in the worksheets are often considered proprietary by potential suppliers of data. The method used to collect and review data provides each supplier the opportunity to review the aggregated average data calculated from all data supplied by industry. This allows each supplier to verify that their company's data are not being published and that the averaged data are not aggregated in such a way that individual company data can be calculated or identified.

Objectivity. Each process is researched independently of all other processes. No calculations are performed to link processes together with the production of their raw materials until after data gathering and review is complete. The procedure of providing the aggregated data and documentation to suppliers and other industry experts provides several opportunities to review the individual data sets without affecting the objectivity of the research. This process serves as an external expert review of each process. Also, because these data are reviewed individually, assumptions are reviewed based on their relevance to the process rather than their effect on the overall outcome of the study.

Sources. Most process data used in this study were drawn from Franklin Associates' U.S. LCI database, which was developed using the data collection and review process described above. In addition, some new data were developed specifically for this study. Data for the production of molded pulp and cornstarch-based loose fill were developed for this study. Oregon DEQ also provided transportation data representative of the locations of Pacific Northwest packaging producers (and, in some cases, their material suppliers), mail-order fulfillment centers, and mail-order customers.

The source and age of the material production and fabrication data for each packaging material are summarized in Table 1-1. A complete list of data sources used for each packaging material is provided in Appendix C of the appendices, a separate document.

Fuel Data. The energy and emissions released when fuels are burned are only one part of the energy and emissions associated with the use of a fuel. Before each fuel is usable, it must be mined, as in the case of coal or uranium, or extracted from the earth in some manner. Further processing is often necessary before the fuel is usable. Coal is crushed or pulverized and sometimes cleaned. Crude oil is refined to produce fuel oils and liquefied petroleum gases.

To avoid confusion regarding environmental emissions from the combustion of fuels and emissions resulting from the fuel production process, it is necessary to define terms to describe the different emissions. The combustion products of fuels are defined as "combustion data." Energy consumption and emissions which result from the mining, refining, and transportation of fuels are defined as "precombustion data." Precombustion data and combustion data together are referred to as "fuel-related data."

Fuel-related data are developed for fuels that are burned directly in industrial furnaces, boilers, and transport vehicles. Fuel-related data are also developed for the production of electricity. These data are assembled into a database from which the energy requirements and environmental emissions for the production and combustion of process fuels are calculated. The fuels and energy database used for this analysis was last completely updated in 1998 using the most current data sources that were available at that time. Most of the public data sources for fuel use and emissions were 1995-1997 publications. Specific sources of data on the production and combustion of each fuel and for electricity generation are referenced in the text and tables of Appendix A of the appendices (a separate document), with full source information (including age) provided in the References section at the end of Appendix A.

Energy data are developed in the form of measured units of each primary fuel required per measured unit of each fuel type. For electricity production, statistics from the International Energy Agency provided data for the amount of fuel required to produce electricity from each fuel source, and the total amount of electricity generated from petroleum, natural gas, coal, nuclear, hydropower, and other (solar, geothermal, etc.). Literature sources and international statistical records provided data for the emissions resulting from the combustion of fuels in utility boilers, industrial boilers, stationary equipment such as pumps and compressors, and transportation equipment. Because electricity is required to produce primary fuels, which are in turn used to generate electricity, a circular loop is created. Iteration techniques are utilized to resolve this loop.

Table 1-1

OVERVIEW OF DATA FOR PRODUCTION AND FABRICATION OF PACKAGING COMPONENTS

Packaging Component	Data Source and Age
Corrugated box	
Material use	Compiled by Franklin Associates using 1997 paper industry statistical publications
Production of linerboard and medium	Private industry sources 1990-1996; 1997 paper industry publication
Box fabrication	Private industry sources 1990-1992
LDPE Film for Inflated Polyethylene Air Packets and Shipping Bags	
LDPE resin production	Private industry sources 1989-1990, 1997 petrochemical industry publication
LDPE film production	Estimated based on 1993 APME publication
Air packet inflation and sealing	Data provided by Oregon DEQ 2003
Polystyrene Foam Loose Fill	
EPS resin production	Private industry sources 1991-1994, 2003
Fabrication	Estimated based on 2003 private industry data for similar EPS product
Starch-based Loose Fill	
Cornstarch production	Private industry sources 1992-1993
Fabrication	Developed from 2003 plant polymer research center information, extrusion equipment specifications, and U.S. biodegradable packaging patent
Molded Pulp Loose Fill	
Fabrication from postconsumer newspaper	Private industry data 2003
Unbleached Kraft Paper for Dunnage and Shipping Bags	
Production of unbleached kraft paper	Private industry sources 1989-1996
Newsprint Dunnage	
Production of newsprint	Private industry sources 1989-1996; 1987 paper industry technology handbook
Shredded Postconsumer Paper(board) Dunnage	
Shredding of corrugated	Data developed by DEQ for operation of shredding equipment, 2003
Shredding of office paper	Data developed by DEQ for operation of shredding equipment, 2003
Bleached Kraft Paper for Shipping Bags	
Production of bleached kraft paper	Private industry sources 1989-1996
Shredded Newspaper Padding for Shipping Bags	
Shredding of newspaper	Data developed by DEQ for operation of shredding equipment, 2003
LLDPE Film for Shipping Bags	
LLDPE resin production	Private industry sources 1989-1994; 2000 DOE publication
LLDPE film production	Estimated based on 1993 APME publication
Postconsumer Recycled Content for Packaging Components	
Postconsumer paper(board) collection	Private industry sources 1992; 1991 EPA report on material recovery
Recycled paper(board) production	Private industry sources 1991-1996
Postconsumer plastic collection and recycling	Private industry sources 1991-1993

Data Accuracy. An important issue in considering the use of this study is the reliability of the calculations. In a complex study with literally thousands of numbers, the accuracy of the data and how it affects conclusions is truly a complex subject, and one that does not lend itself to standard error analysis techniques. Techniques such as Monte Carlo analysis can be used to study uncertainty, but the greatest challenge is the lack of uncertainty data or probability distributions for key parameters, which are often only available as single point estimates. However, the reliability of the study can be assessed in other ways.

An important consideration is whether the conclusions are correct. There are many processes in each system, so there are many numbers added together to arrive at the total values (energy, solid waste, etc.) for each system. Each number by itself may contribute little to the total (depending on the magnitude of the uncertainty for each parameter and the sensitivity of the final result to changes in each parameter). There is no analytical method for assessing the accuracy of each number to any degree of confidence. In many cases, data represent actual plant data reported by plant personnel. The data reported may represent operations for the previous year or may be representative of the upcoming year. All data are scrutinized when they are received to evaluate whether or not they are representative of the type of operation or process being evaluated.

There are several other important points with regard to data accuracy. Each number generally contributes a small part to the total value, so a large error in one data point does not necessarily create a problem. For process steps that make a larger than average contribution to the total, special care is taken with the data quality. It is assumed that with careful scrutiny of the data, any errors will be random. That is, some numbers will be a little high due to errors, and some will be slightly low, but in the summing process these random high and low errors will offset each other to some extent.

There is another dimension to the reliability of the data. Certain numbers do not stand alone, but rather affect several numbers in the system. An example is the amount of a raw material required for a process. This number will affect every step in the production sequence prior to the process. Errors such as this that propagate throughout the system are more significant in steps that are closest to the end of the production sequence.

Data Quality Indicators and Uncertainty Analysis

ISO standards 14040, 14041 and 14043 each detail various aspects of data quality and data quality analysis. These items are essential to give a study credibility. In particular, when comparative assertions are made, the estimates of uncertainty in the results are essential to determine if two numbers are most likely the same or different. No standard methods have been adopted for this activity, but Franklin Associates has developed methods that have been peer reviewed in technical journals and are described in part in the SETAC documents "Life Cycle Assessment Data Quality: A Conceptual Framework," 1992, and "Life Cycle Impact Assessment: The State of the Art," 1997.

Life Cycle Inventories are an attempt to determine all of the inputs (in terms of energy and natural resource use) and all of the outputs (in terms of products, coproducts, and environmental emissions to the air, water, and soil) over the entire life of a product or service, within the boundaries of the study. Thousands of data points are needed in a typical LCI, including values for the extraction of raw materials, the manufacturing of intermediate materials, the fabrication of the product, the use/reuse/maintenance of the product, and the ultimate disposal or recycling of the product.

In the best of possible worlds, classical statistics could be used to determine the uncertainties in Life Cycle Inventories. Classical statistics, however, requires that the data conform to several restrictive assumptions such as independence, randomness, and representativeness.

In LCIs, as in many areas of complex assessments, data often do not meet the stringent requirements of classical statistics. There may be no option to control the representativeness of samples, the number of data points, or the randomness of the data collected. In that case, expert judgment becomes important.

The ISO Standards 14041 and 14042 specify three techniques of data quality analysis to be used to assist in resolving these complexities. Franklin Associates employs all of these in assessing results.

- Gravity analysis – identifies those data which give the greatest contribution to end results so that they can be more intensively scrutinized.
- Uncertainty analysis – describes statistical variability in data sets in order to assist in determination of significant differences.
- Sensitivity analysis – measures the extent to which changes in data or assumptions influence results.

Recent research has shown that expert judgment can be translated into quantifiable statements about data quality and uncertainty with high reproducibility.[2,3] While this introduces subjectivity into the uncertainty analysis, it is presently the best available methodology. It brings to LCI assessments valuable information that has historically been missing. It has the potential of greatly increasing the credibility of comparative LCI results and making the database in a research project as sound as possible.

Franklin Associates has developed methodologies to deal with the issues of uncertainty and data quality in Life Cycle Analysis. In traditional LCIs, single point estimates of input variables (such as fuel requirements) are used to determine single point estimates for the output variables (such as total energy used or solid waste generated). These point estimates contain no information about the uncertainty of the data; therefore they give a false sense of precision. Analysis of meaningful differences in LCI results obtained using point value modeling thus relies upon the experience and expert judgment

2 Kennedy, D.J., D.C. Montgomery, and B.H. Quay, **Stochastic Environmental Life Cycle Assessment Modeling: A Probabilistic Approach to Incorporating Variable Input Data Quality.** Int. J. LCA 1(4) pp. 199-207 (1996).

3 Kusko, Bruce H. and Robert G. Hunt, **Managing Uncertainty in Life Cycle Inventories**. Published by the Society of Automotive Engineers, Inc. Paper No. 970693 1997.

of the practitioner. Chapter 4 of this report provides an explanation of Franklin Associates' criteria for meaningful differences in LCI results, supported by statistical arguments with hypothetical, but similar, data.

The Franklin Associates methodology has been adapted to allow for the assignment of data quality indicators (DQIs) to the variables used as inputs to LCI computer models. These indicators can then be used as a basis for modeling input values as distributions rather than as single point estimates. This approach more accurately reflects the level of confidence in the values. The deterministic model is therefore changed into a stochastic model. This means that the output of the model is also a distribution of values, rather than a single point estimate. It is then easier to judge, for example, whether two values for total solid waste are the same or different. This stochastic approach requires considerable additional modeling time and expense, however, and is outside the scope of this project.

Critical Review

Critical review is specified in ISO standard 14040 as an optional component for LCI/LCA studies, although ISO 14040 goes on to say that "a critical review shall be conducted for LCA studies used to make a comparative assertion that is disclosed to the public…" This study is limited to an inventory rather than a full life cycle assessment; however, it will be made publicly available and thus a peer review of the study was conducted. The purpose of the peer review is to verify that the study has met the requirements of the international standards for methodology, data and reporting. The review may be conducted by internal experts other than the persons performing the study, external experts, or by a review panel of interested parties.

Review by internal experts is a standard procedure at Franklin Associates. Our internal standards by which a study is judged include the items in ISO standards. We also routinely submit relevant portions of our LCI studies to external data experts, that is, to data contributors, so that they may verify that we have interpreted and used their data properly. The study is also submitted to the client for critical review.

For this study, a peer review was commissioned by the U.S. EPA Environmentally Preferable Purchasing (EPP) Program at the request of the Oregon DEQ. The peer review was conducted by a panel of three independent life cycle experts. The report of the peer review panel and Franklin Associates' responses to their comments are included as an attachment to this final peer-reviewed report. This final version of the report incorporates all revisions noted in the response to the peer review comments.

Because the study will be made publicly available, EPA has also provided funding to revise the Appendix document which contains the supporting data for the LCI. Confidential data in the Appendices have been aggregated to protect confidentiality so that the Appendices can likewise be made publicly available.

METHODOLOGY

There is general consensus among life cycle practitioners on the fundamental methodology for performing LCIs.[4] These are described in ISO Standards 14040-14041, and the series of documents developed under the leadership of SETAC in Europe and the U.S. However, these documents describe that, for some specific aspects of life cycle inventory, there are minor variations in methodology used by experienced practitioners. These areas include: the method used to allocate energy requirements and environmental releases among more than one useful product produced by a process; the method used to account for the energy contained in material feedstocks; and the recycling of materials. LCI practitioners vary to some extent in their approaches to these issues. The following sections describe the approach to each issue used in this study.

Coproduct Credit

One unique feature of life cycle inventories is that the quantification of inputs and outputs are related to a specific amount of product from a process. However, controversy in LCI studies often occurs because it is sometimes difficult or impossible to identify which inputs and outputs are associated with one of multiple products from a process. The practice of allocating inputs and outputs among multiple products from a process is often referred to as "coproduct credit"[5] or "partitioning"[6].

Coproduct credit is done out of necessity when raw materials and emissions cannot be directly attributed to one of several product outputs from a system. It has long been recognized that the practice of giving coproduct credit is less desirable than being able to identify which inputs lead to particular outputs.

It is possible to divide a larger process into sub-processes. To use this approach, data must be available for sub-processes. In many cases, this may not be possible either due to the nature of the process or to less detailed data. Eventually, a sub-process will be reached where it is necessary to allocate energy and emissions among multiple products based on some calculated ratio. The method of calculating this ratio is subject to much discussion among LCA researchers, and various methods of calculating this ratio are discussed in literature.[7,8,9,10,11]

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4 SETAC. 1993. **Guidelines for Life-Cycle Assessment: A "Code of Practice."** 1st ed. Workshop report from the Sesimbra, Portugal, workshop held March 31 through April 3, 1993.

5 Hunt, Robert G., Sellers, Jere D., and Franklin, William E. **Resource and Environmental Profile Analysis: A Life Cycle Environmental Assessment for Products and Procedures.** Environmental Impact Assessment Review. 1992; 12:245-269.

6 Boustead, Ian. **Eco-balance Methodology for Commodity Thermoplastics.** A report for The Centre for Plastics in the Environment (PWMI). Brussels, Belgium. December, 1992.

7 Hunt, Robert G., Sellers, Jere D., and Franklin, William E. **Resource and Environmental Profile Analysis: A Life Cycle Environmental Assessment for Products and Procedures.** Environmental Impact Assessment Review. 1992; 12:245-269.

8 Boustead, Ian. **Eco-balance Methodology for Commodity Thermoplastics.** A report for The Centre for Plastics in the Environment (PWMI). Brussels, Belgium. December, 1992.

9 SETAC. 1993. **Guidelines for Life-Cycle Assessment: A "Code of Practice."** 1st ed. Workshop report from the Sesimbra, Portugal, workshop held March 31 through April 3, 1993.

Where allocation of energy and emissions among multiple products based on a calculated ratio is necessary in this study, the ratio is calculated based on the relative **mass** outputs of products, which is the most common approach by experienced practitioners. Figure 1-3 illustrates the concept of coproduct allocation on a mass basis.

Energy of Material Resource

For some raw materials, such as petroleum, natural gas, and coal, the amount consumed in all applications as fuel far exceeds the amount consumed as raw materials (feedstock) for products. The primary use of these materials is for energy. The total amount of these materials can be viewed as an energy pool or reserve. This concept is illustrated in Figure 1-4.

The use of a certain amount of these materials as feedstocks for products, rather than as fuels, removes that amount of material from the energy pool, thereby reducing the amount of energy available for consumption. This use of available energy as feedstock is called the "energy of material resource" and is included in the inventory. The energy of material resource represents the amount the energy pool is reduced by the consumption of fuel materials as raw materials in products and is quantified in energy units.

The energy of material resource is the energy content of the fuel materials *input* as raw materials or feedstocks. The energy of material resource assigned to a material is *not* the energy value of the final product, but is the energy value of the raw material at the point of extraction from its natural environment. For fossil fuels, this definition is straightforward. For instance, petroleum is extracted in the form of crude oil. Therefore, the energy of material resource for petroleum is the higher heating value of crude oil.

Once the feedstock is converted to a product, there is energy content that could be recovered, for instance through combustion in a waste-to-energy waste disposal facility. The energy that can be recovered in this manner is always somewhat less than the feedstock energy because the steps to convert from a gas or liquid to a solid material reduces the amount of energy left in the product itself.

The materials which are primarily used as fuels can change over time and with location. In the industrially developed countries included in this analysis, the material resources whose primary use is for fuel are petroleum, natural gas, coal, and nuclear material. While some wood is burned for energy, the primary use for wood is as a material input for products such as paper and lumber. Similarly, some oleochemical oils such as palm oils are burned for fuels, often referred to as "bio-diesel." However, as in the case of wood, their primary consumption is as raw materials for products such as soaps, surfactants, cosmetics, etc.

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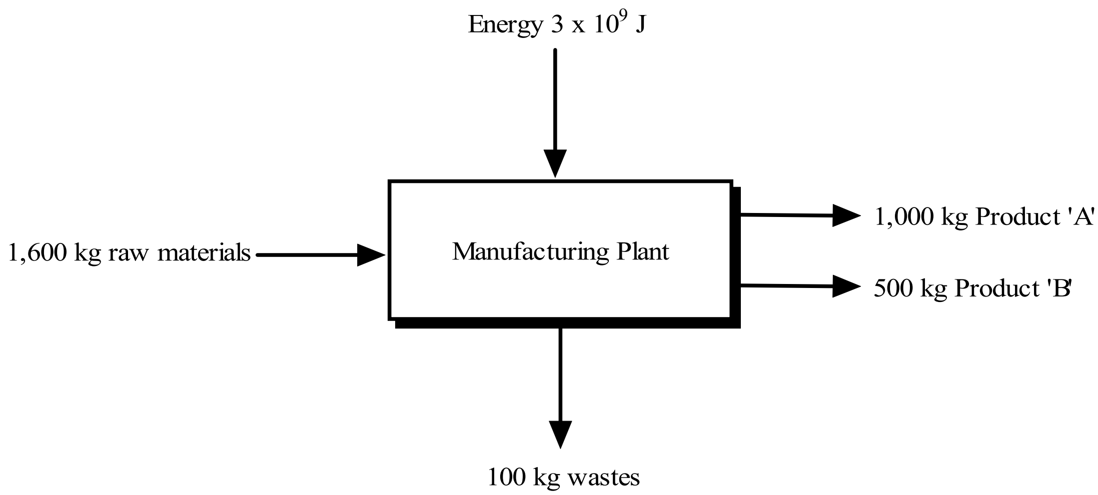
[10] **Life-Cycle Assessment: Inventory Guidelines and Principles.** Risk Reduction Engineering Laboratory, Office of Research and Development, United States Environmental Protection Agency. EPA/600/R-92/245. February, 1993.

[11] **Product Life Cycle Assessment–Principles and Methodology.** Nord 1992:9. ISBN 92 9120 012 3.



Using coproduct allocation, the flow diagram utilized in the LCI for product 'A', which accounts for 2/3 of the output, would be as shown below.

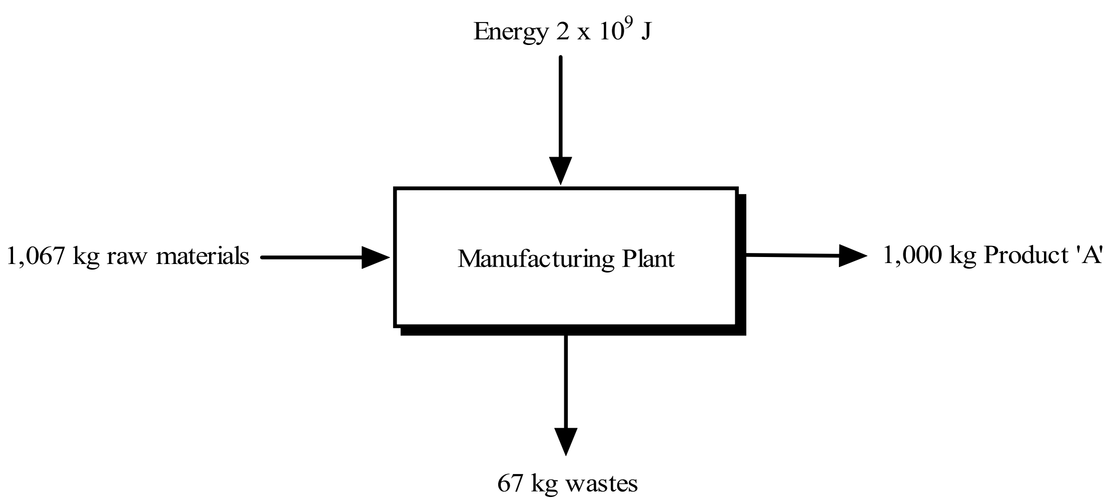


Figure 1-3. Flow diagrams illustrating coproduct allocation for product 'A'.

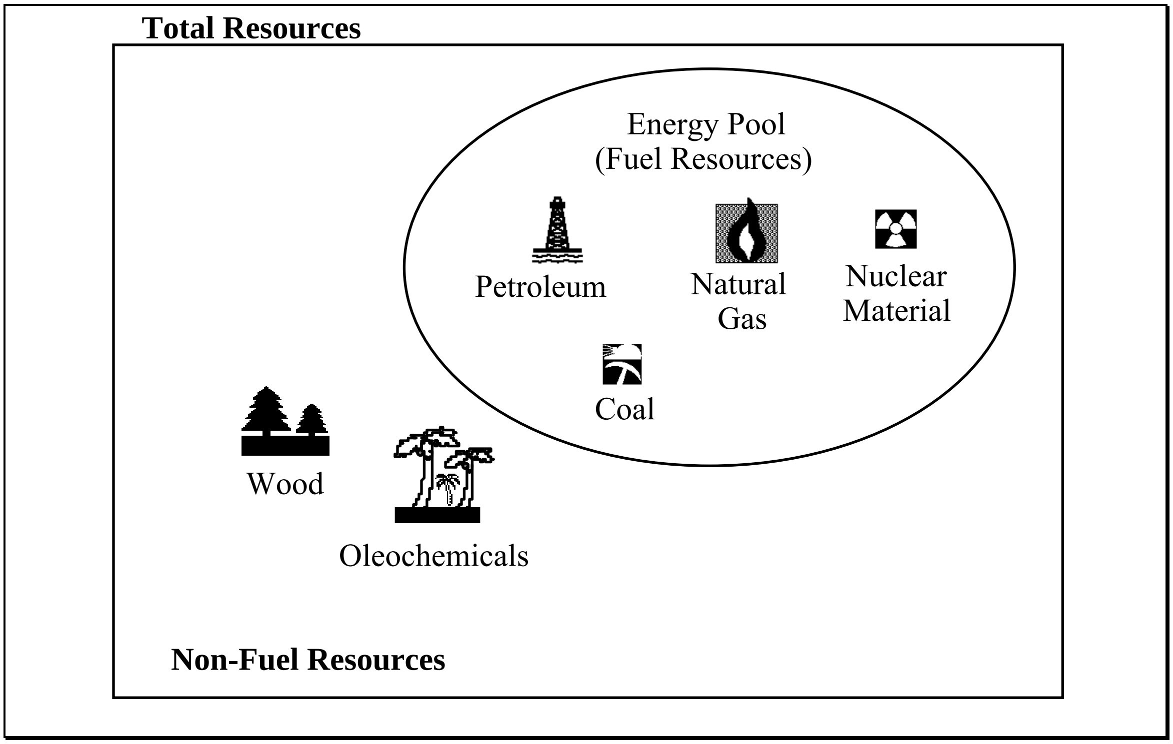


Figure 1-4. Illustration of the Energy of Material Resource concept.

Recycling

Recycling is evaluated in this analysis as a means intended to reduce the environmental burdens for production of packaging materials and to divert products from the municipal solid waste stream at end of life. Practitioners generally use one of two methodologies for allocating environmental burdens among product systems with recycled content. One approach is a shared allocation approach that allocates the burdens for virgin material production and end-of-life disposal among all systems that use the material, whether it is the first system using the virgin material or the last system using postconsumer material recovered from a previous useful life. Each useful life of the material carries its own fabrication and use burdens. Recovery and reprocessing burdens are allocated to each useful life of the recycled material using the equation (R x n)/(n+1), where R is the recycling burdens and n is the number of times the material is recycled. Thus, (n+1) is the total number of useful lives of the material: initial use + recycled uses. For material that is recycled once, n=1; thus, the equation reduces to R/2, and half the recycling burdens are allocated to each useful life.

The alternative approach used in this study is to assign full burdens for virgin material production and end-of-life disposal to the product system for which they occur. Using this approach, all burdens for virgin material production and initial product fabrication and use are assigned to the first product system using the material. The first system bears no disposal burdens for any material that is recovered and reused or recycled for use in a second product system. Postconsumer material recovered from the first system comes into the second system free of its virgin material production burdens. The system using the postconsumer material bears the full burdens of collecting and reprocessing the material for use in the second product system, as well as the full burdens for the second product fabrication and use. The system using the postconsumer recycled material also bears the full burdens for disposal of the material at end of life, minus the weight of material that is diverted from disposal for further reuse or recycling.

One reason for this choice of methodology is that one of the purposes of this analysis is to test the "conventional wisdom" that recycled content is the most important criteria in making packaging decisions. The methodology used was chosen in part because it provides the most favorable treatment of recycled content. The chosen methodology validates the credibility of those study results that show that other packaging criteria, such as lightweighting or minimizing package volume, can result in lower burdens than high recycled content packaging.

Another reason for this choice of methodology is that companies that purchase packaging to ship mail-order goods typically have direct control over the level of postconsumer material in their packaging. In contrast, these companies typically have less control over how their customers manage the packaging at the end of its life (recycling vs. disposal). Thus, this study uses a methodology that models postconsumer content as coming in free of environmental burdens associated with virgin materials extraction and manufacturing. This approach demonstrates the maximum reduction in energy use and emissions for packaging production that can be assigned to postconsumer recycled content. Changes in end-of-life reuse/recycling only affect burdens related to disposal/recycling, which tend to be small in comparison to material production burdens. Because this methodology provides the most favorable treatment of postconsumer recycled content, it provides a "best case" illustration to mail-order companies of the environmental benefits they can achieve by exerting their purchasing power to influence this variable.

Readers interested in using the shared allocation approach can use the 1,000 lb virgin and 100% recycled material modules in Chapter 2 to approximate results for the shared allocation methodology. Using the shared methodology, the recycled portion of the material would be assigned half the burdens for production of the equivalent quantity of virgin material and half the burdens for production of the equivalent quantity of 100% recycled material. For example, using the shared allocation approach, kraft paper with 30 percent postconsumer recycled content would be modeled as follows:

70% virgin kraft + 30% recycled kraft
= .70 x (burdens/1000 lb virgin kraft) + .30/2 x (burdens/1000 lb virgin kraft) + .30/2 x (burdens/1000 lb 100% recycled kraft)
= .85 x (burdens/1000 lb virgin kraft) + .15 x (burdens/1000 lb 100% recycled kraft)

In general, for recycled content percent R and materials recycled once, burdens for the shared allocation approach would be calculated as (1-R/2) x virgin burdens + R/2 x recycled burdens.

GENERAL DECISIONS

Some general decisions are always necessary to limit a study such as this to a reasonable scope. It is important to know what those decisions are. The principal decisions and limitations for this study are discussed in the following sections.

Geographic Scope

In some cases, data for non-U.S. processes are not available. This is usually only a consideration for the production of oil that is obtained from overseas. In cases such as this, the energy requirements and emissions are assumed to be the same as if the materials originated in the United States. Since foreign standards and regulations vary from those of the United States, it is acknowledged that this assumption will likely introduce error. Emissions data for oil production include U.S. data for unflared methane emissions but do not include fossil carbon dioxide emissions from flaring of natural gas. In the U.S. flaring is usually done as a last resort to minimize the global warming impact of methane releases that are unavoidable or are too small to capture economically; however, methane flaring may be practiced to a greater extent in overseas countries. Fuel usage for transportation of materials from overseas locations is included in the study.

Of the two companies selling unpadded plastic shipping bags that provided data for this study, one company produced bags domestically and one provided bags produced overseas. Thus, in this study, half of the unpadded LLDPE film bags are assumed to be produced overseas and imported to the West Coast. Resin production and film fabrication processes for these bags are modeled based on U.S. data, with transportation representing long-distance transportation from overseas to distributors in the Pacific Northwest. It is assumed that all other packaging materials are manufactured in the U.S.

Precombustion Energy and Emissions

In addition to the energy obtained from combustion of a fuel, energy is required for resource extraction, processing, and transportation to deliver the fuel in the form in which it is used. In this study, this additional energy is called precombustion energy. Precombustion energy refers to all the energy that must be expended to prepare and deliver the primary fuel. Adjustments for losses during transmission, spills, leaks, exploration, and drilling/mining operations are incorporated into the calculation of precombustion energy.

Precombustion environmental emissions (air, waterborne, and solid waste) are also associated with the acquisition, processing, and transportation of the primary fuel. These precombustion emissions are added to the emissions resulting from the burning of the fuels.

Electricity Fuel Profile

In general, detailed data do not exist on the fuels used to generate the electricity consumed by each industry. Electricity production and distribution systems in the United States are interlinked and are not easily separated. Users of electricity, in general, cannot specify the fuels used to produce their share of the electric power grid. Therefore, the national average fuel consumption by electrical utilities is assumed.

Electricity generated on-site at a manufacturing facility is represented in the process data by the fuels used to produce it. A portion of on-site generated electricity is sold to the electricity grid. This portion is accounted for in the calculations for the fuel mix in the grid.

Postconsumer Waste Disposal and Combustion

Except for materials that are recycled or reused, postconsumer waste in the United States is normally either landfilled or incinerated. In the U.S., approximately 20 percent of postconsumer municipal solid waste, after diversion for recycling and reuse, is burned in a combustion facility which recovers energy.[12] The energy released from the combustion of those postconsumer materials is shown separately in the results as a potential energy credit offsetting some of the total energy requirements of the system. The gross energy credit is calculated based on the pounds of each material burned and the higher heating value of the material. The usable energy is based on the gross energy adjusted for an estimated 33 percent thermal efficiency for generation of electricity from WTE combustion of MSW and transmission losses of about 8 percent. Energy credits are shown separately in the report in the LCI energy tables 2-3-BOX, 2-3-BAG, 3-2-BOX, 3-2-BAG, 3-3-BOX, and 3-3-BAG.

Postconsumer solid waste for the system is reduced by the quantity of materials burned in combustion facilities. The ash from combustion facilities then becomes part of the postconsumer solid waste for the system.

No emissions credits are assigned to the WTE energy credit because (1) no assumptions are made as to what electricity generation fuel is displaced by the electricity from MSW combustion, so the emissions from combustion of that fuel are not specified, and (2) the net emissions credit would be (emissions from displaced fuel) – (emissions from MSW WTE combustion), and the emissions from WTE combustion are not included in this analysis, as discussed below in the section **Emissions from Combustion and Landfilling of Postconsumer Waste**.

This study assumes that all postconsumer packaging materials discarded by end-users or businesses enter the managed municipal solid waste stream described above (e.g., a permitted solid waste landfill or a permitted waste-to-energy incinerator that

[12] **Municipal Solid Waste in the United States: 2001 Facts and Figures.** U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response. August 2003.

operates at high temperatures and employs pollution control equipment). A small fraction of postconsumer packaging may actually end up being burned in consumers' fireplaces or yards, or disposed as litter. Environmental burdens from these activities are not included in this report, because (1) the quantity of postconsumer packaging disposed in this manner is not known, and (2) material-specific emissions from low-temperature on-site combustion (e.g., in fireplaces or trash burn barrels) have not been documented.

System Components Not Included

The following components of each system are not included in this study:

Emissions from Combustion and Landfilling of Postconsumer Waste. It is recognized that the combustion of postconsumer products in waste-to-energy facilities produces atmospheric and waterborne emissions; however, these emissions are not included in this study. Allocating atmospheric and waterborne wastes from municipal waste combustion facilities to specific packaging systems is not feasible, due to the variety of materials present in combusted municipal solid waste and a lack of data regarding combustion emissions for individual materials burned with mixed municipal solid waste. Theoretical carbon dioxide emissions from incinerated packaging could be calculated based on their carbon content and assuming complete oxidation; however, this may not be an accurate representation of the results of mixed MSW combustion (which often contains wet wastes and is burned with very low efficiency under less than ideal conditions for complete combustion to carbon dioxide). Therefore, emissions from incineration of packaging components in mixed MSW are not included in the analysis. Although electricity production from the combustion of solid waste reduces the need to generate electricity from the combustion of other fuels, no assumptions are made in this study as to what specific fuels are replaced by combustion of solid waste, and no associated emissions credits are assigned.

Similarly, emissions of methane and carbon dioxide from aerobic and anaerobic decomposition of landfilled paperboard or bio-based packaging components are not estimated for this analysis, nor are estimates of leachate from landfilled packaging items included. Historically, LCI studies have not included emissions from landfilled materials because of a lack of data of suitable quality.

Although some packaging components in this study contain paperboard or bio-based materials (such as cornstarch foam loose fill) that may degrade in a landfill, the fate of degradable materials in a landfill is a very complex subject. A large number of variables come into play, such as moisture, permeability of cover, temperature, pH of surroundings and time. Landfill decomposition generally is strongly affected by moisture content, which is highly variable from landfill to landfill, and even more so from place to place within a landfill. Anaerobic decomposition proceeds only under a narrow range of environmental conditions, including appropriate temperature, pH and moisture level.

Decomposition in a landfill proceeds by some combination of aerobic and anaerobic processes. At first, there is air entrapped in the landfill, but with time, probably within a few weeks or months, the conditions become anaerobic. Time is also an element to consider. It may take a century or more for degradable material to decompose completely in a landfill, although many products are suspected to partially decompose rapidly at first.

Even when degradable materials decompose, not all gas produced by the decomposition enters the atmosphere. Some methane reacts with other chemicals in a landfill, some is oxidized in the soil, and some is recovered and flared or burned as a fuel. Possibly an even greater fraction of CO_2 generated never makes it through the landfill cover because it is soluble in water and may exit the landfill as leachate.

In summary, emissions from landfills (particularly greenhouse gas emissions) are potentially important to consider in LCI calculations, but it is premature to report them along with other LCI emissions data until there is general agreement among experts on an acceptable methodology for estimating actual releases.

Readers interested in this topic may wish to refer to the report EPA530-R-02-006, **Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks**, 2nd edition, May 2002, available at www.epa.gov. This report presents data on net GHG releases from WTE combustion (Exhibit 6-6) and landfilling (Exhibit 7-6) of various products and materials in municipal solid waste. It is beyond the scope of this study to attempt to evaluate the applicability of the EPA GHG methodology and models to the specific packaging components studied in this analysis.

Capital Equipment. The energy and wastes associated with the manufacture of capital equipment are not included. This includes equipment to manufacture buildings, motor vehicles, and industrial machinery. These types of capital equipment are used to produce large quantities of product output over a useful life of many years. Thus, energy and emissions associated with production of these facilities and equipment generally become negligible when allocated to 1,000-pound product output modules.

Space Conditioning. The fuels and power consumed to heat, cool, and light manufacturing establishments are omitted from the calculations in most cases. Space conditioning was not explicitly included in the scope of the study; however, primary LCI unit process data are often based on overall facility utility use and may include some space conditioning data.

For most industries, space conditioning energy is quite low compared to process energy. A possible exception may be processes that are relatively low in energy requirements but occupy large amounts of plant floor space, such as assembly line operations. DOE data for the industrial sector indicates that non-process energy use including HVAC and lighting accounts for 10 -15 percent of the total end use fuel energy consumption in the case of electricity and natural gas (http://www.eia.doe.gov/emeu/mecs/mecs98/datatables/d98n6_4.htm). A significant amount of the overall industrial HVAC and lighting energy is likely for office areas, cafeteria space, etc. not directly associated with specific unit processes (see Support

Personnel Requirements, below), as opposed to HVAC and lighting requirements for the plant floor space associated with specific unit processes.

Support Personnel Requirements. The energy and wastes associated with research and development, sales, and administrative personnel or related activities have not been included in this study. Similar to space conditioning, energy requirements and related emissions are assumed to be quite small for support personnel activities.

Miscellaneous Materials and Additives. Selected materials such as catalysts, pigments, or other additives which total less than one percent of the net process inputs are often excluded from the inventory if their contributions are estimated to be negligible. Omitting miscellaneous materials and additives helps keep the scope of the study focused and manageable within budget and time constraints.

In this study it was necessary to exclude proprietary plasticizers used in the production of cornstarch loose fill. Although some producers reported that these materials represented more than one percent by weight of the loose fill product, no information was available on the chemical composition of these materials or the processes used to produce them. Thus, the cornstarch loose fill was modeled as 100% cornstarch.

Fabrication of Shipping Bags. Data were not available for the fabrication of shipping bags from their component materials; thus, the burdens for shipping bags are understated by an unknown amount. Based on data for the fabrication of corrugated boxes, it is expected that fabrication data might account for five to ten percent of the total energy required to produce a package.

Secondary Packaging. Packaging used to unitize and deliver packaging components to the order fulfillment center, such as pallets, boxes, strapping, plastic film shrink or stretch wrap, etc., are not included in this analysis. Similarly, pallets and containers (such as reusable plastic bins, nylon mesh bags, etc.) used by shipping services such as UPS to hold assorted small packages in delivery vans are not included.

OTHER LIMITATIONS

The data and methodology used for this study represent **average** values for environmental burdens associated with the production, transportation, shipment, recycling, and disposal of packaging options. The **marginal** environmental burdens (e.g., incremental changes in environmental burdens associated with changes in supply and demand for packaging materials, associated inputs of raw materials and energy, or solid waste produced) may be significantly different. For example, an incremental increase in electricity demand may result in increased generation from a specific fuel, rather than a scaled-up increase of electricity production by the average grid mix represented in this study.

The study methodology uses a linear approach to modeling the effects of increasing recycled content. That is, the environmental burdens of recycling are modeled as if they change in a linear fashion from 0 to 100 percent. It is possible that some environmental burdens associated with recycled content may change in a non-linear way, due for example to recycling capacity limits or the economics of recycling at various levels.

As described in the data quality section, the data used in this analysis are the best available and have been updated to the extent possible within the scope of this study. The data may not necessarily reflect the most recent improvements in energy efficiency or changes in the mix of fuels used for various industrial processes, nor does this study project future improvements in energy efficiency or changes in fuel use, including increased use of alternative non-fossil fuels. Also, within a specific industry, some companies will be less polluting and/or use fewer resources than their industry average, while other companies will be higher than average.

CHAPTER 2

ENERGY AND ENVIRONMENTAL RESULTS FOR 1,000 POUNDS OF MATERIALS USED IN SOFT GOODS PACKAGING

INTRODUCTION

A life cycle inventory (LCI) study quantifies the energy use and environmental emissions associated with the life cycle of specific products. In this chapter, results are presented for components of an LCI of packaging options, namely 1,000-pound modules for materials used in soft goods packaging: cradle-to-production modules, modules for transportation of finished packaging products to the order fulfillment center (or distribution center), and end-of-life disposal modules.

Purpose of the Study

The purpose of this study is to evaluate the energy, solid wastes, and atmospheric and waterborne emissions associated with various packaging options for the delivery of mail-order soft goods. This chapter presents cradle-to-production results for the components of box and dunnage systems and shipping bag systems, including all life cycle steps beginning with raw material extraction and continuing through manufacture of the material in the form used to package mail-order soft goods. This chapter also presents results for the transportation of 1,000 pounds of each packaging material to the order fulfillment center and for the end-of-life disposal of 1,000 pounds of each packaging material.

IMPORTANT: In the context of an LCI study with a defined functional unit as a basis for comparing systems, the 1,000-pound modules presented in this chapter **do not** serve as a meaningful basis for comparing materials as used in packaging systems. In order to make meaningful comparisons of packaging systems, the 1,000-pound modules presented in this chapter must be multiplied by the appropriate weighting factors to reflect their use in a defined packaging application and then combined to model packaging systems on an equivalent use basis. This is done in Chapter 3. However, the 1,000-pound modules presented in this chapter are useful for understanding the environmental profiles of various packaging materials.

Systems Studied

Two general types of packaging systems for mail-order soft goods are analyzed in this study: corrugated boxes with various types of dunnage and shipping bags composed of paper and/or plastic. Table 2-1 shows the compositions of the various packaging options that are analyzed in each of these categories.

Table 2-1

DEFINITION OF INDIVIDUAL PACKAGING COMPONENTS MODELED IN THE STUDY
(Study models corrugated boxes used in combination with various dunnage options.)

		Postconsumer Recycled Content	Pounds/ Package	Thou Lb/ 10,000 Packages
CORRUGATED BOX				
Option 1	industry average linerboard	28%	0.95	9.49
	industry average medium	59%	0.44	4.41
	overall box	38%	1.39	13.90
Option 2	recycled linerboard	71%	0.95	9.49
	recycled medium	100%	0.44	4.41
	overall box	80%	1.39	13.90
DUNNAGE (used with corrugated box)				
Inflated Polyethylene Air Packets				
Option 1	LDPE	0%	0.084	0.84
Option 2	LDPE	30%	0.084	0.84
Polystyrene Foam Loose Fill				
Option 1	EPS	0%	0.048	0.48
Option 2	EPS	30%	0.048	0.48
Starch-based Loose Fill				
	cornstarch	0%	0.086	0.86
Molded Pulp Loose Fill				
	newspaper	100% (1)	0.38	3.79
Kraft Paper (Crumpled)				
Option 1	unbleached kraft	0%	0.18	1.84
Option 2	unbleached kraft	50%	0.18	1.84
Newsprint (Crumpled)				
Option 1	newsprint	10%	0.17	1.68
Option 2	newsprint	50%	0.17	1.68
Shredded Postconsumer Paper(board)				
Option 1	corrugated	100% (1)	0.32	3.18
Option 2	office paper (2)	100% (1)	0.15	1.48

(1) 100% postconsumer material; postconsumer content of postconsumer material may be less than 100%.
(2) 83.6% printing-writing, 16.4% newspaper

Table 2-1 (cont.)

DEFINITION OF INDIVIDUAL PACKAGING COMPONENTS MODELED IN THE STUDY

SHIPPING BAGS		Postconsumer Recycled Content	Pounds/ Package	Thou Lb/ 10,000 Packages
Unpadded Kraft				
Option 1	bleached kraft	0%	0.14	1.41
Option 2	bleached kraft	30%	0.14	1.41
Kraft with Paper Padding				
Option 1	bleached kraft outer	0%	0.10	0.95
	unbleached kraft inner	0%	0.090	0.90
	shredded newspaper pad	100% (1)	0.19	1.92
			0.38	3.77
Option 2	bleached kraft outer	30%	0.10	0.95
	unbleached kraft inner	30%	0.090	0.90
	shredded newspaper pad	100% (1)	0.19	1.92
			0.38	3.77
Kraft with Bubble Wrap				
Option 1	bleached kraft bag	0%	0.086	0.86
	LDPE film (50% of bubble)	0%	0.024	0.24
	LLDPE film (50% of bubble)	0%	0.024	0.24
			0.13	1.33
Option 2	bleached kraft bag	30%	0.086	0.86
	LDPE film (50% of bubble)	30%	0.024	0.24
	LLDPE film (50% of bubble)	30%	0.024	0.24
			0.13	1.33
Unpadded Film Bag				
Option 1	LLDPE	0%	0.067	0.67
Option 2	LLDPE	30%	0.067	0.67
Film Bag with Bubble Wrap				
Option 1	LLDPE bag	0%	0.063	0.63
	LDPE film (50% of bubble)	0%	0.035	0.35
	LLDPE film (50% of bubble)	0%	0.035	0.35
			0.13	1.33
Option 2	LLDPE bag	30%	0.063	0.63
	LDPE film (50% of bubble)	30%	0.035	0.35
	LLDPE film (50% of bubble)	30%	0.035	0.35
			0.13	1.33

(1) 100% postconsumer material; postconsumer content of postconsumer material may be less than 100%.

Functional Unit

In order to insure a valid basis for comparison for the packaging systems studied, a common functional unit is essential. For this study, the functional unit for each system is the packaging required to deliver 10,000 representative packages of soft goods items to customers. The dimensions and weight of the representative packaged item were determined by Oregon Department of Environmental Quality (DEQ) staff, based on data provided by a large Oregon-based mail-order company. The dimensions and weights of each packaging configuration required to ship the representative item were determined by DEQ staff based on data provided by several mail-order companies, packaging vendors, and a packaging study and other analysis conducted by Pack Edge Development, a packaging engineering firm also under contract to DEQ. The material composition of each packaging configuration was determined by DEQ staff and Franklin Associates staff, with assistance from Pack Edge Development. The development of these data are described in detail in the report appendices. The weights of each component of each packaging system are shown in Table 2-1.

Scope and Boundaries

The 1,000 pound module results presented in this chapter include the following:

- Manufacture of all packaging material components, beginning with the extraction of raw materials from the ground and continuing through all subsequent processing and transportation steps up to manufacture into packaging materials. Data were not available for the fabrication of shipping bags from their component materials; thus, the burdens for shipping bags are understated by an unknown amount. Based on data for the fabrication of corrugated boxes, it is expected that fabrication data might account for five to ten percent of the total energy required to produce a package.
- Glues, adhesives, printing inks, and other inputs accounting for less than one percent of the weight of product were not included. Starch-based adhesive for corrugated box manufacture, which accounts for more than one percent of the box weight, was included.
- Other system components not included in the study, in order to keep the scope of the study focused and manageable within practical budget and time constraints, include capital equipment, space conditioning, support personnel requirements, a proprietary plasticizer used in the production of cornstarch loose fill, and certain process emissions for which data were not available. (See Chapter 1 and the Appendices for additional details.)
- Transportation of finished packaging items from the manufacturer to the order fulfillment center or distribution center is included. The representative order fulfillment center is assumed to be located in Western Oregon. DEQ provided region-specific data for the transportation of packaging items from the packaging producers to the order fulfillment center, as well as some data on transportation of input materials such as

resins to packaging producers. Transportation data for all other steps are from Franklin Associates' U.S. life cycle inventory database.

- Disposal of packaging, adjusted to account for diversion for reuse and recycling, is included.
- The results shown in each module include the burdens for extraction, processing, delivery, and combustion of all process and transportation fuels used.

1,000-POUND MODULE RESULTS

Energy, solid waste, and emissions results are presented in this chapter for the following 1,000-pound modules:

- Cradle-to-production results for packaging materials, with separate columns for process and transportation energy.
- Transportation of packaging materials from the producer to the order fulfillment center.
- Disposal of packaging materials at end of life (after diversion for reuse and recycling).

Energy results are shown in Tables 2-2 and 2-3. Solid waste results are shown in Tables 2-4 and 2-5, atmospheric emissions in Tables 2-6 and 2-7, and waterborne emissions in Tables 2-8 and 2-9. In each set of tables, the first (even-numbered) shows cradle-to-production results and the second (odd-numbered) shows order fulfillment center transportation and end-of-life disposal. There are two versions of each table, "-BOX" showing results for boxes and dunnage, and "-BAG" showing results for shipping bags. **Because of the length of the tables, all results tables are placed at the end of the chapter.**

Figure 2-1 shows cradle-to-production energy results by category and Figure 2-2 shows cradle-to-production solid waste results by category. There are "–BOX" and "–BAG" versions of both figures. The following abbreviations are used in the figures: V = virgin, R = 100% postconsumer recycled content, LF = loose fill, PC = postconsumer, Bl = bleached, Unbl = unbleached, NP = newspaper. For example, the material "EPS LF-R" translates as "EPS loose fill with 100% postconsumer recycled content." Results figures are inserted in the chapter as they are discussed in the text.

Boxes and dunnage can be modeled as "stand-alone" products that are produced, transported to the order fulfillment center, and disposed of as individual products. Shipping bags are different. The bag component materials are produced individually and transported to the bag producer where they are fabricated into a bag. The assembled bag is transported to the order fulfillment center as a composite product and disposed as a composite product. Thus, the cradle-to-production data shown in the even-numbered results tables are for bag materials and include production of the material and fabrication into the form in which it is used in the bag (e.g., kraft paper, LLDPE film), ending with transportation of the material to the bag fabricator. Transportation and disposal data shown in the odd-numbered results tables are for the fabricated bag.

Data were not available for the fabrication of shipping bags from their component materials; thus, the burdens for shipping bags are understated by an unknown amount. Energy for assembling materials into a fabricated product is generally very low in comparison to energy for the production of materials, so the effect of missing fabrication energy should be minimal. However, fabrication scrap losses can have a significant effect on results. For example, fabrication losses of 10 percent of input materials would mean that 1,100 pounds of input materials must be produced for 1,000 pounds of fabricated product. The 10 percent scrap (if not recycled) would become process waste. (Ten percent is used for illustration purposes only; actual fabrication losses may be significantly lower.) The results for shipping bag systems presented in Chapter 3 can be adjusted using the compositional data in Table 2-1 and the 1,000-pound modules in this chapter to model any level of fabrication losses for shipping bag fabrication.

The cradle-to-production results for corrugated boxes shown in this chapter include transportation from the box converter to the order fulfillment center; correspondingly, no transportation is shown for corrugated boxes on the order center/end-of-life table (Table 2-3-BOX). For this study, DEQ provided region-specific data for transportation of packaging materials from packaging producers to order fulfillment centers, and in some cases, data for transportation of input materials (such as resins or cornstarch) to packaging producers. Transportation data provided by DEQ for corrugated boxes did not separate transportation from mill to converter to order fulfillment center; thus, the cradle-to-production transportation data for corrugated boxes includes transportation to the order fulfillment center. Transportation of materials is described in detail in the report appendices.

Transportation data may appear to be "missing" for some other packaging components, namely dunnage manufactured at the order fulfillment center from on-site postconsumer office paper and corrugated. Because the material is acquired on-site, no transportation is required to produce the material (no cradle-to-production transportation data) nor to transport it to the order fulfillment center.

The location of the final cradle-to-production fabrication step raises some issues for some products, namely LDPE inflated air packets and dunnage produced at the order fulfillment center by shredding postconsumer office paper and corrugated recovered on-site**.** Filled LDPE air packets have an extremely low density so that it is not practical to inflate them off-site and transport them to an order fulfillment center; in effect, the delivery vehicle would be transporting air. Instead, LDPE resin is fabricated into tube stock, which is transported to the order fulfillment center where it is filled and sealed. For the purpose of grouping environmental data into cradle-to-production process data, cradle-to-production transportation data, and transportation to order fulfillment center, the LDPE air packet data are grouped as follows: All process and transportation steps through fabrication of tube stock are included in cradle-to-production data. Transportation to the order fulfillment center is transportation of rolls of uninflated tube stock. Since the cradle-to-production category does not specify where the final production step takes place (although it usually occurs at an off-site user), the energy used in filling and sealing of the air packets, which actually occurs at the order fulfillment center, is included in the cradle-to-production data. On-site shredding of postconsumer office paper and corrugated at the order fulfillment center to produce dunnage is likewise reported in cradle-to-production process data.

On the cradle-to-production tables, the "percent of total" **column** to the right of the "total" column shows the percentage of the total from each category (e.g., for energy, the percentages of process energy, energy of material resource, and transportation energy, or the percentage from each fuel source). The "percent of total" **row** under the "total" row show the percentage of the total from each life cycle stage (e.g., from cradle-to-production process and cradle-to-production transportation).

With the exception of corrugated boxes, which are modeled as containing either 38 percent or 80 percent postconsumer material, modules presented in this chapter are for either virgin or 100% recycled material. To model intermediate recycled contents, the virgin and 100% recycled material modules would be weighted according to the desired recycled content. For example, to model LDPE with 30% recycled content, the data set would be modeled as (0.3 x 100% recycled module) + (0.7 x virgin module).

In Chapter 3, the 1,000-pound modules presented in this chapter are multiplied by the appropriate weighting factors (shown in Table 2-1) and combined with transportation from the order fulfillment center to the customer to model scenarios with different material combinations and recycled contents, for the delivery of 10,000 packages to residential customers.

It is important to realize that, in the context of this LCI study, the 1,000-pound modules presented in this chapter do not serve as a meaningful stand-alone basis for comparing materials as used in packaging systems. It is necessary to multiply the modules by the weights of each material required for equivalent functional use in delivering packages, as is done in Chapter 3. However, the 1,000-pound modules presented in this chapter are useful for understanding the environmental profiles of various packaging materials.

Energy Results

The energy results are shown in Figure 2-1 and in different levels of detail in Tables 2-2 and 2-3. Cradle-to-production data for each material component in Table 2-2 is separated into process energy and transportation energy. The first set of energy results in Tables 2-2 and 2-3 shows the total energy separated into categories of process energy, energy of material resource, and transportation energy. The next two sections show process energy and energy of material resource (combined) and transportation energy broken out by the sources of energy. Table 2-3 has an additional line that shows an energy credit for the energy recovered from waste-to-energy incineration of 20 percent of the solid waste that is not diverted for reuse or recycling.

Based on the uncertainty in the energy data, energy differences between systems are not considered significant unless the percent difference between systems is greater than 10 percent. (Percent difference between systems is defined as the difference between energy totals divided by the average of the two system totals.) This minimum percent difference criterion was developed based on the experience and professional judgment of the analysts and supported by sample statistical calculations (see Chapter 4).

Energy by Category. In the first set of results in Table 2-2, the category of **process energy** includes totals for all processes (other than transportation) required to produce the packaging materials, from acquisition of raw materials through manufacture into packaging materials. **Transportation energy** is the energy used to move material from location to location during its journey from raw material to product. **Energy of material resource** is not an expended energy but the energy value of fuel resources withdrawn from the planet's finite fossil reserves and used as material inputs for materials such as plastic resins. Use of fuel resources as a material input is a depletion of fuel resources just as the combustion of fuels for energy. In this study, energy of material resource is reported for the plastic film components of the packaging systems. Natural gas and petroleum are the primary material feedstocks for resin production. No energy of material resource is assigned to wood used as a material input for paper(board) packaging components because wood's primary use in the United States is as a material input, not as a fuel resource. Wood combusted for energy (such as bark and black liquor burned for fuel in virgin pulp and paper mills) is counted as process energy.

Figure 2-1-BOX shows that process energy dominates total energy for most systems, although energy of material resource is significant for the virgin EPS loose fill and virgin LDPE air packets. The results for 100% postconsumer recycled plastic products does not show any energy of material resource because the methodology used in this study assigns all virgin material production burdens to the first system using the material. Since the 100% recycled system is the second use of the material, it bears only the burdens of collecting and reprocessing the postconsumer material and fabricating into the recycled product. Figure 2-1-BAG shows similar results. Again, process energy dominates except for the virgin plastic components, which have a high energy of material resource.

The transportation energy shown in Table 2-2 and Figure 2-1 includes all transportation steps from material acquisition (raw material extraction for virgin materials or collection of postconsumer paper or plastic for recycled products) up through material production. Table 2-2-BOX shows that transportation energy per 1,000 pounds of box or dunnage material is generally a small percentage of total cradle-to-production energy, even for corrugated boxes, where transportation to order fulfillment center is included, and for plastics, where petroleum and resin are transported greater distances than paper (see Appendix D in the separate Appendices document). Transportation energy is a higher percentage of the total for those systems that have low total energy requirements, such as cornstarch loose fill and dunnage made with recycled postconsumer material. There is no transportation energy for the shredded loose fill made from postconsumer office paper and corrugated recovered and produced at the order fulfillment center.

Figure 2-1-BOX. Cradle-to-Production Energy by Category for Boxes and Dunnage (Million Btu/1,000 lb)

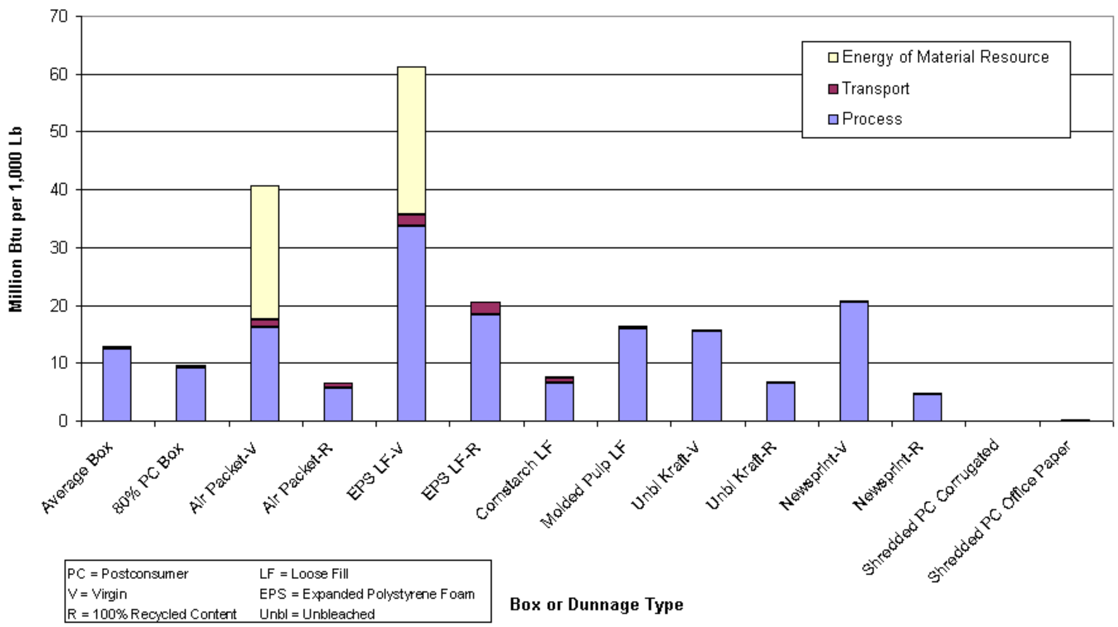
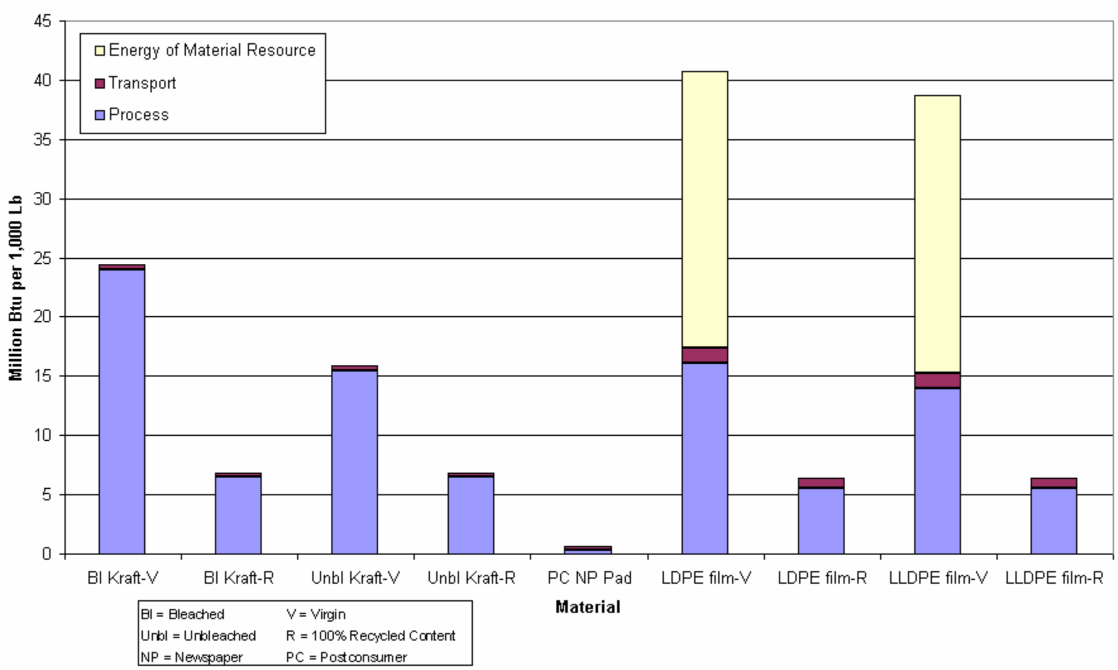


Figure 2-1-BAG. Cradle-to-Production Energy by Category for Shipping Bag Component Materials (Million Btu/1,000 lb)



In Table 2-2-BAG, transportation energy for all systems is less than 5 percent of the total cradle-to-production energy, except for 100% postconsumer plastics and macerated postconsumer newspaper padding for shipping bags. Because the recycled plastic systems bear none of the burdens of virgin resin production, transportation energy, while low, is a significant percentage of the total energy. Similarly, the transportation energy for macerated newspaper is low yet accounts for slightly more than half of the total energy requirements, since the process energy for shredding is very low.

In Table 2-3 (both -BOX and -BAG), the energy requirements for transportation of packaging materials to the order fulfillment center is less than one million Btu per 1,000 pounds for all packaging components except loose fill (EPS, cornstarch, and molded pulp shapes). These types of loose fill have a low density; thus, trucks hauling these materials fill by volume before they fill by weight, making transportation inefficient. Several truckloads may be required to haul the same weight of material that would fit in one weight-limited truckload.

Table 2-3 also shows that very little energy is required for disposal of packaging materials at end of life, after diversion for reuse or recycling. Disposal energy includes both transportation energy (for residential trash collection and transport to municipal landfill or incinerator) and process energy (for operation of landfill equipment).

Based on information obtained by Oregon DEQ from mail-order companies, an estimated 10 percent of mail-order packaging is reused by customers to return items to the order fulfillment center. Of the 90 percent remaining in the customer's home, it is estimated that 12 percent of corrugated boxes and 50 percent of loose fill are reused or recycled. For this study, it was assumed that molded pulp loose fill, while technically as reusable as other types of loose fill, is not likely to be reused because of its significantly different appearance from EPS and starch-based foam loose fill. (A detailed discussion of these diversion rates and the data sources used to develop them is provided in the report appendices.)

Table 2-3-BOX shows disposal results for all boxes and dunnage at 0 percent diversion and at the diversion rates assumed for this study. This allows the reader to compare the burdens for disposal of different dunnage materials on an equivalent basis (no diversion) as well as at the diversion rates assumed for this study. End-of-life results for shipping bags are all based on the same diversion rate, so they can be compared on an equivalent diversion basis in Table 2-3-BAG.

For the purposes of separating cradle-to-production energy into process energy and transportation energy, the logical place to put energy of material resource is with process energy. The "% of total" row in Table 2-2 shows that cradle-to-production process energy (including energy of material resource) accounts for the majority of the total cradle-to-production energy, at least 87 percent of the total for all boxes, dunnage, and bag component materials.

Energy Profiles. Table 2-2 (-BOX and –BAG) also shows the sources of cradle-to-production energy by fuel, including the fuels used to generate electricity. Precombustion energy (the energy used to extract and process fuels used for process energy and transportation energy) is included in the results shown in the table. The fossil fuels–natural gas, petroleum and coal–are used for direct combustion for process fuels and generation of electricity. Natural gas and petroleum use as raw material inputs for the production of plastics is reported as energy of material resource. Petroleum is the dominant energy source for transportation. Non-fossil sources, such as hydropower, nuclear and other (geothermal, wind, etc.) shown in the table are used to generate electricity along with the fossil fuels. Use of wood for energy occurs at integrated forest product manufacturing sites, particularly those that produce virgin pulp and paper.

Table 2-2 (-BOX and –BAG) shows that wood is a significant source of process energy only for corrugated boxes and virgin paper components. Integrated pulp and paper mills that produce virgin chemically pulped paper products use wood wastes and liquor from the pulping process to provide a significant part of their operating energy, while recycled paper mills generally do not have access to these materials and rely on fossil fuels for energy.

Otherwise, fossil fuels dominate the energy profiles, both the process/energy of material resource profile and the transportation profile. Natural gas and petroleum are used as directly combusted process and transportation fuels as well as in the generation of electricity. Natural gas and petroleum use reported for virgin plastic components also includes its use as energy of material resource. The use of coal, nuclear energy, and hydropower reflects their use in the generation of electricity.

In Table 2-3 (-BOX and –BAG), both transportation and disposal energy are dominated by petroleum, as these processes rely on trucks and earth-moving equipment at landfills.

Energy Credit. The energy results reported in Table 2-3 include energy recovered from the combustion of 20 percent of postconsumer packaging that is discarded after diversion for reuse and recycling, based on the national average percentage of municipal solid waste (MSW) that is disposed by waste-to-energy (WTE) combustion[13]. Two energy credit values are shown. The gross energy credit is calculated based on the pounds of each material burned multiplied by the higher heating value of the material. The usable energy credit is based on the gross energy adjusted for an estimated 33 percent thermal efficiency for generation of electricity from WTE combustion of MSW and transmission losses of about 8 percent.

As can be expected, the energy credit per 1,000 pounds disposed is highest for those materials with energy of material resource, that is, materials produced using fuel resources as raw materials.

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13 **Municipal Solid Waste in the United States: 2001 Facts and Figures.** U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response. August 2003.

Solid Waste

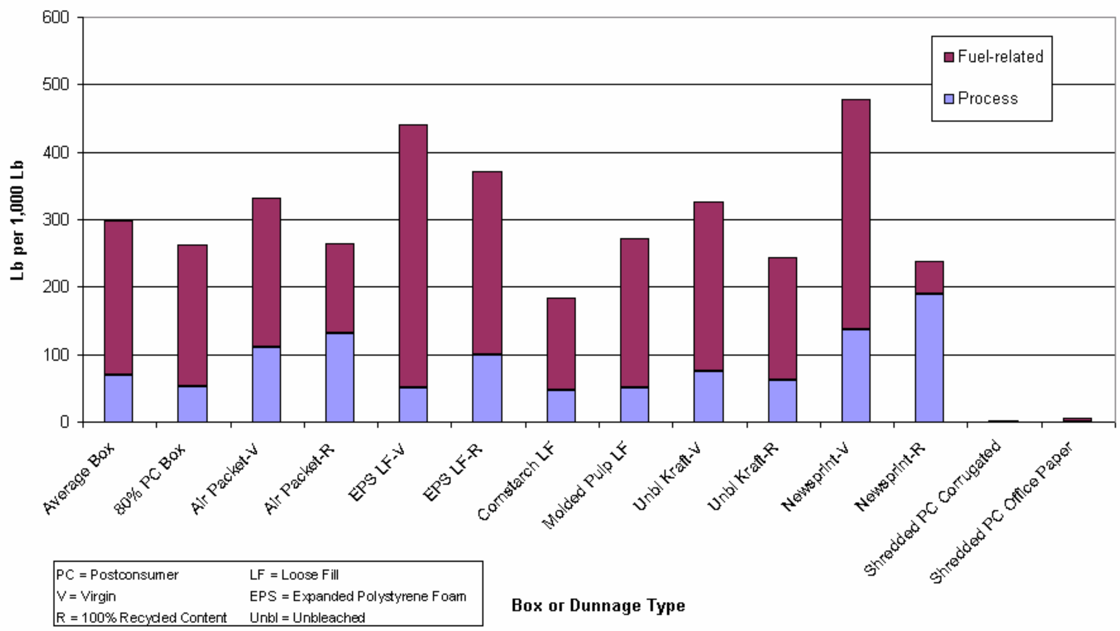
Solid waste is shown in Figure 2-2 and Table 2-4 and 2-5. Solid waste is broadly categorized into process wastes, fuel-related wastes, and postconsumer wastes. **Process wastes** reported in Table 2-4 are the solid wastes generated by the various processes from raw material acquisition through material manufacture. (No process wastes are reported in Table 2-5, since the transportation and disposal steps involve only operation of trucks and landfill equipment.) **Fuel-related wastes** are the wastes from the production and combustion of fuels used for process energy and transportation energy (e.g., ash from combustion of coal). **Postconsumer wastes** are the wastes discarded by the end users of the product after diversion for reuse and recycling, i.e., the boxes, dunnage, and shipping bags that are discarded by the soft goods mail-order residential customer. Waste materials that are left on-site or diverted from landfill and returned to the land without treatment (e.g., cornstalks returned to the field or forest residues left in the forest to decompose) are not reported as wastes. As with energy results, cradle-to-product results in Table 2-4 are separated into process and transportation, with "percent of total" columns showing the contribution of each solid waste category to solid waste, and "percent of total" rows showing the relative contributions of process and transportation wastes.

It is helpful to understand how the results for solid waste by category in Table 2-4 relate to the results for energy by category in Table 2-2. Cradle-to-production process solid wastes include not only solid waste generated from the processes themselves, but also solid wastes from the production and combustion of process fuels. Thus, the fuel-related solid waste shown in the cradle-to-production process column in Table 2-4 is the solid waste associated with the process energy shown in the cradle-to-production process column in Table 2-2.

Solid Waste by Weight. Table 2-4 shows solid waste by weight and by volume for production of the materials used in the packaging systems. Table 2-5 shows solid waste by weight and by volume for transportation of materials to the order fulfillment center and end-of-life disposal. Results by category are shown graphically in Figure 2-2. Differences in solid waste results between systems are not considered significant unless the percent difference is greater than 25 percent for process and fuel-related wastes, or greater than 10 percent for postconsumer wastes. (Percent difference between systems is defined as the difference between solid waste totals divided by the average of the two system totals.) This minimum percent difference criterion was developed based on the experience and professional judgment of the analysts and supported by sample statistical calculations (see Chapter 4).

In Table 2-4-BOX, fuel-related waste accounts for 77 to 80 percent of the total solid waste for corrugated boxes. The remainder of the solid waste is process waste. For dunnage options, fuel-related waste also accounts for 65 percent or more of cradle-to-production solid waste for most materials. Exceptions are recycled LDPE air packets (50 percent fuel-related) and recycled newsprint (20 percent). The process waste percentages for these materials are higher because the material losses in collection and processing of postconsumer materials are higher compared to the relatively low fuel-related wastes from process energy and transportation requirements.

Figure 2-2-BOX. Cradle-to-Production Solid Waste by Category for Boxes and Dunnage
(lb of waste/1,000 lb of packaging material)



In Table 2-4-BAG, the same general observations are true for shipping bag component materials. Fuel-related solid waste is 63 percent or more of the total cradle-to-production solid waste for all bag materials except recycled LDPE and LLDPE films (both 52 percent fuel-related). Again, this is because the process solid wastes from collection and processing of postconsumer material are high relative to the fuel-related wastes for the low process energy and transportation requirements.

The first column of Table 2-4 also shows that cradle-to-production process solid waste accounts for nearly 100 percent of the total cradle-to-production solid waste for all boxes, dunnage, and bag materials.

Table 2-5 (-BOX and -BAG) shows that fuel-related wastes for transportation of materials to the order fulfillment center are generally less than 3 pounds per 1,000 pounds of material. Transportation solid waste is highest for cornstarch foam loose fill and EPS foam loose fill, which have the lowest densities, resulting in less efficient volume-limited shipping.

Figure 2-2-BAG. Cradle-to-Production Solid Waste by Category for Shipping Bag Component Materials (lb of waste/1,000 lb of packaging material)

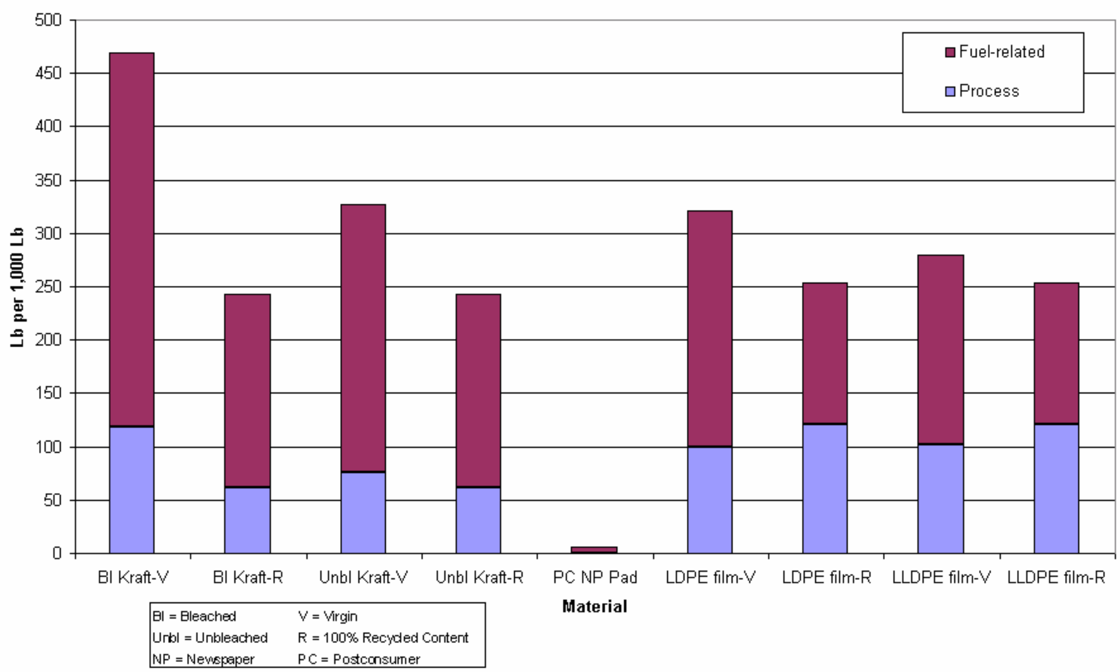


Table 2-5 also shows that postconsumer solid waste, the waste discarded by mail-order customers after diversion of packaging for reuse and recycling, dominates disposal solid wastes. Table 2-5-BOX shows disposal solid waste results at 0 percent diversion, so that dunnages can be compared on an equivalent basis, and at the diversion rates modeled for this study. Table 2-5-BAG shows all shipping bags at the same 10 percent diversion rate, which is the diversion rate modeled for this study. Because the rate is the same for all bags, it is not necessary to show results at 0 percent diversion for equivalent comparison of bags.

Solid Waste by Volume. Landfills fill up because of volume, not weight. While weight is the conventional measure of waste, landfill volume is more relevant to the environmental concerns of land use. The problem is the difficulty in deriving accurate landfill volume factors. However, Franklin Associates has developed a set of landfill density factors for different materials based upon an extensive sampling by the University of Arizona. While these factors are considered to be only estimates, their use helps add valuable perspective. Volume factors are estimated to be accurate to +/- 25%. This means that waste volume values must differ by at least 25 percent in order to be interpreted as a significant difference. (Percent difference is defined as the difference between two system totals divided by their average.) This minimum percent difference criterion was developed based on the experience and professional judgment of the analysts and supported by sample statistical calculations (see Chapter 4).

In Tables 2-4 and 2-5, weights of solid waste are converted into volumes using landfill density factors. Process and fuel-related solid waste are generally reported as totals without detail on the composition and densities of individual substances within these categories; thus, the weights of process and fuel-related waste are converted to volume using an average conversion factor for industrial solid waste. As a result, the analysis of solid waste results in Table 2-4 are the same by volume as they are by weight. The same is true for fuel-related solid waste data for transportation of materials to the order fulfillment center. The weight to volume conversions for postconsumer solid waste, however, are based on the landfill densities for materials from the University of Arizona studies and reflect the volumes that specific materials are likely to take up in a landfill. As would be expected, the lower density materials such as loose fill occupy more landfill space relative to equivalent quantities of higher density materials.

Environmental Emissions

Atmospheric and waterborne emissions for each system include emissions from processes and those associated with the combustion of fuels. Tables 2-6 and 2-7 present atmospheric emissions results and Tables 2-8 and 2-9 show waterborne emissions for the 1,000-pound modules.

The emissions tables in this section present emission quantities based upon the best data available. However, some of the data are reported from industrial sources, some are from standard emissions tables, and some have been calculated. This means there are significant uncertainties with regards to the application of the data to these particular packaging systems. Because of these uncertainties, two systems' emissions of a given substance are not considered significantly different unless the percent difference exceeds 25 percent. (Percent difference is defined as the difference between two system totals divided by their average.) This minimum percent difference criterion was developed based on the experience and professional judgment of the analysts and supported by sample statistical calculations (see Chapter 4).

Substances are reported in the tables in speciated or unspeciated form, depending on the compositional information available. General categories such as "Acid" and "Metal Ion" are used to report unspeciated data. Emissions are reported only in the most descriptive single category applicable; speciated data are not reported again in the broadly applicable unspeciated category. For example, emissions reported as "HCl" are not additionally reported under the category "Acid," nor are emissions reported as "Chromium" additionally reported under "Metal Ion."

It is important to realize that interpretation of air and water emission data requires great care. The effects of the various emissions on humans and on the environment are not fully known. The degree of potential environmental disruption due to environmental releases is not related to the weight of the releases in a simple way. Research on this evaluation problem is ongoing, but no valid impact assessment methodology currently exists for a life cycle study.

Atmospheric Emissions. Atmospheric emissions results are shown in Table 2-6 for cradle-to-production of each packaging material and in Table 2-7 for transportation of the packaging to the order fulfillment center and end-of-life disposal. This analysis does not include emissions from the combustion of 20 percent of packaging components discarded after diversion for reuse and recycling. No data are available on combustion emissions for individual materials burned with mixed municipal solid waste. As a result, the carbon dioxide emissions, as well as other products of incomplete combustion, are understated by an unknown amount.

It is not practical to attempt to discuss all the atmospheric emission categories listed in Table 2-6 and 2-7 (over 40 different substances listed for more than 20 packaging materials); therefore, the following discussion focuses on the high priority atmospheric issue of greenhouse gas emissions. The primary three atmospheric emissions reported in this analysis that contribute to global warming are fossil carbon dioxide, methane, and nitrous oxide. (Non-fossil carbon dioxide emissions, such as those from the burning of wood, are considered part of the natural carbon cycle and are not considered a net contributor to global warming.) The 100-year global warming potential for each of these substances as reported in the International Panel on Climate Change (IPCC) 2001 report are: carbon dioxide 1, methane 23, and nitrous oxide 296. The global warming potential represents the relative global warming contribution of a pound of a particular greenhouse gas compared to a pound of carbon dioxide. The weights of each of these substances in the top section of Tables 2-6 and 2-7 are multiplied by their global warming potential and totaled in the GHG (greenhouse gas) section at the bottom of the tables.

Greenhouse gas totals for different materials and different life cycle stages vary widely, based largely on their material compositions and transportation profiles. Materials produced using fossil fuels as raw materials or as process fuels have higher GHG profiles than materials that use non-fossil resources for raw materials or process energy. The longer the transportation distance, the higher the GHG emissions from the combustion of fossil fuels for transportation. Materials with low densities and volume-limited transportation have higher GHG emissions per 1,000 pounds compared to denser materials that can be shipped compactly with efficient use of vehicle cargo space.

Waterborne Emissions. Waterborne emissions results are shown in Table 2-8 for cradle-to-production of each packaging material and in Table 2-9 for order fulfillment center transportation and end-of-life disposal. With over 40 different waterborne emissions listed for over 20 packaging materials, it is not practical to attempt to discuss individual emissions results for individual packaging materials. Detailed results are presented here for the reader to examine and use to draw conclusions for specific materials of interest to the reader.

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Table 2-2-BOX
ENERGY RESULTS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Average (38%) PC Corrugated Box				**80% PC Corrugated Box**				**LDPE Inflated Air Packets Virgin**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Energy (MM Btu/1,000 lb)												
By Type												
Process	12.5		**12.5**	97.6%	9.29		**9.29**	96.7%	16.1		**16.1**	39.6%
Transport		0.31	**0.31**	2.4%		0.31	**0.31**	3.2%		1.29	**1.29**	3.2%
Energy of Material Resource	0.0067		**0.0067**	0.1%	0.0053		**0.0053**	0.1%	23.3		**23.3**	57.3%
Total	**12.5**	**0.31**	**12.8**	**100.0%**	**9.30**	**0.31**	**9.60**	**100.0%**	**39.4**	**1.29**	**40.7**	**100.0%**
% of Total	97.6%	2.4%	**100.0%**		96.8%	3.2%	**100.0%**		96.8%	3.2%	**100.0%**	
By Source - Process + EMR												
Nat. Gas	1.95		**1.95**	15.6%	1.84		**1.84**	19.8%	27.6		**27.6**	70.1%
Petroleum	0.36		**0.36**	2.8%	0.31		**0.31**	3.3%	5.74		**5.74**	14.6%
Coal	3.99		**3.99**	31.9%	4.41		**4.41**	47.5%	4.05		**4.05**	10.3%
Hydropower	0.13		**0.13**	1.0%	0.11		**0.11**	1.2%	0.25		**0.25**	0.6%
Nuclear	0.59		**0.59**	4.7%	0.68		**0.68**	7.3%	1.53		**1.53**	3.9%
Wood	5.40		**5.40**	43.2%	1.85		**1.85**	19.9%	0		**0**	0.0%
Other	0.080		**0.080**	0.6%	0.093		**0.093**	1.0%	0.21		**0.21**	0.5%
Total	**12.5**		**12.5**	**100.0%**	**9.30**		**9.30**	**100.0%**	**39.4**		**39.4**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Source - Transp												
Nat. Gas		0.020	**0.020**	6.6%		0.020	**0.020**	6.6%		0.22	**0.22**	17.0%
Petroleum		0.28	**0.28**	92.1%		0.28	**0.28**	92.1%		1.03	**1.03**	80.1%
Coal		0.0026	**0.0026**	0.9%		0.0026	**0.0026**	0.9%		0.026	**0.026**	2.0%
Hydropower		1.6E-04	**1.6E-04**	0.1%		1.6E-04	**1.6E-04**	0.1%		0.0016	**0.0016**	0.1%
Nuclear		0.0010	**0.0010**	0.3%		0.0010	**0.0010**	0.3%		0.0097	**0.0097**	0.8%
Wood			**0**	0.0%			**0**	0.0%			**0**	0.0%
Other		1.4E-04	**1.4E-04**	0.0%		1.5E-04	**1.5E-04**	0.0%		0.0013	**0.0013**	0.1%
Total		**0.31**	**0.31**	**100.0%**		**0.31**	**0.31**	**100.0%**		**1.29**	**1.29**	**100.0%**
% of Total	0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**	

Table 2-2-BOX
ENERGY RESULTS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	LDPE Inflated Air Packets 100% PC Recycled Content				EPS Loose Fill Virgin				EPS Loose Fill 100% PC Recycled Content			
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total
Energy (MM Btu/1,000 lb)												
By Type												
Process	5.64		**5.64**	87.4%	33.6		**33.6**	55.0%	18.3		**18.3**	88.5%
Transport		0.81	**0.81**	12.6%		2.02	**2.02**	3.3%		2.38	**2.38**	11.5%
Energy of Material Resource	0		**0**	0.0%	25.5		**25.5**	41.7%	0		**0**	0.0%
Total	**5.64**	**0.81**	**6.45**	**100.0%**	**59.1**	**2.02**	**61.2**	**100.0%**	**18.3**	**2.38**	**20.7**	**100.0%**
% of Total	87.4%	12.6%	**100.0%**		96.7%	3.3%	**100.0%**		88.5%	11.5%	**100.0%**	
By Source - Process + EMR												
Nat. Gas	1.00		**1.00**	17.7%	28.1		**28.1**	47.5%	10.2		**10.2**	56.0%
Petroleum	0.23		**0.23**	4.0%	21.4		**21.4**	36.2%	0.47		**0.47**	2.6%
Coal	2.96		**2.96**	52.5%	6.46		**6.46**	10.9%	5.08		**5.08**	27.8%
Hydropower	0.18		**0.18**	3.2%	0.39		**0.39**	0.7%	0.31		**0.31**	1.7%
Nuclear	1.12		**1.12**	19.9%	2.45		**2.45**	4.1%	1.93		**1.93**	10.5%
Wood	0		**0**	0.0%	0		**0**	0.0%	0		**0**	0.0%
Other	0.15		**0.15**	2.7%	0.33		**0.33**	0.6%	0.26		**0.26**	1.4%
Total	**5.64**		**5.64**	**100.0%**	**59.1**		**59.1**	**100.0%**	**18.3**		**18.3**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Source - Transp												
Nat. Gas		0.054	**0.054**	6.6%		0.19	**0.19**	9.2%		0.16	**0.16**	6.6%
Petroleum		0.75	**0.75**	92.1%		1.74	**1.74**	86.2%		2.20	**2.20**	92.1%
Coal		0.0070	**0.0070**	0.9%		0.062	**0.062**	3.1%		0.020	**0.020**	0.9%
Hydropower		4.3E-04	**4.3E-04**	0.1%		0.0038	**0.0038**	0.2%		0.0013	**0.0013**	0.1%
Nuclear		0.0027	**0.0027**	0.3%		0.024	**0.024**	1.2%		0.0078	**0.0078**	0.3%
Wood			**0**	0.0%			**0**	0.0%			**0**	0.0%
Other		3.8E-04	**3.8E-04**	0.0%		0.0032	**0.0032**	0.2%		0.0011	**0.0011**	0.0%
Total		**0.81**	**0.81**	**100.0%**		**2.02**	**2.02**	**100.0%**		**2.38**	**2.38**	**100.0%**
% of Total	0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**	

Table 2-2-BOX
ENERGY RESULTS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Cornstarch Loose Fill				Molded Pulp Loose Fill 100% PC Recycled Content				Unbleached Kraft Paper Virgin			
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total
Energy (MM Btu/1,000 lb)												
By Type												
Process	6.55		**6.55**	86.0%	16.0		**16.0**	98.0%	15.4		**15.4**	98.0%
Transport		0.83	**0.83**	10.9%		0.33	**0.33**	2.0%		0.31	**0.31**	2.0%
Energy of Material Resource	0.23		**0.23**	3.1%	0		**0**	0.0%	0.0045		**0.0045**	0.0%
Total	**6.78**	**0.83**	**7.61**	**100.0%**	**16.0**	**0.33**	**16.3**	**100.0%**	**15.4**	**0.31**	**15.7**	**100.0%**
% of Total	89.1%	10.9%	**100.0%**		98.0%	2.0%	**100.0%**		98.0%	2.0%	**100.0%**	
By Source - Process + EMR												
Nat. Gas	1.96		**1.96**	29.0%	9.55		**9.55**	59.7%	1.60		**1.60**	10.4%
Petroleum	0.43		**0.43**	6.4%	0.41		**0.41**	2.6%	0.45		**0.45**	2.9%
Coal	3.00		**3.00**	44.3%	4.04		**4.04**	25.3%	3.69		**3.69**	23.9%
Hydropower	0.17		**0.17**	2.5%	0.25		**0.25**	1.5%	0.038		**0.038**	0.2%
Nuclear	1.07		**1.07**	15.7%	1.53		**1.53**	9.6%	0.24		**0.24**	1.5%
Wood	0		**0**	0.0%	0		**0**	0.0%	9.39		**9.39**	60.8%
Other	0.14		**0.14**	2.1%	0.21		**0.21**	1.3%	0.032		**0.032**	0.2%
Total	**6.78**		**6.78**	**100.0%**	**16.0**		**16.0**	**100.0%**	**15.4**		**15.4**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Source - Transp												
Nat. Gas		0.057	**0.057**	6.8%		0.022	**0.022**	6.6%		0.021	**0.021**	6.6%
Petroleum		0.76	**0.76**	91.9%		0.30	**0.30**	92.1%		0.29	**0.29**	92.1%
Coal		0.0072	**0.0072**	0.9%		0.0028	**0.0028**	0.9%		0.0027	**0.0027**	0.9%
Hydropower		4.5E-04	**4.5E-04**	0.1%		1.8E-04	**1.8E-04**	0.1%		1.7E-04	**1.7E-04**	0.1%
Nuclear		0.0027	**0.0027**	0.3%		0.0011	**0.0011**	0.3%		0.0010	**0.0010**	0.3%
Wood			**0**	0.0%			**0**	0.0%			**0**	0.0%
Other		3.9E-04	**3.9E-04**	0.0%		1.6E-04	**1.6E-04**	0.0%		1.5E-04	**1.5E-04**	0.0%
Total		**0.83**	**0.83**	**100.0%**		**0.33**	**0.33**	**100.0%**		**0.31**	**0.31**	**100.0%**
% of Total	0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**	

Table 2-2-BOX
ENERGY RESULTS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Unbleached Kraft Paper 100% PC Recycled Content				**Newsprint 100% PC Recycled Content**				**Newsprint Virgin**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Energy (MM Btu/1,000 lb)												
By Type												
Process	6.55		**6.55**	95.4%	4.68		**4.68**	95.8%	20.6		**20.6**	98.8%
Transport		0.32	**0.32**	4.6%		0.20	**0.20**	4.2%		0.25	**0.25**	1.2%
Energy of Material Resource	0		**0**	0.0%	0		**0**	0.0%	0		**0**	0.0%
Total	**6.55**	**0.32**	**6.87**	**100.0%**	**4.68**	**0.20**	**4.88**	**100.0%**	**20.6**	**0.25**	**20.8**	**100.0%**
% of Total	95.4%	4.6%	**100.0%**		95.8%	4.2%	**100.0%**		98.8%	1.2%	**100.0%**	
By Source - Process + EMR												
Nat. Gas	1.19		**1.19**	18.1%	3.48		**3.48**	74.4%	8.33		**8.33**	40.5%
Petroleum	0.25		**0.25**	3.8%	0.12		**0.12**	2.5%	0.77		**0.77**	3.8%
Coal	4.24		**4.24**	64.7%	0.72		**0.72**	15.5%	6.57		**6.57**	32.0%
Hydropower	0.11		**0.11**	1.7%	0.044		**0.044**	0.9%	0.39		**0.39**	1.9%
Nuclear	0.68		**0.68**	10.3%	0.27		**0.27**	5.9%	2.41		**2.41**	11.7%
Wood	0		**0**	0.0%	0		**0**	0.0%	1.76		**1.76**	8.5%
Other	0.092		**0.092**	1.4%	0.037		**0.037**	0.8%	0.33		**0.33**	1.6%
Total	**6.55**		**6.55**	**100.0%**	**4.68**		**4.68**	**100.0%**	**20.6**		**20.6**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Source - Transp												
Nat. Gas		0.021	**0.021**	6.6%		0.013	**0.013**	6.6%		0.016	**0.016**	6.6%
Petroleum		0.29	**0.29**	92.1%		0.19	**0.19**	92.1%		0.23	**0.23**	92.1%
Coal		0.0027	**0.0027**	0.9%		0.0017	**0.0017**	0.9%		0.0021	**0.0021**	0.9%
Hydropower		1.7E-04	**1.7E-04**	0.1%		1.1E-04	**1.1E-04**	0.1%		1.3E-04	**1.3E-04**	0.1%
Nuclear		0.0010	**0.0010**	0.3%		6.7E-04	**6.7E-04**	0.3%		8.1E-04	**8.1E-04**	0.3%
Wood			**0**	0.0%			**0**	0.0%			**0**	0.0%
Other		1.5E-04	**1.5E-04**	0.0%		9.6E-05	**9.6E-05**	0.0%		1.2E-04	**1.2E-04**	0.0%
Total		**0.32**	**0.32**	**100.0%**		**0.20**	**0.20**	**100.0%**		**0.25**	**0.25**	**100.0%**
% of Total	0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**	

Table 2-2-BOX
ENERGY RESULTS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Shredded PC Corrugated Dunnage				Shredded PC Office Paper Dunnage			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Energy (MM Btu/1,000 lb)								
By Type								
Process	0.080		**0.080**	100.0%	0.25		**0.25**	100.0%
Transport		0	**0**	0.0%		0	**0**	0.0%
Energy of Material Resource	0		**0**	0.0%	0		**0**	0.0%
Total	**0.080**	**0**	**0.080**	**100.0%**	**0.25**	**0**	**0.25**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	0.014		**0.014**	17.1%	0.043		**0.043**	17.1%
Petroleum	0.0031		**0.0031**	3.8%	0.0096		**0.0096**	3.8%
Coal	0.042		**0.042**	53.0%	0.13		**0.13**	53.0%
Hydropower	0.0026		**0.0026**	3.2%	0.0081		**0.0081**	3.2%
Nuclear	0.016		**0.016**	20.1%	0.050		**0.050**	20.1%
Wood	0		**0**	0.0%	0		**0**	0.0%
Other	0.0022		**0.0022**	2.7%	0.0068		**0.0068**	2.7%
Total	**0.080**		**0.080**	**100.0%**	**0.25**		**0.25**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas		0	**0**			0	**0**	
Petroleum		0	**0**			0	**0**	
Coal		0	**0**			0	**0**	
Hydropower		0	**0**			0	**0**	
Nuclear		0	**0**			0	**0**	
Wood			**0**				**0**	
Other		0	**0**			0	**0**	
Total		**0**	**0**			**0**	**0**	
% of Total								

Table 2-2-BAG

ENERGY RESULTS FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	Bleached Kraft Virgin				**Bleached Kraft 100% PC Recycled Content**				**Unbleached Kraft Virgin**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Energy (MM Btu/1,000 lb)												
By Type												
Process	24.0		**24.0**	98.2%	6.55		**6.55**	95.4%	15.4		**15.4**	97.1%
Transport		0.44	**0.44**	1.8%		0.32	**0.32**	4.6%		0.46	**0.46**	2.9%
Energy of Material Resource	0.0070		**0.0070**	0.0%	0		**0**	0.0%	0.0045		**0.0045**	0.0%
Total	**24.0**	**0.44**	**24.4**	**100.0%**	**6.55**	**0.32**	**6.87**	**100.0%**	**15.4**	**0.46**	**15.9**	**100.0%**
% of Total	98.2%	1.8%	**100.0%**		95.4%	4.6%	**100.0%**		97.1%	2.9%	**100.0%**	
By Source - Process + EMR												
Nat. Gas	3.33		**3.33**	13.9%	1.19		**1.19**	18.1%	1.60		**1.60**	10.4%
Petroleum	3.34		**3.34**	13.9%	0.25		**0.25**	3.8%	0.45		**0.45**	2.9%
Coal	5.48		**5.48**	22.8%	4.24		**4.24**	64.7%	3.69		**3.69**	23.9%
Hydropower	0.16		**0.16**	0.7%	0.11		**0.11**	1.7%	0.038		**0.038**	0.2%
Nuclear	1.01		**1.01**	4.2%	0.68		**0.68**	10.3%	0.24		**0.24**	1.5%
Wood	10.5		**10.5**	43.9%	0		**0**	0.0%	9.39		**9.39**	60.8%
Other	0.14		**0.14**	0.6%	0.092		**0.092**	1.4%	0.032		**0.032**	0.2%
Total	**24.0**		**24.0**	**100.0%**	**6.55**		**6.55**	**100.0%**	**15.4**		**15.4**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Source - Transp												
Nat. Gas		0.029	**0.029**	6.6%		0.021	**0.021**	6.6%		0.030	**0.030**	6.6%
Petroleum		0.41	**0.41**	92.1%		0.29	**0.29**	92.1%		0.42	**0.42**	92.1%
Coal		0.0038	**0.0038**	0.9%		0.0027	**0.0027**	0.9%		0.0040	**0.0040**	0.9%
Hydropower		2.3E-04	**2.3E-04**	0.1%		1.7E-04	**1.7E-04**	0.1%		2.5E-04	**2.5E-04**	0.1%
Nuclear		0.0014	**0.0014**	0.3%		0.0010	**0.0010**	0.3%		0.0015	**0.0015**	0.3%
Wood			**0**	0.0%			**0**	0.0%			**0**	0.0%
Other		2.1E-04	**2.1E-04**	0.0%		1.5E-04	**1.5E-04**	0.0%		2.2E-04	**2.2E-04**	0.0%
Total		**0.44**	**0.44**	**100.0%**		**0.32**	**0.32**	**100.0%**		**0.46**	**0.46**	**100.0%**
% of Total	0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**	

Table 2-2-BAG

ENERGY RESULTS FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	Unbleached Kraft 100% PC Recycled Content				Macerated 100% PC Newspaper Padding				LDPE Film Virgin			
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total
Energy (MM Btu/1,000 lb)												
By Type												
Process	6.55		**6.55**	95.4%	0.28		**0.28**	47.5%	16.1		**16.1**	39.5%
Transport		0.32	**0.32**	4.6%		0.31	**0.31**	52.5%		1.33	**1.33**	3.3%
Energy of Material Resource	0		**0**	0.0%	0		**0**	0.0%	23.3		**23.3**	57.3%
Total	**6.55**	**0.32**	**6.87**	**100.0%**	**0.28**	**0.31**	**0.60**	**100.0%**	**39.4**	**1.33**	**40.7**	**100.0%**
% of Total	95.4%	4.6%	**100.0%**		47.5%	52.5%	**100.0%**		96.7%	3.3%	**100.0%**	
By Source - Process + EMR												
Nat. Gas	1.19		**1.19**	18.1%	0.046		**0.046**	16.3%	27.6		**27.6**	70.2%
Petroleum	0.25		**0.25**	3.8%	0.030		**0.030**	10.7%	5.73		**5.73**	14.6%
Coal	4.24		**4.24**	64.7%	0.14		**0.14**	48.9%	4.02		**4.02**	10.2%
Hydropower	0.11		**0.11**	1.7%	0.0084		**0.0084**	3.0%	0.24		**0.24**	0.6%
Nuclear	0.68		**0.68**	10.3%	0.053		**0.053**	18.6%	1.52		**1.52**	3.9%
Wood	0		**0**	0.0%	0		**0**	0.0%	0		**0**	0.0%
Other	0.092		**0.092**	1.4%	0.0071		**0.0071**	2.5%	0.21		**0.21**	0.5%
Total	**6.55**		**6.55**	**100.0%**	**0.28**		**0.28**	**100.0%**	**39.4**		**39.4**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Source - Transp												
Nat. Gas		0.021	**0.021**	6.6%		0.021	**0.021**	6.6%		0.22	**0.22**	16.7%
Petroleum		0.29	**0.29**	92.1%		0.29	**0.29**	92.1%		1.07	**1.07**	80.4%
Coal		0.0027	**0.0027**	0.9%		0.0027	**0.0027**	0.9%		0.026	**0.026**	2.0%
Hydropower		1.7E-04	**1.7E-04**	0.1%		1.7E-04	**1.7E-04**	0.1%		0.0016	**0.0016**	0.1%
Nuclear		0.0010	**0.0010**	0.3%		0.0010	**0.0010**	0.3%		0.0098	**0.0098**	0.7%
Wood			**0**	0.0%			**0**	0.0%			**0**	0.0%
Other		1.5E-04	**1.5E-04**	0.0%		1.5E-04	**1.5E-04**	0.0%		0.0014	**0.0014**	0.1%
Total		**0.32**	**0.32**	**100.0%**		**0.31**	**0.31**	**100.0%**		**1.33**	**1.33**	**100.0%**
% of Total	0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**		0.0%	100.0%	**100.0%**	

Table 2-2-BAG

ENERGY RESULTS FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	LDPE Film 100% PC Recycled Content				LLDPE Film Virgin				LLDPE Film 100% PC Recycled Content			
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total
Energy (MM Btu/1,000 lb)												
By Type												
Process	5.59		5.59	87.3%	13.9		13.9	36.1%	5.59		5.59	87.3%
Transport		0.81	0.81	12.7%		1.32	1.32	3.4%		0.81	0.81	12.7%
Energy of Material Resource	0		0	0.0%	23.4		23.4	60.5%	0		0	0.0%
Total	5.59	0.81	6.40	100.0%	37.4	1.32	38.7	100.0%	5.59	0.81	6.40	100.0%
% of Total	87.3%	12.7%	100.0%		96.6%	3.4%	100.0%		87.3%	12.7%	100.0%	
By Source - Process + EMR												
Nat. Gas	0.99		0.99	17.7%	27.1		27.1	72.6%	0.99		0.99	17.7%
Petroleum	0.22		0.22	4.0%	5.69		5.69	15.2%	0.22		0.22	4.0%
Coal	2.93		2.93	52.5%	3.06		3.06	8.2%	2.93		2.93	52.5%
Hydropower	0.18		0.18	3.2%	0.19		0.19	0.5%	0.18		0.18	3.2%
Nuclear	1.11		1.11	19.9%	1.16		1.16	3.1%	1.11		1.11	19.9%
Wood	0		0	0.0%	0		0	0.0%	0		0	0.0%
Other	0.15		0.15	2.7%	0.16		0.16	0.4%	0.15		0.15	2.7%
Total	5.59		5.59	100.0%	37.4		37.4	100.0%	5.59		5.59	100.0%
% of Total	100.0%	0.0%	100.0%		100.0%	0.0%	100.0%		100.0%	0.0%	100.0%	
By Source - Transp												
Nat. Gas		0.054	0.054	6.6%		0.22	0.22	16.7%		0.054	0.054	6.6%
Petroleum		0.75	0.75	92.1%		1.06	1.06	80.7%		0.75	0.75	92.1%
Coal		0.0070	0.0070	0.9%		0.022	0.022	1.7%		0.0070	0.0070	0.9%
Hydropower		4.3E-04	4.3E-04	0.1%		0.0014	0.0014	0.1%		4.3E-04	4.3E-04	0.1%
Nuclear		0.0027	0.0027	0.3%		0.0085	0.0085	0.6%		0.0027	0.0027	0.3%
Wood			0	0.0%			0	0.0%			0	0.0%
Other		3.8E-04	3.8E-04	0.0%		0.0012	0.0012	0.1%		3.8E-04	3.8E-04	0.0%
Total		0.81	0.81	100.0%		1.32	1.32	100.0%		0.81	0.81	100.0%
% of Total	0.0%	100.0%	100.0%		0.0%	100.0%	100.0%		0.0%	100.0%	100.0%	

Table 2-3-BOX

ENERGY RESULTS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Average (38%) PC Corrugated Box			**80% PC Corrugated Box**			**LDPE Inflated Air Packets Virgin**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	20.8		0	20.8		0	10
Energy (MM Btu/1,000 lb)									
By Type									
Process	0	0.032	0.025	0	0.032	0.025	0	0.035	0.032
Transport	0	0.13	0.11	0	0.13	0.11	0.88	0.15	0.14
Energy of Material Resource	0	0	0	0	0	0	0	0	0
Total	**0**	**0.17**	**0.13**	**0**	**0.17**	**0.13**	**0.88**	**0.19**	**0.17**
By Source - Process + EMR									
Nat. Gas		0.0021	0.0017		0.0021	0.0017		0.0023	0.0021
Petroleum		0.029	0.023		0.029	0.023		0.033	0.029
Coal		2.7E-04	2.1E-04		2.7E-04	2.1E-04		3.0E-04	2.7E-04
Hydropower		1.7E-05	1.3E-05		1.7E-05	1.3E-05		1.9E-05	1.7E-05
Nuclear		1.0E-04	8.2E-05		1.0E-04	8.2E-05		1.2E-04	1.0E-04
Wood		0	0		0	0		0	0
Other		1.5E-05	1.2E-05		1.5E-05	1.2E-05		1.7E-05	1.5E-05
Total		**0.032**	**0.025**		**0.032**	**0.025**		**0.035**	**0.032**
By Source - Transp									
Nat. Gas	0	0.0089	0.0070	0	0.0089	0.0070	0.058	0.0100	0.0090
Petroleum	0	0.124	0.098	0	0.124	0.098	0.81	0.14	0.13
Coal	0	1.2E-03	9.1E-04	0	1.2E-03	9.1E-04	0.0075	0.0013	0.0012
Hydropower	0	7.2E-05	5.7E-05	0	7.2E-05	5.7E-05	4.7E-04	8.0E-05	7.2E-05
Nuclear	0	4.4E-04	3.5E-04	0	4.4E-04	3.5E-04	0.0029	5.0E-04	4.5E-04
Wood		0	0		0	0		0	0
Other	0	6.4E-05	5.0E-05	0	6.4E-05	5.0E-05	4.1E-04	7.1E-05	6.4E-05
Total	**0**	**0.13**	**0.11**	**0**	**0.13**	**0.11**	**0.88**	**0.15**	**0.14**
to-Energy Incineration of 20% of MSW after Diversion (MM Btu/1,000 lb)	Gross	1.59	1.26	Gross	1.59	1.26	Gross	3.99	3.59
	Usable	0.49	0.38	Usable	0.49	0.38	Usable	1.22	1.10

Table 2-3-BOX

ENERGY RESULTS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	LDPE Inflated Air Packets 100% PC Recycled Content			EPS Loose Fill Virgin			EPS Loose Fill 100% PC Recycled Content		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	55		0	55
Energy (MM Btu/1,000 lb)									
By Type									
Process	0	0.035	0.032	0	0.099	0.044	0	0.099	0.044
Transport	0.88	0.15	0.14	3.08	0.41	0.18	6.27	0.41	0.18
Energy of Material Resource	0	0	0	0	0	0	0	0	0
Total	**0.88**	**0.19**	**0.17**	**3.08**	**0.51**	**0.23**	**6.27**	**0.51**	**0.23**
By Source - Process + EMR									
Nat. Gas		0.0023	0.0021		0.0065	0.0029		0.0065	0.0029
Petroleum		0.033	0.029		0.091	0.041		0.091	0.041
Coal		3.0E-04	2.7E-04		8.5E-04	3.8E-04		8.5E-04	3.8E-04
Hydropower		1.9E-05	1.7E-05		5.3E-05	2.4E-05		5.3E-05	2.4E-05
Nuclear		1.2E-04	1.0E-04		3.2E-04	1.5E-04		3.2E-04	1.5E-04
Wood		0	0		0	0		0	0
Other		1.7E-05	1.5E-05		4.7E-05	2.1E-05		4.7E-05	2.1E-05
Total		**0.035**	**0.032**		**0.099**	**0.044**		**0.099**	**0.044**
By Source - Transp									
Nat. Gas	0.058	0.0100	0.0090	0.20	0.027	0.012	0.41	0.027	0.012
Petroleum	0.81	0.14	0.13	2.83	0.38	0.17	5.78	0.38	0.17
Coal	0.0075	0.0013	0.0012	0.026	0.0035	0.0016	0.054	0.0035	0.0016
Hydropower	4.7E-04	8.0E-05	7.2E-05	0.0016	2.2E-04	9.8E-05	0.0033	2.2E-04	9.8E-05
Nuclear	0.0029	5.0E-04	4.5E-04	0.010	1.3E-03	6.1E-04	0.021	1.3E-03	6.1E-04
Wood		0	0		0	0		0	0
Other	4.1E-04	7.1E-05	6.4E-05	0.0015	1.9E-04	8.7E-05	0.0030	1.9E-04	8.7E-05
Total	**0.88**	**0.15**	**0.14**	**3.08**	**0.41**	**0.18**	**6.27**	**0.41**	**0.18**
to-Energy Incineration of 20% of MSW after Diversion (MM Btu/1,000 lb)	Gross	3.99	3.59	Gross	3.57	1.61	Gross	3.57	1.61
	Usable	1.22	1.10	Usable	1.09	0.49	Usable	1.09	0.49

Table 2-3-BOX

ENERGY RESULTS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Cornstarch Loose Fill			**Molded Pulp Loose Fill 100% PC Recycled Content**			**Unbleached Kraft Paper Virgin**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	55		0	10		0	10
Energy (MM Btu/1,000 lb)									
By Type									
Process	0	0.0118	0.0053	0	0.029	0.026	0	0.032	0.029
Transport	3.79	0.048	0.022	2.85	0.12	0.11	0.091	0.14	0.12
Energy of Material Resource	0	0	0	0	0	0	0	0	0
Total	**3.79**	**0.060**	**0.027**	**2.85**	**0.15**	**0.14**	**0.091**	**0.17**	**0.15**
By Source - Process + EMR									
Nat. Gas		7.8E-04	3.5E-04		0.0019	0.0017		0.0021	0.0019
Petroleum		0.0109	0.0049		0.027	0.024		0.029	0.027
Coal		1.0E-04	4.6E-05		2.5E-04	2.2E-04		2.7E-04	2.5E-04
Hydropower		6.3E-06	2.8E-06		1.5E-05	1.4E-05		1.7E-05	1.5E-05
Nuclear		3.9E-05	1.7E-05		9.5E-05	8.5E-05		1.1E-04	9.5E-05
Wood		0	0		0	0		0	0
Other		5.6E-06	2.5E-06		1.4E-05	1.2E-05		1.5E-05	1.4E-05
Total		**0.0118**	**0.0053**		**0.029**	**0.026**		**0.032**	**0.029**
By Source - Transp									
Nat. Gas	0.25	0.0032	0.0014	0.19	0.0082	0.0073	0.0060	0.0090	0.0081
Petroleum	3.49	0.045	0.020	2.63	0.11	0.10	0.083	0.13	0.11
Coal	0.032	4.1E-04	1.9E-04	0.024	1.1E-03	9.5E-04	7.8E-04	0.0012	0.0011
Hydropower	0.0020	2.6E-05	1.2E-05	0.0015	6.6E-05	5.9E-05	4.8E-05	7.3E-05	6.5E-05
Nuclear	0.012	1.6E-04	7.1E-05	0.0094	4.1E-04	3.7E-04	3.0E-04	4.5E-04	4.0E-04
Wood		0	0		0	0		0	0
Other	0.0018	2.3E-05	1.0E-05	0.0013	5.8E-05	5.3E-05	4.3E-05	6.4E-05	5.8E-05
Total	**3.79**	**0.048**	**0.022**	**2.85**	**0.12**	**0.11**	**0.091**	**0.14**	**0.12**
to-Energy Incineration of 20% of MSW after Diversion (MM Btu/1,000 lb)	Gross	1.51	0.68	Gross	1.60	1.44	Gross	1.45	1.31
	Usable	0.46	0.21	Usable	0.49	0.44	Usable	0.44	0.40

Table 2-3-BOX

ENERGY RESULTS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Unbleached Kraft Paper 100% PC Recycled Content			**Newsprint Virgin**			**Newsprint 100% PC Recycled Content**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	10		0	10
Energy (MM Btu/1,000 lb)									
By Type									
Process	0	0.032	0.029	0	0.032	0.029	0	0.032	0.029
Transport	0.091	0.14	0.12	0.075	0.14	0.12	0.075	0.14	0.12
Energy of Material Resource	0	0	0	0	0	0	0	0	0
Total	**0.091**	**0.17**	**0.15**	**0.075**	**0.17**	**0.15**	**0.075**	**0.17**	**0.15**
By Source - Process + EMR									
Nat. Gas		0.0021	0.0019		0.0021	0.0019		0.0021	0.0019
Petroleum		0.029	0.027		0.029	0.027		0.029	0.027
Coal		2.7E-04	2.5E-04		2.7E-04	2.5E-04		2.7E-04	2.5E-04
Hydropower		1.7E-05	1.5E-05		1.7E-05	1.5E-05		1.7E-05	1.5E-05
Nuclear		1.1E-04	9.5E-05		1.1E-04	9.5E-05		1.1E-04	9.5E-05
Wood		0	0		0	0		0	0
Other		1.5E-05	1.4E-05		1.5E-05	1.4E-05		1.5E-05	1.4E-05
Total		**0.032**	**0.029**		**0.032**	**0.029**		**0.032**	**0.029**
By Source - Transp									
Nat. Gas	0.0060	0.0090	0.0081	0.0049	0.0090	0.0081	0.0049	0.0090	0.0081
Petroleum	0.083	0.13	0.11	0.069	0.13	0.11	0.069	0.13	0.11
Coal	7.8E-04	0.0012	0.0011	6.4E-04	0.0012	0.0011	6.4E-04	0.0012	0.0011
Hydropower	4.8E-05	7.3E-05	6.5E-05	4.0E-05	7.3E-05	6.5E-05	4.0E-05	7.3E-05	6.5E-05
Nuclear	3.0E-04	4.5E-04	4.0E-04	2.5E-04	4.5E-04	4.0E-04	2.5E-04	4.5E-04	4.0E-04
Wood		0	0		0	0		0	0
Other	4.3E-05	6.4E-05	5.8E-05	3.5E-05	6.4E-05	5.8E-05	3.5E-05	6.4E-05	5.8E-05
Total	**0.091**	**0.14**	**0.12**	**0.075**	**0.14**	**0.12**	**0.075**	**0.14**	**0.12**
to-Energy Incineration of 20% of MSW after Diversion (MM	Gross	1.45	1.31	Gross	1.60	1.44	Gross	1.60	1.44
Btu/1,000 lb)	Usable	0.44	0.40	Usable	0.49	0.44	Usable	0.49	0.44

Table 2-3-BOX

ENERGY RESULTS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Shredded PC Corrugated Dunnage			Shredded PC Office Paper Dunnage		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	10
Energy (MM Btu/1,000 lb)						
By Type						
Process		0.032	0.028		0.032	0.029
Transport		0.13	0.12		0.14	0.12
Energy of Material Resource		0	0		0	0
Total		**0.17**	**0.15**		**0.17**	**0.15**
By Source - Process + EMR						
Nat. Gas		0.0021	0.0019		0.0021	0.0019
Petroleum		0.029	0.026		0.029	0.027
Coal		2.7E-04	2.4E-04		2.7E-04	2.5E-04
Hydropower		1.7E-05	1.5E-05		1.7E-05	1.5E-05
Nuclear		1.0E-04	9.3E-05		1.1E-04	9.5E-05
Wood		0	0		0	0
Other		1.5E-05	1.3E-05		1.5E-05	1.4E-05
Total		**0.032**	**0.028**		**0.032**	**0.029**
By Source - Transp						
Nat. Gas		0.0089	0.0080		0.0090	0.0081
Petroleum		0.12	0.11		0.13	0.11
Coal		0.0012	0.0010		0.0012	0.0011
Hydropower		7.2E-05	6.5E-05		7.3E-05	6.5E-05
Nuclear		4.4E-04	4.0E-04		4.5E-04	4.0E-04
Wood		0	0		0	0
Other		6.4E-05	5.7E-05		6.4E-05	5.8E-05
Total		**0.13**	**0.12**		**0.14**	**0.12**
to-Energy Incineration of 20% of MSW after Diversion (MM Btu/1,000 lb)	Gross	1.59	1.43	Gross	1.45	1.31
	Usable	0.49	0.44	Usable	0.44	0.40

Table 2-3-BAG

ENERGY RESULTS FOR TRANSP TO DIST CTR AND DISPOSAL OF 1,000 LB OF SHIPPING BAGS

	Unpadded Bleached Kraft Bag		**All-Paper Padded Kraft Bag**		**Bubble Padded Kraft Bag**		**Unpadded LLDPE Film Bag**		**Bubble Padded LLDPE Bag**	
	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion
		10		10		10		10		10
Energy (MM Btu/1,000 lb)										
By Type										
Process	0	0.029	0	0.029	0	0.030	0	0.032	0	0.032
Transport	0.88	0.12	0.88	0.12	0.88	0.13	1.68	0.14	0.88	0.14
Energy of Material Resource	0	0	0	0	0	0	0	0	0	0
Total	**0.88**	**0.15**	**0.88**	**0.15**	**0.88**	**0.16**	**1.68**	**0.17**	**0.88**	**0.17**
By Source - Process + EMR										
Nat. Gas		0.0019		0.0019		0.0020		0.0021		0.0021
Petroleum		0.027		0.027		0.027		0.029		0.029
Coal		2.5E-04		2.5E-04		2.6E-04		2.7E-04		2.7E-04
Hydropower		1.5E-05		1.5E-05		1.6E-05		1.7E-05		1.7E-05
Nuclear		9.5E-05		9.5E-05		9.8E-05		1.0E-04		1.0E-04
Wood		0		0		0		0		0
Other		1.4E-05		1.4E-05		1.4E-05		1.5E-05		1.5E-05
Total		**0.029**		**0.029**		**0.030**		**0.032**		**0.032**
By Source - Transp										
Nat. Gas	0.058	0.0081	0.058	0.0081	0.058	0.0084	0.11	0.0090	0.058	0.0090
Petroleum	0.81	0.11	0.81	0.11	0.81	0.12	1.54	0.13	0.81	0.13
Coal	0.0075	0.0011	0.0075	0.0011	0.0075	0.0011	0.014	0.0012	0.0075	0.0012
Hydropower	4.7E-04	6.5E-05	4.7E-04	6.5E-05	4.7E-04	6.8E-05	8.9E-04	7.2E-05	4.7E-04	7.2E-05
Nuclear	0.0029	4.0E-04	0.0029	4.0E-04	0.0029	4.2E-04	0.0055	4.5E-04	0.0029	4.5E-04
Wood		0		0		0		0		0
Other	4.1E-04	5.8E-05	4.1E-04	5.8E-05	4.1E-04	6.0E-05	7.9E-04	6.4E-05	4.1E-04	6.4E-05
Total	**0.88**	**0.12**	**0.88**	**0.12**	**0.88**	**0.13**	**1.68**	**0.14**	**0.88**	**0.14**
Energy Credit for Waste-										
to-Energy Incineration	Gross	1.31	Gross	1.37	Gross	2.12	Gross	3.60	Gross	3.60
of 20% of MSW after	Usable	0.40	Usable	0.42	Usable	0.65	Usable	1.10	Usable	1.10

Table 2-4-BOX
SOLID WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Average (38%) PC Corrugated Box			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes				
By Weight (lb/1,000 lb)				
Process	69.5	0	**69.5**	23.3%
Fuel	228	0.26	**228**	76.7%
Postconsumer	0	0	**0**	0.0%
Total	**298**	**0.26**	**298**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**	
By Volume (cu ft/1,000 lb)				
Process	1.39	0	**1.39**	23.3%
Fuel	4.56	0.0052	**4.57**	76.7%
Postconsumer	0	0	**0**	0.0%
Total	**5.95**	**0.0052**	**5.96**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**	

	80% PC Corrugated Box			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes				
By Weight (lb/1,000 lb)				
Process	52.2	0	**52.2**	19.9%
Fuel	210	0.26	**210**	80.1%
Postconsumer	0	0	**0**	0.0%
Total	**262**	**0.26**	**262**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**	
By Volume (cu ft/1,000 lb)				
Process	1.04	0	**1.04**	19.9%
Fuel	4.19	0.0052	**4.20**	80.1%
Postconsumer	0	0	**0**	0.0%
Total	**5.24**	**0.0052**	**5.24**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**	

	LDPE Inflated Air Packets Virgin			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes				
By Weight (lb/1,000 lb)				
Process	110.0	0	**110.0**	33.1%
Fuel	220	2.32	**223**	66.9%
Postconsumer	0	0	**0**	0.0%
Total	**330**	**2.32**	**333**	**100.0%**
% of Total	99.3%	0.7%	**100.0%**	
By Volume (cu ft/1,000 lb)				
Process	2.20	0	**2.20**	33.1%
Fuel	4.41	0.046	**4.45**	66.9%
Postconsumer	0	0	**0**	0.0%
Total	**6.61**	**0.046**	**6.65**	**100.0%**
% of Total	99.3%	0.7%	**100.0%**	

Table 2-4-BOX
SOLID WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	LDPE Inflated Air Packets 100% PC Recycled Content				EPS Loose Fill Virgin				EPS Loose Fill 100% PC Recycled Content			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes												
By Weight (lb/1,000 lb)												
Process	131	0	**131**	49.6%	50.3	0	**50.3**	11.4%	100	0	**100**	27.0%
Fuel	132	0.68	**133**	50.4%	386	3.85	**390**	88.6%	268	2.00	**270**	73.0%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**264**	**0.68**	**264**	**100.0%**	**437**	**3.85**	**441**	**100.0%**	**368**	**2.00**	**370**	**100.0%**
% of Total	99.7%	0.3%	**100.0%**		99.1%	0.9%	**100.0%**		99.5%	0.5%	**100.0%**	
By Volume (cu ft/1,000 lb)												
Process	2.62	0	**2.62**	49.6%	1.01	0	**1.01**	11.4%	2.00	0	**2.00**	27.0%
Fuel	2.65	0.014	**2.66**	50.4%	7.73	0.077	**7.81**	88.6%	5.37	0.040	**5.41**	73.0%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**5.27**	**0.014**	**5.28**	**100.0%**	**8.73**	**0.077**	**8.81**	**100.0%**	**7.37**	**0.040**	**7.41**	**100.0%**
% of Total	99.7%	0.3%	**100.0%**		99.1%	0.9%	**100.0%**		99.5%	0.5%	**100.0%**	

Table 2-4-BOX
SOLID WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Cornstarch Loose Fill				**Molded Pulp Loose Fill 100% PC Recycled Content**				**Unbleached Kraft Paper Virgin**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes												
By Weight (lb/1,000 lb)												
Process	46.0	0	**46.0**	25.0%	50	0	**50**	18.4%	75.6	0	**75.6**	23.1%
Fuel	137	0.71	**138**	75.0%	221	0.28	**221**	81.6%	251	0.26	**252**	76.9%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**183**	**0.71**	**184**	**100.0%**	**271**	**0.28**	**271**	**100.0%**	**327**	**0.26**	**327**	**100.0%**
% of Total	99.6%	0.4%	**100.0%**		99.9%	0.1%	**100.0%**		99.9%	0.1%	**100.0%**	
By Volume (cu ft/1,000 lb)												
Process	0.92	0	**0.92**	25.0%	1.00	0	**1.00**	18.4%	1.51	0	**1.51**	23.1%
Fuel	2.75	0.014	**2.76**	75.0%	4.41	0.0055	**4.42**	81.6%	5.03	0.0053	**5.03**	76.9%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**3.67**	**0.014**	**3.68**	**100.0%**	**5.41**	**0.0055**	**5.42**	**100.0%**	**6.54**	**0.0053**	**6.54**	**100.0%**
% of Total	99.6%	0.4%	**100.0%**		99.9%	0.1%	**100.0%**		99.9%	0.1%	**100.0%**	

Table 2-4-BOX

SOLID WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Unbleached Kraft Paper 100% PC Recycled Content				Newsprint 100% PC Recycled Content				Newsprint Virgin			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes												
By Weight (lb/1,000 lb)												
Process	62.2	0	**62.2**	25.6%	190	0	**190**	79.7%	138	0	**138**	28.8%
Fuel	181	0.27	**181**	74.4%	48.1	0.17	**48.3**	20.3%	341	0.21	**341**	71.2%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**243**	**0.27**	**243**	**100.0%**	**238**	**0.17**	**238**	**100.0%**	**478**	**0.21**	**479**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**		99.9%	0.1%	**100.0%**		100.0%	0.0%	**100.0%**	
By Volume (cu ft/1,000 lb)												
Process	1.24	0	**1.24**	25.6%	3.80	0	**3.80**	79.7%	2.75	0	**2.75**	28.8%
Fuel	3.62	0.0053	**3.62**	74.4%	0.96	0.0034	**0.97**	20.3%	6.81	0.0042	**6.82**	71.2%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**4.86**	**0.0053**	**4.87**	**100.0%**	**4.76**	**0.0034**	**4.77**	**100.0%**	**9.57**	**0.0042**	**9.57**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**		99.9%	0.1%	**100.0%**		100.0%	0.0%	**100.0%**	

Table 2-4-BOX
SOLID WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Shredded PC Corrugated Dunnage				Shredded PC Office Paper Dunnage			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/1,000 lb)								
Process	0	0	**0**	0.0%	0	0	**0**	0.0%
Fuel	1.89	0	**1.89**	100.0%	5.94	0	**5.94**	100.0%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**1.89**	**0**	**1.89**	**100.0%**	**5.94**	**0**	**5.94**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	
By Volume (cu ft/1,000 lb)								
Process	0	0	**0**	0.0%	0	0	**0**	0.0%
Fuel	0.038	0	**0.038**	100.0%	0.12	0	**0.12**	100.0%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**0.038**	**0**	**0.038**	**100.0%**	**0.12**	**0**	**0.12**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	

Table 2-4-BAG
SOLID WASTES FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	Bleached Kraft Virgin				Bleached Kraft 100% PC Recycled Content				Unbleached Kraft Virgin			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes												
By Weight (lb/1,000 lb)												
Process	118	0	**118**	25.2%	62.2	0	**62.2**	25.6%	75.6	0	**75.6**	23.1%
Fuel	350	0.37	**350**	74.8%	181	0.27	**181**	74.4%	251	0.39	**252**	76.9%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**468**	**0.37**	**469**	**100.0%**	**243**	**0.27**	**243**	**100.0%**	**327**	**0.39**	**327**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**		99.9%	0.1%	**100.0%**		99.9%	0.1%	**100.0%**	
By Volume (cu ft/1,000 lb)												
Process	2.37	0	**2.37**	25.2%	1.24	0	**1.24**	25.6%	1.51	0	**1.51**	23.1%
Fuel	7.00	0.0074	**7.01**	74.8%	3.62	0.0053	**3.62**	74.4%	5.03	0.0077	**5.03**	76.9%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**9.37**	**0.0074**	**9.38**	**100.0%**	**4.86**	**0.0053**	**4.87**	**100.0%**	**6.54**	**0.0077**	**6.54**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**		99.9%	0.1%	**100.0%**		99.9%	0.1%	**100.0%**	

Table 2-4-BAG

SOLID WASTES FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	Unbleached Kraft 100% PC Recycled Content				**Macerated 100% PC Newspaper Padding**				**LDPE Film Virgin**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes												
By Weight (lb/1,000 lb)												
Process	62.2	0	**62.2**	25.6%	0	0	**0**	0.0%	100	0	**100**	31.1%
Fuel	181	0.27	**181**	74.4%	6.21	0.26	**6.47**	100.0%	219	2.35	**221**	68.9%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**243**	**0.27**	**243**	**100.0%**	**6.21**	**0.26**	**6.47**	**100.0%**	**319**	**2.35**	**322**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**		95.9%	4.1%	**100.0%**		99.3%	0.7%	**100.0%**	
By Volume (cu ft/1,000 lb)												
Process	1.24	0	**1.24**	25.6%	0	0	**0**	0.0%	2.00	0	**2.00**	31.1%
Fuel	3.62	0.0053	**3.62**	74.4%	0.12	0.0053	**0.13**	100.0%	4.38	0.047	**4.43**	68.9%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**4.86**	**0.0053**	**4.87**	**100.0%**	**0.12**	**0.0053**	**0.13**	**100.0%**	**6.38**	**0.047**	**6.43**	**100.0%**
% of Total	99.9%	0.1%	**100.0%**		95.9%	4.1%	**100.0%**		99.3%	0.7%	**100.0%**	

Table 2-4-BAG

SOLID WASTES FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	LDPE Film 100% PC Recycled Content				**LLDPE Film Virgin**				**LLDPE Film 100% PC Recycled Content**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Solid Wastes												
By Weight (lb/1,000 lb)												
Process	121	0	**121**	47.8%	102	0	**102**	36.7%	121	0	**121**	47.8%
Fuel	131	0.68	**132**	52.2%	175	2.20	**177**	63.3%	131	0.68	**132**	52.2%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**252**	**0.68**	**253**	**100.0%**	**277**	**2.20**	**279**	**100.0%**	**252**	**0.68**	**253**	**100.0%**
% of Total	99.7%	0.3%	**100.0%**		99.2%	0.8%	**100.0%**		99.7%	0.3%	**100.0%**	
By Volume (cu ft/1,000 lb)												
Process	2.42	0	**2.42**	47.8%	2.05	0	**2.05**	36.7%	2.42	0	**2.42**	47.8%
Fuel	2.63	0.014	**2.64**	52.2%	3.49	0.044	**3.54**	63.3%	2.63	0.014	**2.64**	52.2%
Postconsumer	0	0	**0**	0.0%	0	0	**0**	0.0%	0	0	**0**	0.0%
Total	**5.05**	**0.014**	**5.06**	**100.0%**	**5.54**	**0.044**	**5.59**	**100.0%**	**5.05**	**0.014**	**5.06**	**100.0%**
% of Total	99.7%	0.3%	**100.0%**		99.2%	0.8%	**100.0%**		99.7%	0.3%	**100.0%**	

Table 2-5-BOX

SOLID WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Average (38%) PC Corrugated Box			80% PC Corrugated Box			LDPE Inflated Air Packets Virgin		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	20.8		0	20.8		0	10
Solid Wastes									
By Weight (lb/1,000 lb)									
Process	0	0	0	0	0	0	0	0	0
Fuel	0	0.14	0.11	0	0.14	0.11	0.74	0.16	0.14
Postconsumer	0	810	642	0	810	642	0	800	720
Total	**0**	**810**	**642**	**0**	**810**	**642**	**0.74**	**800**	**720**
By Volume (cu ft/1,000 lb)									
Process	0	0	0	0	0	0	0	0	0
Fuel	0	0.0028	0.0022	0	0.0028	0.0022	0.015	0.0031	0.0028
Postconsumer	0	29.0	23.0	0	29.0	23.0	0	32.2	29.0
Total	**0**	**29.0**	**23.0**	**0**	**29.0**	**23.0**	**0.015**	**32.2**	**29.0**

Table 2-5-BOX

SOLID WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	LDPE Inflated Air Packets 100% PC Recycled Content			EPS Loose Fill Virgin			EPS Loose Fill 100% PC Recycled Content		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	55		0	55
Solid Wastes									
By Weight (lb/1,000 lb)									
Process	0	0	0	0	0	0	0	0	0
Fuel	0.74	0.16	0.14	2.58	0.43	0.19	5.26	0.43	0.19
Postconsumer	0	800	720	0	800	360	0	800	360
Total	**0.74**	**800**	**720**	**2.58**	**800**	**360**	**5.26**	**800**	**360**
By Volume (cu ft/1,000 lb)									
Process	0	0	0	0	0	0	0	0	0
Fuel	0.015	0.0031	0.0028	0.052	0.0086	0.0038	0.11	0.0086	0.0038
Postconsumer	0	32.2	29.0	0	90.0	40.5	0	90.0	40.5
Total	**0.015**	**32.2**	**29.0**	**0.052**	**90.0**	**40.5**	**0.11**	**90.0**	**40.5**

Table 2-5-BOX

SOLID WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Cornstarch Loose Fill			**Molded Pulp Loose Fill 100% PC Recycled Content**			**Unbleached Kraft Paper Virgin**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	55		0	10		0	10
Solid Wastes									
By Weight (lb/1,000 lb)									
Process	0	0	0	0	0	0	0	0	0
Fuel	3.18	0.051	0.023	2.40	0.13	0.12	0.076	0.14	0.13
Postconsumer	0	802	361	0	803	723	0	802	722
Total	**3.18**	**802**	**361**	**2.40**	**803**	**723**	**0.076**	**802**	**722**
By Volume (cu ft/1,000 lb)									
Process	0	0	0	0	0	0	0	0	0
Fuel	0.064	1.0E-03	4.5E-04	0.048	0.0026	0.0023	0.0015	0.0028	0.0025
Postconsumer	0	10.84	4.88	0	26.4	23.8	0	29.2	26.3
Total	**0.064**	**10.84**	**4.88**	**0.048**	**26.4**	**23.8**	**0.0015**	**29.2**	**26.3**

Table 2-5-BOX

SOLID WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Unbleached Kraft Paper 100% PC Recycled Content			**Newsprint Virgin**			**Newsprint 100% PC Recycled Content**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	10		0	10
Solid Wastes									
By Weight (lb/1,000 lb)									
Process	0	0	0	0	0	0	0	0	0
Fuel	0.076	0.14	0.13	0.063	0.14	0.13	0.063	0.14	0.13
Postconsumer	0	802	722	0	803	723	0	803	723
Total	**0.076**	**802**	**722**	**0.063**	**803**	**723**	**0.063**	**803**	**723**
By Volume (cu ft/1,000 lb)									
Process	0	0	0	0	0	0	0	0	0
Fuel	0.0015	0.0028	0.0025	0.0013	0.0028	0.0025	0.0013	0.0028	0.0025
Postconsumer	0	29.2	26.3	0	29.2	26.3	0	29.2	26.3
Total	**0.0015**	**29.2**	**26.3**	**0.0013**	**29.2**	**26.3**	**0.0013**	**29.2**	**26.3**

Table 2-5-BOX

SOLID WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Shredded PC Corrugated Dunnage			Shredded PC Office Paper Dunnage		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	10
Solid Wastes						
By Weight (lb/1,000 lb)						
Process		0	0		0	0
Fuel		0.14	0.13		0.14	0.13
Postconsumer		810	729		802	722
Total		**810**	**729**		**802**	**722**
By Volume (cu ft/1,000 lb)						
Process		0	0		0	0
Fuel		0.0028	0.0025		0.0028	0.0025
Postconsumer		29.0	26.1		29.2	26.3
Total		**29.0**	**26.1**		**29.2**	**26.3**

Table 2-5-BAG
SOLID WASTES FOR TRANSP TO DIST CTR AND DISPOSAL OF 1,000 LB OF SHIPPING BAGS

	Unpadded Bleached Kraft Bag		All-Paper Padded Kraft Bag		Bubble Padded Kraft Bag		Unpadded LLDPE Film Bag		Bubble Padded LLDPE Bag	
	Retail Order Center	End of Life Disposal	Retail Order Center	End of Life Disposal	Retail Order Center	End of Life Disposal	Retail Order Center	End of Life Disposal	Retail Order Center	End of Life Disposal
		% diversion		% diversion		% diversion		% diversion		% diversion
		10		10		10		10		10
Solid Wastes										
By Weight (lb/1,000 lb)										
Process	0	0	0	0	0	0	0	0	0	0
Fuel	0.74	0.13	0.74	0.13	0.74	0.13	1.41	0.14	0.74	0.14
Postconsumer	0	722	0	722	0	721	0	720	0	720
Total	**0.74**	**722**	**0.74**	**722**	**0.74**	**721**	**1.41**	**720**	**0.74**	**720**
By Volume (cu ft/1,000 lb)										
Process	0	0	0	0	0	0	0	0	0	0
Fuel	0.015	0.0025	0.015	0.0025	0.015	0.0026	0.028	0.0028	0.015	0.0028
Postconsumer	0	26.3	0	26.3	0	27.2	0	29.0	0	29.0
Total	**0.015**	**26.3**	**0.015**	**26.3**	**0.015**	**27.2**	**0.028**	**29.0**	**0.015**	**29.0**

Table 2-6-BOX
ATMOSPHERIC EMISSIONS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Average (38%) PC Corrugated Box				80% PC Corrugated Box				LDPE Inflated Air Packets Virgin			
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related												
Particulates	3.24	0.073	**3.31**		2.74	0.071	**2.81**		1.47	0.27	**1.74**	
Nitrogen Oxides	8.03	0.44	**8.47**		5.41	0.45	**5.86**		7.99	1.73	**9.72**	
Hydrocarbons	1.11	0.18	**1.29**		1.03	0.18	**1.20**		17.3	0.82	**18.1**	
Sulfur Oxides	15.0	0.12	**15.1**		11.7	0.12	**11.9**		52.5	0.70	**53.2**	
Carbon Monoxide	13.1	0.41	**13.5**		5.24	0.44	**5.68**		5.99	1.26	**7.25**	
Aldehydes	0.021	0.012	**0.032**		0.011	0.012	**0.022**		0.019	0.042	**0.061**	
Methane	2.40	0.0079	**2.40**		2.54	0.0079	**2.55**		11.0	0.084	**11.1**	
Other Organics	0.13	0.21	**0.35**		0.049	0.24	**0.29**		0.011	0.56	**0.57**	
Odorous Sulfur	0.029	0	**0.029**		0.011	0	**0.011**		0	0	**0**	
Kerosene	1.3E-04	2.0E-07	**1.3E-04**		1.5E-04	2.0E-07	**1.5E-04**		3.4E-04	2.1E-06	**3.5E-04**	
Ammonia	0.047	7.8E-05	**0.047**		0.020	7.8E-05	**0.020**		0.0049	3.0E-04	**0.0052**	
Ethylene Oxide	0	0	**0**		0	0	**0**		0	0	**0**	
Hydrogen Fluoride	0.0036	6.3E-06	**0.0036**		0.0041	6.4E-06	**0.0042**		0.0093	5.9E-05	**0.0094**	
Lead	7.5E-04	2.6E-07	**7.5E-04**		2.9E-04	2.6E-07	**2.9E-04**		5.2E-05	1.2E-06	**5.3E-05**	
Mercury	6.5E-05	5.0E-08	**6.5E-05**		3.7E-05	5.0E-08	**3.7E-05**		2.7E-05	2.9E-07	**2.7E-05**	
Chlorine	0.0047	3.0E-06	**0.0047**		0.0016	3.0E-06	**0.0016**		6.1E-05	1.1E-05	**7.2E-05**	
HCl	0.026	4.8E-05	**0.026**		0.030	4.8E-05	**0.030**		0.068	4.4E-04	**0.068**	
Phosphorus	0	0	**0**		0	0	**0**		0	0	**0**	
CO2 (fossil)	1,125	49.4	**1,174**		1,189	49.7	**1,239**		2,019	202	**2,222**	
CO2 (non-fossil)	1,260	0.012	**1,260**		431	0.012	**431**		0.58	0.048	**0.63**	
Total Reduced Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Chlorine Dioxide	0	0	**0**		0	0	**0**		0	0	**0**	
Metals	0.51	4.8E-06	**0.51**		0.18	4.9E-06	**0.18**		2.4E-04	2.0E-05	**2.6E-04**	
Mercaptan	0	0	**0**		0	0	**0**		0	0	**0**	
Antimony	3.7E-06	7.4E-08	**3.8E-06**		3.8E-06	7.4E-08	**3.9E-06**		8.3E-06	3.0E-07	**8.6E-06**	
Arsenic	2.6E-04	1.5E-07	**2.6E-04**		2.4E-04	1.5E-07	**2.4E-04**		5.1E-05	7.5E-07	**5.2E-05**	
Beryllium	2.5E-05	1.1E-08	**2.5E-05**		2.7E-05	1.1E-08	**2.7E-05**		5.9E-06	6.1E-08	**5.9E-06**	
Cadmium	6.9E-05	2.3E-07	**6.9E-05**		7.3E-05	2.3E-07	**7.3E-05**		1.8E-05	9.0E-07	**1.8E-05**	
Chromium	4.5E-04	1.7E-07	**4.5E-04**		4.6E-04	1.8E-07	**4.6E-04**		8.1E-05	9.4E-07	**8.2E-05**	
Cobalt	1.1E-05	2.1E-07	**1.1E-05**		1.1E-05	2.1E-07	**1.1E-05**		2.3E-05	8.5E-07	**2.4E-05**	
Manganese	0.0061	2.1E-07	**0.0061**		0.0026	2.1E-07	**0.0026**		1.5E-04	1.4E-06	**1.6E-04**	
Nickel	6.8E-04	3.2E-06	**6.9E-04**		4.8E-04	3.3E-06	**4.8E-04**		2.7E-04	1.3E-05	**2.9E-04**	
Selenium	3.8E-05	1.4E-07	**3.8E-05**		4.3E-05	1.4E-07	**4.4E-05**		9.7E-05	8.9E-07	**9.8E-05**	
Acreolin	5.1E-06	9.1E-09	**5.2E-06**		5.9E-06	9.1E-09	**6.0E-06**		1.3E-05	8.5E-08	**1.3E-05**	
Nitrous Oxide	0.012	5.5E-06	**0.012**		0.013	5.6E-06	**0.013**		0.0084	5.3E-05	**0.0085**	
Benzene	0.0022	2.9E-08	**0.0022**		8.3E-04	2.9E-08	**8.3E-04**		1.9E-05	1.8E-07	**1.9E-05**	
Perchloroethylene	4.9E-06	9.0E-09	**4.9E-06**		5.7E-06	9.0E-09	**5.7E-06**		1.3E-05	8.3E-08	**1.3E-05**	
Trichloroethylene	4.9E-06	8.6E-09	**4.9E-06**		5.6E-06	8.6E-09	**5.6E-06**		1.3E-05	8.1E-08	**1.3E-05**	
Methylene Chloride	2.2E-05	4.0E-08	**2.2E-05**		2.5E-05	4.0E-08	**2.5E-05**		5.7E-05	3.7E-07	**5.7E-05**	
Carbon Tetrachloride	8.4E-06	3.7E-08	**8.5E-06**		9.7E-06	3.7E-08	**9.7E-06**		2.1E-05	2.2E-07	**2.1E-05**	
Phenols	0.023	2.4E-07	**0.023**		0.0080	2.4E-07	**0.0080**		3.9E-05	1.1E-06	**4.0E-05**	
Naphthalene	0.0014	1.4E-08	**0.0014**		4.8E-04	1.4E-08	**4.8E-04**		9.7E-07	5.6E-08	**1.0E-06**	
Dioxins	2.8E-11	4.9E-14	**2.8E-11**		3.2E-11	5.0E-14	**3.3E-11**		7.3E-11	4.7E-13	**7.3E-11**	
n-nitrosodimethlamine	1.1E-06	1.9E-09	**1.1E-06**		1.3E-06	1.9E-09	**1.3E-06**		2.8E-06	1.8E-08	**2.8E-06**	
Radionuclides	8.7E-05	1.7E-07	**8.8E-05**		1.0E-04	1.7E-07	**1.0E-04**		2.3E-04	1.5E-06	**2.3E-04**	
GHG Summary (lb CO2 Equivalents/1,000 lb)												
Fossil CO2	1,125	49.4	**1,174**	95.2%	1,189	49.7	**1,239**	95.2%	2,019	202	**2,222**	89.6%
Methane	55.1	0.18	**55.3**	4.5%	58.5	0.18	**58.7**	4.5%	253	1.94	**255**	10.3%
Nitrous Oxide	3.48	0.0016	**3.48**	0.3%	3.81	0.0016	**3.82**	0.3%	2.50	0.016	**2.51**	0.1%
Total	**1,183**	**49.6**	**1,233**	**100.0%**	**1,252**	**49.8**	**1,302**	**100.0%**	**2,275**	**204**	**2,479**	**100.0%**
% of Total	96.0%	4.0%	**100.0%**		96.2%	3.8%	**100.0%**		91.8%	8.2%	**100.0%**	

Table 2-6-BOX

ATMOSPHERIC EMISSIONS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	LDPE Inflated Air Packets 100% PC Recycled Content				**EPS Loose Fill Virgin**				**EPS Loose Fill 100% PC Recycled Content**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related												
Particulates	0.87	0.29	**1.16**		2.25	0.42	**2.67**		1.58	0.85	**2.44**	
Nitrogen Oxides	2.76	1.46	**4.22**		14.2	2.31	**16.5**		8.00	4.19	**12.2**	
Hydrocarbons	0.56	0.51	**1.07**		20.6	1.10	**21.7**		5.84	1.54	**7.38**	
Sulfur Oxides	5.43	0.32	**5.75**		58.6	0.89	**59.5**		24.5	0.94	**25.5**	
Carbon Monoxide	0.40	1.41	**1.80**		7.38	1.60	**8.98**		2.84	3.85	**6.69**	
Aldehydes	0.0019	0.031	**0.033**		0.055	0.070	**0.12**		0.0059	0.090	**0.096**	
Methane	1.68	0.021	**1.70**		12.4	0.089	**12.5**		5.76	0.061	**5.82**	
Other Organics	0.0029	0.83	**0.83**		0.024	0.72	**0.75**		0.012	2.16	**2.17**	
Odorous Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Kerosene	2.5E-04	5.4E-07	**2.5E-04**		5.5E-04	5.1E-06	**5.5E-04**		4.3E-04	1.6E-06	**4.3E-04**	
Ammonia	0.0025	2.1E-04	**0.0027**		0.011	5.2E-04	**0.012**		0.0044	6.1E-04	**0.0050**	
Ethylene Oxide	0	0	**0**		0	0	**0**		0	0	**0**	
Hydrogen Fluoride	0.0068	1.7E-05	**0.0068**		0.015	1.4E-04	**0.015**		0.012	4.9E-05	**0.012**	
Lead	3.2E-05	7.0E-07	**3.3E-05**		1.3E-04	2.1E-06	**1.3E-04**		5.7E-05	2.0E-06	**5.9E-05**	
Mercury	1.9E-05	1.3E-07	**1.9E-05**		5.0E-05	6.0E-07	**5.0E-05**		3.2E-05	3.9E-07	**3.3E-05**	
Chlorine	3.1E-06	7.9E-06	**1.1E-05**		2.3E-04	1.8E-05	**2.5E-04**		6.7E-06	2.3E-05	**3.0E-05**	
HCl	0.049	1.3E-04	**0.050**		0.11	0.0011	**0.11**		0.085	3.7E-04	**0.085**	
Phosphorus	0	0	**0**		0	0	**0**		0	0	**0**	
CO2 (fossil)	766	130	**896**		4,220	325	**4,544**		2,303	383	**2,686**	
CO2 (non-fossil)	0.27	0.031	**0.30**		1.13	0.078	**1.20**		0.67	0.092	**0.77**	
Total Reduced Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Chlorine Dioxide	0	0	**0**		0	0	**0**		0	0	**0**	
Metals	1.1E-04	1.3E-05	**1.2E-04**		4.6E-04	3.2E-05	**4.9E-04**		2.8E-04	3.8E-05	**3.1E-04**	
Mercaptan	0	0	**0**		0	0	**0**		0	0	**0**	
Antimony	4.3E-06	2.0E-07	**4.5E-06**		2.8E-05	5.3E-07	**2.8E-05**		8.0E-06	5.7E-07	**8.6E-06**	
Arsenic	3.4E-05	4.0E-07	**3.4E-05**		1.1E-04	1.5E-06	**1.1E-04**		5.9E-05	1.2E-06	**6.1E-05**	
Beryllium	4.1E-06	2.8E-08	**4.1E-06**		1.1E-05	1.3E-07	**1.1E-05**		7.0E-06	8.3E-08	**7.1E-06**	
Cadmium	7.1E-06	6.1E-07	**7.7E-06**		7.6E-05	1.5E-06	**7.7E-05**		1.4E-05	1.8E-06	**1.6E-05**	
Chromium	5.5E-05	4.6E-07	**5.6E-05**		1.6E-04	1.9E-06	**1.6E-04**		9.5E-05	1.4E-06	**9.7E-05**	
Cobalt	1.2E-05	5.5E-07	**1.3E-05**		7.9E-05	1.5E-06	**8.0E-05**		2.2E-05	1.6E-06	**2.4E-05**	
Manganese	1.1E-04	5.5E-07	**1.1E-04**		2.7E-04	3.0E-06	**2.7E-04**		1.9E-04	1.6E-06	**1.9E-04**	
Nickel	1.2E-04	8.6E-06	**1.3E-04**		0.0011	2.2E-05	**0.0011**		2.3E-04	2.5E-05	**2.6E-04**	
Selenium	6.9E-05	3.7E-07	**7.0E-05**		1.7E-04	1.9E-06	**1.7E-04**		1.2E-04	1.1E-06	**1.2E-04**	
Acreolin	9.8E-06	2.4E-08	**9.8E-06**		2.1E-05	2.1E-07	**2.2E-05**		1.7E-05	7.0E-08	**1.7E-05**	
Nitrous Oxide	0.0062	1.5E-05	**0.0062**		0.014	1.3E-04	**0.014**		0.011	4.3E-05	**0.011**	
Benzene	1.4E-05	7.7E-08	**1.4E-05**		3.1E-05	3.9E-07	**3.1E-05**		2.4E-05	2.3E-07	**2.4E-05**	
Perchloroethylene	9.3E-06	2.4E-08	**9.3E-06**		2.0E-05	2.0E-07	**2.1E-05**		1.6E-05	7.0E-08	**1.6E-05**	
Trichloroethylene	9.2E-06	2.3E-08	**9.3E-06**		2.0E-05	2.0E-07	**2.0E-05**		1.6E-05	6.7E-08	**1.6E-05**	
Methylene Chloride	4.1E-05	1.1E-07	**4.1E-05**		9.0E-05	8.9E-07	**9.1E-05**		7.1E-05	3.1E-07	**7.1E-05**	
Carbon Tetrachloride	1.5E-05	9.7E-08	**1.5E-05**		3.4E-05	4.6E-07	**3.5E-05**		2.6E-05	2.9E-07	**2.7E-05**	
Phenols	2.6E-05	6.3E-07	**2.6E-05**		6.6E-05	1.9E-06	**6.8E-05**		4.8E-05	1.8E-06	**5.0E-05**	
Naphthalene	5.4E-07	3.6E-08	**5.8E-07**		1.8E-06	9.3E-08	**1.9E-06**		1.2E-06	1.1E-07	**1.3E-06**	
Dioxins	5.3E-11	1.3E-13	**5.4E-11**		1.2E-10	1.1E-12	**1.2E-10**		9.2E-11	3.8E-13	**9.2E-11**	
n-nitrosodimethlamine	2.1E-06	5.1E-09	**2.1E-06**		4.5E-06	4.4E-08	**4.6E-06**		3.5E-06	1.5E-08	**3.6E-06**	
Radionuclides	1.7E-04	4.5E-07	**1.7E-04**		3.6E-04	3.6E-06	**3.7E-04**		2.9E-04	1.3E-06	**2.9E-04**	
GHG Summary (lb CO2 Equivalents/1,000 lb)												
Fossil CO2	766	130	**896**	95.6%	4,220	325	**4,544**	94.0%	2,303	383	**2,686**	95.1%
Methane	38.6	0.48	**39.1**	4.2%	285	2.06	**287**	5.9%	133	1.40	**134**	4.7%
Nitrous Oxide	1.82	0.0043	**1.83**	0.2%	4.00	0.038	**4.04**	0.1%	3.12	0.013	**3.14**	0.1%
Total	**806**	**131**	**937**	**100.0%**	**4,508**	**327**	**4,835**	**100.0%**	**2,438**	**385**	**2,823**	**100.0%**
% of Total	86.0%	14.0%	**100.0%**		93.2%	6.8%	**100.0%**		86.4%	13.6%	**100.0%**	

Table 2-6-BOX

ATMOSPHERIC EMISSIONS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Cornstarch Loose Fill				Molded Pulp Loose Fill 100% PC Recycled Content				Unbleached Kraft Paper Virgin			
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related												
Particulates	1.74	0.21	**1.95**		1.28	0.15	**1.43**		3.12	0.064	**3.18**	
Nitrogen Oxides	3.37	1.21	**4.58**		6.87	0.67	**7.54**		12.1	0.43	**12.6**	
Hydrocarbons	1.36	0.52	**1.88**		4.66	0.22	**4.88**		1.01	0.18	**1.19**	
Sulfur Oxides	7.81	0.33	**8.14**		22.1	0.13	**22.2**		20.3	0.12	**20.4**	
Carbon Monoxide	0.68	1.04	**1.72**		2.61	0.64	**3.25**		23.3	0.42	**23.7**	
Aldehydes	0.0077	0.031	**0.039**		0.0062	0.012	**0.019**		0.037	0.012	**0.049**	
Methane	1.94	0.022	**1.96**		5.06	0.0084	**5.07**		2.12	0.0080	**2.13**	
Other Organics	0.0039	0.49	**0.50**		0.010	0.39	**0.40**		0.23	0.23	**0.45**	
Odorous Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Kerosene	2.4E-04	5.5E-07	**2.4E-04**		3.4E-04	2.2E-07	**3.4E-04**		5.3E-05	2.1E-07	**5.3E-05**	
Ammonia	0.022	2.1E-04	**0.022**		0.0035	8.4E-05	**0.0036**		0.092	7.9E-05	**0.092**	
Ethylene Oxide	0	0	**0**		0	0	**0**		0	0	**0**	
Hydrogen Fluoride	0.0065	1.7E-05	**0.0065**		0.0093	6.8E-06	**0.0093**		0.0014	6.4E-06	**0.0014**	
Lead	3.9E-05	7.1E-07	**4.0E-05**		4.6E-05	2.8E-07	**4.6E-05**		0.0013	2.7E-07	**0.0013**	
Mercury	1.9E-05	1.4E-07	**1.9E-05**		2.6E-05	5.4E-08	**2.6E-05**		1.1E-04	5.1E-08	**1.1E-04**	
Chlorine	5.3E-06	8.1E-06	**1.3E-05**		5.9E-06	3.2E-06	**9.1E-06**		0.0082	3.0E-06	**0.0082**	
HCl	0.047	1.3E-04	**0.047**		0.068	5.2E-05	**0.068**		0.010	4.9E-05	**0.010**	
Phosphorus	0	0	**0**		0	0	**0**		0	0	**0**	
CO2 (fossil)	894	134	**1,028**		2,001	52.8	**2,054**		1,043	50.3	**1,094**	
CO2 (non-fossil)	0.62	0.032	**0.65**		0.57	0.013	**0.59**		2,188	0.012	**2,188**	
Total Reduced Sulfur	0	0	**0**		0	0	**0**		0.058	0	**0.058**	
Chlorine Dioxide	0	0	**0**		0	0	**0**		0	0	**0**	
Metals	1.2E-04	1.3E-05	**1.3E-04**		2.3E-04	5.2E-06	**2.4E-04**		0.89	4.9E-06	**0.89**	
Mercaptan	0	0	**0**		0	0	**0**		0	0	**0**	
Antimony	6.2E-06	2.0E-07	**6.4E-06**		6.5E-06	7.9E-08	**6.6E-06**		2.9E-06	7.5E-08	**3.0E-06**	
Arsenic	5.1E-05	4.1E-07	**5.2E-05**		4.8E-05	1.6E-07	**4.8E-05**		3.4E-04	1.6E-07	**3.4E-04**	
Beryllium	5.9E-06	2.9E-08	**5.9E-06**		5.6E-06	1.1E-08	**5.6E-06**		2.9E-05	1.1E-08	**2.9E-05**	
Cadmium	1.8E-05	6.2E-07	**1.9E-05**		1.2E-05	2.5E-07	**1.2E-05**		8.4E-05	2.3E-07	**8.4E-05**	
Chromium	8.7E-05	4.7E-07	**8.8E-05**		7.6E-05	1.9E-07	**7.6E-05**		5.5E-04	1.8E-07	**5.5E-04**	
Cobalt	1.8E-05	5.7E-07	**1.8E-05**		1.8E-05	2.2E-07	**1.8E-05**		8.2E-06	2.1E-07	**8.4E-06**	
Manganese	1.6E-04	5.7E-07	**1.6E-04**		1.5E-04	2.2E-07	**1.5E-04**		0.010	2.1E-07	**0.010**	
Nickel	2.3E-04	8.8E-06	**2.4E-04**		1.9E-04	3.5E-06	**1.9E-04**		9.7E-04	3.3E-06	**9.8E-04**	
Selenium	6.8E-05	3.8E-07	**6.8E-05**		9.5E-05	1.5E-07	**9.5E-05**		1.7E-05	1.4E-07	**1.7E-05**	
Acreolin	9.3E-06	2.5E-08	**9.3E-06**		1.3E-05	9.7E-09	**1.3E-05**		2.1E-06	9.3E-09	**2.1E-06**	
Nitrous Oxide	0.0065	1.5E-05	**0.0065**		0.0084	5.9E-06	**0.0084**		0.012	5.6E-06	**0.012**	
Benzene	1.9E-05	7.9E-08	**1.9E-05**		1.9E-05	3.1E-08	**1.9E-05**		0.0039	3.0E-08	**0.0039**	
Perchloroethylene	8.9E-06	2.4E-08	**8.9E-06**		1.3E-05	9.6E-09	**1.3E-05**		2.0E-06	9.1E-09	**2.0E-06**	
Trichloroethylene	8.8E-06	2.3E-08	**8.8E-06**		1.3E-05	9.2E-09	**1.3E-05**		1.9E-06	8.7E-09	**2.0E-06**	
Methylene Chloride	3.9E-05	1.1E-07	**3.9E-05**		5.7E-05	4.3E-08	**5.7E-05**		8.8E-06	4.1E-08	**8.8E-06**	
Carbon Tetrachloride	1.4E-05	1.0E-07	**1.4E-05**		2.1E-05	4.0E-08	**2.1E-05**		3.8E-06	3.7E-08	**3.9E-06**	
Phenols	2.5E-05	6.4E-07	**2.6E-05**		3.9E-05	2.6E-07	**3.9E-05**		0.040	2.4E-07	**0.040**	
Naphthalene	5.5E-07	3.7E-08	**5.9E-07**		9.6E-07	1.5E-08	**9.8E-07**		0.0024	1.4E-08	**0.0024**	
Dioxins	5.1E-11	1.3E-13	**5.1E-11**		7.3E-11	5.3E-14	**7.3E-11**		1.1E-11	5.0E-14	**1.1E-11**	
n-nitrosodimethlamine	2.0E-06	5.2E-09	**2.0E-06**		2.8E-06	2.1E-09	**2.8E-06**		4.3E-07	2.0E-09	**4.4E-07**	
Radionuclides	1.6E-04	4.6E-07	**1.6E-04**		2.3E-04	1.8E-07	**2.3E-04**		3.5E-05	1.7E-07	**3.5E-05**	
GHG Summary (lb CO2 Equivalents/1,000 lb)												
Fossil CO2	894	134	**1,028**	95.6%	2,001	52.8	**2,054**	94.5%	1,043	50.3	**1,094**	95.4%
Methane	44.6	0.51	**45.1**	4.2%	116	0.19	**117**	5.4%	48.8	0.18	**49.0**	4.3%
Nitrous Oxide	1.93	0.0045	**1.93**	0.2%	2.49	0.0018	**2.49**	0.1%	3.56	0.0017	**3.56**	0.3%
Total	**941**	**135**	**1,075**	**100.0%**	**2,120**	**53.0**	**2,173**	**100.0%**	**1,096**	**50.5**	**1,146**	**100.0%**
% of Total	87.5%	12.5%	**100.0%**		97.6%	2.4%	**100.0%**		95.6%	4.4%	**100.0%**	

Table 2-6-BOX

ATMOSPHERIC EMISSIONS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Unbleached Kraft Paper 100% PC Recycled Content				**Newsprint 100% PC Recycled Content**				**Newsprint Virgin**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related												
Particulates	1.23	0.074	**1.31**		1.25	0.054	**1.31**		3.62	0.058	**3.68**	
Nitrogen Oxides	3.25	0.47	**3.72**		1.96	0.32	**2.27**		9.44	0.35	**9.80**	
Hydrocarbons	0.68	0.18	**0.86**		1.69	0.12	**1.81**		4.34	0.15	**4.49**	
Sulfur Oxides	7.93	0.12	**8.06**		7.11	0.080	**7.19**		23.8	0.097	**23.9**	
Carbon Monoxide	0.62	0.46	**1.08**		0.93	0.31	**1.24**		5.18	0.32	**5.51**	
Aldehydes	0.0043	0.012	**0.016**		0.0028	0.0077	**0.010**		0.025	0.0094	**0.034**	
Methane	2.25	0.0081	**2.26**		1.51	0.0052	**1.51**		5.79	0.0063	**5.80**	
Other Organics	0.0037	0.25	**0.26**		1.00	0.17	**1.18**		1.05	0.16	**1.22**	
Odorous Sulfur	0	0	**0**		0	0	**0**		0.11	0	**0.11**	
Kerosene	1.5E-04	2.1E-07	**1.5E-04**		6.2E-05	1.3E-07	**6.2E-05**		5.4E-04	1.6E-07	**5.4E-04**	
Ammonia	0.0016	8.1E-05	**0.0017**		6.4E-04	5.2E-05	**6.9E-04**		0.0055	6.3E-05	**0.0056**	
Ethylene Oxide	0	0	**0**		0	0	**0**		0	0	**0**	
Hydrogen Fluoride	0.0041	6.6E-06	**0.0041**		0.0017	4.2E-06	**0.0017**		0.015	5.1E-06	**0.015**	
Lead	4.4E-05	2.7E-07	**4.4E-05**		8.5E-06	1.7E-07	**8.7E-06**		3.1E-04	2.1E-07	**3.1E-04**	
Mercury	1.7E-05	5.2E-08	**1.7E-05**		4.7E-06	3.3E-08	**4.7E-06**		5.1E-05	4.1E-08	**5.1E-05**	
Chlorine	3.1E-06	3.1E-06	**6.2E-06**		1.6E-06	2.0E-06	**3.6E-06**		0.0015	2.4E-06	**0.0015**	
HCl	0.030	5.0E-05	**0.030**		0.012	3.2E-05	**0.012**		0.11	3.9E-05	**0.11**	
Phosphorus	0	0	**0**		0	0	**0**		0	0	**0**	
CO2 (fossil)	1,066	51.2	**1,118**		568	32.7	**601**		2,447	39.9	**2,487**	
CO2 (non-fossil)	0.25	0.012	**0.26**		0.15	0.0078	**0.15**		410	0.0096	**410**	
Total Reduced Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Chlorine Dioxide	0	0	**0**		0	0	**0**		0.0041	0	**0.0041**	
Metals	1.0E-04	5.0E-06	**1.1E-04**		6.0E-05	3.2E-06	**6.3E-05**		0.17	3.9E-06	**0.17**	
Mercaptan	0	0	**0**		0	0	**0**		0	0	**0**	
Antimony	3.5E-06	7.7E-08	**3.6E-06**		1.3E-06	4.9E-08	**1.3E-06**		1.1E-05	6.0E-08	**1.2E-05**	
Arsenic	2.1E-04	1.6E-07	**2.1E-04**		8.7E-06	1.0E-07	**8.8E-06**		1.1E-04	1.2E-07	**1.1E-04**	
Beryllium	2.5E-05	1.1E-08	**2.5E-05**		1.0E-06	7.1E-09	**1.0E-06**		1.1E-05	8.6E-09	**1.1E-05**	
Cadmium	6.8E-05	2.4E-07	**6.8E-05**		2.5E-06	1.5E-07	**2.6E-06**		2.8E-05	1.8E-07	**2.8E-05**	
Chromium	4.3E-04	1.8E-07	**4.3E-04**		1.4E-05	1.2E-07	**1.4E-05**		1.7E-04	1.4E-07	**1.7E-04**	
Cobalt	9.9E-06	2.2E-07	**1.0E-05**		3.6E-06	1.4E-07	**3.8E-06**		3.2E-05	1.7E-07	**3.2E-05**	
Manganese	7.1E-04	2.2E-07	**7.1E-04**		2.7E-05	1.4E-07	**2.8E-05**		0.0021	1.7E-07	**0.0021**	
Nickel	3.4E-04	3.4E-06	**3.4E-04**		4.0E-05	2.2E-06	**4.2E-05**		4.9E-04	2.6E-06	**4.9E-04**	
Selenium	4.3E-05	1.5E-07	**4.3E-05**		1.7E-05	9.3E-08	**1.7E-05**		1.5E-04	1.1E-07	**1.5E-04**	
Acreolin	5.9E-06	9.4E-09	**5.9E-06**		2.4E-06	6.0E-09	**2.4E-06**		2.1E-05	7.3E-09	**2.1E-05**	
Nitrous Oxide	0.012	5.7E-06	**0.012**		0.0015	3.7E-06	**0.0015**		0.014	4.5E-06	**0.014**	
Benzene	8.5E-05	3.0E-08	**8.6E-05**		3.5E-06	1.9E-08	**3.5E-06**		7.4E-04	2.3E-08	**7.4E-04**	
Perchloroethylene	5.6E-06	9.3E-09	**5.6E-06**		2.3E-06	5.9E-09	**2.3E-06**		2.0E-05	7.2E-09	**2.0E-05**	
Trichloroethylene	5.6E-06	8.9E-09	**5.6E-06**		2.3E-06	5.7E-09	**2.3E-06**		2.0E-05	6.9E-09	**2.0E-05**	
Methylene Chloride	2.5E-05	4.2E-08	**2.5E-05**		1.0E-05	2.7E-08	**1.0E-05**		8.9E-05	3.2E-08	**8.9E-05**	
Carbon Tetrachloride	9.5E-06	3.8E-08	**9.6E-06**		3.9E-06	2.4E-08	**3.9E-06**		3.3E-05	3.0E-08	**3.3E-05**	
Phenols	1.7E-05	2.5E-07	**1.7E-05**		7.8E-06	1.6E-07	**7.9E-06**		0.0076	1.9E-07	**0.0076**	
Naphthalene	4.2E-07	1.4E-08	**4.3E-07**		2.2E-07	9.0E-09	**2.3E-07**		4.6E-04	1.1E-08	**4.6E-04**	
Dioxins	3.2E-11	5.1E-14	**3.2E-11**		1.3E-11	3.3E-14	**1.3E-11**		1.1E-10	4.0E-14	**1.1E-10**	
n-nitrosodimethlamine	1.2E-06	2.0E-09	**1.2E-06**		5.1E-07	1.3E-09	**5.1E-07**		4.4E-06	1.5E-09	**4.4E-06**	
Radionuclides	1.0E-04	1.8E-07	**1.0E-04**		4.1E-05	1.1E-07	**4.1E-05**		3.6E-04	1.4E-07	**3.6E-04**	
GHG Summary (lb CO2 Equivalents/1,000 lb)												
Fossil CO2	1,066	51.2	**1,118**	95.3%	568	32.7	**601**	94.5%	2,447	39.9	**2,487**	94.8%
Methane	51.7	0.19	**51.9**	4.4%	34.6	0.12	**34.7**	5.5%	133	0.15	**133**	5.1%
Nitrous Oxide	3.64	0.0017	**3.64**	0.3%	0.45	0.0011	**0.45**	0.1%	4.13	0.0013	**4.14**	0.2%
Total	**1,122**	**51.4**	**1,173**	**100.0%**	**603**	**32.8**	**636**	**100.0%**	**2,584**	**40.1**	**2,624**	**100.0%**
% of Total	95.6%	4.4%	**100.0%**		94.8%	5.2%	**100.0%**		98.5%	1.5%	**100.0%**	

Table 2-6-BOX

ATMOSPHERIC EMISSIONS FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Shredded PC Corrugated Dunnage				Shredded PC Office Paper Dunnage			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related								
Particulates	0.012	0	**0.012**		0.039	0	**0.039**	
Nitrogen Oxides	0.039	0	**0.039**		0.12	0	**0.12**	
Hydrocarbons	0.0077	0	**0.0077**		0.024	0	**0.024**	
Sulfur Oxides	0.076	0	**0.076**		0.24	0	**0.24**	
Carbon Monoxide	0.0055	0	**0.0055**		0.017	0	**0.017**	
Aldehydes	2.7E-05	0	**2.7E-05**		8.5E-05	0	**8.5E-05**	
Methane	0.024	0	**0.024**		0.075	0	**0.075**	
Other Organics	4.1E-05	0	**4.1E-05**		1.3E-04	0	**1.3E-04**	
Odorous Sulfur	0	0	**0**		0	0	**0**	
Kerosene	3.6E-06	0	**3.6E-06**		1.1E-05	0	**1.1E-05**	
Ammonia	3.6E-05	0	**3.6E-05**		1.1E-04	0	**1.1E-04**	
Ethylene Oxide	0	0	**0**		0	0	**0**	
Hydrogen Fluoride	9.7E-05	0	**9.7E-05**		3.1E-04	0	**3.1E-04**	
Lead	4.6E-07	0	**4.6E-07**		1.4E-06	0	**1.4E-06**	
Mercury	2.7E-07	0	**2.7E-07**		8.4E-07	0	**8.4E-07**	
Chlorine	4.3E-08	0	**4.3E-08**		1.3E-07	0	**1.3E-07**	
HCl	7.1E-04	0	**7.1E-04**		0.0022	0	**0.0022**	
Phosphorus	0	0	**0**		0	0	**0**	
CO2 (fossil)	10.8	0	**10.8**		34.1	0	**34.1**	
CO2 (non-fossil)	0.0039	0	**0.0039**		0.012	0	**0.012**	
Total Reduced Sulfur	0	0	**0**		0	0	**0**	
Chlorine Dioxide	0	0	**0**		0	0	**0**	
Metals	1.6E-06	0	**1.6E-06**		5.0E-06	0	**5.0E-06**	
Mercaptan	0	0	**0**		0	0	**0**	
Antimony	6.2E-08	0	**6.2E-08**		1.9E-07	0	**1.9E-07**	
Arsenic	4.9E-07	0	**4.9E-07**		1.5E-06	0	**1.5E-06**	
Beryllium	5.8E-08	0	**5.8E-08**		1.8E-07	0	**1.8E-07**	
Cadmium	1.0E-07	0	**1.0E-07**		3.2E-07	0	**3.2E-07**	
Chromium	7.9E-07	0	**7.9E-07**		2.5E-06	0	**2.5E-06**	
Cobalt	1.7E-07	0	**1.7E-07**		5.4E-07	0	**5.4E-07**	
Manganese	1.6E-06	0	**1.6E-06**		5.0E-06	0	**5.0E-06**	
Nickel	1.7E-06	0	**1.7E-06**		5.4E-06	0	**5.4E-06**	
Selenium	9.9E-07	0	**9.9E-07**		3.1E-06	0	**3.1E-06**	
Acreolin	1.4E-07	0	**1.4E-07**		4.4E-07	0	**4.4E-07**	
Nitrous Oxide	8.8E-05	0	**8.8E-05**		2.8E-04	0	**2.8E-04**	
Benzene	2.0E-07	0	**2.0E-07**		6.2E-07	0	**6.2E-07**	
Perchloroethylene	1.3E-07	0	**1.3E-07**		4.2E-07	0	**4.2E-07**	
Trichloroethylene	1.3E-07	0	**1.3E-07**		4.1E-07	0	**4.1E-07**	
Methylene Chloride	5.9E-07	0	**5.9E-07**		1.9E-06	0	**1.9E-06**	
Carbon Tetrachloride	2.1E-07	0	**2.1E-07**		6.7E-07	0	**6.7E-07**	
Phenols	3.7E-07	0	**3.7E-07**		1.2E-06	0	**1.2E-06**	
Naphthalene	7.7E-09	0	**7.7E-09**		2.4E-08	0	**2.4E-08**	
Dioxins	7.6E-13	0	**7.6E-13**		2.4E-12	0	**2.4E-12**	
n-nitrosodimethlamine	2.9E-08	0	**2.9E-08**		9.3E-08	0	**9.3E-08**	
Radionuclides	2.4E-06	0	**2.4E-06**		7.5E-06	0	**7.5E-06**	
GHG Summary (lb CO2 Equivalents/1,000 lb)								
Fossil CO2	10.8	0	**10.8**	95.0%	34.1	0	**34.1**	95.0%
Methane	0.55	0	**0.55**	4.8%	1.72	0	**1.72**	4.8%
Nitrous Oxide	0.026	0	**0.026**	0.2%	0.082	0	**0.082**	0.2%
Total	**11.4**	**0**	**11.4**	**100.0%**	**35.9**	**0**	**35.9**	**100.0%**
% of Total	100.0%	0.0%	**100.0%**		100.0%	0.0%	**100.0%**	

Table 2-6-BAG

ATMOSPHERIC EMISSIONS FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	Bleached Kraft Virgin				Bleached Kraft 100% PC Recycled Content				Unbleached Kraft Virgin			
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	% of Total
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related												
Particulates	3.58	0.089	**3.67**		1.23	0.074	**1.31**		3.12	0.093	**3.21**	
Nitrogen Oxides	14.1	0.61	**14.7**		3.25	0.47	**3.72**		12.1	0.64	**12.8**	
Hydrocarbons	2.72	0.25	**2.97**		0.68	0.18	**0.86**		1.01	0.26	**1.27**	
Sulfur Oxides	20.7	0.17	**20.8**		7.93	0.12	**8.06**		20.3	0.18	**20.4**	
Carbon Monoxide	18.4	0.60	**19.0**		0.62	0.46	**1.08**		23.3	0.62	**23.9**	
Aldehydes	0.034	0.017	**0.050**		0.0043	0.012	**0.016**		0.037	0.017	**0.055**	
Methane	3.54	0.011	**3.55**		2.25	0.0081	**2.26**		2.12	0.012	**2.13**	
Other Organics	0.36	0.32	**0.68**		0.0037	0.25	**0.26**		0.23	0.34	**0.56**	
Odorous Sulfur	0.020	0	**0.020**		0	0	**0**		0	0	**0**	
Kerosene	2.3E-04	2.9E-07	**2.3E-04**		1.5E-04	2.1E-07	**1.5E-04**		5.3E-05	3.0E-07	**5.3E-05**	
Ammonia	0.043	1.1E-04	**0.043**		0.0016	8.1E-05	**0.0017**		0.092	1.2E-04	**0.092**	
Ethylene Oxide	0	0	**0**		0	0	**0**		0	0	**0**	
Hydrogen Fluoride	0.0062	9.1E-06	**0.0062**		0.0041	6.6E-06	**0.0041**		0.0014	9.5E-06	**0.0014**	
Lead	0.0016	3.8E-07	**0.0016**		4.4E-05	2.7E-07	**4.4E-05**		0.0013	3.9E-07	**0.0013**	
Mercury	6.6E-05	7.2E-08	**6.6E-05**		1.7E-05	5.2E-08	**1.7E-05**		1.1E-04	7.5E-08	**1.1E-04**	
Chlorine	0.024	4.3E-06	**0.024**		3.1E-06	3.1E-06	**6.2E-06**		0.0082	4.5E-06	**0.0082**	
HCl	0.045	6.9E-05	**0.045**		0.030	5.0E-05	**0.030**		0.010	7.2E-05	**0.010**	
Phosphorus	0	0	**0**		0	0	**0**		0	0	**0**	
CO2 (fossil)	2,107	71.2	**2,178**		1,066	51.2	**1,118**		1,043	74.2	**1,118**	
CO2 (non-fossil)	2,455	0.017	**2,455**		0.25	0.012	**0.26**		2,188	0.018	**2,188**	
Total Reduced Sulfur	0.40	0	**0.40**		0	0	**0**		0.058	0	**0.058**	
Chlorine Dioxide	0	0	**0**		0	0	**0**		0	0	**0**	
Metals	1.00	7.0E-06	**1.00**		1.0E-04	5.0E-06	**1.1E-04**		0.89	7.2E-06	**0.89**	
Mercaptan	0	0	**0**		0	0	**0**		0	0	**0**	
Antimony	5.4E-05	1.1E-07	**5.4E-05**		3.5E-06	7.7E-08	**3.6E-06**		2.9E-06	1.1E-07	**3.0E-06**	
Arsenic	4.5E-04	2.2E-07	**4.5E-04**		2.1E-04	1.6E-07	**2.1E-04**		3.4E-04	2.3E-07	**3.4E-04**	
Beryllium	3.6E-05	1.5E-08	**3.6E-05**		2.5E-05	1.1E-08	**2.5E-05**		2.9E-05	1.6E-08	**2.9E-05**	
Cadmium	2.4E-04	3.3E-07	**2.4E-04**		6.8E-05	2.4E-07	**6.8E-05**		8.4E-05	3.4E-07	**8.4E-05**	
Chromium	6.6E-04	2.5E-07	**6.6E-04**		4.3E-04	1.8E-07	**4.3E-04**		5.5E-04	2.6E-07	**5.5E-04**	
Cobalt	1.5E-04	3.0E-07	**1.5E-04**		9.9E-06	2.2E-07	**1.0E-05**		8.2E-06	3.1E-07	**8.5E-06**	
Manganese	0.011	3.0E-07	**0.011**		7.1E-04	2.2E-07	**7.1E-04**		0.010	3.1E-07	**0.010**	
Nickel	0.0033	4.7E-06	**0.0033**		3.4E-04	3.4E-06	**3.4E-04**		9.7E-04	4.9E-06	**9.8E-04**	
Selenium	1.2E-04	2.0E-07	**1.2E-04**		4.3E-05	1.5E-07	**4.3E-05**		1.7E-05	2.1E-07	**1.7E-05**	
Acreolin	8.8E-06	1.3E-08	**8.8E-06**		5.9E-06	9.4E-09	**5.9E-06**		2.1E-06	1.4E-08	**2.1E-06**	
Nitrous Oxide	0.015	8.0E-06	**0.015**		0.012	5.7E-06	**0.012**		0.012	8.3E-06	**0.012**	
Benzene	0.0043	4.2E-08	**0.0043**		8.5E-05	3.0E-08	**8.6E-05**		0.0039	4.4E-08	**0.0039**	
Perchloroethylene	8.4E-06	1.3E-08	**8.4E-06**		5.6E-06	9.3E-09	**5.6E-06**		2.0E-06	1.3E-08	**2.0E-06**	
Trichloroethylene	8.3E-06	1.2E-08	**8.3E-06**		5.6E-06	8.9E-09	**5.6E-06**		1.9E-06	1.3E-08	**2.0E-06**	
Methylene Chloride	3.7E-05	5.8E-08	**3.7E-05**		2.5E-05	4.2E-08	**2.5E-05**		8.8E-06	6.0E-08	**8.8E-06**	
Carbon Tetrachloride	1.4E-05	5.3E-08	**1.5E-05**		9.5E-06	3.8E-08	**9.6E-06**		3.8E-06	5.5E-08	**3.9E-06**	
Phenols	0.045	3.4E-07	**0.045**		1.7E-05	2.5E-07	**1.7E-05**		0.040	3.6E-07	**0.040**	
Naphthalene	0.0027	2.0E-08	**0.0027**		4.2E-07	1.4E-08	**4.3E-07**		0.0024	2.0E-08	**0.0024**	
Dioxins	4.8E-11	7.1E-14	**4.8E-11**		3.2E-11	5.1E-14	**3.2E-11**		1.1E-11	7.4E-14	**1.1E-11**	
n-nitrosodimethlamine	1.9E-06	2.8E-09	**1.9E-06**		1.2E-06	2.0E-09	**1.2E-06**		4.3E-07	2.9E-09	**4.4E-07**	
Radionuclides	1.5E-04	2.4E-07	**1.5E-04**		1.0E-04	1.8E-07	**1.0E-04**		3.5E-05	2.5E-07	**3.5E-05**	
GHG Summary (lb CO2 Equivalents/1,000 lb)												
Fossil CO2	2,107	71.2	**2,178**	96.2%	1,066	51.2	**1,118**	95.3%	1,043	74.2	**1,118**	95.5%
Methane	81.4	0.26	**81.7**	3.6%	51.7	0.19	**51.9**	4.4%	48.8	0.27	**49.0**	4.2%
Nitrous Oxide	4.56	0.0024	**4.57**	0.2%	3.64	0.0017	**3.64**	0.3%	3.56	0.0025	**3.56**	0.3%
Total	**2,193**	**71.4**	**2,264**	**100.0%**	**1,122**	**51.4**	**1,173**	**100.0%**	**1,096**	**74.5**	**1,170**	**100.0%**
% of Total	96.8%	3.2%	**100.0%**		95.6%	4.4%	**100.0%**		93.6%	6.4%	**100.0%**	

Table 2-6-BAG
ATMOSPHERIC EMISSIONS FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	Unbleached Kraft 100% PC Recycled Content				**Macerated 100% PC Newspaper Padding**				**LDPE Film Virgin**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related												
Particulates	1.23	0.074	**1.31**		0.046	0.14	**0.19**		1.46	0.28	**1.75**	
Nitrogen Oxides	3.25	0.47	**3.72**		0.20	0.64	**0.83**		7.97	1.79	**9.76**	
Hydrocarbons	0.68	0.18	**0.86**		0.037	0.21	**0.24**		17.3	0.84	**18.1**	
Sulfur Oxides	7.93	0.12	**8.06**		0.26	0.12	**0.38**		52.4	0.72	**53.2**	
Carbon Monoxide	0.62	0.46	**1.08**		0.033	0.61	**0.64**		5.98	1.31	**7.29**	
Aldehydes	0.0043	0.012	**0.016**		0.0011	0.012	**0.013**		0.019	0.043	**0.063**	
Methane	2.25	0.0081	**2.26**		0.078	0.0080	**0.087**		11.0	0.085	**11.1**	
Other Organics	0.0037	0.25	**0.26**		1.8E-04	0.37	**0.37**		0.011	0.59	**0.60**	
Odorous Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Kerosene	1.5E-04	2.1E-07	**1.5E-04**		1.2E-05	2.1E-07	**1.2E-05**		3.4E-04	2.1E-06	**3.4E-04**	
Ammonia	0.0016	8.1E-05	**0.0017**		1.2E-04	8.0E-05	**2.0E-04**		0.0049	3.1E-04	**0.0052**	
Ethylene Oxide	0	0	**0**		0	0	**0**		0	0	**0**	
Hydrogen Fluoride	0.0041	6.6E-06	**0.0041**		3.2E-04	6.5E-06	**3.3E-04**		0.0093	6.0E-05	**0.0093**	
Lead	4.4E-05	2.7E-07	**4.4E-05**		1.5E-06	2.7E-07	**1.8E-06**		5.2E-05	1.2E-06	**5.3E-05**	
Mercury	1.7E-05	5.2E-08	**1.7E-05**		8.8E-07	5.1E-08	**9.3E-07**		2.7E-05	2.9E-07	**2.7E-05**	
Chlorine	3.1E-06	3.1E-06	**6.2E-06**		3.6E-07	3.1E-06	**3.4E-06**		6.1E-05	1.1E-05	**7.3E-05**	
HCl	0.030	5.0E-05	**0.030**		0.0023	4.9E-05	**0.0024**		0.067	4.4E-04	**0.068**	
Phosphorus	0	0	**0**		0	0	**0**		0	0	**0**	
CO2 (fossil)	1,066	51.2	**1,118**		39.1	50.3	**89.5**		2,013	208	**2,221**	
CO2 (non-fossil)	0.25	0.012	**0.26**		0.014	0.012	**0.026**		0.58	0.049	**0.63**	
Total Reduced Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Chlorine Dioxide	0	0	**0**		0	0	**0**		0	0	**0**	
Metals	1.0E-04	5.0E-06	**1.1E-04**		5.5E-06	4.9E-06	**1.0E-05**		2.3E-04	2.0E-05	**2.6E-04**	
Mercaptan	0	0	**0**		0	0	**0**		0	0	**0**	
Antimony	3.5E-06	7.7E-08	**3.6E-06**		2.1E-07	7.6E-08	**2.8E-07**		8.3E-06	3.1E-07	**8.6E-06**	
Arsenic	2.1E-04	1.6E-07	**2.1E-04**		1.6E-06	1.6E-07	**1.8E-06**		5.1E-05	7.7E-07	**5.1E-05**	
Beryllium	2.5E-05	1.1E-08	**2.5E-05**		1.9E-07	1.1E-08	**2.0E-07**		5.8E-06	6.3E-08	**5.9E-06**	
Cadmium	6.8E-05	2.4E-07	**6.8E-05**		3.5E-07	2.3E-07	**5.8E-07**		1.8E-05	9.3E-07	**1.8E-05**	
Chromium	4.3E-04	1.8E-07	**4.3E-04**		2.6E-06	1.8E-07	**2.8E-06**		8.1E-05	9.7E-07	**8.1E-05**	
Cobalt	9.9E-06	2.2E-07	**1.0E-05**		5.8E-07	2.1E-07	**8.0E-07**		2.3E-05	8.8E-07	**2.4E-05**	
Manganese	7.1E-04	2.2E-07	**7.1E-04**		5.2E-06	2.1E-07	**5.4E-06**		1.5E-04	1.4E-06	**1.6E-04**	
Nickel	3.4E-04	3.4E-06	**3.4E-04**		5.9E-06	3.3E-06	**9.2E-06**		2.7E-04	1.3E-05	**2.9E-04**	
Selenium	4.3E-05	1.5E-07	**4.3E-05**		3.2E-06	1.4E-07	**3.4E-06**		9.7E-05	9.1E-07	**9.7E-05**	
Acreolin	5.9E-06	9.4E-09	**5.9E-06**		4.6E-07	9.3E-09	**4.7E-07**		1.3E-05	8.6E-08	**1.3E-05**	
Nitrous Oxide	0.012	5.7E-06	**0.012**		2.9E-04	5.7E-06	**2.9E-04**		0.0084	5.4E-05	**0.0084**	
Benzene	8.5E-05	3.0E-08	**8.6E-05**		6.5E-07	3.0E-08	**6.8E-07**		1.9E-05	1.9E-07	**1.9E-05**	
Perchloroethylene	5.6E-06	9.3E-09	**5.6E-06**		4.4E-07	9.2E-09	**4.5E-07**		1.3E-05	8.4E-08	**1.3E-05**	
Trichloroethylene	5.6E-06	8.9E-09	**5.6E-06**		4.3E-07	8.8E-09	**4.4E-07**		1.3E-05	8.2E-08	**1.3E-05**	
Methylene Chloride	2.5E-05	4.2E-08	**2.5E-05**		1.9E-06	4.1E-08	**2.0E-06**		5.6E-05	3.7E-07	**5.7E-05**	
Carbon Tetrachloride	9.5E-06	3.8E-08	**9.6E-06**		7.1E-07	3.8E-08	**7.4E-07**		2.1E-05	2.3E-07	**2.1E-05**	
Phenols	1.7E-05	2.5E-07	**1.7E-05**		1.2E-06	2.4E-07	**1.5E-06**		3.9E-05	1.1E-06	**4.0E-05**	
Naphthalene	4.2E-07	1.4E-08	**4.3E-07**		2.6E-08	1.4E-08	**4.0E-08**		9.7E-07	5.8E-08	**1.0E-06**	
Dioxins	3.2E-11	5.1E-14	**3.2E-11**		2.5E-12	5.1E-14	**2.6E-12**		7.3E-11	4.7E-13	**7.3E-11**	
n-nitrosodimethlamine	1.2E-06	2.0E-09	**1.2E-06**		9.7E-08	2.0E-09	**9.9E-08**		2.8E-06	1.8E-08	**2.8E-06**	
Radionuclides	1.0E-04	1.8E-07	**1.0E-04**		7.8E-06	1.7E-07	**8.0E-06**		2.3E-04	1.5E-06	**2.3E-04**	
GHG Summary (lb CO2 Equivalents/1,000 lb)												
Fossil CO2	1,066	51.2	**1,118**	95.3%	39.1	50.3	**89.5**	97.7%	2,013	208	**2,221**	89.6%
Methane	51.7	0.19	**51.9**	4.4%	1.81	0.18	**1.99**	2.2%	253	1.96	**255**	10.3%
Nitrous Oxide	3.64	0.0017	**3.64**	0.3%	0.085	0.0017	**0.087**	0.1%	2.48	0.016	**2.50**	0.1%
Total	**1,122**	**51.4**	**1,173**	**100.0%**	**41.0**	**50.5**	**91.5**	**100.0%**	**2,268**	**210**	**2,478**	**100.0%**
% of Total	95.6%	4.4%	**100.0%**		44.8%	55.2%	**100.0%**		91.5%	8.5%	**100.0%**	

Table 2-6-BAG
ATMOSPHERIC EMISSIONS FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	LDPE Film 100% PC Recycled Content				**LLDPE Film Virgin**				**LLDPE Film 100% PC Recycled Content**			
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related												
Particulates	0.87	0.29	**1.16**		1.24	0.28	**1.52**		0.87	0.29	**1.16**	
Nitrogen Oxides	2.73	1.46	**4.20**		6.97	1.78	**8.76**		2.73	1.46	**4.20**	
Hydrocarbons	0.56	0.51	**1.06**		14.9	0.84	**15.7**		0.56	0.51	**1.06**	
Sulfur Oxides	5.38	0.32	**5.70**		50.3	0.71	**51.0**		5.38	0.32	**5.70**	
Carbon Monoxide	0.39	1.41	**1.80**		5.80	1.31	**7.11**		0.39	1.41	**1.80**	
Aldehydes	0.0019	0.031	**0.033**		0.019	0.043	**0.062**		0.0019	0.031	**0.033**	
Methane	1.66	0.021	**1.68**		10.4	0.084	**10.5**		1.66	0.021	**1.68**	
Other Organics	0.0029	0.83	**0.83**		0.0095	0.59	**0.59**		0.0029	0.83	**0.83**	
Odorous Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Kerosene	2.5E-04	5.4E-07	**2.5E-04**		2.6E-04	1.8E-06	**2.6E-04**		2.5E-04	5.4E-07	**2.5E-04**	
Ammonia	0.0025	2.1E-04	**0.0027**		0.0041	3.0E-04	**0.0044**		0.0025	2.1E-04	**0.0027**	
Ethylene Oxide	0	0	**0**		0	0	**0**		0	0	**0**	
Hydrogen Fluoride	0.0068	1.7E-05	**0.0068**		0.0070	5.2E-05	**0.0071**		0.0068	1.7E-05	**0.0068**	
Lead	3.2E-05	7.0E-07	**3.3E-05**		4.1E-05	1.1E-06	**4.2E-05**		3.2E-05	7.0E-07	**3.3E-05**	
Mercury	1.8E-05	1.3E-07	**1.9E-05**		2.0E-05	2.7E-07	**2.1E-05**		1.8E-05	1.3E-07	**1.9E-05**	
Chlorine	3.1E-06	7.9E-06	**1.1E-05**		6.1E-05	1.1E-05	**7.2E-05**		3.1E-06	7.9E-06	**1.1E-05**	
HCl	0.049	1.3E-04	**0.049**		0.051	3.9E-04	**0.051**		0.049	1.3E-04	**0.049**	
Phosphorus	0	0	**0**		0	0	**0**		0	0	**0**	
CO2 (fossil)	759	130	**890**		1,732	207	**1,939**		759	130	**890**	
CO2 (non-fossil)	0.27	0.031	**0.30**		0.48	0.049	**0.53**		0.27	0.031	**0.30**	
Total Reduced Sulfur	0	0	**0**		0	0	**0**		0	0	**0**	
Chlorine Dioxide	0	0	**0**		0	0	**0**		0	0	**0**	
Metals	1.1E-04	1.3E-05	**1.2E-04**		2.0E-04	2.0E-05	**2.2E-04**		1.1E-04	1.3E-05	**1.2E-04**	
Mercaptan	0	0	**0**		0	0	**0**		0	0	**0**	
Antimony	4.3E-06	2.0E-07	**4.5E-06**		6.9E-06	3.1E-07	**7.2E-06**		4.3E-06	2.0E-07	**4.5E-06**	
Arsenic	3.4E-05	4.0E-07	**3.4E-05**		4.0E-05	7.3E-07	**4.0E-05**		3.4E-05	4.0E-07	**3.4E-05**	
Beryllium	4.0E-06	2.8E-08	**4.1E-06**		4.5E-06	5.8E-08	**4.6E-06**		4.0E-06	2.8E-08	**4.1E-06**	
Cadmium	7.0E-06	6.1E-07	**7.6E-06**		1.5E-05	9.2E-07	**1.6E-05**		7.0E-06	6.1E-07	**7.6E-06**	
Chromium	5.5E-05	4.6E-07	**5.5E-05**		6.3E-05	9.0E-07	**6.4E-05**		5.5E-05	4.6E-07	**5.5E-05**	
Cobalt	1.2E-05	5.5E-07	**1.3E-05**		1.9E-05	8.6E-07	**2.0E-05**		1.2E-05	5.5E-07	**1.3E-05**	
Manganese	1.1E-04	5.5E-07	**1.1E-04**		1.2E-04	1.3E-06	**1.2E-04**		1.1E-04	5.5E-07	**1.1E-04**	
Nickel	1.2E-04	8.6E-06	**1.3E-04**		2.3E-04	1.3E-05	**2.5E-04**		1.2E-04	8.6E-06	**1.3E-04**	
Selenium	6.9E-05	3.7E-07	**6.9E-05**		7.4E-05	8.3E-07	**7.5E-05**		6.9E-05	3.7E-07	**6.9E-05**	
Acreolin	9.7E-06	2.4E-08	**9.7E-06**		1.0E-05	7.5E-08	**1.0E-05**		9.7E-06	2.4E-08	**9.7E-06**	
Nitrous Oxide	0.0061	1.5E-05	**0.0061**		0.0064	4.7E-05	**0.0064**		0.0061	1.5E-05	**0.0061**	
Benzene	1.4E-05	7.7E-08	**1.4E-05**		1.5E-05	1.7E-07	**1.5E-05**		1.4E-05	7.7E-08	**1.4E-05**	
Perchloroethylene	9.2E-06	2.4E-08	**9.3E-06**		9.6E-06	7.3E-08	**9.7E-06**		9.2E-06	2.4E-08	**9.3E-06**	
Trichloroethylene	9.2E-06	2.3E-08	**9.2E-06**		9.5E-06	7.1E-08	**9.6E-06**		9.2E-06	2.3E-08	**9.2E-06**	
Methylene Chloride	4.1E-05	1.1E-07	**4.1E-05**		4.3E-05	3.2E-07	**4.3E-05**		4.1E-05	1.1E-07	**4.1E-05**	
Carbon Tetrachloride	1.5E-05	9.7E-08	**1.5E-05**		1.6E-05	2.1E-07	**1.6E-05**		1.5E-05	9.7E-08	**1.5E-05**	
Phenols	2.5E-05	6.3E-07	**2.6E-05**		3.0E-05	1.1E-06	**3.1E-05**		2.5E-05	6.3E-07	**2.6E-05**	
Naphthalene	5.4E-07	3.6E-08	**5.7E-07**		7.8E-07	5.7E-08	**8.4E-07**		5.4E-07	3.6E-08	**5.7E-07**	
Dioxins	5.3E-11	1.3E-13	**5.3E-11**		5.5E-11	4.1E-13	**5.6E-11**		5.3E-11	1.3E-13	**5.3E-11**	
n-nitrosodimethlamine	2.0E-06	5.1E-09	**2.1E-06**		2.1E-06	1.6E-08	**2.2E-06**		2.0E-06	5.1E-09	**2.1E-06**	
Radionuclides	1.6E-04	4.5E-07	**1.7E-04**		1.7E-04	1.3E-06	**1.7E-04**		1.6E-04	4.5E-07	**1.7E-04**	
GHG Summary (lb CO2 Equivalents/1,000 lb)												
Fossil CO2	759	130	**890**	95.6%	1,732	207	**1,939**	88.9%	759	130	**890**	95.6%
Methane	38.3	0.48	**38.8**	4.2%	239	1.92	**241**	11.0%	38.3	0.48	**38.8**	4.2%
Nitrous Oxide	1.81	0.0043	**1.81**	0.2%	1.89	0.014	**1.90**	0.1%	1.81	0.0043	**1.81**	0.2%
Total	**799**	**131**	**930**	**100.0%**	**1,972**	**209**	**2,181**	**100.0%**	**799**	**131**	**930**	**100.0%**
% of Total	85.9%	14.1%	**100.0%**		90.4%	9.6%	**100.0%**		85.9%	14.1%	**100.0%**	

Table 2-7-BOX

ATMOSPHERIC EMISSIONS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Average (38%) PC Corrugated Box			80% PC Corrugated Box			LDPE Inflated Air Packets Virgin		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	20.8		0	20.8		0	10
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related									
Particulates	0	0.067	0.053	0	0.067	0.053	0.17	0.076	0.068
Nitrogen Oxides	0	0.37	0.29	0	0.37	0.29	1.21	0.41	0.37
Hydrocarbons	0	0.107	0.085	0	0.107	0.085	0.49	0.12	0.11
Sulfur Oxides	0	0.064	0.051	0	0.064	0.051	0.34	0.072	0.065
Carbon Monoxide	0	0.28	0.22	0	0.28	0.22	1.19	0.32	0.29
Aldehydes	0	0.0066	0.0052	0	0.0066	0.0052	0.033	0.0074	0.0066
Methane	0	0.0043	0.0034	0	0.0043	0.0034	0.022	0.0048	0.0043
Other Organics	0	0.16	0.13	0	0.16	0.13	0.65	0.18	0.16
Odorous Sulfur	0	0	0	0	0	0	0	0	0
Kerosene	0	1.1E-07	8.7E-08	0	1.1E-07	8.7E-08	5.8E-07	1.2E-07	1.1E-07
Ammonia	0	4.2E-05	3.4E-05	0	4.2E-05	3.4E-05	2.2E-04	4.7E-05	4.3E-05
Ethylene Oxide	0	0	0	0	0	0	0	0	0
Hydrogen Fluoride	0	3.4E-06	2.7E-06	0	3.4E-06	2.7E-06	1.8E-05	3.8E-06	3.5E-06
Lead	0	1.4E-07	1.1E-07	0	1.4E-07	1.1E-07	7.5E-07	1.6E-07	1.4E-07
Mercury	0	2.7E-08	2.2E-08	0	2.7E-08	2.2E-08	1.4E-07	3.1E-08	2.7E-08
Chlorine	0	1.6E-06	1.3E-06	0	1.6E-06	1.3E-06	8.5E-06	1.8E-06	1.6E-06
HCl	0	2.6E-05	2.1E-05	0	2.6E-05	2.1E-05	1.4E-04	2.9E-05	2.6E-05
Phosphorus	0	0	0	0	0	0	0	0	0
CO2 (fossil)	0	26.7	21.2	0	26.7	21.2	141	29.9	26.9
CO2 (non-fossil)	0	0.0064	0.0051	0	0.0064	0.0051	0.034	0.0072	0.0065
Total Reduced Sulfur	0	0	0	0	0	0	0	0	0
Chlorine Dioxide	0	0	0	0	0	0	0	0	0
Metals	0	2.6E-06	2.1E-06	0	2.6E-06	2.1E-06	1.4E-05	2.9E-06	2.6E-06
Mercaptan	0	0	0	0	0	0	0	0	0
Antimony	0	4.0E-08	3.2E-08	0	4.0E-08	3.2E-08	2.1E-07	4.5E-08	4.0E-08
Arsenic	0	8.3E-08	6.6E-08	0	8.3E-08	6.6E-08	4.4E-07	9.3E-08	8.3E-08
Beryllium	0	5.8E-09	4.6E-09	0	5.8E-09	4.6E-09	3.0E-08	6.5E-09	5.8E-09
Cadmium	0	1.2E-07	9.8E-08	0	1.2E-07	9.8E-08	6.5E-07	1.4E-07	1.3E-07
Chromium	0	9.5E-08	7.5E-08	0	9.5E-08	7.5E-08	5.0E-07	1.1E-07	9.5E-08
Cobalt	0	1.1E-07	9.0E-08	0	1.1E-07	9.0E-08	6.0E-07	1.3E-07	1.1E-07
Manganese	0	1.1E-07	8.9E-08	0	1.1E-07	8.9E-08	5.9E-07	1.3E-07	1.1E-07
Nickel	0	1.8E-06	1.4E-06	0	1.8E-06	1.4E-06	9.3E-06	2.0E-06	1.8E-06
Selenium	0	7.6E-08	6.0E-08	0	7.6E-08	6.0E-08	4.0E-07	8.5E-08	7.7E-08
Acreolin	0	4.9E-09	3.9E-09	0	4.9E-09	3.9E-09	2.6E-08	5.5E-09	5.0E-09
Nitrous Oxide	0	3.0E-06	2.4E-06	0	3.0E-06	2.4E-06	1.6E-05	3.4E-06	3.0E-06
Benzene	0	1.6E-08	1.3E-08	0	1.6E-08	1.3E-08	8.3E-08	1.8E-08	1.6E-08
Perchloroethylene	0	4.9E-09	3.8E-09	0	4.9E-09	3.8E-09	2.6E-08	5.4E-09	4.9E-09
Trichloroethylene	0	4.6E-09	3.7E-09	0	4.6E-09	3.7E-09	2.4E-08	5.2E-09	4.7E-09
Methylene Chloride	0	2.2E-08	1.7E-08	0	2.2E-08	1.7E-08	1.1E-07	2.4E-08	2.2E-08
Carbon Tetrachloride	0	2.0E-08	1.6E-08	0	2.0E-08	1.6E-08	1.0E-07	2.2E-08	2.0E-08
Phenols	0	1.3E-07	1.0E-07	0	1.3E-07	1.0E-07	6.8E-07	1.4E-07	1.3E-07
Naphthalene	0	7.4E-09	5.8E-09	0	7.4E-09	5.8E-09	3.9E-08	8.2E-09	7.4E-09
Dioxins	0	2.7E-14	2.1E-14	0	2.7E-14	2.1E-14	1.4E-13	3.0E-14	2.7E-14
n-nitrosodimethlamine	0	1.0E-09	8.2E-10	0	1.0E-09	8.2E-10	5.5E-09	1.2E-09	1.0E-09
Radionuclides	0	9.2E-08	7.3E-08	0	9.2E-08	7.3E-08	4.8E-07	1.0E-07	9.3E-08
GHG Summary (lb CO2 Equivalents/1,000 lb)									
Fossil CO2	0	26.7	21.2	0	26.7	21.2	141	29.9	26.9
Methane	0	0.098	0.078	0	0.098	0.078	0.52	0.110	0.099
Nitrous Oxide	0	8.9E-04	7.0E-04	0	8.9E-04	7.0E-04	0.0047	9.9E-04	8.9E-04
Total	**0**	**26.8**	**21.3**	**0**	**26.8**	**21.3**	**142**	**30.1**	**27.0**

Table 2-7-BOX

ATMOSPHERIC EMISSIONS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	LDPE Inflated Air Packets 100% PC Recycled Content			**EPS Loose Fill Virgin**			**EPS Loose Fill 100% PC Recycled Content**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	55		0	55
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related									
Particulates	0.17	0.076	0.068	0.61	0.206	0.093	1.25	0.206	0.093
Nitrogen Oxides	1.21	0.41	0.37	4.26	1.13	0.51	8.68	1.13	0.51
Hydrocarbons	0.49	0.12	0.11	1.71	0.33	0.15	3.49	0.33	0.15
Sulfur Oxides	0.34	0.072	0.065	1.21	0.197	0.089	2.46	0.197	0.089
Carbon Monoxide	1.19	0.32	0.29	4.18	0.86	0.39	8.53	0.86	0.39
Aldehydes	0.033	0.0074	0.0066	0.12	0.0202	0.0091	0.24	0.0202	0.0091
Methane	0.022	0.0048	0.0043	0.079	0.0130	0.0059	0.16	0.0130	0.0059
Other Organics	0.65	0.18	0.16	2.27	0.49	0.22	4.63	0.49	0.22
Odorous Sulfur	0	0	0	0	0	0	0	0	0
Kerosene	5.8E-07	1.2E-07	1.1E-07	2.0E-06	3.4E-07	1.5E-07	4.1E-06	3.4E-07	1.5E-07
Ammonia	2.2E-04	4.7E-05	4.3E-05	7.8E-04	1.3E-04	5.8E-05	0.0016	1.3E-04	5.8E-05
Ethylene Oxide	0	0	0	0	0	0	0	0	0
Hydrogen Fluoride	1.8E-05	3.8E-06	3.5E-06	6.3E-05	1.0E-05	4.7E-06	1.3E-04	1.0E-05	4.7E-06
Lead	7.5E-07	1.6E-07	1.4E-07	2.6E-06	4.4E-07	2.0E-07	5.4E-06	4.4E-07	2.0E-07
Mercury	1.4E-07	3.1E-08	2.7E-08	5.0E-07	8.3E-08	3.8E-08	1.0E-06	8.3E-08	3.8E-08
Chlorine	8.5E-06	1.8E-06	1.6E-06	3.0E-05	5.0E-06	2.2E-06	6.1E-05	5.0E-06	2.2E-06
HCl	1.4E-04	2.9E-05	2.6E-05	4.8E-04	8.0E-05	3.6E-05	9.8E-04	8.0E-05	3.6E-05
Phosphorus	0	0	0	0	0	0	0	0	0
CO2 (fossil)	141	29.9	26.9	496	81.9	36.8	1,011	81.9	36.8
CO2 (non-fossil)	0.034	0.0072	0.0065	0.12	0.0197	0.0089	0.24	0.0197	0.0089
Total Reduced Sulfur	0	0	0	0	0	0	0	0	0
Chlorine Dioxide	0	0	0	0	0	0	0	0	0
Metals	1.4E-05	2.9E-06	2.6E-06	4.8E-05	8.0E-06	3.6E-06	9.9E-05	8.0E-06	3.6E-06
Mercaptan	0	0	0	0	0	0	0	0	0
Antimony	2.1E-07	4.5E-08	4.0E-08	7.4E-07	1.2E-07	5.5E-08	1.5E-06	1.2E-07	5.5E-08
Arsenic	4.4E-07	9.3E-08	8.3E-08	1.5E-06	2.5E-07	1.1E-07	3.1E-06	2.5E-07	1.1E-07
Beryllium	3.0E-08	6.5E-09	5.8E-09	1.1E-07	1.8E-08	8.0E-09	2.2E-07	1.8E-08	8.0E-09
Cadmium	6.5E-07	1.4E-07	1.3E-07	2.3E-06	3.8E-07	1.7E-07	4.7E-06	3.8E-07	1.7E-07
Chromium	5.0E-07	1.1E-07	9.5E-08	1.7E-06	2.9E-07	1.3E-07	3.6E-06	2.9E-07	1.3E-07
Cobalt	6.0E-07	1.3E-07	1.1E-07	2.1E-06	3.5E-07	1.6E-07	4.3E-06	3.5E-07	1.6E-07
Manganese	5.9E-07	1.3E-07	1.1E-07	2.1E-06	3.5E-07	1.6E-07	4.3E-06	3.5E-07	1.6E-07
Nickel	9.3E-06	2.0E-06	1.8E-06	3.3E-05	5.4E-06	2.4E-06	6.7E-05	5.4E-06	2.4E-06
Selenium	4.0E-07	8.5E-08	7.7E-08	1.4E-06	2.3E-07	1.0E-07	2.9E-06	2.3E-07	1.0E-07
Acreolin	2.6E-08	5.5E-09	5.0E-09	9.1E-08	1.5E-08	6.8E-09	1.9E-07	1.5E-08	6.8E-09
Nitrous Oxide	1.6E-05	3.4E-06	3.0E-06	5.5E-05	9.2E-06	4.1E-06	1.1E-04	9.2E-06	4.1E-06
Benzene	8.3E-08	1.8E-08	1.6E-08	2.9E-07	4.8E-08	2.2E-08	5.9E-07	4.8E-08	2.2E-08
Perchloroethylene	2.6E-08	5.4E-09	4.9E-09	9.0E-08	1.5E-08	6.7E-09	1.8E-07	1.5E-08	6.7E-09
Trichloroethylene	2.4E-08	5.2E-09	4.7E-09	8.6E-08	1.4E-08	6.4E-09	1.8E-07	1.4E-08	6.4E-09
Methylene Chloride	1.1E-07	2.4E-08	2.2E-08	4.0E-07	6.7E-08	3.0E-08	8.2E-07	6.7E-08	3.0E-08
Carbon Tetrachloride	1.0E-07	2.2E-08	2.0E-08	3.7E-07	6.1E-08	2.7E-08	7.5E-07	6.1E-08	2.7E-08
Phenols	6.8E-07	1.4E-07	1.3E-07	2.4E-06	3.9E-07	1.8E-07	4.9E-06	3.9E-07	1.8E-07
Naphthalene	3.9E-08	8.2E-09	7.4E-09	1.4E-07	2.3E-08	1.0E-08	2.8E-07	2.3E-08	1.0E-08
Dioxins	1.4E-13	3.0E-14	2.7E-14	5.0E-13	8.2E-14	3.7E-14	1.0E-12	8.2E-14	3.7E-14
n-nitrosodimethlamine	5.5E-09	1.2E-09	1.0E-09	1.9E-08	3.2E-09	1.4E-09	3.9E-08	3.2E-09	1.4E-09
Radionuclides	4.8E-07	1.0E-07	9.3E-08	1.7E-06	2.8E-07	1.3E-07	3.5E-06	2.8E-07	1.3E-07
GHG Summary (lb CO2 Equivalents/1,000 lb)									
Fossil CO2	141	29.9	26.9	496	81.9	36.8	1,011	81.9	36.8
Methane	0.52	0.110	0.099	1.81	0.30	0.14	3.69	0.30	0.14
Nitrous Oxide	0.0047	9.9E-04	8.9E-04	0.016	0.0027	0.0012	0.033	0.0027	0.0012
Total	**142**	**30.1**	**27.0**	**498**	**82.2**	**37.0**	**1,015**	**82.2**	**37.0**

Table 2-7-BOX

ATMOSPHERIC EMISSIONS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Cornstarch Loose Fill			**Molded Pulp Loose Fill 100% PC Recycled Content**			**Unbleached Kraft Paper Virgin**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	55		0	10		0	10
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related									
Particulates	0.75	0.024	0.011	0.57	0.062	0.056	0.018	0.068	0.061
Nitrogen Oxides	5.24	0.134	0.060	3.95	0.34	0.30	0.13	0.37	0.34
Hydrocarbons	2.11	0.039	0.017	1.59	0.098	0.088	0.050	0.108	0.097
Sulfur Oxides	1.49	0.023	0.010	1.12	0.059	0.053	0.036	0.065	0.059
Carbon Monoxide	5.15	0.102	0.046	3.88	0.26	0.23	0.12	0.29	0.26
Aldehydes	0.14	0.0024	0.0011	0.11	0.0060	0.0054	0.0034	0.0067	0.0060
Methane	0.097	1.5E-03	6.9E-04	0.073	0.0039	0.0035	0.0023	0.0043	0.0039
Other Organics	2.80	0.057	0.026	2.11	0.15	0.13	0.067	0.16	0.15
Odorous Sulfur	0	0	0	0	0	0	0	0	0
Kerosene	2.5E-06	4.0E-08	1.8E-08	1.9E-06	1.0E-07	9.1E-08	6.0E-08	1.1E-07	1.0E-07
Ammonia	9.6E-04	1.5E-05	6.9E-06	7.3E-04	3.9E-05	3.5E-05	2.3E-05	4.3E-05	3.9E-05
Ethylene Oxide	0	0	0	0	0	0	0	0	0
Hydrogen Fluoride	7.8E-05	1.2E-06	5.6E-07	5.9E-05	3.1E-06	2.8E-06	1.9E-06	3.5E-06	3.1E-06
Lead	3.2E-06	5.2E-08	2.3E-08	2.4E-06	1.3E-07	1.2E-07	7.8E-08	1.4E-07	1.3E-07
Mercury	6.2E-07	9.8E-09	4.4E-09	4.7E-07	2.5E-08	2.2E-08	1.5E-08	2.8E-08	2.5E-08
Chlorine	3.7E-05	5.9E-07	2.6E-07	2.8E-05	1.5E-06	1.3E-06	8.8E-07	1.6E-06	1.5E-06
HCl	5.9E-04	9.4E-06	4.2E-06	4.5E-04	2.4E-05	2.1E-05	1.4E-05	2.6E-05	2.4E-05
Phosphorus	0	0	0	0	0	0	0	0	0
CO2 (fossil)	611	9.67	4.35	460	24.5	22.1	14.6	27.1	24.4
CO2 (non-fossil)	0.15	0.0023	0.0010	0.11	0.0059	0.0053	0.0035	0.0065	0.0059
Total Reduced Sulfur	0	0	0	0	0	0	0	0	0
Chlorine Dioxide	0	0	0	0	0	0	0	0	0
Metals	6.0E-05	9.5E-07	4.3E-07	4.5E-05	2.4E-06	2.2E-06	1.4E-06	2.7E-06	2.4E-06
Mercaptan	0	0	0	0	0	0	0	0	0
Antimony	9.1E-07	1.4E-08	6.5E-09	6.9E-07	3.7E-08	3.3E-08	2.2E-08	4.1E-08	3.6E-08
Arsenic	1.9E-06	3.0E-08	1.3E-08	1.4E-06	7.6E-08	6.8E-08	4.5E-08	8.4E-08	7.5E-08
Beryllium	1.3E-07	2.1E-09	9.4E-10	9.9E-08	5.3E-09	4.8E-09	3.1E-09	5.9E-09	5.3E-09
Cadmium	2.8E-06	4.5E-08	2.0E-08	2.1E-06	1.1E-07	1.0E-07	6.8E-08	1.3E-07	1.1E-07
Chromium	2.2E-06	3.4E-08	1.5E-08	1.6E-06	8.7E-08	7.8E-08	5.1E-08	9.6E-08	8.6E-08
Cobalt	2.6E-06	4.1E-08	1.8E-08	1.9E-06	1.0E-07	9.3E-08	6.2E-08	1.1E-07	1.0E-07
Manganese	2.6E-06	4.1E-08	1.8E-08	1.9E-06	1.0E-07	9.3E-08	6.1E-08	1.1E-07	1.0E-07
Nickel	4.0E-05	6.4E-07	2.9E-07	3.0E-05	1.6E-06	1.5E-06	9.6E-07	1.8E-06	1.6E-06
Selenium	1.7E-06	2.7E-08	1.2E-08	1.3E-06	7.0E-08	6.3E-08	4.1E-08	7.7E-08	6.9E-08
Acreolin	1.1E-07	1.8E-09	8.0E-10	8.4E-08	4.5E-09	4.1E-09	2.7E-09	5.0E-09	4.5E-09
Nitrous Oxide	6.8E-05	1.1E-06	4.9E-07	5.1E-05	2.8E-06	2.5E-06	1.6E-06	3.0E-06	2.7E-06
Benzene	3.6E-07	5.7E-09	2.6E-09	2.7E-07	1.4E-08	1.3E-08	8.6E-09	1.6E-08	1.4E-08
Perchloroethylene	1.1E-07	1.8E-09	7.9E-10	8.3E-08	4.5E-09	4.0E-09	2.6E-09	4.9E-09	4.4E-09
Trichloroethylene	1.1E-07	1.7E-09	7.6E-10	8.0E-08	4.3E-09	3.8E-09	2.5E-09	4.7E-09	4.2E-09
Methylene Chloride	4.9E-07	7.9E-09	3.5E-09	3.7E-07	2.0E-08	1.8E-08	1.2E-08	2.2E-08	2.0E-08
Carbon Tetrachloride	4.5E-07	7.2E-09	3.2E-09	3.4E-07	1.8E-08	1.6E-08	1.1E-08	2.0E-08	1.8E-08
Phenols	2.9E-06	4.7E-08	2.1E-08	2.2E-06	1.2E-07	1.1E-07	7.0E-08	1.3E-07	1.2E-07
Naphthalene	1.7E-07	2.7E-09	1.2E-09	1.3E-07	6.8E-09	6.1E-09	4.0E-09	7.5E-09	6.7E-09
Dioxins	6.1E-13	9.7E-15	4.4E-15	4.6E-13	2.5E-14	2.2E-14	1.5E-14	2.7E-14	2.4E-14
n-nitrosodimethlamine	2.4E-08	3.8E-10	1.7E-10	1.8E-08	9.5E-10	8.6E-10	5.7E-10	1.1E-09	9.5E-10
Radionuclides	2.1E-06	3.3E-08	1.5E-08	1.6E-06	8.4E-08	7.6E-08	5.0E-08	9.3E-08	8.4E-08
GHG Summary (lb CO2 Equivalents/1,000 lb)									
Fossil CO2	611	9.67	4.35	460	24.5	22.1	14.6	27.1	24.4
Methane	2.23	0.035	0.016	1.68	0.090	0.081	0.053	0.099	0.089
Nitrous Oxide	0.020	3.2E-04	1.4E-04	0.015	8.1E-04	7.3E-04	4.8E-04	9.0E-04	8.1E-04
Total	**613**	**9.70**	**4.37**	**462**	**24.6**	**22.2**	**14.7**	**27.2**	**24.5**

Table 2-7-BOX

ATMOSPHERIC EMISSIONS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Unbleached Kraft Paper 100% PC Recycled Content			**Newsprint Virgin**			**Newsprint 100% PC Recycled Content**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	10		0	10
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related									
Particulates	0.018	0.068	0.061	0.015	0.068	0.061	0.015	0.068	0.061
Nitrogen Oxides	0.13	0.37	0.34	0.10	0.37	0.34	0.10	0.37	0.34
Hydrocarbons	0.050	0.108	0.097	0.042	0.108	0.097	0.042	0.108	0.097
Sulfur Oxides	0.036	0.065	0.059	0.029	0.065	0.059	0.029	0.065	0.059
Carbon Monoxide	0.12	0.29	0.26	0.10	0.29	0.26	0.10	0.29	0.26
Aldehydes	0.0034	0.0067	0.0060	0.0028	0.0067	0.0060	0.0028	0.0067	0.0060
Methane	0.0023	0.0043	0.0039	0.0019	0.0043	0.0039	0.0019	0.0043	0.0039
Other Organics	0.067	0.16	0.15	0.055	0.16	0.15	0.055	0.16	0.15
Odorous Sulfur	0	0	0	0	0	0	0	0	0
Kerosene	6.0E-08	1.1E-07	1.0E-07	4.9E-08	1.1E-07	1.0E-07	4.9E-08	1.1E-07	1.0E-07
Ammonia	2.3E-05	4.3E-05	3.9E-05	1.9E-05	4.3E-05	3.9E-05	1.9E-05	4.3E-05	3.9E-05
Ethylene Oxide	0	0	0	0	0	0	0	0	0
Hydrogen Fluoride	1.9E-06	3.5E-06	3.1E-06	1.5E-06	3.5E-06	3.1E-06	1.5E-06	3.5E-06	3.1E-06
Lead	7.8E-08	1.4E-07	1.3E-07	6.4E-08	1.4E-07	1.3E-07	6.4E-08	1.4E-07	1.3E-07
Mercury	1.5E-08	2.8E-08	2.5E-08	1.2E-08	2.8E-08	2.5E-08	1.2E-08	2.8E-08	2.5E-08
Chlorine	8.8E-07	1.6E-06	1.5E-06	7.3E-07	1.6E-06	1.5E-06	7.3E-07	1.6E-06	1.5E-06
HCl	1.4E-05	2.6E-05	2.4E-05	1.2E-05	2.6E-05	2.4E-05	1.2E-05	2.6E-05	2.4E-05
Phosphorus	0	0	0	0	0	0	0	0	0
CO2 (fossil)	14.6	27.1	24.4	12.1	27.1	24.4	12.1	27.1	24.4
CO2 (non-fossil)	0.0035	0.0065	0.0059	0.0029	0.0065	0.0059	0.0029	0.0065	0.0059
Total Reduced Sulfur	0	0	0	0	0	0	0	0	0
Chlorine Dioxide	0	0	0	0	0	0	0	0	0
Metals	1.4E-06	2.7E-06	2.4E-06	1.2E-06	2.7E-06	2.4E-06	1.2E-06	2.7E-06	2.4E-06
Mercaptan	0	0	0	0	0	0	0	0	0
Antimony	2.2E-08	4.1E-08	3.6E-08	1.8E-08	4.1E-08	3.6E-08	1.8E-08	4.1E-08	3.6E-08
Arsenic	4.5E-08	8.4E-08	7.5E-08	3.7E-08	8.4E-08	7.5E-08	3.7E-08	8.4E-08	7.5E-08
Beryllium	3.1E-09	5.9E-09	5.3E-09	2.6E-09	5.9E-09	5.3E-09	2.6E-09	5.9E-09	5.3E-09
Cadmium	6.8E-08	1.3E-07	1.1E-07	5.6E-08	1.3E-07	1.1E-07	5.6E-08	1.3E-07	1.1E-07
Chromium	5.1E-08	9.6E-08	8.6E-08	4.3E-08	9.6E-08	8.6E-08	4.3E-08	9.6E-08	8.6E-08
Cobalt	6.2E-08	1.1E-07	1.0E-07	5.1E-08	1.1E-07	1.0E-07	5.1E-08	1.1E-07	1.0E-07
Manganese	6.1E-08	1.1E-07	1.0E-07	5.1E-08	1.1E-07	1.0E-07	5.1E-08	1.1E-07	1.0E-07
Nickel	9.6E-07	1.8E-06	1.6E-06	8.0E-07	1.8E-06	1.6E-06	8.0E-07	1.8E-06	1.6E-06
Selenium	4.1E-08	7.7E-08	6.9E-08	3.4E-08	7.7E-08	6.9E-08	3.4E-08	7.7E-08	6.9E-08
Acreolin	2.7E-09	5.0E-09	4.5E-09	2.2E-09	5.0E-09	4.5E-09	2.2E-09	5.0E-09	4.5E-09
Nitrous Oxide	1.6E-06	3.0E-06	2.7E-06	1.4E-06	3.0E-06	2.7E-06	1.4E-06	3.0E-06	2.7E-06
Benzene	8.6E-09	1.6E-08	1.4E-08	7.1E-09	1.6E-08	1.4E-08	7.1E-09	1.6E-08	1.4E-08
Perchloroethylene	2.6E-09	4.9E-09	4.4E-09	2.2E-09	4.9E-09	4.4E-09	2.2E-09	4.9E-09	4.4E-09
Trichloroethylene	2.5E-09	4.7E-09	4.2E-09	2.1E-09	4.7E-09	4.2E-09	2.1E-09	4.7E-09	4.2E-09
Methylene Chloride	1.2E-08	2.2E-08	2.0E-08	9.8E-09	2.2E-08	2.0E-08	9.8E-09	2.2E-08	2.0E-08
Carbon Tetrachloride	1.1E-08	2.0E-08	1.8E-08	9.0E-09	2.0E-08	1.8E-08	9.0E-09	2.0E-08	1.8E-08
Phenols	7.0E-08	1.3E-07	1.2E-07	5.8E-08	1.3E-07	1.2E-07	5.8E-08	1.3E-07	1.2E-07
Naphthalene	4.0E-09	7.5E-09	6.7E-09	3.3E-09	7.5E-09	6.7E-09	3.3E-09	7.5E-09	6.7E-09
Dioxins	1.5E-14	2.7E-14	2.4E-14	1.2E-14	2.7E-14	2.4E-14	1.2E-14	2.7E-14	2.4E-14
n-nitrosodimethlamine	5.7E-10	1.1E-09	9.5E-10	4.7E-10	1.1E-09	9.5E-10	4.7E-10	1.1E-09	9.5E-10
Radionuclides	5.0E-08	9.3E-08	8.4E-08	4.1E-08	9.3E-08	8.4E-08	4.1E-08	9.3E-08	8.4E-08
GHG Summary (lb CO2 Equivalents/1,000 lb)									
Fossil CO2	14.6	27.1	24.4	12.1	27.1	24.4	12.1	27.1	24.4
Methane	0.053	0.099	0.089	0.044	0.099	0.089	0.044	0.099	0.089
Nitrous Oxide	4.8E-04	9.0E-04	8.1E-04	4.0E-04	9.0E-04	8.1E-04	4.0E-04	9.0E-04	8.1E-04
Total	**14.7**	**27.2**	**24.5**	**12.1**	**27.2**	**24.5**	**12.1**	**27.2**	**24.5**

Table 2-7-BOX

ATMOSPHERIC EMISSIONS FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Shredded PC Corrugated Dunnage			Shredded PC Office Paper Dunnage		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	10
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related						
Particulates		0.067	0.061		0.068	0.061
Nitrogen Oxides		0.37	0.33		0.37	0.34
Hydrocarbons		0.107	0.096		0.108	0.097
Sulfur Oxides		0.064	0.058		0.065	0.059
Carbon Monoxide		0.28	0.25		0.29	0.26
Aldehydes		0.0066	0.0059		0.0067	0.0060
Methane		0.0043	0.0038		0.0043	0.0039
Other Organics		0.16	0.14		0.16	0.15
Odorous Sulfur		0	0		0	0
Kerosene		1.1E-07	9.9E-08		1.1E-07	1.0E-07
Ammonia		4.2E-05	3.8E-05		4.3E-05	3.9E-05
Ethylene Oxide		0	0		0	0
Hydrogen Fluoride		3.4E-06	3.1E-06		3.5E-06	3.1E-06
Lead		1.4E-07	1.3E-07		1.4E-07	1.3E-07
Mercury		2.7E-08	2.5E-08		2.8E-08	2.5E-08
Chlorine		1.6E-06	1.5E-06		1.6E-06	1.5E-06
HCl		2.6E-05	2.3E-05		2.6E-05	2.4E-05
Phosphorus		0	0		0	0
CO2 (fossil)		26.7	24.1		27.1	24.4
CO2 (non-fossil)		0.0064	0.0058		0.0065	0.0059
Total Reduced Sulfur		0	0		0	0
Chlorine Dioxide		0	0		0	0
Metals		2.6E-06	2.4E-06		2.7E-06	2.4E-06
Mercaptan		0	0		0	0
Antimony		4.0E-08	3.6E-08		4.1E-08	3.6E-08
Arsenic		8.3E-08	7.5E-08		8.4E-08	7.5E-08
Beryllium		5.8E-09	5.2E-09		5.9E-09	5.3E-09
Cadmium		1.2E-07	1.1E-07		1.3E-07	1.1E-07
Chromium		9.5E-08	8.5E-08		9.6E-08	8.6E-08
Cobalt		1.1E-07	1.0E-07		1.1E-07	1.0E-07
Manganese		1.1E-07	1.0E-07		1.1E-07	1.0E-07
Nickel		1.8E-06	1.6E-06		1.8E-06	1.6E-06
Selenium		7.6E-08	6.8E-08		7.7E-08	6.9E-08
Acreolin		4.9E-09	4.4E-09		5.0E-09	4.5E-09
Nitrous Oxide		3.0E-06	2.7E-06		3.0E-06	2.7E-06
Benzene		1.6E-08	1.4E-08		1.6E-08	1.4E-08
Perchloroethylene		4.9E-09	4.4E-09		4.9E-09	4.4E-09
Trichloroethylene		4.6E-09	4.2E-09		4.7E-09	4.2E-09
Methylene Chloride		2.2E-08	2.0E-08		2.2E-08	2.0E-08
Carbon Tetrachloride		2.0E-08	1.8E-08		2.0E-08	1.8E-08
Phenols		1.3E-07	1.2E-07		1.3E-07	1.2E-07
Naphthalene		7.4E-09	6.6E-09		7.5E-09	6.7E-09
Dioxins		2.7E-14	2.4E-14		2.7E-14	2.4E-14
n-nitrosodimethlamine		1.0E-09	9.4E-10		1.1E-09	9.5E-10
Radionuclides		9.2E-08	8.3E-08		9.3E-08	8.4E-08
GHG Summary (lb CO2 Equivalents/1,000 lb)						
Fossil CO2	0	26.7	24.1	0	27.1	24.4
Methane	0	0.098	0.088	0	0.099	0.089
Nitrous Oxide	0	8.9E-04	8.0E-04	0	9.0E-04	8.1E-04
Total	**0**	**26.8**	**24.2**	**0**	**27.2**	**24.5**

Table 2-7-BAG
ATMOSPHERIC EMISSIONS FOR TRANSP TO DIST CTR AND DISPOSAL OF 1,000 LB OF SHIPPING BAGS

	Unpadded Bleached Kraft Bag		All-Paper Padded Kraft Bag		Bubble Padded Kraft Bag		Unpadded LLDPE Film Bag		Bubble Padded LLDPE Bag	
	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion
		10		10		10		10		10
Atmospheric Emissions (lb/1,000 lb) - Process + Fuel-Related										
Particulates	0.17	0.061	0.17	0.061	0.17	0.064	0.28	0.068	0.17	0.068
Nitrogen Oxides	1.21	0.34	1.21	0.34	1.21	0.35	1.70	0.37	1.21	0.37
Hydrocarbons	0.49	0.097	0.49	0.097	0.49	0.10	0.80	0.11	0.49	0.11
Sulfur Oxides	0.34	0.059	0.34	0.059	0.34	0.061	0.65	0.065	0.34	0.065
Carbon Monoxide	1.19	0.26	1.19	0.26	1.19	0.27	1.35	0.29	1.19	0.29
Aldehydes	0.033	0.0060	0.033	0.0060	0.033	0.0062	0.062	0.0066	0.033	0.0066
Methane	0.022	0.0039	0.022	0.0039	0.022	0.0040	0.043	0.0043	0.022	0.0043
Other Organics	0.65	0.15	0.65	0.15	0.65	0.15	0.73	0.16	0.65	0.16
Odorous Sulfur	0	0	0	0	0	0	0	0	0	0
Kerosene	5.8E-07	1.0E-07	5.8E-07	1.0E-07	5.8E-07	1.0E-07	1.1E-06	1.1E-07	5.8E-07	1.1E-07
Ammonia	2.2E-04	3.9E-05	2.2E-04	3.9E-05	2.2E-04	4.0E-05	4.3E-04	4.3E-05	2.2E-04	4.3E-05
Ethylene Oxide	0	0	0	0	0	0	0	0	0	0
Hydrogen Fluoride	1.8E-05	3.1E-06	1.8E-05	3.1E-06	1.8E-05	3.2E-06	3.5E-05	3.5E-06	1.8E-05	3.5E-06
Lead	7.5E-07	1.3E-07	7.5E-07	1.3E-07	7.5E-07	1.3E-07	1.4E-06	1.4E-07	7.5E-07	1.4E-07
Mercury	1.4E-07	2.5E-08	1.4E-07	2.5E-08	1.4E-07	2.6E-08	2.7E-07	2.7E-08	1.4E-07	2.7E-08
Chlorine	8.5E-06	1.5E-06	8.5E-06	1.5E-06	8.5E-06	1.5E-06	1.6E-05	1.6E-06	8.5E-06	1.6E-06
HCl	1.4E-04	2.4E-05	1.4E-04	2.4E-05	1.4E-04	2.5E-05	2.6E-04	2.6E-05	1.4E-04	2.6E-05
Phosphorus	0	0	0	0	0	0	0	0	0	0
CO2 (fossil)	141	24.4	141	24.4	141	25.2	273	26.9	141	26.9
CO2 (non-fossil)	0.034	0.0059	0.034	0.0059	0.034	0.0061	0.065	0.0065	0.034	0.0065
Total Reduced Sulfur	0	0	0	0	0	0	0	0	0	0
Chlorine Dioxide	0	0	0	0	0	0	0	0	0	0
Metals	1.4E-05	2.4E-06	1.4E-05	2.4E-06	1.4E-05	2.5E-06	2.6E-05	2.6E-06	1.4E-05	2.6E-06
Mercaptan	0	0	0	0	0	0	0	0	0	0
Antimony	2.1E-07	3.6E-08	2.1E-07	3.7E-08	2.1E-07	3.8E-08	4.0E-07	4.0E-08	2.1E-07	4.0E-08
Arsenic	4.4E-07	7.5E-08	4.4E-07	7.5E-08	4.4E-07	7.8E-08	8.4E-07	8.3E-08	4.4E-07	8.3E-08
Beryllium	3.0E-08	5.3E-09	3.0E-08	5.3E-09	3.0E-08	5.5E-09	5.8E-08	5.8E-09	3.0E-08	5.8E-09
Cadmium	6.5E-07	1.1E-07	6.5E-07	1.1E-07	6.5E-07	1.2E-07	1.3E-06	1.3E-07	6.5E-07	1.3E-07
Chromium	5.0E-07	8.6E-08	5.0E-07	8.6E-08	5.0E-07	8.9E-08	9.5E-07	9.5E-08	5.0E-07	9.5E-08
Cobalt	6.0E-07	1.0E-07	6.0E-07	1.0E-07	6.0E-07	1.1E-07	1.1E-06	1.1E-07	6.0E-07	1.1E-07
Manganese	5.9E-07	1.0E-07	5.9E-07	1.0E-07	5.9E-07	1.1E-07	1.1E-06	1.1E-07	5.9E-07	1.1E-07
Nickel	9.3E-06	1.6E-06	9.3E-06	1.6E-06	9.3E-06	1.7E-06	1.8E-05	1.8E-06	9.3E-06	1.8E-06
Selenium	4.0E-07	6.9E-08	4.0E-07	6.9E-08	4.0E-07	7.2E-08	7.7E-07	7.7E-08	4.0E-07	7.7E-08
Acreolin	2.6E-08	4.5E-09	2.6E-08	4.5E-09	2.6E-08	4.6E-09	5.0E-08	5.0E-09	2.6E-08	5.0E-09
Nitrous Oxide	1.6E-05	2.7E-06	1.6E-05	2.7E-06	1.6E-05	2.8E-06	3.0E-05	3.0E-06	1.6E-05	3.0E-06
Benzene	8.3E-08	1.4E-08	8.3E-08	1.4E-08	8.3E-08	1.5E-08	1.6E-07	1.6E-08	8.3E-08	1.6E-08
Perchloroethylene	2.6E-08	4.4E-09	2.6E-08	4.4E-09	2.6E-08	4.6E-09	4.9E-08	4.9E-09	2.6E-08	4.9E-09
Trichloroethylene	2.4E-08	4.2E-09	2.4E-08	4.2E-09	2.4E-08	4.4E-09	4.7E-08	4.7E-09	2.4E-08	4.7E-09
Methylene Chloride	1.1E-07	2.0E-08	1.1E-07	2.0E-08	1.1E-07	2.1E-08	2.2E-07	2.2E-08	1.1E-07	2.2E-08
Carbon Tetrachloride	1.0E-07	1.8E-08	1.0E-07	1.8E-08	1.0E-07	1.9E-08	2.0E-07	2.0E-08	1.0E-07	2.0E-08
Phenols	6.8E-07	1.2E-07	6.8E-07	1.2E-07	6.8E-07	1.2E-07	1.3E-06	1.3E-07	6.8E-07	1.3E-07
Naphthalene	3.9E-08	6.7E-09	3.9E-08	6.7E-09	3.9E-08	6.9E-09	7.4E-08	7.4E-09	3.9E-08	7.4E-09
Dioxins	1.4E-13	2.4E-14	1.4E-13	2.4E-14	1.4E-13	2.5E-14	2.7E-13	2.7E-14	1.4E-13	2.7E-14
n-nitrosodimethlamine	5.5E-09	9.5E-10	5.5E-09	9.5E-10	5.5E-09	9.8E-10	1.0E-08	1.0E-09	5.5E-09	1.0E-09
Radionuclides	4.8E-07	8.4E-08	4.8E-07	8.4E-08	4.8E-07	8.7E-08	9.3E-07	9.3E-08	4.8E-07	9.3E-08
GHG Summary (lb CO2 Equivalents/1,000 lb)										
Fossil CO2	141	24.4	141	24.4	141	25.2	273	26.9	141	26.9
Methane	0.52	0.089	0.52	0.089	0.52	0.092	0.99	0.099	0.52	0.099
Nitrous Oxide	0.0047	8.1E-04	0.0047	8.1E-04	0.0047	8.4E-04	0.0090	8.9E-04	0.0047	8.9E-04
Total	**142**	**24.5**	**142**	**24.5**	**142**	**25.3**	**274**	**27.0**	**142**	**27.0**

Table 2-8-BOX
WATERBORNE WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Average (38%) PC Corrugated Box			80% PC Corrugated Box			LDPE Inflated Air Packets Virgin		
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	0.014	1.6E-08	**0.014**	0.0067	1.6E-08	**0.0067**	0.13	5.9E-08	**0.13**
Metal Ion	4.0E-04	3.4E-04	**7.5E-04**	3.4E-04	3.5E-04	**6.8E-04**	0.0068	0.0013	**0.0080**
Fluorides	5.3E-04	8.1E-07	**5.3E-04**	6.1E-04	8.1E-07	**6.1E-04**	0.0014	8.3E-06	**0.0014**
Dissolved Solids	5.44	0.068	**5.51**	5.25	0.068	**5.32**	73.4	0.63	**74.1**
Suspended Solids	3.70	0.0015	**3.70**	3.83	0.0015	**3.83**	1.41	0.0088	**1.42**
BOD	2.45	2.5E-04	**2.45**	2.82	2.5E-04	**2.82**	0.32	0.0013	**0.32**
COD	9.27	0.0017	**9.27**	6.62	0.0017	**6.62**	1.47	0.0087	**1.47**
Phenol	8.6E-04	1.1E-06	**8.6E-04**	0.0019	1.1E-06	**0.0019**	2.2E-05	4.1E-06	**2.6E-05**
Sulfides	0.072	0	**0.072**	0.16	0	**0.16**	0.060	0	**0.060**
Oil	0.17	0.0016	**0.17**	0.25	0.0016	**0.25**	1.32	0.013	**1.34**
Sulfuric Acid	0.0084	1.3E-05	**0.0084**	0.0093	1.4E-05	**0.0093**	0.0092	8.5E-05	**0.0093**
Iron	0.12	3.7E-05	**0.12**	0.21	3.7E-05	**0.21**	0.054	3.4E-04	**0.054**
Cyanide	4.5E-07	3.6E-09	**4.6E-07**	4.1E-07	3.7E-09	**4.2E-07**	4.9E-06	3.9E-08	**5.0E-06**
Alkalinity	0	0	**0**	0	0	**0**	0	0	**0**
Chromium	2.4E-04	2.6E-06	**2.4E-04**	2.3E-04	2.6E-06	**2.3E-04**	0.0034	2.7E-05	**0.0034**
Aluminum	0.090	0	**0.090**	0.10	0	**0.10**	0	0	**0**
Nickel	1.5E-09	0	**1.5E-09**	3.4E-10	0	**3.4E-10**	0	0	**0**
Mercury	2.1E-08	1.9E-10	**2.1E-08**	1.8E-08	1.9E-10	**1.8E-08**	2.6E-07	2.1E-09	**2.6E-07**
Lead	3.5E-08	2.9E-08	**6.4E-08**	2.8E-08	2.9E-08	**5.7E-08**	5.7E-07	1.1E-07	**6.7E-07**
Phosphates	0.080	6.7E-06	**0.080**	0.081	6.8E-06	**0.081**	0.011	4.3E-05	**0.011**
Phosphorus	0.032	0	**0.032**	0.013	0	**0.013**	0	0	**0**
Nitrogen	0.034	0	**0.034**	0.027	0	**0.027**	0	0	**0**
Zinc	0.0011	1.3E-06	**0.0011**	0.0023	1.3E-06	**0.0023**	0.0023	1.1E-05	**0.0023**
Ammonia	0.023	2.7E-05	**0.024**	0.013	2.8E-05	**0.013**	0.0015	1.0E-04	**0.0016**
Pesticides	8.7E-04	0	**8.7E-04**	8.7E-04	0	**8.7E-04**	0	0	**0**
Other Chemicals	0	0	**0**	0	0	**0**	0	0	**0**
Herbicides	0	0	**0**	0	0	**0**	0	0	**0**
Hydrocarbons	0	0	**0**	0	0	**0**	0	0	**0**
Chlorides	0.24	0.0025	**0.25**	0.23	0.0025	**0.23**	3.38	0.027	**3.41**
Cadmium	2.4E-04	2.5E-06	**2.4E-04**	2.3E-04	2.5E-06	**2.3E-04**	0.0034	2.7E-05	**0.0034**
Organic Carbon	0	0	**0**	0	0	**0**	0.14	0	**0.14**
Sulfates	0.25	0.0020	**0.25**	0.25	0.0020	**0.25**	2.77	0.022	**2.79**
Sodium	2.1E-04	3.2E-07	**2.1E-04**	2.4E-04	3.2E-07	**2.4E-04**	5.4E-04	3.3E-06	**5.5E-04**
Calcium	1.1E-04	1.7E-07	**1.1E-04**	1.3E-04	1.7E-07	**1.3E-04**	3.0E-04	1.8E-06	**3.0E-04**
Manganese	0.029	1.8E-05	**0.029**	0.032	1.8E-05	**0.032**	0.031	1.9E-04	**0.031**
Nitrates	0.0012	7.6E-08	**0.0012**	5.3E-04	7.6E-08	**5.3E-04**	1.3E-04	7.8E-07	**1.3E-04**
Boron	0.034	5.4E-05	**0.034**	0.037	5.4E-05	**0.037**	0.037	3.4E-04	**0.037**
Other Organics	0.022	1.7E-04	**0.022**	0.021	1.7E-04	**0.022**	0.080	0.0017	**0.082**
Chromates	7.1E-06	1.9E-07	**7.3E-06**	7.0E-06	1.9E-07	**7.2E-06**	1.5E-05	7.5E-07	**1.6E-05**
Sodium Dichromate	0	0	**0**	0	0	**0**	0	0	**0**
Methanol	0	0	**0**	0	0	**0**	0	0	**0**

Table 2-8-BOX
WATERBORNE WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	LDPE Inflated Air Packets 100% PC Recycled Content			EPS Loose Fill Virgin			EPS Loose Fill 100% PC Recycled Content		
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	1.2E-08	4.3E-08	**5.5E-08**	0.037	1.0E-07	**0.037**	2.3E-08	1.3E-07	**1.5E-07**
Metal Ion	2.4E-04	9.1E-04	**0.0012**	0.025	0.0021	**0.028**	5.0E-04	0.0027	**0.0032**
Fluorides	0.0010	2.1E-06	**0.0010**	0.0022	2.0E-05	**0.0022**	0.0017	6.3E-06	**0.0017**
Dissolved Solids	2.73	0.18	**2.91**	76.6	0.58	**77.2**	27.8	0.53	**28.3**
Suspended Solids	0.49	0.0041	**0.49**	2.37	0.017	**2.39**	1.25	0.012	**1.26**
BOD	0.0028	6.7E-04	**0.0035**	0.66	0.0017	**0.66**	0.027	0.0020	**0.029**
COD	0.038	0.0045	**0.043**	1.92	0.012	**1.93**	0.39	0.013	**0.40**
Phenol	7.9E-07	3.0E-06	**3.7E-06**	8.3E-05	6.9E-06	**9.0E-05**	1.6E-06	8.7E-06	**1.0E-05**
Sulfides	0	0	**0**	0.020	0	**0.020**	0	0	**0**
Oil	0.048	0.0042	**0.052**	1.40	0.013	**1.41**	0.49	0.012	**0.50**
Sulfuric Acid	0.0066	3.6E-05	**0.0066**	0.016	1.8E-04	**0.017**	0.011	1.0E-04	**0.011**
Iron	0.039	9.7E-05	**0.039**	0.086	8.3E-04	**0.087**	0.067	2.9E-04	**0.067**
Cyanide	1.8E-07	9.6E-09	**1.9E-07**	5.1E-06	3.3E-08	**5.1E-06**	1.9E-06	2.8E-08	**1.9E-06**
Alkalinity	0	0	**0**	0	0	**0**	0	0	**0**
Chromium	1.2E-04	6.7E-06	**1.3E-04**	0.0035	2.3E-05	**0.0035**	0.0013	2.0E-05	**0.0013**
Aluminum	0	0	**0**	0	0	**0**	0	0	**0**
Nickel	0	0	**0**	0	0	**0**	0	0	**0**
Mercury	9.6E-09	5.0E-10	**1.0E-08**	2.7E-07	1.7E-09	**2.7E-07**	9.8E-08	1.5E-09	**9.9E-08**
Lead	2.0E-08	7.6E-08	**9.7E-08**	2.1E-06	1.8E-07	**2.3E-06**	4.1E-08	2.2E-07	**2.7E-07**
Phosphates	0.0033	1.8E-05	**0.0033**	0.010	9.2E-05	**0.010**	0.0057	5.2E-05	**0.0057**
Phosphorus	0	0	**0**	0	0	**0**	0	0	**0**
Nitrogen	0	0	**0**	0	0	**0**	0	0	**0**
Zinc	4.2E-05	3.3E-06	**4.6E-05**	0.0015	1.0E-05	**0.0015**	4.3E-04	9.8E-06	**4.4E-04**
Ammonia	4.5E-04	7.3E-05	**5.2E-04**	0.0038	1.8E-04	**0.0040**	0.0012	2.1E-04	**0.0014**
Pesticides	0	0	**0**	0	0	**0**	0	0	**0**
Other Chemicals	0	0	**0**	0	0	**0**	0	0	**0**
Herbicides	0	0	**0**	0	0	**0**	0	0	**0**
Hydrocarbons	0	0	**0**	0.10	0	**0.10**	0	0	**0**
Chlorides	0.13	0.0066	**0.13**	3.47	0.023	**3.49**	1.27	0.019	**1.29**
Cadmium	1.2E-04	6.6E-06	**1.3E-04**	0.0035	2.3E-05	**0.0035**	0.0013	1.9E-05	**0.0013**
Organic Carbon	0	0	**0**	0.046	0	**0.046**	0	0	**0**
Sulfates	0.22	0.0053	**0.23**	2.94	0.020	**2.96**	1.19	0.016	**1.21**
Sodium	4.0E-04	8.5E-07	**4.0E-04**	8.7E-04	8.1E-06	**8.8E-04**	6.8E-04	2.5E-06	**6.9E-04**
Calcium	2.2E-04	4.6E-07	**2.2E-04**	4.7E-04	4.4E-06	**4.8E-04**	3.7E-04	1.4E-06	**3.7E-04**
Manganese	0.023	4.7E-05	**0.023**	0.049	4.6E-04	**0.050**	0.039	1.4E-04	**0.039**
Nitrates	9.5E-05	2.0E-07	**9.5E-05**	2.1E-04	1.9E-06	**2.1E-04**	1.6E-04	5.9E-07	**1.6E-04**
Boron	0.026	1.4E-04	**0.026**	0.065	7.4E-04	**0.066**	0.045	4.2E-04	**0.046**
Other Organics	0.013	4.4E-04	**0.013**	0.18	0.0016	**0.19**	0.088	0.0013	**0.089**
Chromates	6.3E-06	5.0E-07	**6.8E-06**	6.2E-05	1.3E-06	**6.4E-05**	1.2E-05	1.5E-06	**1.4E-05**
Sodium Dichromate	0	0	**0**	0	0	**0**	0	0	**0**
Methanol	0	0	**0**	0	0	**0**	0	0	**0**

Table 2-8-BOX
WATERBORNE WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Cornstarch Loose Fill			Molded Pulp Loose Fill 100% PC Recycled Content			Unbleached Kraft Paper Virgin		
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	Cradle-to-production Process	Cradle-to-production Transp	TOTAL
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	0.10	4.4E-08	**0.10**	2.1E-08	1.7E-08	**3.8E-08**	0.025	1.7E-08	**0.025**
Metal Ion	4.9E-04	9.3E-04	**0.0014**	4.4E-04	3.7E-04	**8.1E-04**	5.2E-04	3.5E-04	**8.8E-04**
Fluorides	9.5E-04	2.2E-06	**9.6E-04**	0.0014	8.7E-07	**0.0014**	2.1E-04	8.2E-07	**2.1E-04**
Dissolved Solids	8.08	0.19	**8.27**	25.9	0.073	**26.0**	4.42	0.069	**4.48**
Suspended Solids	11.6	0.0042	**11.6**	1.06	0.0017	**1.06**	2.55	0.0016	**2.55**
BOD	1.23	6.9E-04	**1.23**	0.026	2.7E-04	**0.026**	1.32	2.6E-04	**1.32**
COD	2.02	0.0046	**2.03**	0.36	0.0018	**0.36**	13.1	0.0017	**13.1**
Phenol	3.5E-06	3.0E-06	**6.5E-06**	1.4E-06	1.2E-06	**2.6E-06**	1.7E-06	1.1E-06	**2.9E-06**
Sulfides	0	0	**0**	0	0	**0**	1.6E-07	0	**1.6E-07**
Oil	0.085	0.0044	**0.090**	0.46	0.0017	**0.46**	0.077	0.0016	**0.079**
Sulfuric Acid	0.0069	3.7E-05	**0.0069**	0.0090	1.4E-05	**0.0091**	0.0076	1.4E-05	**0.0077**
Iron	0.040	1.0E-04	**0.040**	0.053	4.0E-05	**0.053**	0.041	3.8E-05	**0.041**
Cyanide	4.1E-06	1.0E-08	**4.1E-06**	1.7E-06	3.9E-09	**1.7E-06**	3.6E-07	3.7E-09	**3.6E-07**
Alkalinity	0	0	**0**	0	0	**0**	0	0	**0**
Chromium	2.2E-04	7.1E-06	**2.2E-04**	0.0012	2.7E-06	**0.0012**	2.0E-04	2.6E-06	**2.0E-04**
Aluminum	0	0	**0**	0	0	**0**	0.11	0	**0.11**
Nickel	0	0	**0**	0	0	**0**	1.2E-09	0	**1.2E-09**
Mercury	1.7E-08	5.4E-10	**1.7E-08**	9.1E-08	2.0E-10	**9.1E-08**	1.7E-08	2.0E-10	**1.7E-08**
Lead	4.1E-08	7.8E-08	**1.2E-07**	3.7E-08	3.1E-08	**6.8E-08**	4.5E-08	2.9E-08	**7.4E-08**
Phosphates	0.30	1.8E-05	**0.30**	0.0045	7.2E-06	**0.0045**	0.10	6.8E-06	**0.10**
Phosphorus	0	0	**0**	0	0	**0**	0.065	0	**0.065**
Nitrogen	1.29	0	**1.29**	0	0	**0**	0.023	0	**0.023**
Zinc	7.3E-05	3.5E-06	**7.7E-05**	4.0E-04	1.4E-06	**4.0E-04**	6.8E-05	1.3E-06	**6.9E-05**
Ammonia	0.0017	7.4E-05	**0.0017**	0.0010	3.0E-05	**0.0011**	0.043	2.8E-05	**0.043**
Pesticides	0	0	**0**	0	0	**0**	0	0	**0**
Other Chemicals	0	0	**0**	0	0	**0**	0	0	**0**
Herbicides	0	0	**0**	0	0	**0**	0	0	**0**
Hydrocarbons	0	0	**0**	0	0	**0**	0	0	**0**
Chlorides	0.22	0.0070	**0.22**	1.19	0.0027	**1.19**	0.20	0.0025	**0.20**
Cadmium	2.1E-04	7.0E-06	**2.2E-04**	0.0012	2.7E-06	**0.0012**	2.0E-04	2.5E-06	**2.0E-04**
Organic Carbon	0	0	**0**	0	0	**0**	0	0	**0**
Sulfates	0.28	0.0056	**0.29**	1.08	0.0022	**1.08**	0.18	0.0021	**0.18**
Sodium	3.8E-04	8.7E-07	**3.8E-04**	5.4E-04	3.4E-07	**5.5E-04**	8.4E-05	3.3E-07	**8.4E-05**
Calcium	2.1E-04	4.7E-07	**2.1E-04**	3.0E-04	1.9E-07	**3.0E-04**	4.5E-05	1.8E-07	**4.6E-05**
Manganese	0.023	4.9E-05	**0.023**	0.031	1.9E-05	**0.031**	0.026	1.8E-05	**0.026**
Nitrates	9.0E-05	2.1E-07	**9.0E-05**	1.3E-04	8.2E-08	**1.3E-04**	0.0024	7.8E-08	**0.0024**
Boron	0.027	1.5E-04	**0.028**	0.036	5.8E-05	**0.036**	0.031	5.5E-05	**0.031**
Other Organics	0.019	4.6E-04	**0.019**	0.081	1.8E-04	**0.081**	0.018	1.7E-04	**0.018**
Chromates	1.2E-05	5.1E-07	**1.2E-05**	1.0E-05	2.0E-07	**1.0E-05**	6.6E-06	1.9E-07	**6.8E-06**
Sodium Dichromate	0	0	**0**	0	0	**0**	0	0	**0**
Methanol	0	0	**0**	0	0	**0**	0	0	**0**

Table 2-8-BOX

WATERBORNE WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Unbleached Kraft Paper 100% PC Recycled Content			Newsprint 100% PC Recycled Content			Newsprint Virgin		
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	1.2E-08	1.7E-08	**2.9E-08**	5.9E-09	1.1E-08	**1.7E-08**	4.1E-08	1.3E-08	**5.4E-08**
Metal Ion	2.6E-04	3.6E-04	**6.2E-04**	1.3E-04	2.3E-04	**3.5E-04**	8.6E-04	2.8E-04	**0.0011**
Fluorides	6.0E-04	8.3E-07	**6.0E-04**	2.5E-04	5.3E-07	**2.5E-04**	0.0022	6.5E-07	**0.0022**
Dissolved Solids	3.53	0.070	**3.60**	9.44	0.045	**9.48**	22.7	0.055	**22.8**
Suspended Solids	3.67	0.0016	**3.67**	5.30	0.0010	**5.31**	6.94	0.0012	**6.95**
BOD	3.03	2.6E-04	**3.03**	3.03	1.7E-04	**3.03**	5.66	2.0E-04	**5.66**
COD	4.81	0.0018	**4.81**	0.13	0.0011	**0.13**	4.35	0.0014	**4.36**
Phenol	0.0024	1.2E-06	**0.0024**	4.1E-07	7.4E-07	**1.1E-06**	3.1E-06	9.0E-07	**4.0E-06**
Sulfides	0.20	0	**0.20**	0	0	**0**	2.7E-06	0	**2.7E-06**
Oil	0.26	0.0016	**0.26**	0.17	0.0010	**0.17**	0.40	0.0013	**0.40**
Sulfuric Acid	0.0089	1.4E-05	**0.0089**	0.0016	8.9E-06	**0.0016**	0.015	1.1E-05	**0.015**
Iron	0.25	3.8E-05	**0.25**	0.0096	2.4E-05	**0.0096**	0.086	3.0E-05	**0.086**
Cyanide	2.2E-07	3.8E-09	**2.2E-07**	6.3E-07	2.4E-09	**6.3E-07**	1.5E-06	2.9E-09	**1.5E-06**
Alkalinity	0	0	**0**	0	0	**0**	0	0	**0**
Chromium	1.5E-04	2.6E-06	**1.5E-04**	4.3E-04	1.7E-06	**4.3E-04**	0.0010	2.1E-06	**0.0010**
Aluminum	0.10	0	**0.10**	0	0	**0**	0	0	**0**
Nickel	0	0	**0**	0	0	**0**	2.0E-08	0	**2.0E-08**
Mercury	1.1E-08	2.0E-10	**1.2E-08**	3.3E-08	1.3E-10	**3.3E-08**	1.1E-07	1.5E-10	**1.1E-07**
Lead	2.2E-08	3.0E-08	**5.2E-08**	1.0E-08	1.9E-08	**3.0E-08**	1.5E-06	2.3E-08	**1.5E-06**
Phosphates	0.069	7.0E-06	**0.069**	8.2E-04	4.5E-06	**8.2E-04**	0.0074	5.4E-06	**0.0074**
Phosphorus	0	0	**0**	0	0	**0**	0	0	**0**
Nitrogen	0	0	**0**	0	0	**0**	0	0	**0**
Zinc	0.0029	1.3E-06	**0.0029**	1.5E-04	8.4E-07	**1.5E-04**	5.2E-04	1.0E-06	**5.2E-04**
Ammonia	0.0053	2.8E-05	**0.0053**	2.8E-04	1.8E-05	**2.9E-04**	0.0013	2.2E-05	**0.0013**
Pesticides	0	0	**0**	0	0	**0**	0	0	**0**
Other Chemicals	0	0	**0**	0	0	**0**	0	0	**0**
Herbicides	0	0	**0**	0	0	**0**	0	0	**0**
Hydrocarbons	0	0	**0**	0	0	**0**	0	0	**0**
Chlorides	0.15	0.0026	**0.15**	0.43	0.0016	**0.43**	1.04	0.0020	**1.04**
Cadmium	1.5E-04	2.6E-06	**1.5E-04**	4.3E-04	1.6E-06	**4.3E-04**	0.0010	2.0E-06	**0.0010**
Organic Carbon	0	0	**0**	0	0	**0**	0	0	**0**
Sulfates	0.19	0.0021	**0.19**	0.36	0.0013	**0.36**	1.06	0.0016	**1.07**
Sodium	2.4E-04	3.3E-07	**2.4E-04**	9.8E-05	2.1E-07	**9.8E-05**	8.6E-04	2.6E-07	**8.6E-04**
Calcium	1.3E-04	1.8E-07	**1.3E-04**	5.3E-05	1.2E-07	**5.3E-05**	4.6E-04	1.4E-07	**4.6E-04**
Manganese	0.031	1.8E-05	**0.031**	0.0055	1.2E-05	**0.0055**	0.050	1.4E-05	**0.050**
Nitrates	5.7E-05	7.9E-08	**5.7E-05**	2.3E-05	5.0E-08	**2.3E-05**	2.0E-04	6.1E-08	**2.0E-04**
Boron	0.036	5.6E-05	**0.036**	0.0065	3.6E-05	**0.0066**	0.059	4.3E-05	**0.059**
Other Organics	0.016	1.7E-04	**0.016**	0.028	1.1E-04	**0.028**	0.076	1.3E-04	**0.076**
Chromates	6.2E-06	2.0E-07	**6.4E-06**	2.2E-06	1.3E-07	**2.3E-06**	1.9E-05	1.5E-07	**1.9E-05**
Sodium Dichromate	0	0	**0**	0	0	**0**	0	0	**0**
Methanol	0	0	**0**	0	0	**0**	0.014	0	**0.014**

Table 2-8-BOX
WATERBORNE WASTES FOR PRODUCTION OF 1,000 LB OF BOXES AND DUNNAGE

	Shredded PC Corrugated Dunnage				Shredded PC Office Paper Dunnage		
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	% of Total	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related							
Acid	1.6E-10	0	**1.6E-10**		4.9E-10	0	**4.9E-10**
Metal Ion	3.3E-06	0	**3.3E-06**		1.0E-05	0	**1.0E-05**
Fluorides	1.4E-05	0	**1.4E-05**		4.5E-05	0	**4.5E-05**
Dissolved Solids	0.037	0	**0.037**		0.12	0	**0.12**
Suspended Solids	0.0069	0	**0.0069**		0.022	0	**0.022**
BOD	3.8E-05	0	**3.8E-05**		1.2E-04	0	**1.2E-04**
COD	5.3E-04	0	**5.3E-04**		0.0017	0	**0.0017**
Phenol	1.1E-08	0	**1.1E-08**		3.4E-08	0	**3.4E-08**
Sulfides	0	0	**0**		0	0	**0**
Oil	6.6E-04	0	**6.6E-04**		0.0021	0	**0.0021**
Sulfuric Acid	9.4E-05	0	**9.4E-05**		2.9E-04	0	**2.9E-04**
Iron	5.6E-04	0	**5.6E-04**		0.0018	0	**0.0018**
Cyanide	2.5E-09	0	**2.5E-09**		7.8E-09	0	**7.8E-09**
Alkalinity	0	0	**0**		0	0	**0**
Chromium	1.7E-06	0	**1.7E-06**		5.3E-06	0	**5.3E-06**
Aluminum	0	0	**0**		0	0	**0**
Nickel	0	0	**0**		0	0	**0**
Mercury	1.3E-10	0	**1.3E-10**		4.1E-10	0	**4.1E-10**
Lead	2.8E-10	0	**2.8E-10**		8.7E-10	0	**8.7E-10**
Phosphates	4.7E-05	0	**4.7E-05**		1.5E-04	0	**1.5E-04**
Phosphorus	0	0	**0**		0	0	**0**
Nitrogen	0	0	**0**		0	0	**0**
Zinc	5.8E-07	0	**5.8E-07**		1.8E-06	0	**1.8E-06**
Ammonia	6.3E-06	0	**6.3E-06**		2.0E-05	0	**2.0E-05**
Pesticides	0	0	**0**		0	0	**0**
Other Chemicals	0	0	**0**		0	0	**0**
Herbicides	0	0	**0**		0	0	**0**
Hydrocarbons	0	0	**0**		0	0	**0**
Chlorides	0.0017	0	**0.0017**		0.0055	0	**0.0055**
Cadmium	1.7E-06	0	**1.7E-06**		5.3E-06	0	**5.3E-06**
Organic Carbon	0	0	**0**		0	0	**0**
Sulfates	0.0031	0	**0.0031**		0.0097	0	**0.0097**
Sodium	5.7E-06	0	**5.7E-06**		1.8E-05	0	**1.8E-05**
Calcium	3.1E-06	0	**3.1E-06**		9.7E-06	0	**9.7E-06**
Manganese	3.2E-04	0	**3.2E-04**		0.0010	0	**0.0010**
Nitrates	1.4E-06	0	**1.4E-06**		4.2E-06	0	**4.2E-06**
Boron	3.8E-04	0	**3.8E-04**		0.0012	0	**0.0012**
Other Organics	1.8E-04	0	**1.8E-04**		5.6E-04	0	**5.6E-04**
Chromates	8.9E-08	0	**8.9E-08**		2.8E-07	0	**2.8E-07**
Sodium Dichromate	0	0	**0**		0	0	**0**
Methanol	0	0	**0**		0	0	**0**

Table 2-8-BAG

WATERBORNE WASTES FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	Bleached Kraft Virgin			Bleached Kraft 100% PC Recycled Content			Unbleached Kraft Virgin		
	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	Cradle-to-production Process	Cradle-to-production Transp	TOTAL	Cradle-to-production Process	Cradle-to-production Transp	TOTAL
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	0.0030	2.3E-08	**0.0030**	1.2E-08	1.7E-08	**2.9E-08**	0.025	2.4E-08	**0.025**
Metal Ion	0.0041	5.0E-04	**0.0045**	2.6E-04	3.6E-04	**6.2E-04**	5.2E-04	5.2E-04	**0.0010**
Fluorides	9.0E-04	1.2E-06	**9.0E-04**	6.0E-04	8.3E-07	**6.0E-04**	2.1E-04	1.2E-06	**2.1E-04**
Dissolved Solids	9.45	0.098	**9.55**	3.53	0.070	**3.60**	4.42	0.10	**4.52**
Suspended Solids	7.15	0.0022	**7.15**	3.67	0.0016	**3.67**	2.55	0.0023	**2.55**
BOD	2.84	3.6E-04	**2.84**	3.03	2.6E-04	**3.03**	1.32	3.8E-04	**1.32**
COD	4.49	0.0024	**4.50**	4.81	0.0018	**4.81**	13.1	0.0025	**13.1**
Phenol	1.3E-05	1.6E-06	**1.5E-05**	0.0024	1.2E-06	**0.0024**	1.7E-06	1.7E-06	**3.4E-06**
Sulfides	5.2E-06	0	**5.2E-06**	0.20	0	**0.20**	1.6E-07	0	**1.6E-07**
Oil	0.17	0.0023	**0.17**	0.26	0.0016	**0.26**	0.077	0.0024	**0.079**
Sulfuric Acid	0.017	1.9E-05	**0.017**	0.0089	1.4E-05	**0.0089**	0.0076	2.0E-05	**0.0077**
Iron	0.065	5.3E-05	**0.066**	0.25	3.8E-05	**0.25**	0.041	5.5E-05	**0.041**
Cyanide	7.2E-07	5.2E-09	**7.2E-07**	2.2E-07	3.8E-09	**2.2E-07**	3.6E-07	5.5E-09	**3.6E-07**
Alkalinity	0	0	**0**	0	0	**0**	0	0	**0**
Chromium	4.1E-04	3.7E-06	**4.2E-04**	1.5E-04	2.6E-06	**1.5E-04**	2.0E-04	3.8E-06	**2.0E-04**
Aluminum	0	0	**0**	0.10	0	**0.10**	0.11	0	**0.11**
Nickel	3.8E-08	0	**3.8E-08**	0	0	**0**	1.2E-09	0	**1.2E-09**
Mercury	8.5E-08	2.8E-10	**8.6E-08**	1.1E-08	2.0E-10	**1.2E-08**	1.7E-08	2.9E-10	**1.7E-08**
Lead	3.8E-07	4.2E-08	**4.2E-07**	2.2E-08	3.0E-08	**5.2E-08**	4.5E-08	4.3E-08	**8.8E-08**
Phosphates	0.067	9.7E-06	**0.067**	0.069	7.0E-06	**0.069**	0.10	1.0E-05	**0.10**
Phosphorus	0.10	0	**0.10**	0	0	**0**	0.065	0	**0.065**
Nitrogen	0.039	0	**0.039**	0	0	**0**	0.023	0	**0.023**
Zinc	1.4E-04	1.8E-06	**1.5E-04**	0.0029	1.3E-06	**0.0029**	6.8E-05	1.9E-06	**6.9E-05**
Ammonia	0.28	4.0E-05	**0.28**	0.0053	2.8E-05	**0.0053**	0.043	4.1E-05	**0.043**
Pesticides	0	0	**0**	0	0	**0**	0	0	**0**
Other Chemicals	0	0	**0**	0	0	**0**	0	0	**0**
Herbicides	0	0	**0**	0	0	**0**	0	0	**0**
Hydrocarbons	0	0	**0**	0	0	**0**	0	0	**0**
Chlorides	0.42	0.0036	**0.42**	0.15	0.0026	**0.15**	0.20	0.0037	**0.20**
Cadmium	4.1E-04	3.6E-06	**4.2E-04**	1.5E-04	2.6E-06	**1.5E-04**	2.0E-04	3.7E-06	**2.0E-04**
Organic Carbon	0	0	**0**	0	0	**0**	0	0	**0**
Sulfates	0.43	0.0029	**0.43**	0.19	0.0021	**0.19**	0.18	0.0030	**0.18**
Sodium	3.6E-04	4.6E-07	**3.6E-04**	2.4E-04	3.3E-07	**2.4E-04**	8.4E-05	4.8E-07	**8.4E-05**
Calcium	1.9E-04	2.5E-07	**2.0E-04**	1.3E-04	1.8E-07	**1.3E-04**	4.5E-05	2.6E-07	**4.6E-05**
Manganese	0.040	2.6E-05	**0.040**	0.031	1.8E-05	**0.031**	0.026	2.7E-05	**0.026**
Nitrates	8.5E-05	1.1E-07	**8.5E-05**	5.7E-05	7.9E-08	**5.7E-05**	0.0024	1.1E-07	**0.0024**
Boron	0.068	7.7E-05	**0.068**	0.036	5.6E-05	**0.036**	0.031	8.1E-05	**0.031**
Other Organics	0.039	2.4E-04	**0.039**	0.016	1.7E-04	**0.016**	0.018	2.5E-04	**0.018**
Chromates	1.4E-04	2.7E-07	**1.4E-04**	6.2E-06	2.0E-07	**6.4E-06**	6.6E-06	2.8E-07	**6.9E-06**
Sodium Dichromate	3.4E-06	0	**3.4E-06**	0	0	**0**	0	0	**0**
Methanol	0	0	**0**	0	0	**0**	0	0	**0**

Table 2-8-BAG
WATERBORNE WASTES FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	Unbleached Kraft 100% PC Recycled Content			**Macerated 100% PC Newspaper Padding**			**LDPE Film Virgin**		
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	1.2E-08	1.7E-08	**2.9E-08**	1.7E-09	1.7E-08	**1.8E-08**	0.13	6.1E-08	**0.13**
Metal Ion	2.6E-04	3.6E-04	**6.2E-04**	3.6E-05	3.5E-04	**3.9E-04**	0.0068	0.0013	**0.0081**
Fluorides	6.0E-04	8.3E-07	**6.0E-04**	4.7E-05	8.2E-07	**4.8E-05**	0.0014	8.4E-06	**0.0014**
Dissolved Solids	3.53	0.070	**3.60**	0.13	0.069	**0.20**	73.4	0.64	**74.1**
Suspended Solids	3.67	0.0016	**3.67**	0.023	0.0016	**0.024**	1.40	0.0089	**1.41**
BOD	3.03	2.6E-04	**3.03**	1.4E-04	2.6E-04	**4.0E-04**	0.32	0.0013	**0.32**
COD	4.81	0.0018	**4.81**	0.0018	0.0017	**0.0036**	1.47	0.0089	**1.47**
Phenol	0.0024	1.2E-06	**0.0024**	1.2E-07	1.1E-06	**1.3E-06**	2.2E-05	4.2E-06	**2.6E-05**
Sulfides	0.20	0	**0.20**	0	0	**0**	0.060	0	**0.060**
Oil	0.26	0.0016	**0.26**	0.0023	0.0016	**0.0039**	1.32	0.013	**1.34**
Sulfuric Acid	0.0089	1.4E-05	**0.0089**	3.1E-04	1.4E-05	**3.2E-04**	0.0092	8.7E-05	**0.0093**
Iron	0.25	3.8E-05	**0.25**	0.0018	3.8E-05	**0.0019**	0.053	3.5E-04	**0.054**
Cyanide	2.2E-07	3.8E-09	**2.2E-07**	8.4E-09	3.7E-09	**1.2E-08**	4.9E-06	4.0E-08	**5.0E-06**
Alkalinity	0	0	**0**	0	0	**0**	0	0	**0**
Chromium	1.5E-04	2.6E-06	**1.5E-04**	5.8E-06	2.6E-06	**8.4E-06**	0.0034	2.8E-05	**0.0034**
Aluminum	0.10	0	**0.10**	0	0	**0**	0	0	**0**
Nickel	0	0	**0**	0	0	**0**	0	0	**0**
Mercury	1.1E-08	2.0E-10	**1.2E-08**	4.4E-10	2.0E-10	**6.4E-10**	2.6E-07	2.1E-09	**2.6E-07**
Lead	2.2E-08	3.0E-08	**5.2E-08**	3.0E-09	3.0E-08	**3.3E-08**	5.7E-07	1.1E-07	**6.7E-07**
Phosphates	0.069	7.0E-06	**0.069**	1.5E-04	6.9E-06	**1.6E-04**	0.011	4.3E-05	**0.011**
Phosphorus	0	0	**0**	0	0	**0**	0	0	**0**
Nitrogen	0	0	**0**	0	0	**0**	0	0	**0**
Zinc	0.0029	1.3E-06	**0.0029**	2.0E-06	1.3E-06	**3.3E-06**	0.0023	1.1E-05	**0.0023**
Ammonia	0.0053	2.8E-05	**0.0053**	2.3E-05	2.8E-05	**5.1E-05**	0.0015	1.1E-04	**0.0016**
Pesticides	0	0	**0**	0	0	**0**	0	0	**0**
Other Chemicals	0	0	**0**	0	0	**0**	0	0	**0**
Herbicides	0	0	**0**	0	0	**0**	0	0	**0**
Hydrocarbons	0	0	**0**	0	0	**0**	0	0	**0**
Chlorides	0.15	0.0026	**0.15**	0.0059	0.0025	**0.0084**	3.38	0.027	**3.41**
Cadmium	1.5E-04	2.6E-06	**1.5E-04**	5.8E-06	2.5E-06	**8.3E-06**	0.0034	2.7E-05	**0.0034**
Organic Carbon	0	0	**0**	0	0	**0**	0.14	0	**0.14**
Sulfates	0.19	0.0021	**0.19**	0.010	0.0021	**0.012**	2.76	0.022	**2.79**
Sodium	2.4E-04	3.3E-07	**2.4E-04**	1.9E-05	3.3E-07	**1.9E-05**	5.4E-04	3.3E-06	**5.4E-04**
Calcium	1.3E-04	1.8E-07	**1.3E-04**	1.0E-05	1.8E-07	**1.0E-05**	2.9E-04	1.8E-06	**3.0E-04**
Manganese	0.031	1.8E-05	**0.031**	0.0011	1.8E-05	**0.0011**	0.031	1.9E-04	**0.031**
Nitrates	5.7E-05	7.9E-08	**5.7E-05**	4.4E-06	7.8E-08	**4.5E-06**	1.3E-04	7.9E-07	**1.3E-04**
Boron	0.036	5.6E-05	**0.036**	0.0012	5.5E-05	**0.0013**	0.037	3.5E-04	**0.037**
Other Organics	0.016	1.7E-04	**0.016**	6.0E-04	1.7E-04	**7.7E-04**	0.080	0.0018	**0.082**
Chromates	6.2E-06	2.0E-07	**6.4E-06**	3.1E-07	1.9E-07	**5.0E-07**	1.5E-05	7.7E-07	**1.6E-05**
Sodium Dichromate	0	0	**0**	0	0	**0**	0	0	**0**
Methanol	0	0	**0**	0	0	**0**	0	0	**0**

Table 2-8-BAG
WATERBORNE WASTES FOR PRODUCTION OF 1,000 LB OF SHIPPING BAG COMPONENTS

	LDPE Film 100% PC Recycled Content			LLDPE Film Virgin			LLDPE Film 100% PC Recycled Content		
	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**	Cradle-to-production Process	Cradle-to-production Transp	**TOTAL**
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	1.1E-08	4.3E-08	**5.5E-08**	0.13	6.1E-08	**0.13**	1.1E-08	4.3E-08	**5.5E-08**
Metal Ion	2.4E-04	9.1E-04	**0.0012**	0.0067	0.0013	**0.0080**	2.4E-04	9.1E-04	**0.0012**
Fluorides	0.0010	2.1E-06	**0.0010**	0.0010	7.2E-06	**0.0010**	0.0010	2.1E-06	**0.0010**
Dissolved Solids	2.71	0.18	**2.89**	72.0	0.64	**72.6**	2.71	0.18	**2.89**
Suspended Solids	0.48	0.0041	**0.49**	1.00	0.0084	**1.01**	0.48	0.0041	**0.49**
BOD	0.0028	6.7E-04	**0.0034**	0.12	0.0013	**0.12**	0.0028	6.7E-04	**0.0034**
COD	0.038	0.0045	**0.043**	0.92	0.0088	**0.93**	0.038	0.0045	**0.043**
Phenol	7.8E-07	3.0E-06	**3.7E-06**	2.2E-05	4.2E-06	**2.6E-05**	7.8E-07	3.0E-06	**3.7E-06**
Sulfides	0	0	**0**	0.060	0	**0.060**	0	0	**0**
Oil	0.048	0.0042	**0.052**	1.30	0.013	**1.31**	0.048	0.0042	**0.052**
Sulfuric Acid	0.0065	3.6E-05	**0.0066**	0.0070	7.9E-05	**0.0071**	0.0065	3.6E-05	**0.0066**
Iron	0.039	9.7E-05	**0.039**	0.040	3.0E-04	**0.041**	0.039	9.7E-05	**0.039**
Cyanide	1.8E-07	9.6E-09	**1.9E-07**	4.8E-06	4.0E-08	**4.9E-06**	1.8E-07	9.6E-09	**1.9E-07**
Alkalinity	0	0	**0**	0	0	**0**	0	0	**0**
Chromium	1.2E-04	6.7E-06	**1.3E-04**	0.0033	2.7E-05	**0.0033**	1.2E-04	6.7E-06	**1.3E-04**
Aluminum	0	0	**0**	0	0	**0**	0	0	**0**
Nickel	0	0	**0**	0	0	**0**	0	0	**0**
Mercury	9.5E-09	5.0E-10	**1.0E-08**	2.6E-07	2.1E-09	**2.6E-07**	9.5E-09	5.0E-10	**1.0E-08**
Lead	2.0E-08	7.6E-08	**9.7E-08**	5.6E-07	1.1E-07	**6.7E-07**	2.0E-08	7.6E-08	**9.7E-08**
Phosphates	0.0033	1.8E-05	**0.0033**	0.010	4.0E-05	**0.010**	0.0033	1.8E-05	**0.0033**
Phosphorus	0	0	**0**	0	0	**0**	0	0	**0**
Nitrogen	0	0	**0**	0	0	**0**	0	0	**0**
Zinc	4.2E-05	3.3E-06	**4.5E-05**	0.0023	1.1E-05	**0.0023**	4.2E-05	3.3E-06	**4.5E-05**
Ammonia	4.4E-04	7.3E-05	**5.1E-04**	0.0013	1.1E-04	**0.0014**	4.4E-04	7.3E-05	**5.1E-04**
Pesticides	0	0	**0**	0	0	**0**	0	0	**0**
Other Chemicals	0	0	**0**	0	0	**0**	0	0	**0**
Herbicides	0	0	**0**	0	0	**0**	0	0	**0**
Hydrocarbons	0	0	**0**	0	0	**0**	0	0	**0**
Chlorides	0.13	0.0066	**0.13**	3.32	0.027	**3.35**	0.13	0.0066	**0.13**
Cadmium	1.2E-04	6.6E-06	**1.3E-04**	0.0033	2.7E-05	**0.0033**	1.2E-04	6.6E-06	**1.3E-04**
Organic Carbon	0	0	**0**	0.14	0	**0.14**	0	0	**0**
Sulfates	0.22	0.0053	**0.22**	2.67	0.022	**2.70**	0.22	0.0053	**0.22**
Sodium	4.0E-04	8.5E-07	**4.0E-04**	4.1E-04	2.9E-06	**4.1E-04**	4.0E-04	8.5E-07	**4.0E-04**
Calcium	2.1E-04	4.6E-07	**2.2E-04**	2.2E-04	1.6E-06	**2.3E-04**	2.1E-04	4.6E-07	**2.2E-04**
Manganese	0.022	4.7E-05	**0.022**	0.023	1.6E-04	**0.023**	0.022	4.7E-05	**0.022**
Nitrates	9.4E-05	2.0E-07	**9.4E-05**	9.8E-05	6.8E-07	**9.8E-05**	9.4E-05	2.0E-07	**9.4E-05**
Boron	0.026	1.4E-04	**0.026**	0.028	3.2E-04	**0.029**	0.026	1.4E-04	**0.026**
Other Organics	0.013	4.4E-04	**0.013**	0.074	0.0018	**0.075**	0.013	4.4E-04	**0.013**
Chromates	6.2E-06	5.0E-07	**6.7E-06**	1.3E-05	7.7E-07	**1.4E-05**	6.2E-06	5.0E-07	**6.7E-06**
Sodium Dichromate	0	0	**0**	0	0	**0**	0	0	**0**
Methanol	0	0	**0**	0	0	**0**	0	0	**0**

Table 2-9-BOX

WATERBORNE WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Average (38%) PC Corrugated Box			**80% PC Corrugated Box**			**LDPE Inflated Air Packets Virgin**		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	20.8		0	20.8		0	10
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	0	8.8E-09	7.0E-09	0	8.8E-09	7.0E-09	4.6E-08	9.9E-09	8.9E-09
Metal Ion	0	1.9E-04	1.5E-04	0	1.9E-04	1.5E-04	9.8E-04	2.1E-04	1.9E-04
Fluorides	0	4.4E-07	3.5E-07	0	4.4E-07	3.5E-07	2.3E-06	4.9E-07	4.4E-07
Dissolved Solids	0	0.037	0.029	0	0.037	0.029	0.19	0.041	0.037
Suspended Solids	0	8.4E-04	6.6E-04	0	8.4E-04	6.6E-04	0.0044	9.4E-04	8.4E-04
BOD	0	1.4E-04	1.1E-04	0	1.4E-04	1.1E-04	7.2E-04	1.5E-04	1.4E-04
COD	0	9.2E-04	7.3E-04	0	9.2E-04	7.3E-04	0.0048	1.0E-03	9.3E-04
Phenol	0	6.1E-07	4.8E-07	0	6.1E-07	4.8E-07	3.2E-06	6.8E-07	6.1E-07
Sulfides	0	0	0	0	0	0	0	0	0
Oil	0	8.6E-04	6.8E-04	0	8.6E-04	6.8E-04	0.0045	9.6E-04	8.7E-04
Sulfuric Acid	0	7.3E-06	5.8E-06	0	7.3E-06	5.8E-06	3.8E-05	8.2E-06	7.4E-06
Iron	0	2.0E-05	1.6E-05	0	2.0E-05	1.6E-05	1.1E-04	2.2E-05	2.0E-05
Cyanide	0	2.0E-09	1.6E-09	0	2.0E-09	1.6E-09	1.0E-08	2.2E-09	2.0E-09
Alkalinity	0	0	0	0	0	0	0	0	0
Chromium	0	1.4E-06	1.1E-06	0	1.4E-06	1.1E-06	7.3E-06	1.5E-06	1.4E-06
Aluminum	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0
Mercury	0	1.0E-10	8.2E-11	0	1.0E-10	8.2E-11	5.4E-10	1.2E-10	1.0E-10
Lead	0	1.6E-08	1.2E-08	0	1.6E-08	1.2E-08	8.2E-08	1.8E-08	1.6E-08
Phosphates	0	3.6E-06	2.9E-06	0	3.6E-06	2.9E-06	1.9E-05	4.1E-06	3.7E-06
Phosphorus	0	0	0	0	0	0	0	0	0
Nitrogen	0	0	0	0	0	0	0	0	0
Zinc	0	6.8E-07	5.4E-07	0	6.8E-07	5.4E-07	3.6E-06	7.7E-07	6.9E-07
Ammonia	0	1.5E-05	1.2E-05	0	1.5E-05	1.2E-05	7.8E-05	1.7E-05	1.5E-05
Pesticides	0	0	0	0	0	0	0	0	0
Other Chemicals	0	0	0	0	0	0	0	0	0
Herbicides	0	0	0	0	0	0	0	0	0
Hydrocarbons	0	0	0	0	0	0	0	0	0
Chlorides	0	0.0013	0.0011	0	0.0013	0.0011	0.0071	0.0015	0.0014
Cadmium	0	1.3E-06	1.1E-06	0	1.3E-06	1.1E-06	7.1E-06	1.5E-06	1.4E-06
Organic Carbon	0	0	0	0	0	0	0	0	0
Sulfates	0	1.1E-03	8.6E-04	0	1.1E-03	8.6E-04	0.0057	0.0012	0.0011
Sodium	0	1.7E-07	1.4E-07	0	1.7E-07	1.4E-07	9.1E-07	1.9E-07	1.8E-07
Calcium	0	9.4E-08	7.5E-08	0	9.4E-08	7.5E-08	5.0E-07	1.1E-07	9.5E-08
Manganese	0	9.7E-06	7.7E-06	0	9.7E-06	7.7E-06	5.1E-05	1.1E-05	9.7E-06
Nitrates	0	4.1E-08	3.3E-08	0	4.1E-08	3.3E-08	2.2E-07	4.6E-08	4.2E-08
Boron	0	2.9E-05	2.3E-05	0	2.9E-05	2.3E-05	1.5E-04	3.3E-05	2.9E-05
Other Organics	0	9.0E-05	7.1E-05	0	9.0E-05	7.1E-05	4.7E-04	1.0E-04	9.0E-05
Chromates	0	1.0E-07	8.2E-08	0	1.0E-07	8.2E-08	5.4E-07	1.2E-07	1.0E-07
Sodium Dichromate	0	0	0	0	0	0	0	0	0
Methanol	0	0	0	0	0	0	0	0	0

Table 2-9-BOX

WATERBORNE WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	LDPE Inflated Air Packets 100% PC Recycled Content			EPS Loose Fill Virgin			EPS Loose Fill 100% PC Recycled Content		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	55		0	55
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	4.6E-08	9.9E-09	8.9E-09	1.6E-07	2.7E-08	1.2E-08	3.3E-07	2.7E-08	1.2E-08
Metal Ion	9.8E-04	2.1E-04	1.9E-04	0.0035	5.7E-04	2.6E-04	0.0070	5.7E-04	2.6E-04
Fluorides	2.3E-06	4.9E-07	4.4E-07	8.1E-06	1.3E-06	6.0E-07	1.6E-05	1.3E-06	6.0E-07
Dissolved Solids	0.19	0.041	0.037	0.68	0.112	0.051	1.38	0.112	0.051
Suspended Solids	0.0044	9.4E-04	8.4E-04	0.015	0.0026	0.0012	0.032	0.0026	0.0012
BOD	7.2E-04	1.5E-04	1.4E-04	0.0025	4.2E-04	1.9E-04	0.0052	4.2E-04	1.9E-04
COD	0.0048	1.0E-03	9.3E-04	0.017	0.0028	0.0013	0.035	0.0028	0.0013
Phenol	3.2E-06	6.8E-07	6.1E-07	1.1E-05	1.9E-06	8.3E-07	2.3E-05	1.9E-06	8.3E-07
Sulfides	0	0	0	0	0	0	0	0	0
Oil	0.0045	9.6E-04	8.7E-04	0.016	0.0026	0.0012	0.032	0.0026	0.0012
Sulfuric Acid	3.8E-05	8.2E-06	7.4E-06	1.3E-04	2.2E-05	1.0E-05	2.7E-04	2.2E-05	1.0E-05
Iron	1.1E-04	2.2E-05	2.0E-05	3.7E-04	6.1E-05	2.8E-05	7.5E-04	6.1E-05	2.8E-05
Cyanide	1.0E-08	2.2E-09	2.0E-09	3.6E-08	6.0E-09	2.7E-09	7.4E-08	6.0E-09	2.7E-09
Alkalinity	0	0	0	0	0	0	0	0	0
Chromium	7.3E-06	1.5E-06	1.4E-06	2.6E-05	4.2E-06	1.9E-06	5.2E-05	4.2E-06	1.9E-06
Aluminum	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0
Mercury	5.4E-10	1.2E-10	1.0E-10	1.9E-09	3.2E-10	1.4E-10	3.9E-09	3.2E-10	1.4E-10
Lead	8.2E-08	1.8E-08	1.6E-08	2.9E-07	4.8E-08	2.2E-08	5.9E-07	4.8E-08	2.2E-08
Phosphates	1.9E-05	4.1E-06	3.7E-06	6.7E-05	1.1E-05	5.0E-06	1.4E-04	1.1E-05	5.0E-06
Phosphorus	0	0	0	0	0	0	0	0	0
Nitrogen	0	0	0	0	0	0	0	0	0
Zinc	3.6E-06	7.7E-07	6.9E-07	1.3E-05	2.1E-06	9.4E-07	2.6E-05	2.1E-06	9.4E-07
Ammonia	7.8E-05	1.7E-05	1.5E-05	2.8E-04	4.6E-05	2.1E-05	5.6E-04	4.6E-05	2.1E-05
Pesticides	0	0	0	0	0	0	0	0	0
Other Chemicals	0	0	0	0	0	0	0	0	0
Herbicides	0	0	0	0	0	0	0	0	0
Hydrocarbons	0	0	0	0	0	0	0	0	0
Chlorides	0.0071	0.0015	0.0014	0.025	0.0041	0.0019	0.051	0.0041	0.0019
Cadmium	7.1E-06	1.5E-06	1.4E-06	2.5E-05	4.1E-06	1.9E-06	5.1E-05	4.1E-06	1.9E-06
Organic Carbon	0	0	0	0	0	0	0	0	0
Sulfates	0.0057	0.0012	0.0011	0.020	0.0033	0.0015	0.041	0.0033	0.0015
Sodium	9.1E-07	1.9E-07	1.8E-07	3.2E-06	5.3E-07	2.4E-07	6.5E-06	5.3E-07	2.4E-07
Calcium	5.0E-07	1.1E-07	9.5E-08	1.7E-06	2.9E-07	1.3E-07	3.6E-06	2.9E-07	1.3E-07
Manganese	5.1E-05	1.1E-05	9.7E-06	1.8E-04	3.0E-05	1.3E-05	3.6E-04	3.0E-05	1.3E-05
Nitrates	2.2E-07	4.6E-08	4.2E-08	7.6E-07	1.3E-07	5.7E-08	1.6E-06	1.3E-07	5.7E-08
Boron	1.5E-04	3.3E-05	2.9E-05	5.4E-04	8.9E-05	4.0E-05	0.0011	8.9E-05	4.0E-05
Other Organics	4.7E-04	1.0E-04	9.0E-05	0.0017	2.7E-04	1.2E-04	0.0034	2.7E-04	1.2E-04
Chromates	5.4E-07	1.2E-07	1.0E-07	1.9E-06	3.1E-07	1.4E-07	3.9E-06	3.1E-07	1.4E-07
Sodium Dichromate	0	0	0	0	0	0	0	0	0
Methanol	0	0	0	0	0	0	0	0	0

Table 2-9-BOX

WATERBORNE WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Cornstarch Loose Fill			Molded Pulp Loose Fill 100% PC Recycled Content			Unbleached Kraft Paper Virgin		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	55		0	10		0	10
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	2.0E-07	3.2E-09	1.4E-09	1.5E-07	8.1E-09	7.3E-09	4.8E-09	8.9E-09	8.0E-09
Metal Ion	0.0043	6.8E-05	3.0E-05	0.0032	1.7E-04	1.5E-04	1.0E-04	1.9E-04	1.7E-04
Fluorides	9.9E-06	1.6E-07	7.1E-08	7.5E-06	4.0E-07	3.6E-07	2.4E-07	4.4E-07	4.0E-07
Dissolved Solids	0.84	0.0133	0.0060	0.63	0.034	0.030	0.020	0.037	0.033
Suspended Solids	0.019	3.0E-04	1.4E-04	0.014	7.7E-04	6.9E-04	4.6E-04	8.5E-04	7.6E-04
BOD	0.0031	5.0E-05	2.2E-05	0.0024	1.3E-04	1.1E-04	7.5E-05	1.4E-04	1.3E-04
COD	0.021	3.3E-04	1.5E-04	0.016	8.4E-04	7.6E-04	5.0E-04	9.3E-04	8.4E-04
Phenol	1.4E-05	2.2E-07	9.9E-08	1.0E-05	5.6E-07	5.0E-07	3.3E-07	6.1E-07	5.5E-07
Sulfides	0	0	0	0	0	0	0	0	0
Oil	0.020	3.1E-04	1.4E-04	0.015	7.9E-04	7.1E-04	4.7E-04	8.7E-04	7.8E-04
Sulfuric Acid	1.7E-04	2.6E-06	1.2E-06	1.3E-04	6.7E-06	6.0E-06	4.0E-06	7.4E-06	6.6E-06
Iron	4.5E-04	7.2E-06	3.2E-06	3.4E-04	1.8E-05	1.6E-05	1.1E-05	2.0E-05	1.8E-05
Cyanide	4.5E-08	7.1E-10	3.2E-10	3.4E-08	1.8E-09	1.6E-09	1.1E-09	2.0E-09	1.8E-09
Alkalinity	0	0	0	0	0	0	0	0	0
Chromium	3.1E-05	5.0E-07	2.2E-07	2.4E-05	1.3E-06	1.1E-06	7.5E-07	1.4E-06	1.3E-06
Aluminum	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0
Mercury	2.4E-09	3.7E-11	1.7E-11	1.8E-09	9.5E-11	8.5E-11	5.6E-11	1.0E-10	9.4E-11
Lead	3.6E-07	5.7E-09	2.5E-09	2.7E-07	1.4E-08	1.3E-08	8.5E-09	1.6E-08	1.4E-08
Phosphates	8.3E-05	1.3E-06	5.9E-07	6.3E-05	3.3E-06	3.0E-06	2.0E-06	3.7E-06	3.3E-06
Phosphorus	0	0	0	0	0	0	0	0	0
Nitrogen	0	0	0	0	0	0	0	0	0
Zinc	1.6E-05	2.5E-07	1.1E-07	1.2E-05	6.3E-07	5.7E-07	3.7E-07	6.9E-07	6.2E-07
Ammonia	3.4E-04	5.4E-06	2.4E-06	2.6E-04	1.4E-05	1.2E-05	8.1E-06	1.5E-05	1.4E-05
Pesticides	0	0	0	0	0	0	0	0	0
Other Chemicals	0	0	0	0	0	0	0	0	0
Herbicides	0	0	0	0	0	0	0	0	0
Hydrocarbons	0	0	0	0	0	0	0	0	0
Chlorides	0.031	4.9E-04	2.2E-04	0.023	0.0012	0.0011	7.3E-04	0.0014	0.0012
Cadmium	3.1E-05	4.9E-07	2.2E-07	2.3E-05	1.2E-06	1.1E-06	7.3E-07	1.4E-06	1.2E-06
Organic Carbon	0	0	0	0	0	0	0	0	0
Sulfates	0.025	3.9E-04	1.8E-04	0.019	1.0E-03	9.0E-04	5.9E-04	0.0011	0.0010
Sodium	4.0E-06	6.3E-08	2.8E-08	3.0E-06	1.6E-07	1.4E-07	9.5E-08	1.8E-07	1.6E-07
Calcium	2.1E-06	3.4E-08	1.5E-08	1.6E-06	8.6E-08	7.8E-08	5.1E-08	9.5E-08	8.6E-08
Manganese	2.2E-04	3.5E-06	1.6E-06	1.7E-04	8.9E-06	8.0E-06	5.3E-06	9.8E-06	8.8E-06
Nitrates	9.4E-07	1.5E-08	6.7E-09	7.1E-07	3.8E-08	3.4E-08	2.2E-08	4.2E-08	3.8E-08
Boron	6.6E-04	1.1E-05	4.7E-06	5.0E-04	2.7E-05	2.4E-05	1.6E-05	3.0E-05	2.7E-05
Other Organics	0.0020	3.2E-05	1.5E-05	0.0015	8.2E-05	7.4E-05	4.9E-05	9.1E-05	8.2E-05
Chromates	2.3E-06	3.7E-08	1.7E-08	1.8E-06	9.4E-08	8.5E-08	5.6E-08	1.0E-07	9.4E-08
Sodium Dichromate	0	0	0	0	0	0	0	0	0
Methanol	0	0	0	0	0	0	0	0	0

Table 2-9-BOX

WATERBORNE WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Unbleached Kraft Paper 100% PC Recycled Content			Newsprint Virgin			Newsprint 100% PC Recycled Content		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	10		0	10
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related									
Acid	4.8E-09	8.9E-09	8.0E-09	4.0E-09	8.9E-09	8.0E-09	4.0E-09	8.9E-09	8.0E-09
Metal Ion	1.0E-04	1.9E-04	1.7E-04	8.4E-05	1.9E-04	1.7E-04	8.4E-05	1.9E-04	1.7E-04
Fluorides	2.4E-07	4.4E-07	4.0E-07	2.0E-07	4.4E-07	4.0E-07	2.0E-07	4.4E-07	4.0E-07
Dissolved Solids	0.020	0.037	0.033	0.017	0.037	0.033	0.017	0.037	0.033
Suspended Solids	4.6E-04	8.5E-04	7.6E-04	3.8E-04	8.5E-04	7.6E-04	3.8E-04	8.5E-04	7.6E-04
BOD	7.5E-05	1.4E-04	1.3E-04	6.2E-05	1.4E-04	1.3E-04	6.2E-05	1.4E-04	1.3E-04
COD	5.0E-04	9.3E-04	8.4E-04	4.1E-04	9.3E-04	8.4E-04	4.1E-04	9.3E-04	8.4E-04
Phenol	3.3E-07	6.1E-07	5.5E-07	2.7E-07	6.1E-07	5.5E-07	2.7E-07	6.1E-07	5.5E-07
Sulfides	0	0	0	0	0	0	0	0	0
Oil	4.7E-04	8.7E-04	7.8E-04	3.9E-04	8.7E-04	7.8E-04	3.9E-04	8.7E-04	7.8E-04
Sulfuric Acid	4.0E-06	7.4E-06	6.6E-06	3.3E-06	7.4E-06	6.6E-06	3.3E-06	7.4E-06	6.6E-06
Iron	1.1E-05	2.0E-05	1.8E-05	9.0E-06	2.0E-05	1.8E-05	9.0E-06	2.0E-05	1.8E-05
Cyanide	1.1E-09	2.0E-09	1.8E-09	8.9E-10	2.0E-09	1.8E-09	8.9E-10	2.0E-09	1.8E-09
Alkalinity	0	0	0	0	0	0	0	0	0
Chromium	7.5E-07	1.4E-06	1.3E-06	6.2E-07	1.4E-06	1.3E-06	6.2E-07	1.4E-06	1.3E-06
Aluminum	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0
Mercury	5.6E-11	1.0E-10	9.4E-11	4.7E-11	1.0E-10	9.4E-11	4.7E-11	1.0E-10	9.4E-11
Lead	8.5E-09	1.6E-08	1.4E-08	7.1E-09	1.6E-08	1.4E-08	7.1E-09	1.6E-08	1.4E-08
Phosphates	2.0E-06	3.7E-06	3.3E-06	1.6E-06	3.7E-06	3.3E-06	1.6E-06	3.7E-06	3.3E-06
Phosphorus	0	0	0	0	0	0	0	0	0
Nitrogen	0	0	0	0	0	0	0	0	0
Zinc	3.7E-07	6.9E-07	6.2E-07	3.1E-07	6.9E-07	6.2E-07	3.1E-07	6.9E-07	6.2E-07
Ammonia	8.1E-06	1.5E-05	1.4E-05	6.7E-06	1.5E-05	1.4E-05	6.7E-06	1.5E-05	1.4E-05
Pesticides	0	0	0	0	0	0	0	0	0
Other Chemicals	0	0	0	0	0	0	0	0	0
Herbicides	0	0	0	0	0	0	0	0	0
Hydrocarbons	0	0	0	0	0	0	0	0	0
Chlorides	7.3E-04	0.0014	0.0012	6.1E-04	0.0014	0.0012	6.1E-04	0.0014	0.0012
Cadmium	7.3E-07	1.4E-06	1.2E-06	6.1E-07	1.4E-06	1.2E-06	6.1E-07	1.4E-06	1.2E-06
Organic Carbon	0	0	0	0	0	0	0	0	0
Sulfates	5.9E-04	0.0011	0.0010	4.9E-04	0.0011	0.0010	4.9E-04	0.0011	0.0010
Sodium	9.5E-08	1.8E-07	1.6E-07	7.8E-08	1.8E-07	1.6E-07	7.8E-08	1.8E-07	1.6E-07
Calcium	5.1E-08	9.5E-08	8.6E-08	4.2E-08	9.5E-08	8.6E-08	4.2E-08	9.5E-08	8.6E-08
Manganese	5.3E-06	9.8E-06	8.8E-06	4.4E-06	9.8E-06	8.8E-06	4.4E-06	9.8E-06	8.8E-06
Nitrates	2.2E-08	4.2E-08	3.8E-08	1.9E-08	4.2E-08	3.8E-08	1.9E-08	4.2E-08	3.8E-08
Boron	1.6E-05	3.0E-05	2.7E-05	1.3E-05	3.0E-05	2.7E-05	1.3E-05	3.0E-05	2.7E-05
Other Organics	4.9E-05	9.1E-05	8.2E-05	4.0E-05	9.1E-05	8.2E-05	4.0E-05	9.1E-05	8.2E-05
Chromates	5.6E-08	1.0E-07	9.4E-08	4.6E-08	1.0E-07	9.4E-08	4.6E-08	1.0E-07	9.4E-08
Sodium Dichromate	0	0	0	0	0	0	0	0	0
Methanol	0	0	0	0	0	0	0	0	0

Table 2-9-BOX

WATERBORNE WASTES FOR TRANSP TO DIST CENTER AND DISPOSAL OF 1,000 LB OF BOXES AND DUNNAGE

	Shredded PC Corrugated Dunnage			Shredded PC Office Paper Dunnage		
	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion	Transp to Retail Order Center	End of Life Disposal % diversion	End of Life Disposal % diversion
		0	10		0	10
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related						
Acid		8.8E-09	8.0E-09		8.9E-09	8.0E-09
Metal Ion		1.9E-04	1.7E-04		1.9E-04	1.7E-04
Fluorides		4.4E-07	3.9E-07		4.4E-07	4.0E-07
Dissolved Solids		0.037	0.033		0.037	0.033
Suspended Solids		8.4E-04	7.5E-04		8.5E-04	7.6E-04
BOD		1.4E-04	1.2E-04		1.4E-04	1.3E-04
COD		9.2E-04	8.3E-04		9.3E-04	8.4E-04
Phenol		6.1E-07	5.5E-07		6.1E-07	5.5E-07
Sulfides		0	0		0	0
Oil		8.6E-04	7.7E-04		8.7E-04	7.8E-04
Sulfuric Acid		7.3E-06	6.6E-06		7.4E-06	6.6E-06
Iron		2.0E-05	1.8E-05		2.0E-05	1.8E-05
Cyanide		2.0E-09	1.8E-09		2.0E-09	1.8E-09
Alkalinity		0	0		0	0
Chromium		1.4E-06	1.2E-06		1.4E-06	1.3E-06
Aluminum		0	0		0	0
Nickel		0	0		0	0
Mercury		1.0E-10	9.3E-11		1.0E-10	9.4E-11
Lead		1.6E-08	1.4E-08		1.6E-08	1.4E-08
Phosphates		3.6E-06	3.3E-06		3.7E-06	3.3E-06
Phosphorus		0	0		0	0
Nitrogen		0	0		0	0
Zinc		6.8E-07	6.2E-07		6.9E-07	6.2E-07
Ammonia		1.5E-05	1.3E-05		1.5E-05	1.4E-05
Pesticides		0	0		0	0
Other Chemicals		0	0		0	0
Herbicides		0	0		0	0
Hydrocarbons		0	0		0	0
Chlorides		0.0013	0.0012		0.0014	0.0012
Cadmium		1.3E-06	1.2E-06		1.4E-06	1.2E-06
Organic Carbon		0	0		0	0
Sulfates		1.1E-03	9.8E-04		0.0011	0.0010
Sodium		1.7E-07	1.6E-07		1.8E-07	1.6E-07
Calcium		9.4E-08	8.5E-08		9.5E-08	8.6E-08
Manganese		9.7E-06	8.7E-06		9.8E-06	8.8E-06
Nitrates		4.1E-08	3.7E-08		4.2E-08	3.8E-08
Boron		2.9E-05	2.6E-05		3.0E-05	2.7E-05
Other Organics		9.0E-05	8.1E-05		9.1E-05	8.2E-05
Chromates		1.0E-07	9.3E-08		1.0E-07	9.4E-08
Sodium Dichromate		0	0		0	0
Methanol		0	0		0	0

Table 2-9-BAG
WATERBORNE WASTES FOR TRANSP TO DIST CTR AND DISPOSAL OF 1,000 LB OF SHIPPING BAGS

	Unpadded Bleached Kraft Bag		All-Paper Padded Kraft Bag		Bubble Padded Kraft Bag		Unpadded LLDPE Film Bag		Bubble Padded LLDPE Bag	
	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion	Retail Order Center	End of Life Disposal % diversion
		10		10		10		10		10
Waterborne Wastes (lb/1,000 lb) - Process + Fuel-Related										
Acid	4.6E-08	8.0E-09	4.6E-08	8.1E-09	4.6E-08	8.3E-09	8.9E-08	8.9E-09	4.6E-08	8.9E-09
Metal Ion	9.8E-04	1.7E-04	9.8E-04	1.7E-04	9.8E-04	1.8E-04	0.0019	1.9E-04	9.8E-04	1.9E-04
Fluorides	2.3E-06	4.0E-07	2.3E-06	4.0E-07	2.3E-06	4.1E-07	4.4E-06	4.4E-07	2.3E-06	4.4E-07
Dissolved Solids	0.19	0.033	0.19	0.033	0.19	0.035	0.37	0.037	0.19	0.037
Suspended Solids	0.0044	7.6E-04	0.0044	7.6E-04	0.0044	7.9E-04	0.0084	8.4E-04	0.0044	8.4E-04
BOD	7.2E-04	1.3E-04	7.2E-04	1.3E-04	7.2E-04	1.3E-04	0.0014	1.4E-04	7.2E-04	1.4E-04
COD	0.0048	8.4E-04	0.0048	8.4E-04	0.0048	8.7E-04	0.0093	9.3E-04	0.0048	9.3E-04
Phenol	3.2E-06	5.5E-07	3.2E-06	5.5E-07	3.2E-06	5.7E-07	6.1E-06	6.1E-07	3.2E-06	6.1E-07
Sulfides	0	0	0	0	0	0	0	0	0	0
Oil	0.0045	7.8E-04	0.0045	7.8E-04	0.0045	8.1E-04	0.0087	8.7E-04	0.0045	8.7E-04
Sulfuric Acid	3.8E-05	6.6E-06	3.8E-05	6.7E-06	3.8E-05	6.9E-06	7.4E-05	7.4E-06	3.8E-05	7.4E-06
Iron	1.1E-04	1.8E-05	1.1E-04	1.8E-05	1.1E-04	1.9E-05	2.0E-04	2.0E-05	1.1E-04	2.0E-05
Cyanide	1.0E-08	1.8E-09	1.0E-08	1.8E-09	1.0E-08	1.9E-09	2.0E-08	2.0E-09	1.0E-08	2.0E-09
Alkalinity	0	0	0	0	0	0	0	0	0	0
Chromium	7.3E-06	1.3E-06	7.3E-06	1.3E-06	7.3E-06	1.3E-06	1.4E-05	1.4E-06	7.3E-06	1.4E-06
Aluminum	0	0	0	0	0	0	0	0	0	0
Nickel	0	0	0	0	0	0	0	0	0	0
Mercury	5.4E-10	9.4E-11	5.4E-10	9.4E-11	5.4E-10	9.8E-11	1.0E-09	1.0E-10	5.4E-10	1.0E-10
Lead	8.2E-08	1.4E-08	8.2E-08	1.4E-08	8.2E-08	1.5E-08	1.6E-07	1.6E-08	8.2E-08	1.6E-08
Phosphates	1.9E-05	3.3E-06	1.9E-05	3.3E-06	1.9E-05	3.4E-06	3.7E-05	3.7E-06	1.9E-05	3.7E-06
Phosphorus	0	0	0	0	0	0	0	0	0	0
Nitrogen	0	0	0	0	0	0	0	0	0	0
Zinc	3.6E-06	6.2E-07	3.6E-06	6.2E-07	3.6E-06	6.5E-07	6.9E-06	6.9E-07	3.6E-06	6.9E-07
Ammonia	7.8E-05	1.4E-05	7.8E-05	1.4E-05	7.8E-05	1.4E-05	1.5E-04	1.5E-05	7.8E-05	1.5E-05
Pesticides	0	0	0	0	0	0	0	0	0	0
Other Chemicals	0	0	0	0	0	0	0	0	0	0
Herbicides	0	0	0	0	0	0	0	0	0	0
Hydrocarbons	0	0	0	0	0	0	0	0	0	0
Chlorides	0.0071	0.0012	0.0071	0.0012	0.0071	0.0013	0.014	0.0014	0.0071	0.0014
Cadmium	7.1E-06	1.2E-06	7.1E-06	1.2E-06	7.1E-06	1.3E-06	1.4E-05	1.4E-06	7.1E-06	1.4E-06
Organic Carbon	0	0	0	0	0	0	0	0	0	0
Sulfates	0.0057	0.0010	0.0057	0.0010	0.0057	0.0010	0.011	0.0011	0.0057	0.0011
Sodium	9.1E-07	1.6E-07	9.1E-07	1.6E-07	9.1E-07	1.6E-07	1.8E-06	1.8E-07	9.1E-07	1.8E-07
Calcium	5.0E-07	8.6E-08	5.0E-07	8.6E-08	5.0E-07	8.9E-08	9.5E-07	9.5E-08	5.0E-07	9.5E-08
Manganese	5.1E-05	8.8E-06	5.1E-05	8.8E-06	5.1E-05	9.1E-06	9.7E-05	9.7E-06	5.1E-05	9.7E-06
Nitrates	2.2E-07	3.8E-08	2.2E-07	3.8E-08	2.2E-07	3.9E-08	4.2E-07	4.2E-08	2.2E-07	4.2E-08
Boron	1.5E-04	2.7E-05	1.5E-04	2.7E-05	1.5E-04	2.8E-05	2.9E-04	2.9E-05	1.5E-04	2.9E-05
Other Organics	4.7E-04	8.2E-05	4.7E-04	8.2E-05	4.7E-04	8.4E-05	9.0E-04	9.0E-05	4.7E-04	9.0E-05
Chromates	5.4E-07	9.4E-08	5.4E-07	9.4E-08	5.4E-07	9.7E-08	1.0E-06	1.0E-07	5.4E-07	1.0E-07
Sodium Dichromate	0	0	0	0	0	0	0	0	0	0
Methanol	0	0	0	0	0	0	0	0	0	0

CHAPTER 3

ENERGY AND ENVIRONMENTAL RESULTS FOR PACKAGING OPTIONS FOR SHIPMENT OF RETAIL MAIL-ORDER SOFT GOODS

INTRODUCTION

A life cycle inventory (LCI) quantifies the energy use and environmental emissions associated with the life cycle of specific products. This study examines the environmental profiles of various packaging options used to ship mail-order soft goods to residential customers. The two main types of packaging considered in the analysis are corrugated boxes with dunnage and shipping bags.

The results presented in this chapter comprise a full LCI, beginning with extraction of raw materials from the earth and continuing through packaging production, use, and disposal. Results are broken out into several life cycle stages, including production of packaging (all steps from raw material extraction through packaging manufacture), transportation of finished packaging items to the mail order distribution center or order fulfillment center, transportation of the packaged soft goods to the consumer, and disposal of the packaging discarded after diversion for reuse and/or recycling.

Purpose of the Study

The purpose of this study is to evaluate the energy, solid wastes, and atmospheric and waterborne emissions associated with various packaging options for the delivery of mail-order soft goods.

Systems Studied

Two general types of packaging systems for mail-order soft goods are analyzed in this study: corrugated boxes with various types of dunnage and shipping bags composed of paper and/or plastic. Table 3-1 shows the compositions by material and by weight of the various packaging options that are analyzed in each of these categories.

Within the category of boxes and dunnage, Table 3-1 shows that the weight of boxes is much greater than the weight of all associated dunnage options. The weight of boxes per 10,000 packages is 3.7 to 29 times higher than the weights of the various types of dunnages used with the box. The box accounts for 79 to 97 percent of the weight of the various box and dunnage combinations. The heaviest box and dunnage combination (box with molded pulp loose fill) is 23 percent heavier than the lightest box and dunnage combination (box with EPS loose fill).

Table 3-1

DEFINITION OF INDIVIDUAL PACKAGING COMPONENTS MODELED IN THE STUDY
(Study models corrugated boxes used in combination with various dunnage options.)

		Postconsumer Recycled Content	Pounds/ Package	Thou Lb/ 10,000 Packages
CORRUGATED BOX				
Option 1	industry average linerboard	28%	0.95	9.49
	industry average medium	59%	0.44	4.41
	overall box	38%	1.39	13.90
Option 2	recycled linerboard	71%	0.95	9.49
	recycled medium	100%	0.44	4.41
	overall box	80%	1.39	13.90
DUNNAGE (used with corrugated box)				
Inflated Polyethylene Air Packets				
Option 1	LDPE	0%	0.084	0.84
Option 2	LDPE	30%	0.084	0.84
Polystyrene Foam Loose Fill				
Option 1	EPS	0%	0.048	0.48
Option 2	EPS	30%	0.048	0.48
Starch-based Loose Fill				
	cornstarch	0%	0.086	0.86
Molded Pulp Loose Fill				
	newspaper	100% (1)	0.38	3.79
Kraft Paper (Crumpled)				
Option 1	unbleached kraft	0%	0.18	1.84
Option 2	unbleached kraft	50%	0.18	1.84
Newsprint (Crumpled)				
Option 1	newsprint	10%	0.17	1.68
Option 2	newsprint	50%	0.17	1.68
Shredded Postconsumer Paper(board)				
Option 1	corrugated	100% (1)	0.32	3.18
Option 2	office paper (2)	100% (1)	0.15	1.48

(1) 100% postconsumer material; postconsumer content of postconsumer material may be less than 100%.
(2) 83.6% printing-writing, 16.4% newspaper

Table 3-1 (cont.)

DEFINITION OF INDIVIDUAL PACKAGING COMPONENTS MODELED IN THE STUDY

SHIPPING BAGS		Postconsumer Recycled Content	Pounds/ Package	Thou Lb/ 10,000 Packages
Unpadded Kraft				
Option 1	bleached kraft	0%	0.14	1.41
Option 2	bleached kraft	30%	0.14	1.41
Kraft with Paper Padding				
Option 1	bleached kraft outer	0%	0.10	0.95
	unbleached kraft inner	0%	0.090	0.90
	shredded newspaper pad	100% (1)	0.19	1.92
			0.38	3.77
Option 2	bleached kraft outer	30%	0.10	0.95
	unbleached kraft inner	30%	0.090	0.90
	shredded newspaper pad	100% (1)	0.19	1.92
			0.38	3.77
Kraft with Bubble Wrap				
Option 1	bleached kraft bag	0%	0.086	0.86
	LDPE film (50% of bubble)	0%	0.024	0.24
	LLDPE film (50% of bubble)	0%	0.024	0.24
			0.13	1.33
Option 2	bleached kraft bag	30%	0.086	0.86
	LDPE film (50% of bubble)	30%	0.024	0.24
	LLDPE film (50% of bubble)	30%	0.024	0.24
			0.13	1.33
Unpadded Film Bag				
Option 1	LLDPE	0%	0.067	0.67
Option 2	LLDPE	30%	0.067	0.67
Film Bag with Bubble Wrap				
Option 1	LLDPE bag	0%	0.063	0.63
	LDPE film (50% of bubble)	0%	0.035	0.35
	LLDPE film (50% of bubble)	0%	0.035	0.35
			0.13	1.33
Option 2	LLDPE bag	30%	0.063	0.63
	LDPE film (50% of bubble)	30%	0.035	0.35
	LLDPE film (50% of bubble)	30%	0.035	0.35
			0.13	1.33

(1) 100% postconsumer material; postconsumer content of postconsumer material may be less than 100%.

Within the category of shipping bags, the heaviest bag (all-paper padded) is more than 5 times as heavy as the lightest bag (unpadded LLDPE). Padded bags are heavier than the corresponding unpadded bags. The all-paper padded bag is 2.7 times the weight of the unpadded kraft bag, while the bubble-padded plastic film bag is almost twice as heavy as the unpadded LLDPE bag. The unlined kraft bag and both bubble-padded bags (paper and plastic) are all very similar in weight.

When the weights of boxes with dunnage are compared to the weights of shipping bags, the data in Table 3-1 show that the lightest box and dunnage combination is nearly 4 times as heavy as the heaviest bag. In the most extreme weight comparison, the heaviest box and dunnage combination weighs 26 times as much as the lightest bag.

Functional Unit

In order to insure a valid basis for comparison for the packaging systems studied, a common functional unit is essential. For this study, the functional unit for each system is the packaging required to deliver 10,000 representative packages of soft goods items to customers. The dimensions and weight of the representative packaged item were determined by Oregon Department of Environmental Quality (DEQ) staff, based on data provided in 2003 by a large Oregon-based mail-order company. The item to be packaged (also called "shipped product") for the purposes of this study has dimensions of 17.5" x 12" x 2.5" (uncompressed height) and a weight of 1.28 pounds.

The dimensions and weights of each packaging configuration required to ship the representative item were determined by DEQ staff based on data provided by several mail-order companies, packaging vendors, and a packaging study and other analysis conducted in March 2003 by Pack Edge Development, a packaging engineering firm also under contract to DEQ. The material composition of each packaging configuration was determined by DEQ staff and Franklin Associates staff, with assistance from Pack Edge Development. The development of the functional unit product and packaging data are described in detail in Appendix B of the report appendices, published as a separate document.

The analysis also includes delivery of the packaging materials to the order fulfillment center where they are used to package the product that is then shipped to a customer. The representative mail order fulfillment center location selected for this study is Salem, Oregon. The representative customer location is modeled as Edgar Springs, Missouri, which is the town nearest the population center of the United States for the 2000 Census. Transportation modes and distances for delivery of packaged product were based on tracking histories for sample parcels sent by UPS and FedEx in 2003, and MapQuest mileage distances. Detailed description of the development of the representative mail order location, customer location, and shipping mode and distance is provided in Appendix D.

It is assumed that all packaging options in this study provide equivalent protection for the packaged product, so it is not necessary to take into account different rates of product damage, returns, and replacement shipments for the various packaging options.

Scope and Boundaries

The LCI results presented in this chapter include the following:

- Manufacture of all packaging material components, beginning with the extraction of raw materials from the ground and continuing through all subsequent processing and transportation steps up to manufacture into packaging materials. Data were not available for the fabrication of shipping bags from their component materials; thus, the burdens for shipping bags are understated by an unknown amount. Based on data for the fabrication of corrugated boxes, it is expected that fabrication data might account for five to ten percent of the total energy required to produce a package.
- Glues, adhesives, printing inks, and other inputs accounting for less than one percent of the weight of product were not included. Starch-based adhesive for corrugated box manufacture, which accounts for more than one percent of the box weight, was included.
- Other system components not included in the study, in order to keep the scope of the study focused and manageable within practical budget and time constraints, include capital equipment, space conditioning, support personnel requirements, a proprietary plasticizer used in the production of cornstarch loose fill, and certain process emissions for which data were not available. (See Chapter 1 and the Appendices for additional details.)
- Transportation of finished packaging items from the manufacturer to the order fulfillment center or distribution center is included. The representative order fulfillment center is assumed to be located in Western Oregon. DEQ provided region-specific data for the transportation of packaging items from the packaging producer to the order fulfillment center, as well as some data on transportation of input materials such as resins to packaging producers. Transportation data for all other steps are from Franklin Associates' U.S. life cycle inventory database.
- Transportation of packaged products from the order fulfillment center to a representative customer located at the population center of the United States, in central Missouri, is included. The environmental burdens for this step reported in the LCI reflect only those burdens allocated to the package itself, based on the total transportation burdens and the packaging's percentage of the total weight of the product with packaging.
- Disposal of packaging, adjusted to account for diversion for reuse and recycling, is included.
- The results shown for each packaging system include the burdens for extraction, processing, delivery, and combustion of all process and transportation fuels used.

LCI RESULTS

Energy, solid waste, and emissions results are presented in this chapter for the packaging systems broken out into the following categories:

- Cradle-to-production results for packaging materials.
- Transportation of packaging materials from the producer to the order fulfillment center.
- Transportation of packaged product from the order fulfillment center to the mail-order customer
- Disposal of packaging materials at end of life (after diversion for reuse and recycling).

Energy results are shown in Tables 3-2 and 3-3. Solid waste results are shown in Tables 3-4 and 3-5, atmospheric emissions in Tables 3-6 and 3-7, and waterborne emissions in Tables 3-8 and 3-9. In each set of tables, the first (even-numbered) shows results for the lower postconsumer recycled content options defined in Table 3-1, and the second (odd-numbered) shows results for the higher postconsumer recycled content options defined in Table 3-1. There are two versions of each table, "-BOX" showing results for boxes and dunnage, and "-BAG" showing results for shipping bags. **Because of the length of the tables, all results tables are placed at the end of the chapter.** (Note: Readers interested in comparing the relative environmental burdens for higher and lower recycled content boxes *without dunnage* can do so by comparing the burdens for the low and high recycled content option results for boxes with the following types of dunnage: molded pulp loose fill, shredded PC office paper, or shredded PC corrugated. Because these dunnage materials are all modeled at 100 percent PC recycled content, the only difference between the higher and lower recycled content box + dunnage options are due to the difference in PC content of the box.)

Figures 3-1 and 3-2 show energy results by category. Figures 3-3 and 3-4 show energy results by life cycle stage. Solid waste results are presented by category in Figures 3-5 and 3-6 and by life cycle stage in Figures 3-7 and 3-8. Greenhouse gas emissions are shown in Figures 3-9 and 3-10. The odd-numbered figures show results for the low postconsumer options, and the even-numbered figures present results for the high postconsumer options. There are "–BOX" and "–BAG" versions of each figure. Figures are inserted in the chapter as they are discussed in the text.

Data development and assumptions for production, transportation, and disposal of individual packaging components are described in Chapter 2 and the report appendices.

The LCI results presented in this chapter were developed by multiplying the 1,000-pound modules presented in Chapter 2 by the appropriate weighting factors to represent the packaging systems defined in Table 3-1. Modules for material production, transportation, and disposal are then combined to model scenarios with different material combinations and recycled contents for the delivery of 10,000 packages to residential customers. The final section of this chapter provides guidance on how interested readers can use the Chapter 2 data modules for sensitivity analysis (e.g., of varying recycled contents, fabrication losses, and transportation distances).

The only additional data presented in this chapter that was not developed from the 1,000–pound modules in Chapter 2 is the data for delivery of the packaged product to the customer. In this study, mail-order soft goods packaged in corrugated boxes always include some type of dunnage. Because the weight of dunnage in the box varies depending on the type of dunnage used, the total weight of (box + dunnage) per packaged product varies. The weight percentage of packaging per weight of (packaging + product), used to allocate delivery burdens to packaging, varies as the weight of the packaging varies. Thus it was not practical to develop 1,000-pound modules for transportation of packaged product in Chapter 2. Development of data for delivery of the packaged product and allocation of delivery burdens to the packaging is described in detail in the report appendices.

In the results tables in this chapter, the "percent of total" **column** to the right of the "total" column shows the percentage of the total from each category (e.g., for energy, the percentages of process energy, energy of material resource, and transportation energy, or the percentage from each fuel source). The "percent of total" **row** under the "total" row show the percentage of the total from each life cycle stage (e.g., from packaging production, transportation to order fulfillment center, transportation to customer, and disposal).

Energy Results

In the results tables, life cycle stages for each packaging option are shown across the tops of the columns. Energy results are shown in several levels of detail in Tables 3-2 and 3-3. The first set of energy results shows the total energy separated into categories of process energy, energy of material resource, and transportation energy. The next two sections show the process/material resource energy (combined) and transportation energy broken out by the sources of energy. The final line shows an energy credit for the energy recovered from waste-to-energy incineration of 20 percent of the solid waste that is not diverted for reuse or recycling.

Based on the uncertainty in the energy data, energy differences between systems are not considered significant unless the percent difference between systems is greater than 10 percent. (Percent difference between systems is defined as the difference between energy totals divided by the average of the two system totals.) This minimum percent difference criterion was developed based on the experience and professional judgment of the analysts and supported by sample statistical calculations (see Chapter 4).

Energy by Category. Energy results by category are shown in Figures 3-1 and 3-2. The category of **process energy** includes totals for all processes required to produce the packaging materials, from acquisition of raw materials through manufacture into packaging materials. **Transportation energy** is the energy used to move material from location to location during its journey from raw material to product. **Energy of material resource** is not an expended energy but the energy value of fuel resources withdrawn from the planet's finite fossil reserves and used as material inputs for materials such as plastic resins. Use of fuel resources as a material input is a depletion of fuel resources just as the combustion of fuels for energy is. In this study, energy of material resource is reported for the plastic components of the packaging systems. Natural gas and petroleum are the primary material feedstocks for resin production. No energy of material resource is assigned to wood used as a material input for paper(board) packaging components because wood's primary use in the United States is as a material input, not as a fuel resource. Wood combusted for energy (such as bark and black liquor burned for fuel in virgin pulp and paper mills) is counted as process energy.

Table 3-2-BOX and Figure 3-1-BOX show that, for the lower postconsumer recycled content box and dunnage options, process energy accounts for about 2/3 of total energy, and transportation energy accounts for about 1/3. Energy of material resource is about 5 percent or less of total energy. In Table 3-2-BAG and Figure 3-1-BAG, energy of material resource accounts for a significant percentage of total energy for shipping bags using plastics. Transportation energy is highest for the all-paper padded bag, which is the heaviest and bulkiest bag. Process energy is higher for paper bags compared to plastic bags.

Energy results by category for the higher postconsumer (PC) recycled content options are shown in Table 3-3 and Figure 3-2. The higher recycled contents of packaging components affect only the results for material production. Because the quantity of materials used in the package does not change, there is no change in disposal, and any changes in transportation (quite small for most materials) reflect differences in the local availability of recycled content materials. For the box, the 80% PC recycled content box requires 25 percent less total production energy than the average (38% PC) box. The higher recycled content dunnage options use 20 to 33 percent less energy than the lower recycled content options. Overall energy results for the higher recycled content options are 13 to 18 percent lower than for the lower recycled box + dunnage options. For the shipping bags, increasing the PC recycled content of the kraft paper and plastic film components of the bags reduces material production energy by 19 to 25 percent, for a decrease in total energy of 11 to 21 percent.

Energy results by life cycle stage are shown in Figures 3-3 and 3-4. Figure 3-3-BOX shows that box production and transportation of packaged product to customer are the dominant life cycle stages for energy. Even though Chapter 2 shows that corrugated boxes have a relatively low energy profile per 1,000 pounds, Table 3-1 shows that almost 14,000 pounds of boxes are required to ship 10,000 packages. Weights of dunnage are much less than the weight of boxes, so dunnage makes a lower contribution to total energy, regardless of the energy profile per 1,000 pounds of dunnage. For example, the weight of the box relative to the weight of dunnage used with the box ranges from 3.7 for the heaviest dunnage (molded pulp), up to 28 for the lightest dunnage (EPS loose fill). The dunnage materials with the greatest contribution to total energy are those that have a high energy profile per 1,000 pounds, such as virgin EPS loose fill, or those that have a low energy profile but a high weight, such as molded pulp.

Figure 3-1-BOX. Energy by Category for 10,000 Packages Shipped in Box+Dunnage - Lower Postconsumer Recycled Content Options (million Btu/10,000 pkgs)

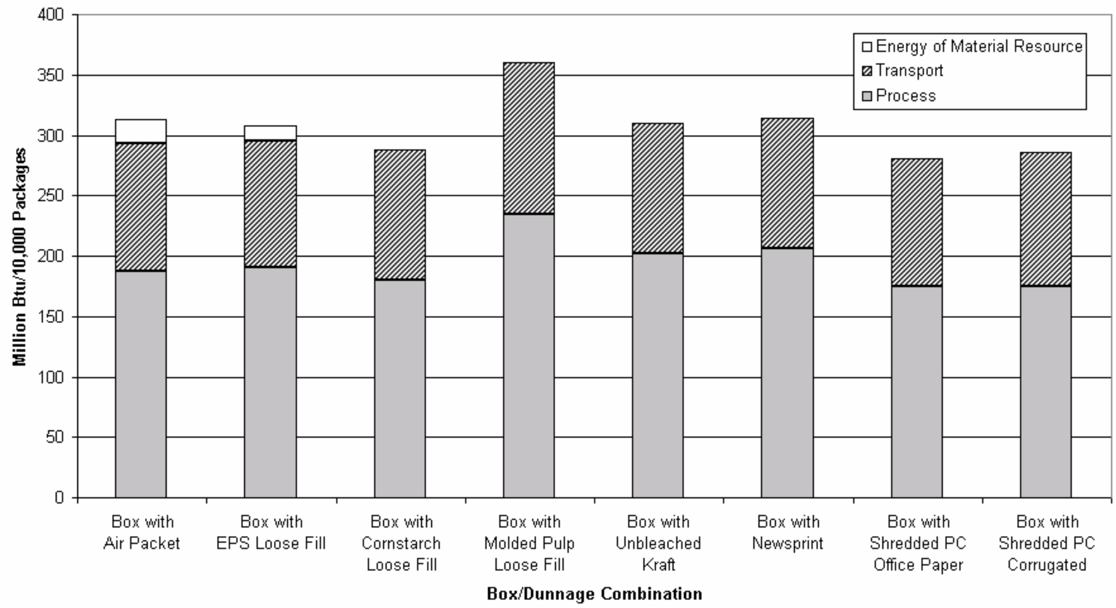
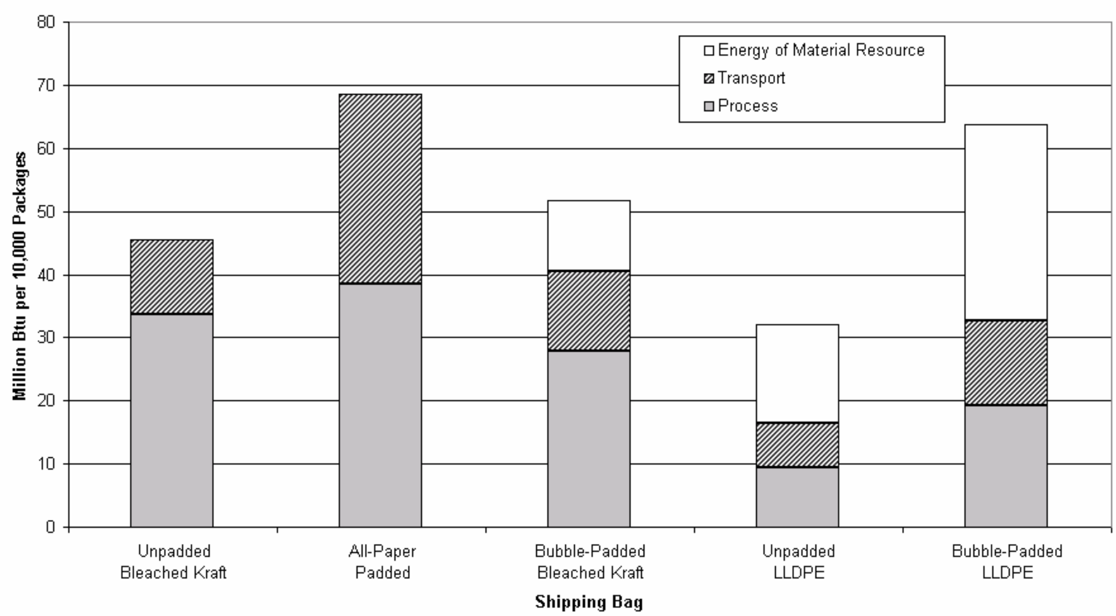


Figure 3-1-BAG. Energy by Category for 10,000 Packages Shipped in Shipping Bags - Lower Postconsumer Recycled Content Options (million Btu/10,000 pkgs)



The transportation energy for delivery of packaged product (to customer) shown in the results tables is the energy allocated to the packaging, based on its weight percentage of the product + packaging. Boxed products take up a large volume relative to their weight. An analysis of the weights and volumes of mail-order soft goods packaged in boxes and bags (described in detail in the report appendices) indicated that delivery vehicles would fill by volume rather than by weight. Volume-limited transportation is less efficient than weight-limited transportation, as a greater number of truckloads are required to haul a given weight of cargo. The volume factor has a significant impact on the transportation results in this study, where the representative packaged product is being shipped over 2,000 miles, from the Pacific Northwest to the Midwest.

Figure 3-3-BAG shows that production of shipping bag materials dominates total energy results. Transportation to customer is lower for bags compared to boxes, for two main reasons. First, bagged product occupies less volume relative to its weight, so more packaged products can fit in a delivery vehicle load. Second, the weight of a shipping bag is less than the weight of box + dunnage used to ship the same product, so a lower percentage of the transportation burdens for the packaged product is allocated to the bag.

Figure 3-2-BOX. Energy by Category for 10,000 Packages Shipped in Box+Dunnage - Higher Postconsumer Recycled Content Options (million Btu/10,000 pkgs)

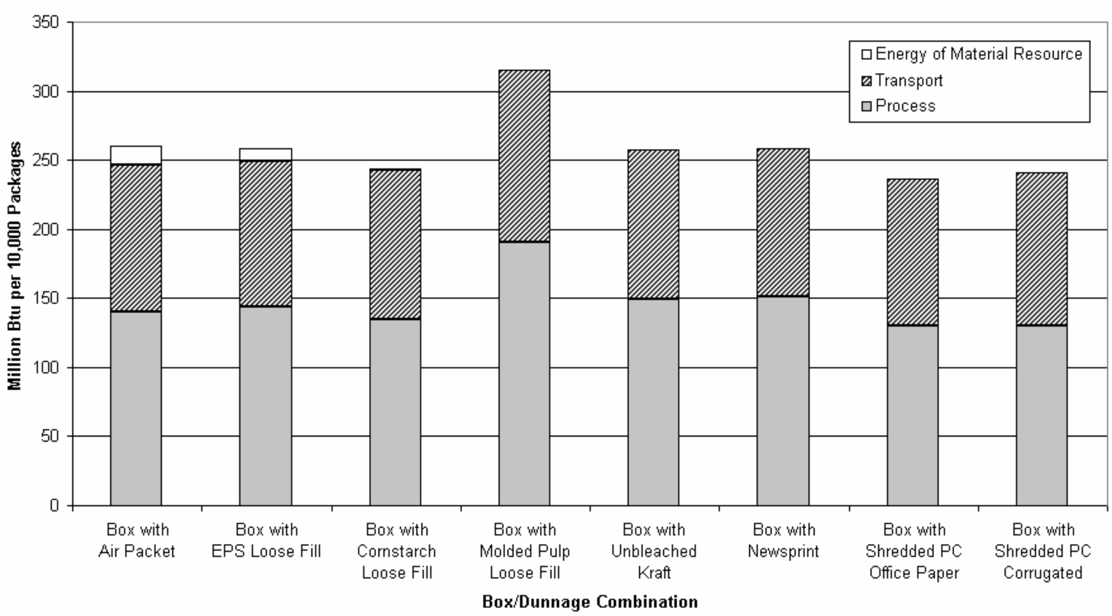


Figure 3-2-BAG. Energy by Category for 10,000 Packages Shipped in Shipping Bags - Higher Postconsumer Recycled Content Options (million Btu/10,000 pkgs)

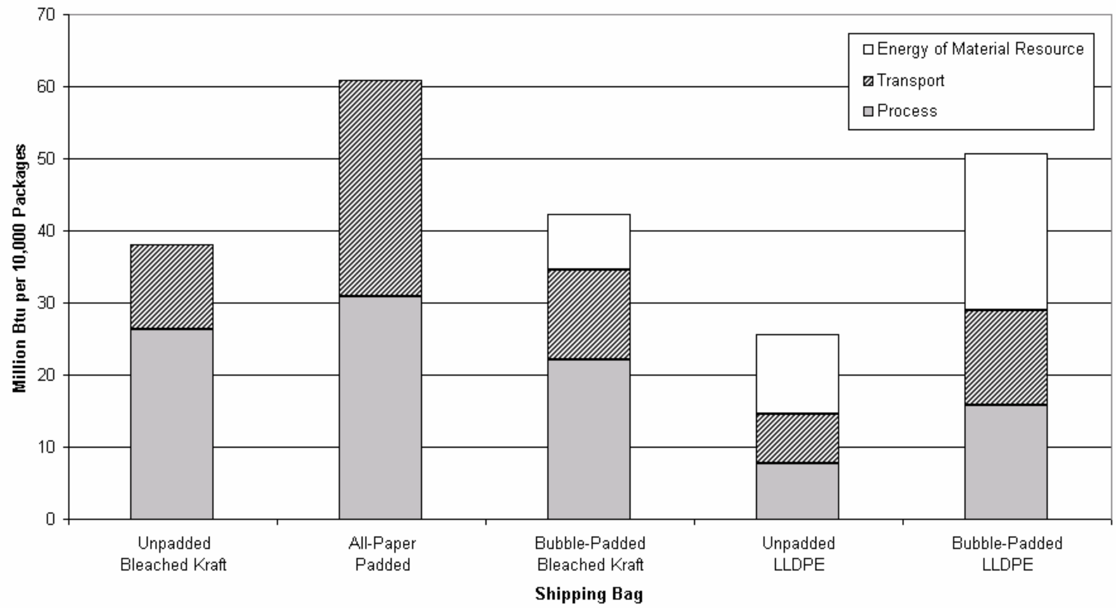


Figure 3-3-BOX. Energy by Life Cycle Stage for 10,000 Packages Shipped in Box+Dunnage - Lower Postconsumer Recycled Content Options (million Btu/10,000 pkgs)

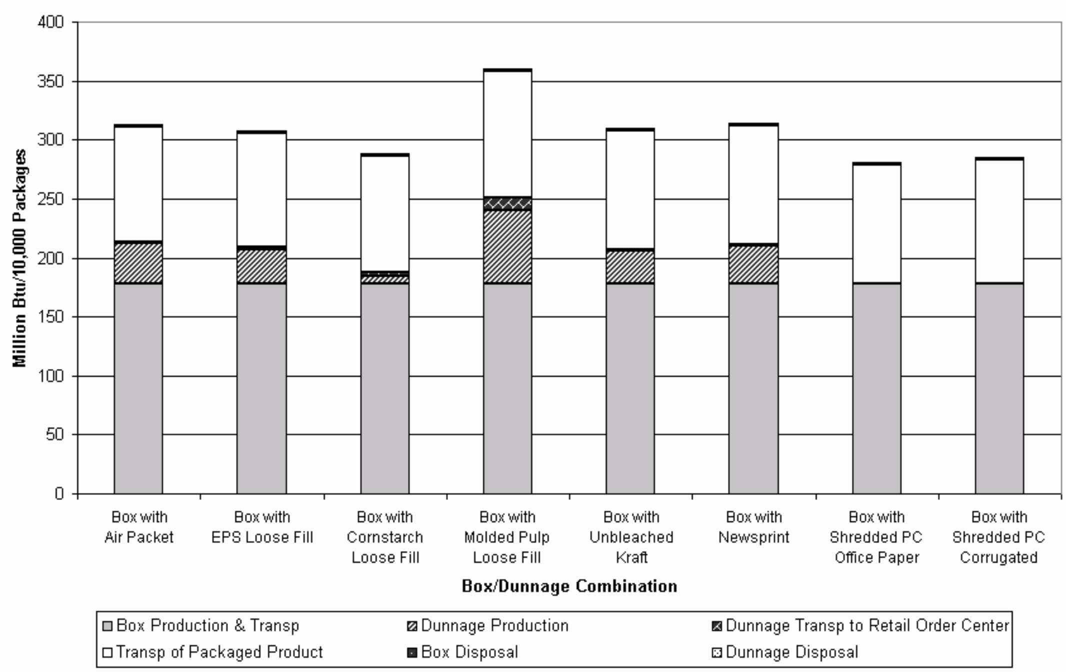
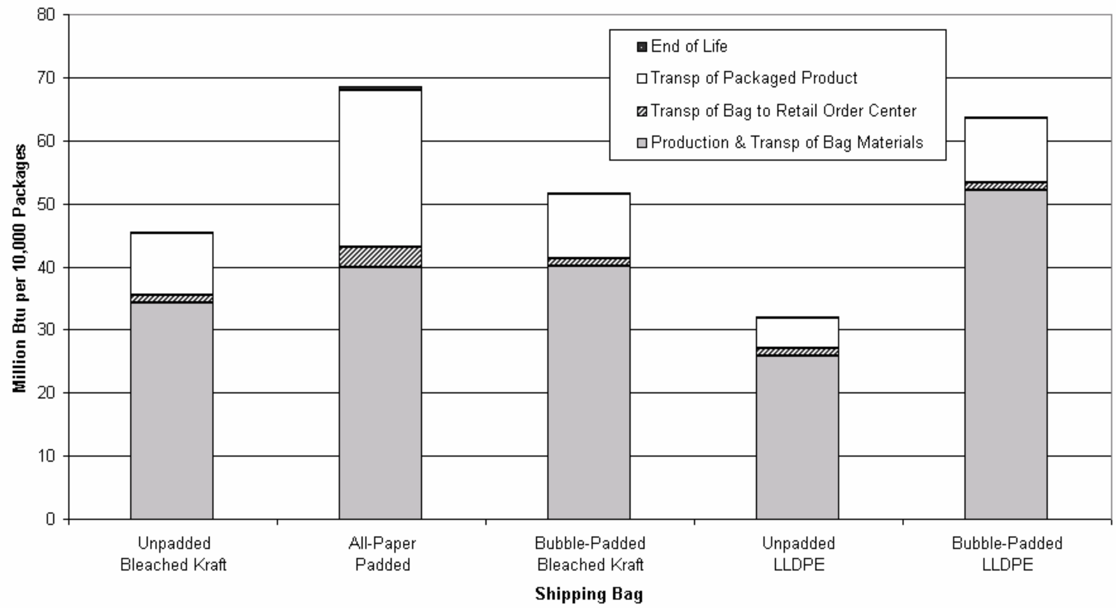


Figure 3-3-BAG. Energy by Life Cycle Stage for 10,000 Packages Shipped in Shipping Bags - Lower Postconsumer Recycled Content Options (million Btu/10,000 pkgs)



As discussed previously, increasing the recycled content of packaging materials affects only the material production life cycle stage; thus, the results shown in Figure 3-4 (-BAG and –BOX) are very similar to those in Figure 3-3, with a lower energy contribution from packaging material production.

Energy Profiles. Tables 3-2 and 3-3 also show the sources of energy by fuel, including the fuels used to generate electricity. Precombustion energy (the energy used to extract and process fuels used for process energy and transportation energy) is also included in the results shown in the table. The fossil fuels–natural gas, petroleum and coal–are used for direct combustion for process fuels and generation of purchased electricity. Natural gas and petroleum use as raw material inputs for the production of plastics is reported as energy of material resource. Petroleum is the dominant energy source for transportation. Non-fossil sources, such as hydropower, nuclear and other (geothermal, wind, etc.) shown in the table are used to generate purchased electricity along with the fossil fuels. Use of wood for energy occurs at integrated forest product manufacturing sites, particularly those that produce virgin chemically pulped paper.

The energy tables show that wood is a significant source of process energy for corrugated boxes and kraft paper components. Integrated pulp and paper mills that produce virgin chemically pulped paper products use wood wastes (e.g., bark) and black liquor from the pulping process to provide a significant part of their operating energy, while recycled paper mills generally do not have access to these materials and rely on fossil fuels for energy.

The weight of the box dominates the material use in box and dunnage packaging options; as a result, the total process energy profile for box systems shown in Tables 3-2-BOX and 3-3-BOX is heavily influenced by the energy profile for box production. For example, Chapter 2 Table 2-2-BOX shows that coal (used for electricity generation) accounts for 32 percent of total process energy for the average (38% PC) box and about 48 percent of the total process energy for production of the 80% PC box. In Table 3-2-BOX, coal accounts for about 30 percent of the total energy requirements for box and dunnage systems using the average box. In Table 3-3-BOX, coal is over 40 percent of the total process energy for systems using the 80% PC box.

Similarly, Table 2-2-BOX shows that wood energy accounts for 43 percent of the total energy for production of the average PC box and 20 percent of the total energy for production of the 80% PC box. Wood energy accounts for about a third or more of the total process energy for average box systems in Table 3-2-BOX and 13 to 23 percent of the total process energy for 80% PC box systems in Table 3-3-BOX.

In Table 3-2-BOX, natural gas accounts for 20 to 24 percent of total process energy for low PC systems using plastic dunnage and 15 to 20 percent of the total for low PC systems using paper dunnage (except for 100% PC molded pulp loose fill, which uses large quantities of natural gas for drying). In Table 3-3-BOX, natural gas ranges from 24 to 27 percent for high PC systems using plastic dunnage and 19 to 24 percent for high PC systems using paper dunnage. For systems using plastic dunnage, natural gas use includes its use as a material input to resin production as well as its use as a fuel for process energy and generation of purchased electricity. Natural gas use reported for systems using paper dunnage is only as fuel for process energy and generation of purchased electricity.

For bag systems, Table 3-2-BAG shows that the process energy fuel profile for all-paper bag systems at low PC content is dominated by wood energy at 44 to 49 percent of the total and coal, used for electricity generation, at about 23 percent. For all-paper bag systems at higher PC content, Table 3-3-BAG shows that wood is 39 to 43 percent of the total and coal is 27 to 29 percent. Natural gas and petroleum each account for about 10 to 14 percent of total process energy for all-paper bag systems in either PC content scenario.

For all-plastic bag systems, Table 3-2-BAG shows that the dominant process fuels for virgin bags are natural gas at 72 percent of the total and petroleum at 15 percent. In Table 3-3-BAG, natural gas accounts for 69 percent of the total and petroleum 15 percent. In addition to use as process fuels and fuels for the generation of purchased electricity, the use of natural gas and petroleum includes its use as a raw material input to the production of plastic resins. Coal, used to generate purchased electricity, accounts for 8 percent of the total for virgin all-plastic bags and 11 percent of the total process energy for 30% PC bags.

Figure 3-4-BOX. Energy by Life Cycle Stage for 10,000 Packages Shipped in Box+Dunnage - Higher Postconsumer Recycled Content Options (million Btu/10,000 pkgs)

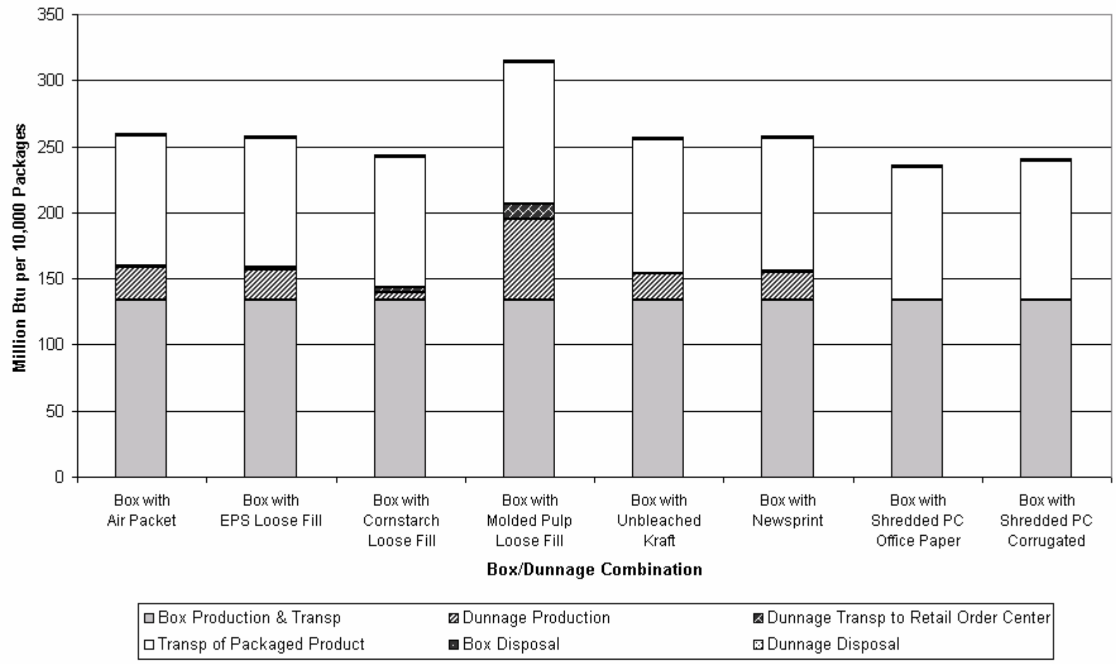
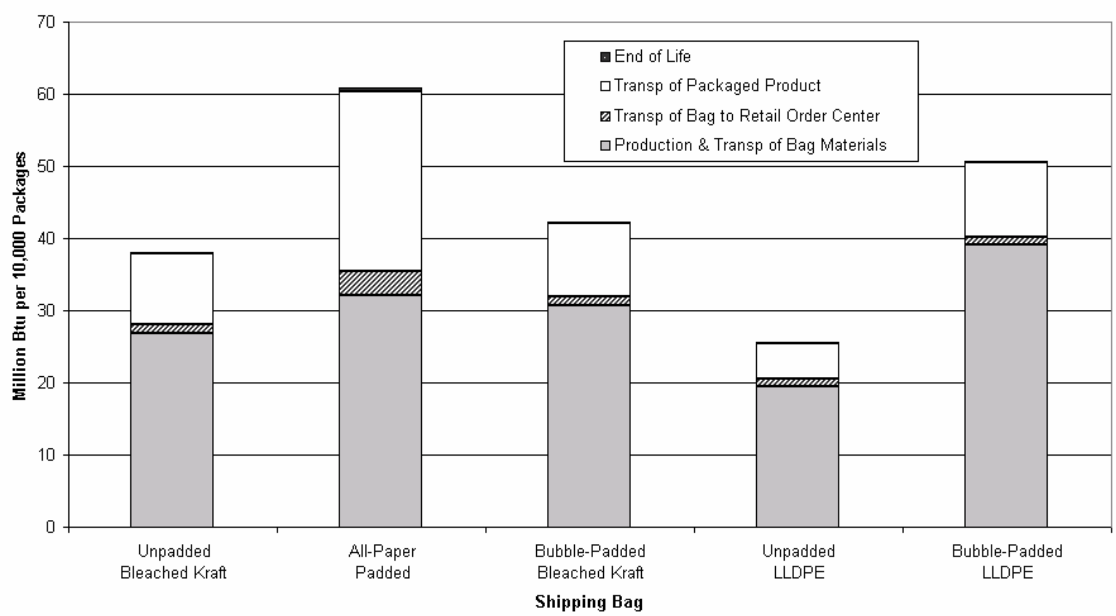


Figure 3-4-BAG. Energy by Life Cycle Stage for 10,000 Packages Shipped in Shipping Bags - Higher Postconsumer Recycled Content Options (million Btu/10,000 pkgs)



The composite paper bag with plastic bubble padding is about 2/3 by weight paper and 1/3 by weight plastic. For the virgin bag, Table 3-2-BAG shows that just over half the process energy is for paper production and 47 percent is for the plastic components. Although paper represents a higher weight percentage of the bag, the energy per 1,000 pounds of paper is lower than the energy per 1,000 pounds of virgin plastic. For the virgin composite bag, 41 percent of total process energy is from natural gas, 23 percent from wood, and 14 to 16 percent each from petroleum and coal. Natural gas and petroleum use includes use as process fuel, generation of purchased electricity, and energy of material resource for plastic components. Wood is used for energy in pulp mills, and coal is used to generate purchased electricity. In Table 3-3-BAG the process energy profile for the composite bag with 30% PC recycled content is very similar, with 39 percent natural gas, 21 percent wood, 20 percent coal, and 14 percent petroleum.

The transportation energy fuel profile is dominated by petroleum, at about 92% of the total for all systems, box and bag, at all recycling levels. The life cycle step of transportation of packaged product to the customer (burdens allocated to the weight of packaging) dominates transportation energy.

Energy Credit. The energy results reported in Tables 3-2 and 3-3 include energy recovered from the combustion of 20 percent of postconsumer packaging that is discarded after diversion for reuse and recycling, based on the national average percentage of municipal solid waste (MSW) that is disposed by waste-to-energy (WTE) combustion. Two energy credit values are shown. The gross energy credit is calculated based on the pounds of each material burned multiplied by the higher heating value of the material. The usable energy credit is based on the gross energy adjusted for an estimated 33 percent thermal efficiency for generation of electricity from WTE combustion of MSW and transmission losses of about 8 percent.

The energy credit reported for a packaging system depends on a number of factors, including the total weight of each material in the package configuration, the diversion rates for each packaging component at end of life, and the higher heating value of each material. For example, in Table 3-2-BOX, the energy credit shown for molded pulp dunnage is higher than the credit shown for EPS loose fill, even though the higher heating value of EPS is greater than the higher heating value for molded pulp. The weight of molded pulp dunnage used in the box is higher and its end-of-life diversion rate lower compared to EPS dunnage; as a result the energy credit for molded pulp is higher.

The energy credit is not affected by the recycled content of the material, so the energy credits shown in Tables 3-2 and 3-3 are the same. In Table 3-2-BOX, the energy credit for each box + dunnage configuration is dominated by the box, largely due to the much greater weight of box compared to dunnage, even after diversion of boxes for reuse and recycling.

Solid Waste

Solid waste is broadly categorized into process wastes, fuel-related wastes, and postconsumer wastes. **Process wastes** reported in Tables 3-4 and 3-5 are the solid wastes generated by the various processes from raw material acquisition through material manufacture. **Fuel-related wastes** are the wastes from the production and combustion of fuels used for process energy and transportation energy. **Postconsumer wastes** are the wastes discarded by the end users of the product after diversion for reuse and recycling, i.e., the boxes, dunnage, and shipping bags that are discarded by the soft goods mail-order residential customer. As with energy results, the results in Tables 3-4 and 3-5 are separated by life cycle stage, with "percent of total" columns showing the contribution of each solid waste category to total solid waste, and "percent of total" rows showing the relative contributions of each life cycle stage.

It is helpful to understand how the results for solid waste by category in Tables 3-4 and 3-5 relate to the results for energy by category in Tables 3-2 and 3-3. Solid wastes for a process include not only waste materials generated from the process itself, but also solid wastes from the production and combustion of fuels used for process energy. Thus, fuel-related solid waste includes the solid waste associated with process energy as well as transportation energy.

Solid Waste by Weight. Tables 3-4 and 3-5 show solid waste by weight and by volume for the packaging systems, separated out by life cycle stage. Results by category are shown graphically in Figures 3-5 and 3-6, and results by life cycle stage are shown in Figures 3-7 and 3-8. Differences in solid waste results between systems are not considered significant unless the percent difference is greater than 25 percent for process and fuel-related wastes, or greater than 10 percent for postconsumer wastes. (Percent difference between systems is defined as the difference between solid waste totals divided by the average of the two system totals.) This minimum percent difference criterion was developed based on the experience and professional judgment of the analysts and supported by sample statistical calculations (see Chapter 4).

Tables 3-4 and 3-5 and Figures 3-5 and 3-6 show that postconsumer solid waste is the dominant contributor to the total weight of solid waste for all packaging options, followed by fuel-related solid wastes. Tables 3-4 and 3-5 show that the majority of fuel-related solid waste is for material production. (Fuel-related wastes include precombustion wastes from the extraction, processing, and delivery of fuels as well as the wastes from fuel combustion.)

For box systems, Tables 3-4-BOX and 3-5-BOX show that the box contributes the majority of postconsumer solid waste. The weight of postconsumer dunnage varies considerably, based on the weight of dunnage used and its diversion rate for reuse and recycling. The only dunnage options modeled with significant postconsumer reuse or recycling in this analysis are EPS and cornstarch foam loose fill, which are often reused by consumers or returned to shipping establishments for reuse. For this study, it was assumed that molded pulp loose fill, while technically as reusable as other types of loose fill, is not likely to be reused along with foam loose fill because of molded pulp shapes' significantly different appearance from foam loose fill. The reader can adapt the 1,000-pound material disposal modules in Chapter 2 to model other diversion rates for molded pulp loose fill or any other individual packaging component. The adapted modules can then be multiplied by the appropriate weighting factors in Table 3-1 to obtain results for their use for delivery of 10,000 packaged items.

Figures 3-7 and 3-8 illustrate the contributions of each life cycle stage to the total weight of solid waste. The –BOX figures show that the majority of solid waste is from production and disposal of the corrugated box. Box production accounts for about 30 percent of total solid waste for lower PC options (Table 3-4-BOX and Figure 3-7-BOX) and 25 percent for higher PC options (Table 3-5-BOX and Figure 3-8-BOX). Box disposal accounts for 60 to 68 percent of total solid waste for all box systems. Disposal of heavier dunnages such as molded pulp and shredded PC corrugated is also significant.

For the bag systems, bag disposal is 60 to 77 percent of total solid waste for lower PC options (Table 3-4-BAG and Figure 3-7-BAG) and 64 to 80 percent of total solid waste for higher PC options (Table 3-5-BAG and Figure 3-8-BAG).

Solid Waste by Volume. Landfills fill up because of volume, not weight. While weight is the conventional measure of waste, landfill volume is more relevant to the environmental concerns of land use. The problem is the difficulty in deriving accurate landfill volume factors. However, Franklin Associates has developed a set of landfill density factors for different materials based upon an extensive sampling by the University of Arizona. While these factors are considered to be only estimates, their use helps add valuable perspective. Volume factors are estimated to be accurate to +/- 25%. This means that waste volume values must differ by at least 25 percent in order to be interpreted as a significant difference. (Percent difference is defined as the difference between two system totals divided by their average.) This minimum percent difference criterion was developed based on the experience and professional judgment of the analysts and supported by sample statistical calculations (see Chapter 4).

In Tables 3-4 and 3-5, weights of solid waste are converted into volumes using landfill density factors. Process and fuel-related solid waste are generally reported as totals without detail on the composition and densities of individual substances within these categories; thus, the weights of process and fuel-related waste are converted to volume using an average conversion factor for industrial solid waste. The weight to volume conversions for postconsumer solid waste, however, are based on the landfill densities for materials from the University of Arizona studies and reflect the volumes that specific materials are likely to take up in a landfill. As would be expected, the lower density materials such as loose fill occupy more landfill space relative to equivalent quantities of higher density materials. For example, Table 3-4-BOX shows that disposal of EPS loose fill accounts for 1.3 percent of the total system solid waste by weight, but 4.5 percent of total solid waste by volume.

Figure 3-5-BOX. Solid Waste by Category for 10,000 Packages Shipped in Box+Dunnage - Lower Postconsumer Recycled Content Options (lb of waste/10,000 pkgs)

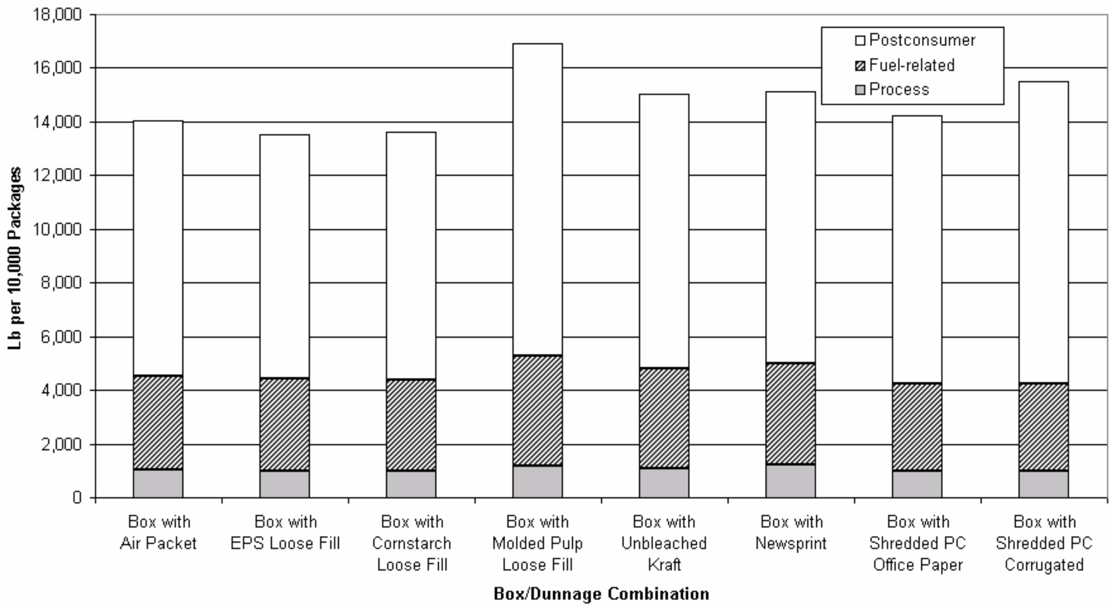


Figure 3-5-BAG. Solid Waste by Category for 10,000 Packages Shipped in Shipping Bags - Lower Postconsumer Recycled Content Options (lb of waste/10,000 pkgs)

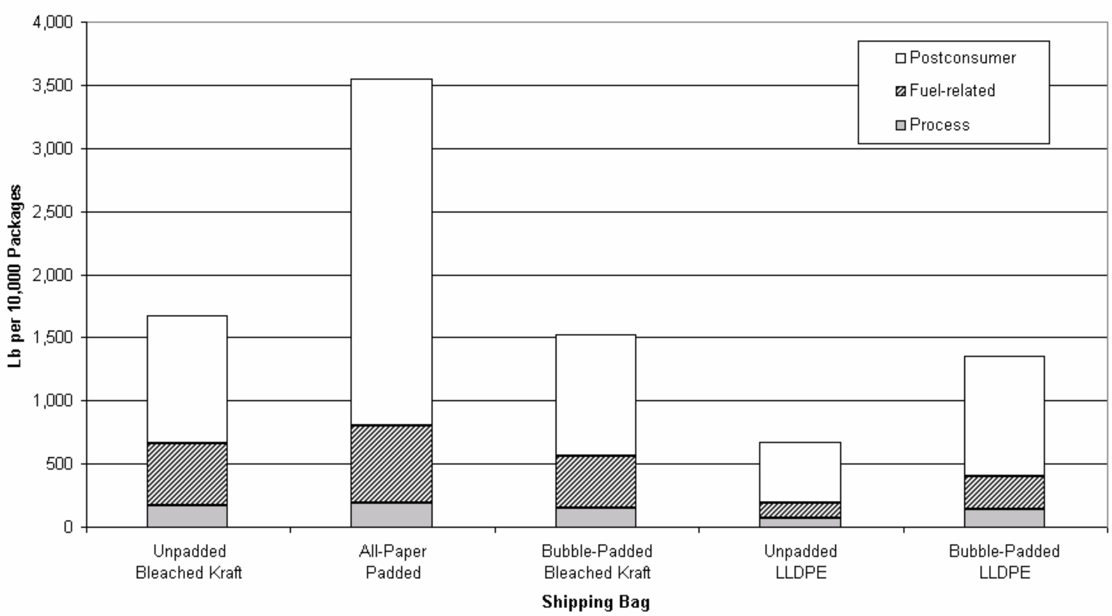


Figure 3-6-BOX. Solid Waste by Category for 10,000 Packages Shipped in Box+Dunnage - Higher Postconsumer Recycled Content Options (lb of waste/10,000 pkgs)

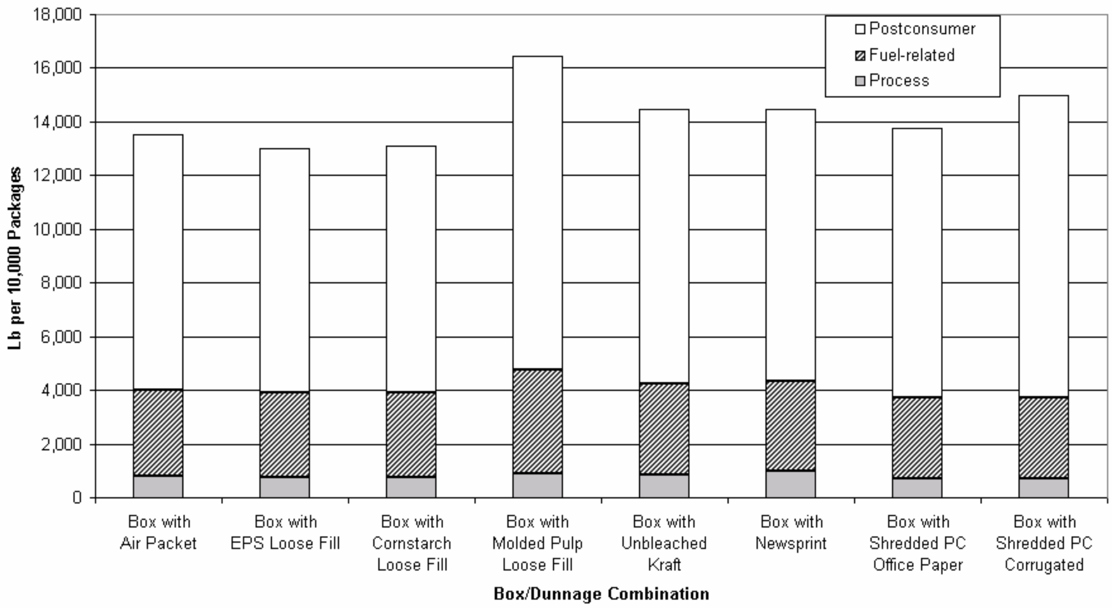
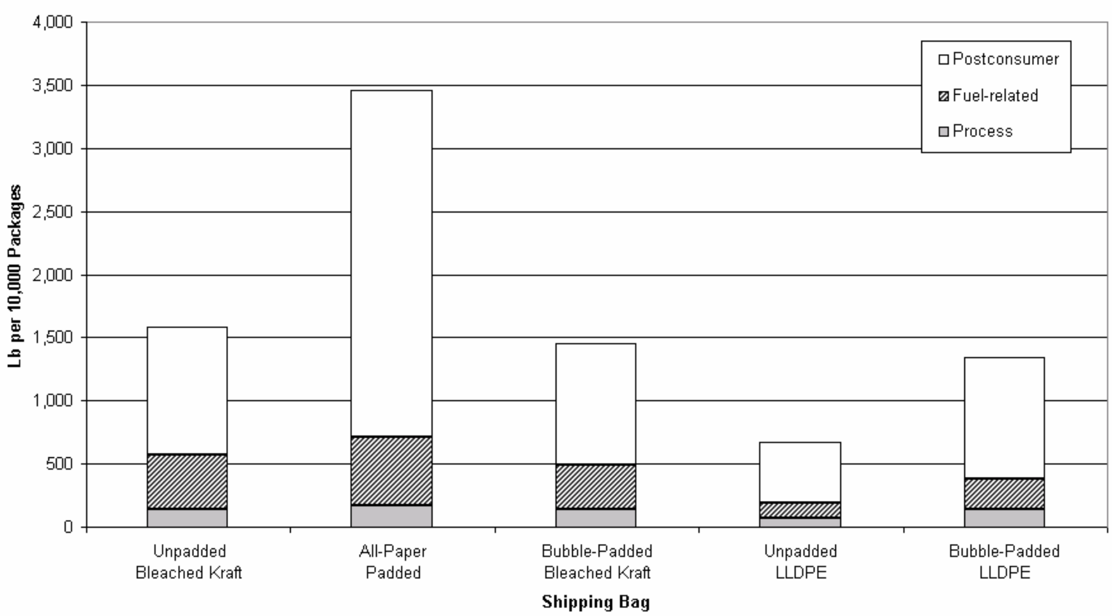


Figure 3-6-BAG. Solid Waste by Category for 10,000 Packages Shipped in Shipping Bags - Higher Postconsumer Recycled Content Options (lb of waste/10,000 pkgs)



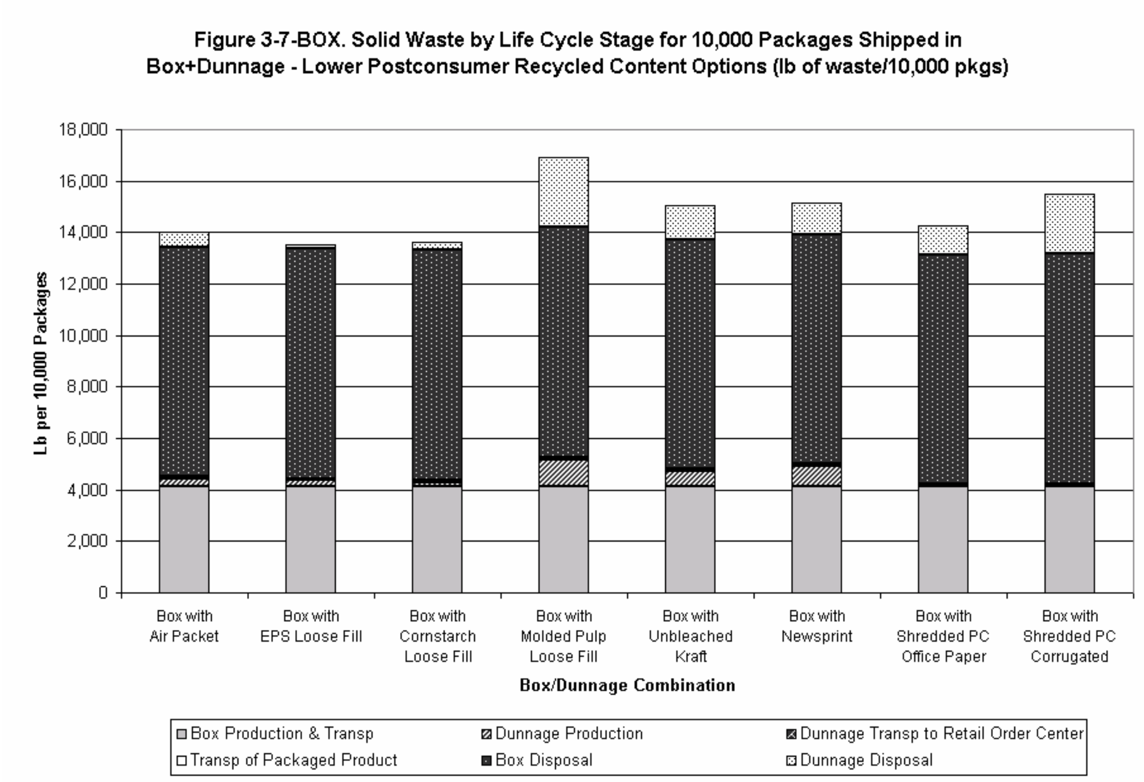


Figure 3-7-BOX. Solid Waste by Life Cycle Stage for 10,000 Packages Shipped in Box+Dunnage - Lower Postconsumer Recycled Content Options (lb of waste/10,000 pkgs)
Lb per 10,000 Packages
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Box with Air Packet
Box with EPS Loose Fill
Box with Cornstarch Loose Fill
Box with Molded Pulp Loose Fill
Box with Unbleached Kraft
Box with Newsprint
Box with Shredded PC Office Paper
Box with Shredded PC Corrugated
Box/Dunnage Combination
Box Production & Transp
Dunnage Production
Dunnage Transp to Retail Order Center
Transp of Packaged Product
Box Disposal
Dunnage Disposal

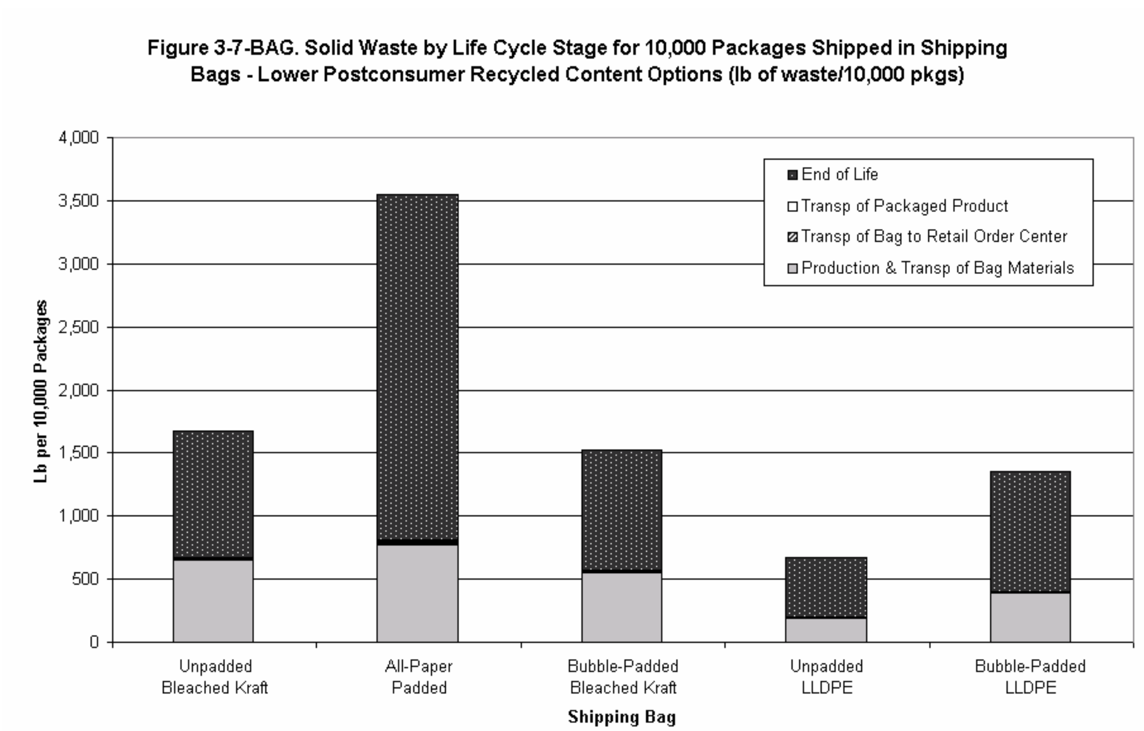


Figure 3-7-BAG. Solid Waste by Life Cycle Stage for 10,000 Packages Shipped in Shipping Bags - Lower Postconsumer Recycled Content Options (lb of waste/10,000 pkgs)
Lb per 10,000 Packages
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
End of Life
Transp of Packaged Product
Transp of Bag to Retail Order Center
Production & Transp of Bag Materials
Unpadded Bleached Kraft
All-Paper Padded
Bubble-Padded Bleached Kraft
Unpadded LLDPE
Bubble-Padded LLDPE
Shipping Bag

Figure 3-8-BOX. Solid Waste by Life Cycle Stage for 10,000 Packages Shipped in Box+Dunnage - Higher Postconsumer Recycled Content Options (lb of waste/10,000 pkgs)

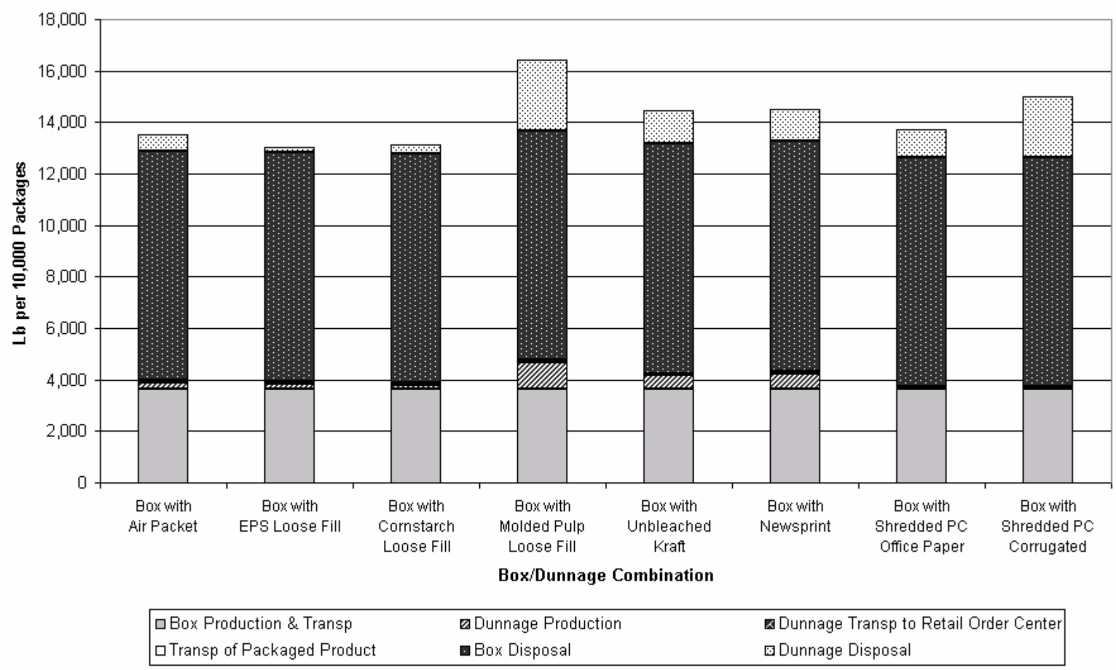
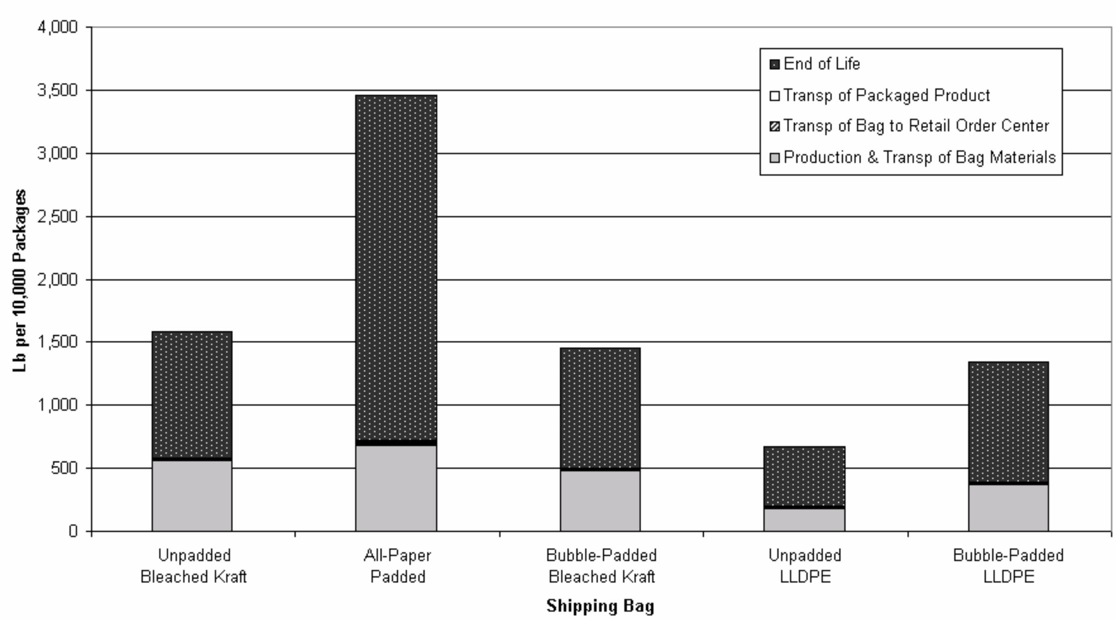


Figure 3-8-BAG. Solid Waste by Life Cycle Stage for 10,000 Packages Shipped in Shipping Bags - Higher Postconsumer Recycled Content Options (lb of waste/10,000 pkgs)



Environmental Emissions

Atmospheric and waterborne emissions for each system include emissions from processes and those associated with the combustion of fuels. This analysis does not include atmospheric or waterborne emissions associated with municipal solid waste landfills or incinerators (see Chapter 1 for a detailed discussion of this topic). Tables 3-6 and 3-7 present atmospheric emissions results, and Tables 3-8 and 3-9 show waterborne emissions for the various packaging options.

The emissions tables in this section present emission quantities based upon the best data available. However, some of the data are reported from industrial sources, some are from standard emissions tables, and some have been calculated. This means there are significant uncertainties with regards to the application of the data to these particular packaging systems. Because of these uncertainties, two systems' emissions of a given substance are not considered significantly different unless the percent difference exceeds 25 percent. (Percent difference is defined as the difference between two system totals divided by their average.) This minimum percent difference criterion was developed based on the experience and professional judgment of the analysts and supported by sample statistical calculations (see Chapter 4).

Substances are reported in the tables in speciated or unspeciated form, depending on the compositional information available. General categories such as "Acid" and "Metal Ion" are used to report unspeciated data. Emissions are reported only in the most descriptive single category applicable; speciated data are not reported again in the broadly applicable unspeciated category. For example, emissions reported as "HCl" are not additionally reported under the category "Acid," nor are emissions reported as "Chromium" additionally reported under "Metal Ion."

It is important to realize that interpretation of air and water emission data requires great care. The effects of the various emissions on humans and on the environment are not fully known. The degree of potential environmental disruption due to environmental releases is not related to the weight of the releases in a simple way. Research on this evaluation problem is ongoing, but no valid impact assessment methodology currently exists for a life cycle study. Although many detailed impact assessment methodologies are available, including the U.S. EPA's TRACI, these models all rely on LCI output as an input for impact modeling. There are inherent problems with this approach because of the limitations of LCI results, which are aggregates of the total quantity of substances released over the life cycle of a product system at different geographic locations, over different time periods, at different concentrations, with different human exposures, into different airspaces and bodies of water, etc. Thus, LCI results are inherently lacking the level of detail necessary for a true evaluation of resulting impacts on human health and the environment. This is not a criticism of any impact assessment methodology but rather an acknowledgement of the limitations of using LCI output as the basis for modeling environmental impacts.

Atmospheric Emissions. Atmospheric emissions results are shown in Table 3-6 for lower PC recycled content options and in Table 3-7 for higher PC recycled content options. This analysis does not include emissions from the decomposition of landfilled or littered packaging or from the combustion in municipal solid waste incinerators of 20 percent of packaging components discarded after diversion for reuse and recycling. No data are available on combustion emissions for individual materials burned with mixed municipal solid waste. This analysis also does not attempt to estimate emissions for combustion of a small unknown fraction of postconsumer packaging burned by consumers at their homes. As a result, the carbon dioxide emissions, as well as other products of incomplete combustion, are understated by an unknown amount.

It is not practical to attempt to discuss all the atmospheric emission categories listed in Table 3-6 and 3-7 (over 40 different substances listed for each packaging option); therefore, most of the following discussion focuses on the high priority atmospheric issue of greenhouse gas emissions. The primary three atmospheric emissions reported in this analysis that contribute to global warming are fossil fuel-derived carbon dioxide, methane, and nitrous oxide.

Consistent with the approach used by the EPA (documented in the report EPA530–R-02-006, **Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks**, 2nd edition, May 2002), non-fossil carbon dioxide emissions, such as those from the burning of wood, are considered part of the natural carbon cycle and are not considered a net contributor to global warming. Unlike the methodology described in the EPA GHG report, the Franklin Associates life cycle methodology does not give credits for carbon sequestration resulting from use of recycled materials. The carbon sequestration credit described in the EPA report is based on a series of complex forestry models. It is beyond the scope of this study to attempt to evaluate the applicability of the EPA methodology and models to the specific packaging components studied in this analysis. The methodology used in this report does not account for end of life carbon sequestration in landfills.

From the International Panel on Climate Change (IPCC) 2001 report, the 100-year global warming potential for the three GHG emissions in this analysis are: carbon dioxide 1, methane 23, and nitrous oxide 296. The global warming potential represents the relative global warming contribution of a pound of a particular greenhouse gas compared to a pound of carbon dioxide. The weights of each of these substances in the top section of Tables 3-6 and 3-7 are multiplied by their global warming potential and totaled in the GHG (greenhouse gas) section at the bottom of the table.

Tables 3-7-BOX. 3-7-BAG, 3-8-BOX, and 3-8-BAG show that fossil carbon dioxide accounts for about 97 percent of the total GHG for box systems and paper shipping bags. For shipping bags with plastic components, fossil carbon dioxide accounts for 93 to 96 percent of total GHG. Methane accounts for most of the remaining GHG for each system, while nitrous oxide is less than one percent of total GHG for all systems. For all systems, fossil carbon dioxide emissions are predominantly from the use of fossil fuels for process and transportation energy. Process emissions of carbon dioxide and methane are very small in comparison to fuel-related emissions of these substances.

Greenhouse gas totals for different packaging materials and different life cycle stages vary widely, based largely on their material compositions and transportation profiles. Materials produced using fossil fuels as raw materials or as process fuels have higher GHG profiles than materials that use non-fossil resources for raw materials or process energy. For volume-limited transportation of packaged product, GHG emissions per 10,000 packages shipped are higher for bulkier packages (e.g., boxes) compared to packages that can be shipped more compactly (e.g., bags) with more efficient use of vehicle cargo space.

GHG results by life cycle stage are shown in Figures 3-9 and 3-10. Production of packaging materials and transportation to customers dominate GHG emissions. The categories "box disposal" and "dunnage disposal" in Figures 3-9 and 3-10 include only transportation of waste to landfill and operation of landfill equipment. As noted elsewhere in this report, this analysis does not include greenhouse gas emissions associated with the combustion and decomposition of packaging waste, or any forestry-related carbon sequestration benefits associated with reducing timber harvesting as a result of using postconsumer fiber.

In addition to emissions of GHG (fossil carbon dioxide, methane, and nitrous oxide), this report evaluates 38 other types of atmospheric emissions, such as SOx, NOx, and particulates. Detailed results are presented in Table 3-6 for lower PC recycled content packaging options and in Table 3-7 for higher PC recycled content packaging options.

For each individual substance, the minimum and maximum emission values from all box/dunnage options and from all bag options were identified. No single packaging option had the highest or lowest emissions in all categories; the box/dunnage or bag system with the highest or lowest emission values for individual substances varied due to differences in the weight and material composition of individual packaging options. The following comparisons were made for each substance: highest bag emission value to lowest box emission value, highest bag emission to highest box emission, lowest bag emission to lowest box emission.

Atmospheric emissions for all types of box/dunnage options are consistently higher than any of the bag options, with only two exceptions. For chlorine, the highest emissions from a bag system were significantly higher than the lowest emissions from a box/dunnage system. For total reduced sulfur, the highest emissions from a bag system were significantly higher than emissions from any box/dunnage system. (These chlorine and sulfur emissions are associated with the production of bleached kraft that is used in shipping bags but not in the box and dunnage systems studied.) For all other substances, emissions from the box and dunnage systems were higher or not significantly different from emissions from the bag systems. In no case was the lowest bag emission significantly higher than the lowest box/dunnage emission.

Figure 3-9-BOX. Greenhouse Gas Summary by Life Cycle Stage for 10,000 Packages Shipped in Box+Dunnage - Lower Postconsumer Recycled Content Options (lb CO2 equivalents/10,000 pkgs)

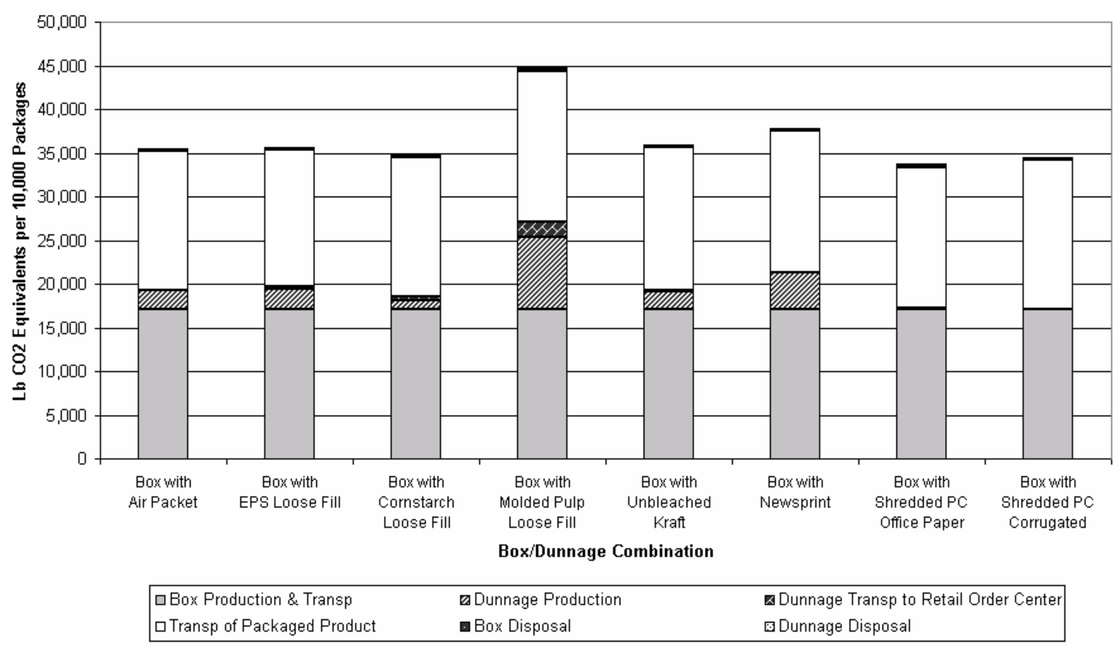


Figure 3-9-BAG. Greenhouse Gas Summary by Life Cycle Stage for 10,000 Packages Shipped in Shipping Bags - Lower Postconsumer Recycled Content Options (lb CO2 equivalents/10,000 pkgs)

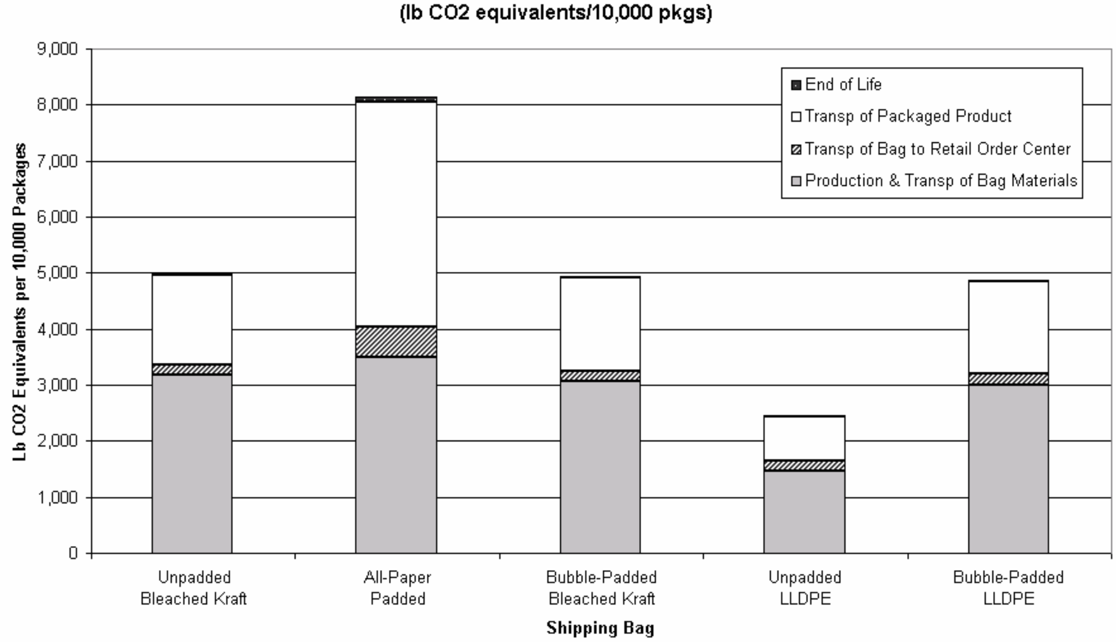


Figure 3-10-BOX. Greenhouse Gas Summary by Life Cycle Stage for 10,000 Packages Shipped in Box+Dunnage - Higher Postconsumer Recycled Content Options (lb CO2 equivalents/10,000 pkgs)

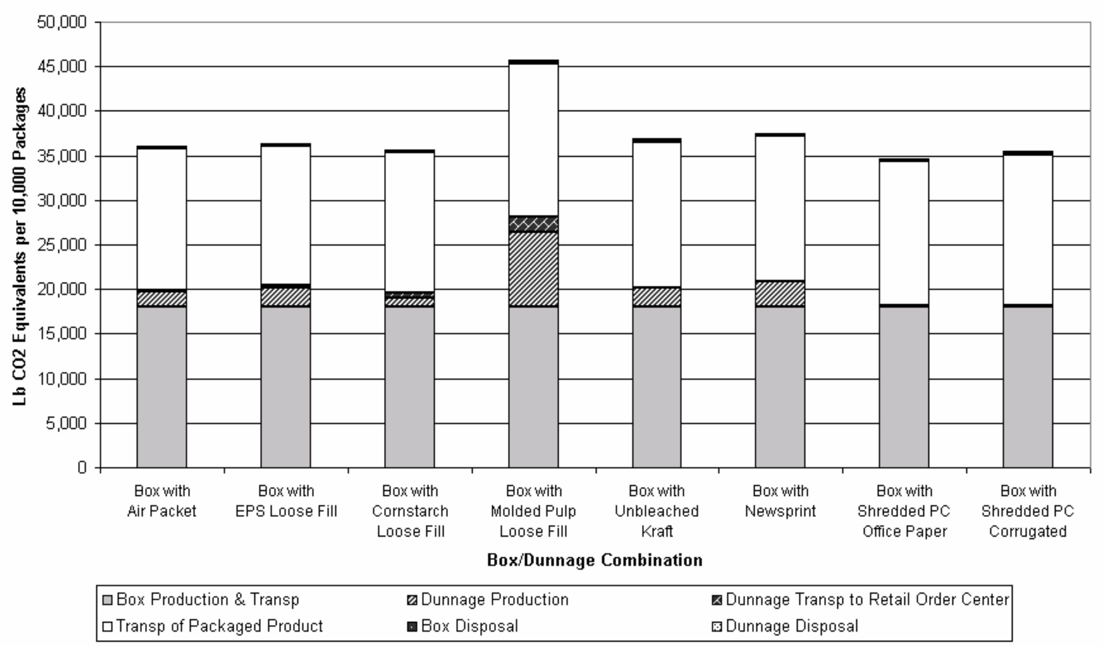
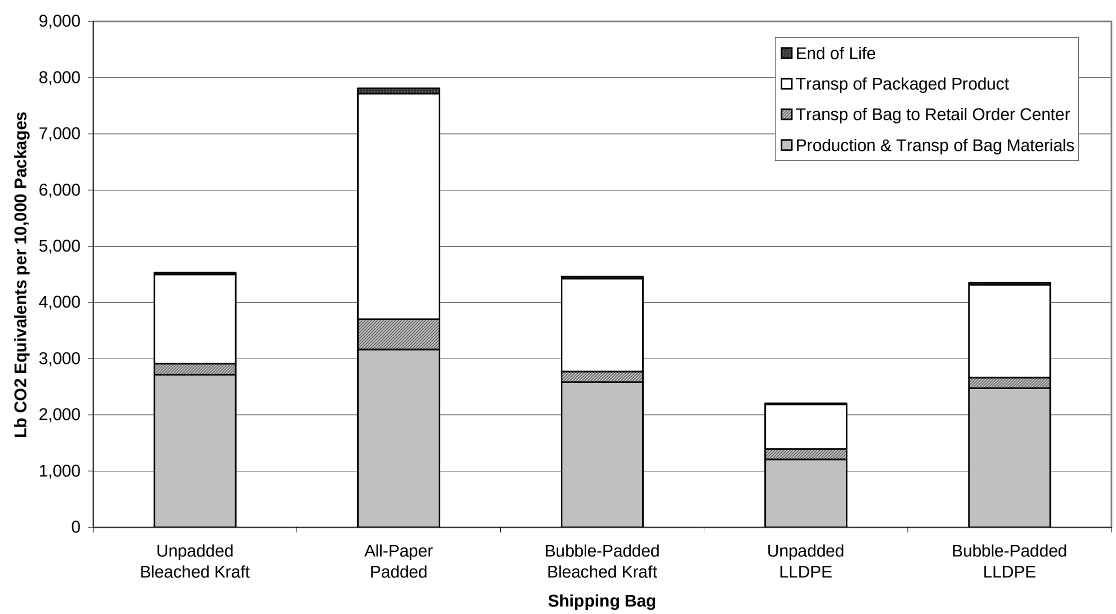


Figure 3-10-BAG. Greenhouse Gas Summary by Life Cycle Stage for 10,000 Packages Shipped in Shipping Bags - Higher Postconsumer Recycled Content Options (lb CO2 equivalents/10,000 pkgs)



Waterborne Emissions. Waterborne emissions results are shown in Table 3-8 for lower PC recycled content packaging options and in Table 3-9 for higher PC recycled content packaging options. With over 40 different waterborne emissions listed for each packaging option, it is not practical to attempt to discuss individual emissions results for individual packaging materials. Detailed results are presented here for the reader to examine and use to draw conclusions for specific packaging options of interest to the reader.

The same comparative analysis of minimum and maximum values for individual emissions from box/dunnage and bag systems was conducted for waterborne emissions as was described above for atmospheric emissions. As with atmospheric emissions, waterborne emissions for all types of box/dunnage options are consistently higher than any of the bag options, with only a few exceptions. For acid, nickel, and ammonia, the highest emissions from a bag system were significantly higher than the lowest emissions from a box/dunnage system. For organic carbon and sodium dichromate, the highest emissions from a bag system were significantly higher than emissions from all box/dunnage systems. For all other substances, emissions from the box and dunnage systems were higher or not significantly different from emissions from the bag systems. In no case was the lowest bag emission significantly higher than the lowest box/dunnage emission.

OBSERVATIONS AND CONCLUSIONS

The main conclusion that can be drawn from this analysis regarding packaging options for shipping mail-order soft goods to residential customers is that the weight of the packaging is the most critical factor influencing the environmental burdens. Burdens for material production, transportation, and disposal all relate directly to the weight of material that is required. In this analysis, heavy packaging components with a relatively low environmental profile per pound have higher overall environmental burdens than packaging options that are made of materials with higher per-pound burdens but that have lower weights used in packaging.

The weight of the lightest box and dunnage combination evaluated (box with EPS foam loose fill) is almost four times the weight of the heaviest shipping bag option (all-paper padded bag). The weight of the heaviest box and dunnage combination (box with molded pulp dunnage) is 26 times the weight of the lightest shipping bag (LLDPE film).

In comparison, Chapter 2 showed that the most energy-intensive shipping bag material (virgin LDPE film) requires four times as much energy **per pound** to produce (cradle-to-production) as the least energy-intensive box (80% PC box). Making the same “highest profile bag material” to “lowest profile box” comparisons for solid waste and GHG, the cradle-to-production solid waste **per pound** of bleached virgin kraft is nearly twice as high as solid waste per pound of 80% PC box, and cradle-to-production GHG **per pound** of virgin LDPE film is twice as high as GHG per pound for the average box.

Since total burdens are based on weight of material multiplied by its environmental profile per pound, this means that any box system that is more than four times as heavy as a shipping bag will require more cradle-to-production energy than the shipping bag. Similarly, any box system that is more than twice as heavy as a shipping bag will produce more cradle-to-production solid waste and GHG emissions. (Although energy and greenhouse gas results generally correlate well, the total energy includes energy of material resource, that is, the energy content of fuel resources used as material inputs to plastic products. This represents an energy content that does not result in combustion emissions; thus, the difference in comparative factors for energy and greenhouse gases.)

Weight is also the basis for determining the packaging's share of environmental burdens for transportation of packaged product to the customer. In this study, transportation to customer accounted for a significant portion of the overall life cycle burdens; however, this is affected not only by the packaging weight but also by the package volume and the transportation distance (over 2,000 miles in this study).

Transportation of mail-order soft goods to customers is volume-limited; as a result, more cargo space and more vehicle loads are required to transport bulky packages compared to compact packages, resulting in higher transportation burdens for bulky packages regardless of their weight. Transportation to customer would be less dominant in the results if transportation of packaged goods was weight-limited or if shorter transportation distances were analyzed.

In addition, the following observations can be made about specific environmental burdens for specific packaging options:

Energy

Box/Dunnage Systems. For the lower recycled content box/dunnage options process energy accounts for about 2/3 of total energy for all box/dunnage options, while transportation energy is about 1/3 of total energy. Because the box dominates the results, there is not much variation in results comparing different box and dunnage combinations.

For the higher recycled content box/dunnage options, the cradle-to-production energy requirements are significantly lower than for the lower recycled content options. The total production energy for the 80% PC recycled content box is about 25 percent lower than the average box, while higher recycled content dunnage options require 20 to 33 percent less energy than the corresponding virgin or low recycled content dunnage options. The principal reason is that the methodology models postconsumer material without any burdens from virgin material production, and the postconsumer material collection and recycling sequence of processes requires less energy than the cradle-to-production series of processes required to produce virgin materials. Overall, using the higher recycled content packaging options reduces box and dunnage packaging systems' total life cycle energy requirements by 13 to 18% compared to the same packaging systems using components with the lower recycled content options.

Energy use for the various stages of the life cycle is dominated by production of the box components and by transportation of the box/dunnage to the customer. Table 3-1 shows that the weight per 10,000 packages for boxes is 3.7 to 29 times the weight of any dunnage used with the box. Also, the space required by boxed soft goods results in volume-limited shipment to customers, which is less efficient than weight-limited shipment, as more cargo space and thus more truckloads are required to ship a given weight of product.

A significant amount of energy for manufacturing chemically pulped (e.g., kraft) virgin paper(board) shipping components is derived from wood wastes, with the remaining energy needs at virgin mills provided by fossil fuels and electricity. Recycled paper(board) mills generally do not have access to wood wastes and thus rely on fossil fuels and electricity for energy, although fossil fuel use for recycled paper production may be lower than fossil fuel use for virgin kraft production. The energy for producing plastic dunnage is essentially all fossil fuel-derived.

Shipping Bag Systems. All-paper shipping bags have higher process energy than corresponding padded or unpadded all-plastic bags. The higher energy per pound of plastics is offset by the greater weight of the paper used in bags. Padded bags are heavier than unpadded bags of the same material and thus have higher energy requirements than corresponding unpadded bags. Overall, shipping bags require only about 20% as much energy as boxes/dunnage.

As with boxes and dunnage, increasing recycled content of shipping bag components improves their energy profiles. Bags using materials with the higher recycled content options show total life cycle energy use 11 to 21% lower compared to the corresponding virgin or lower recycled content bags.

Transportation energy to consumer is less dominant for bags. There are two reasons for this: (1) the more compact dimensions of product packaged in shipping bags means that more packaged products fit in a delivery vehicle so that fewer truckloads are required per 10,000 packages compared to boxed product, and (2) the weight of bags is lower so that a smaller percentage of the packaged product delivery burdens are allocated to the bag.

Solid Waste

In order to provide the recycled content of the packaging options considered, postconsumer solid waste must be recovered from other product systems manufactured from these materials, thus diverting this material from landfill at the end of its previous useful life. The heavier the package and the higher its recycled content, the more postconsumer material it uses. For example, Figure ES-3 in the Executive Summary shows that 10,000 high (80 percent) recycled content corrugated boxes utilize over 11,000 pounds of postconsumer material that might otherwise have been landfilled.

The net solid waste impacts for packaging systems can be calculated as the total solid waste from production, transportation, shipment, and disposal of the package minus the solid waste credit associated with the recycled content of the package. Figure ES-4 in the Executive Summary shows that the net solid waste for high recycled content box and dunnage options are generally comparable to the net solid waste for bag options, while the lower recycled content box and dunnage options are still significantly higher in net solid waste compared to shipping bags.

Box/Dunnage Systems. Postconsumer solid waste dominates total life cycle solid waste for all packaging options. Solid waste from the production of packaging materials is also a significant category of solid waste, even for the higher postconsumer recycled content options.

Shipping Bag Systems. As with the box and dunnage systems, postconsumer solid waste accounts for the majority of total solid waste for the shipping bag systems, followed by material production wastes. The all-paper padded bag is heaviest and thus has the highest life cycle solid wastes of the bags evaluated. On average, the bag systems produce about 85 percent less total solid waste by weight than the box and dunnage systems.

Emissions

While most individual emissions for shipping bags are lower in magnitude than the corresponding emissions for box and dunnage systems, it is not appropriate to attempt to draw overall comparative conclusions about emissions results, as this analysis makes no attempt to evaluate the potential impacts of individual emissions on human health and the environment, other than the global warming potential of GHG emissions.

Greenhouse Gases

Box/Dunnage Systems. Total greenhouse gas emissions are dominated by box production and transportation to the customer. Although higher recycled content paper(board) options have lower total energy requirements compared to lower recycled content options, increasing the recycled content for chemically pulped paper(board) products (such as kraft paper dunnage and the kraft and semichemical paperboard used in corrugated boxes) shifts GHG emissions for production of those packaging components from wood-derived emissions, which are not considered a net contributor to global warming, to fossil fuel-derived emissions, which are considered to contribute to global warming according to the methodology used by both U.S. EPA and Franklin.

Shipping Bag Systems. The same general conclusions regarding GHG apply to bag systems as to box and dunnage systems. However, bags average about 15% as much GHG as the box systems. This observation is consistent with results for energy and solid waste, reinforcing the conclusion that weight is the most critical factor affecting the environmental profile of each packaging option.

LIMITATIONS

It is important to recognize that the results and conclusions presented in this analysis apply to a specific set of packaging options for shipping a soft goods product of a certain weight and dimensions. The packaging options defined represent typical shipping practices and do not necessarily represent the minimum amount of packaging that can be used to ship the product. For example, it may be possible to use smaller or lighter boxes or shipping bags or to ship product in boxes without any dunnage. Also, it is important to recognize that not all the packaging options defined in this study are suitable for many types of items, including items that are fragile, bendable, rigid and bulky, or that have sharp edges, corners, or protrusions.

The general conclusions made in this study regarding the relationship of packaging weight and environmental profile per pound of material are valid for any application. However, general conclusions about the relative overall environmental performance of corrugated boxes compared to shipping bags in this analysis do not necessarily apply to all packaging applications. Comparisons between packaging systems should only be made based on analyses of specific applications in which the sizes, weights, and compositions of each system are clearly identified and modeled on an equivalent use basis.

USING CHAPTER 2 DATA MODULES FOR SENSITIVITY ANALYSIS

Interested readers can use the data modules in Chapter 2 to conduct some sensitivity analysis. Although it is time consuming to do these calculations by hand based on the LCI results tables, the reader can evaluate only those results (e.g., energy, solid waste, or selected emissions) that are of most interest to them. Before attempting any sensitivity analysis, however, it is first necessary to understand how the Chapter 2 modules were weighted and combined to arrive at the packaging system results in Chapter 3.

The average recycled content box with unbleached kraft dunnage with 50% postconsumer recycled content will be used as an example. For the box, the 1,000 lb modules for average box cradle-to-production (process + transportation), transportation to order fulfillment center, and end-of-life disposal are multiplied by 13.9 (the thousand pounds of packaging/10,000 packages factor from Table 3-1). For the 50% postconsumer recycled content unbleached kraft paper, half of the 1.84 thousand pounds required (from Table 3-1) would be modeled using the 1,000 lb virgin unbleached kraft modules (cradle-to-production process + transportation, transportation to order fulfillment center, and end-of-life disposal) and half would be modeled using the 1,000 lb 100% recycled unbleached kraft modules.

As stated earlier in this chapter, Chapter 2 does not include data modules for delivery of the packaged product to the customer. However, the packaged product delivery burdens allocated to the packaging can be backed out of the total LCI results by subtracting the total burdens for the package (cradle-to-production process + transportation, transportation to order fulfillment center, and end-of-life disposal) from the total life cycle results for that system shown in the Chapter 3 results tables. The difference is the baseline transportation burdens for delivery of the package to the customer. This baseline reflects the portion of the overall packaged product delivery burdens that are allocated to the package itself.

Now that the reader understands how all the “pieces” of the life cycle inventory were assembled, sensitivity analysis can be conducted on individual pieces.

Sensitivity Analysis of Different Recycled Content

For all dunnage and shipping bag options, changes in recycled content can be evaluated by first determining the total weight of the packaging component required (thou lb/10,000 packages from Table 3-1) and then modeling the recycled % of the total weight using the 100% recycled modules for the appropriate material cradle-to-production modules, and modeling the balance of the content using the virgin material cradle-to-production modules. If there is no change in the overall weight of the packaging, there would be no change in the modules for transportation to order fulfillment center, transportation of packaged product to customer, and end-of-life disposal.

Because the corrugated box modules were developed using a separate proprietary model and are presented in Chapter 2 only as totals (rather than as virgin and 100% postconsumer recycled content modules), analysis of different recycled content boxes can only be done by interpolation for the desired recycled content between 38% and 80% using the corresponding results for the average and high recycled content boxes.

Sensitivity Analysis of Fabrication Losses for Shipping Bags

As stated earlier in this chapter, data were not available for fabrication of shipping bags from their component materials. A fabrication scrap loss of 5% would mean that 5% more of each component material would have to be produced, and the 5% of scrap material would most likely end up as solid waste (at least for multi-material bags). Thus, to model a scrap loss of 5%, the reader would scale up the cradle-to-production data for each bag component material by 5%, and then 5% of the total weight of the bag material produced would end up as additional process solid waste. (For single-material bags, the fabrication scrap may be recycled, in which case the production data would still be scaled up, but the fabrication scrap would not be added to the process solid waste.) There would be no change to the modules for transportation to order fulfillment center, transportation of packaged product to customer, and end-of-life disposal.

Sensitivity Analysis of Different Transportation Distances for Delivery of Packaged Product

Earlier in this section, instruction was provided on how to determine the baseline packaged product delivery burdens allocated to the packaging (i.e., by subtracting all the material production, transportation, and end-of-life burdens from the total LCI results for each packaging system). These transportation burdens are based on a transportation profile of 2125 miles by tractor-trailer truck and 25 miles delivery van. Thus, the majority of the burdens are for tractor-trailer transport. The effect of shorter or longer shipping distances from the order fulfillment center to the customer can be estimated by scaling the baseline delivery data up or down using the ratio of the new transportation distance to 2150 miles.

CHAPTER 3 RESULTS TABLES

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Table 3-2-BOX

LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Air Pkt
thou lb/ 10,000 pkgs	13.9	0.84
% recycled content		0

	Box	LDPE Inflated Air Packets	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	TOTAL	% of Total
	Box with Inflated Air Packets							
Energy (MM Btu/10,000 pkgs)								
By Type								
Process	174	13.5	0	0	0.35	0.027	**188**	59.9%
Transport	4.26	1.08	0.74	98.2	1.49	0.11	**106**	33.8%
Energy of Material Resource	0.093	19.6	0	0	0	0	**19.7**	6.3%
Total	**178**	**34.2**	**0.74**	**98.2**	**1.83**	**0.14**	**313**	**100.0%**
%of Total	56.9%	10.9%	0.2%	31.4%	0.6%	0.0%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	27.1	23.2	0	0	0.023	0.0018	**50.4**	24.3%
Petroleum	4.94	4.82	0	0	0.32	0.025	**10.11**	4.9%
Coal	55.5	3.40	0	0	0.0030	2.3E-04	**58.9**	28.4%
Hydropower	1.76	0.21	0	0	1.8E-04	1.4E-05	**1.97**	0.9%
Nuclear	8.20	1.29	0	0	0.0011	8.8E-05	**9.50**	4.6%
Wood	75.1	0	0	0	0	0	**75.1**	36.2%
Other	1.11	0.18	0	0	1.6E-04	1.3E-05	**1.29**	0.6%
Total	**174**	**33.1**	**0**	**0**	**0.35**	**0.027**	**207**	**100.0%**
%of Total	83.8%	16.0%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas	0.28	0.18	0.049	6.47	0.098	0.0075	**7.09**	6.7%
Petroleum	3.92	0.87	0.68	90.5	1.37	0.11	**97.4**	92.0%
Coal	0.037	0.021	0.0063	0.84	0.013	9.8E-04	**0.92**	0.9%
Hydropower	0.0023	0.0013	3.9E-04	0.052	7.9E-04	6.1E-05	**0.057**	0.1%
Nuclear	0.014	0.0081	0.0024	0.32	0.0049	3.7E-04	**0.35**	0.3%
Wood	0	0	0	0	0	0	**0**	0.0%
Other	0.0020	1.1E-03	3.5E-04	0.046	7.0E-04	5.4E-05	**0.051**	0.0%
Total	**4.26**	**1.08**	**0.74**	**98.2**	**1.49**	**0.11**	**106**	**100.0%**
%of Total	4.0%	1.0%	0.7%	92.8%	1.4%	0.1%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	0	0	0	0	17.5	3.02	**20.5**	
Usable					5.35	0.92	**6.27**	

Table 3-2-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	EPS
thou lb/ 10,000 pkgs	13.9	0.48
% recycled content		0

		Box with EPS Loose Fill							
		Box	EPS Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)									
By Type									
Process		174	16.1	0	0	0.35	0.021	**190**	61.8%
Transport		4.26	0.97	1.48	97.0	1.49	0.089	**105**	34.2%
Energy of Material Resource		0.093	12.24	0	0	0	0	**12.33**	4.0%
Total		**178**	**29.4**	**1.48**	**97.0**	**1.83**	**0.11**	**308**	**100.0%**
	%of Total	57.8%	9.5%	0.5%	31.5%	0.6%	0.0%	**100.0%**	
By Source - Process + EMR									
Nat. Gas		27.1	13.5	0	0	0.023	0.0014	**40.6**	20.1%
Petroleum		4.94	10.28	0	0	0.32	0.020	**15.6**	7.7%
Coal		55.5	3.10	0	0	0.0030	1.8E-04	**58.6**	28.9%
Hydropower		1.76	0.19	0	0	1.8E-04	1.1E-05	**1.95**	1.0%
Nuclear		8.20	1.18	0	0	0.0011	7.0E-05	**9.38**	4.6%
Wood		75.1	0	0	0	0	0	**75.1**	37.1%
Other		1.11	0.16	0	0	1.6E-04	1.0E-05	**1.27**	0.6%
Total		**174**	**28.4**	**0**	**0**	**0.35**	**0.021**	**203**	**100.0%**
	%of Total	85.8%	14.0%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp									
Nat. Gas		0.28	0.089	0.10	6.40	0.098	0.0059	**6.97**	6.6%
Petroleum		3.92	0.84	1.36	89.4	1.37	0.082	**97.0**	92.1%
Coal		0.037	0.030	0.013	0.83	0.013	7.6E-04	**0.92**	0.9%
Hydropower		0.0023	0.0018	0.0008	0.052	7.9E-04	4.7E-05	**0.057**	0.1%
Nuclear		0.014	0.0113	0.0048	0.32	0.0049	2.9E-04	**0.35**	0.3%
Wood		0	0	0	0	0	0	**0**	0.0%
Other		0.0020	0.0016	7.0E-04	0.046	7.0E-04	4.2E-05	**0.051**	0.0%
Total		**4.26**	**0.97**	**1.48**	**97.0**	**1.49**	**0.089**	**105**	**100.0%**
	%of Total	4.0%	0.9%	1.4%	92.1%	1.4%	0.1%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	0	17.5	0.77	**18.3**	
	Usable					5.35	0.24	**5.58**	

Table 3-2-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Cornstarch
thou lb/ 10,000 pkgs	13.9	0.86

		Box with Cornstarch Loose Fill							
		Box	Cornstarch Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)									
By Type									
Process		174	5.63	0	0	0.35	0.0046	**180**	62.4%
Transport		4.26	0.72	3.26	98.3	1.49	0.019	**108**	37.5%
Energy of Material Resource		0.093	0.20	0	0	0	0	**0.29**	0.1%
Total		**178**	**6.55**	**3.26**	**98.3**	**1.83**	**0.023**	**288**	**100.0%**
	%of Total	61.8%	2.3%	1.1%	34.1%	0.6%	0.0%	**100.0%**	
By Source - Process + EMR									
Nat. Gas		27.1	1.69	0	0	0.023	3.0E-04	**28.9**	16.0%
Petroleum		4.94	0.37	0	0	0.32	0.0042	**5.64**	3.1%
Coal		55.5	2.58	0	0	0.0030	3.9E-05	**58.1**	32.3%
Hydropower		1.76	0.15	0	0	1.8E-04	2.4E-06	**1.91**	1.1%
Nuclear		8.20	0.92	0	0	0.0011	1.5E-05	**9.12**	5.1%
Wood		75.1	0	0	0	0	0	**75.1**	41.7%
Other		1.11	0.12	0	0	1.6E-04	2.2E-06	**1.24**	0.7%
Total		**174**	**5.83**	**0**	**0**	**0.35**	**0.0046**	**180**	**100.0%**
	%of Total	96.6%	3.2%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp									
Nat. Gas		0.28	0.049	0.21	6.48	0.098	0.0012	**7.12**	6.6%
Petroleum		3.92	0.66	3.00	90.5	1.37	0.017	**99.5**	92.1%
Coal		0.037	0.0062	0.028	0.84	0.013	1.6E-04	**0.92**	0.9%
Hydropower		0.0023	3.8E-04	0.0017	0.052	7.9E-04	9.9E-06	**0.057**	0.1%
Nuclear		0.014	0.0024	0.011	0.32	0.0049	6.1E-05	**0.35**	0.3%
Wood		0	0	0	0	0	0	**0**	0.0%
Other		0.0020	3.4E-04	0.0015	0.046	7.0E-04	8.8E-06	**0.051**	0.0%
Total		**4.26**	**0.72**	**3.26**	**98.3**	**1.49**	**0.019**	**108**	**100.0%**
	%of Total	3.9%	0.7%	3.0%	91.0%	1.4%	0.0%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	0	17.5	0.59	**18.1**	
	Usable					5.35	0.18	**5.52**	

Table 3-2-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Mold Pulp
thou lb/ 10,000 pkgs	13.9	3.8

		Box with Molded Pulp Loose Fill							
		Box	Molded Pulp Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)									
By Type									
Process		174	60.8	0	0	0.35	0.099	**235**	65.2%
Transport		4.26	1.25	10.8	107	1.49	0.42	**125**	34.7%
Energy of Material Resource		0.093	0	0	0	0	0	**0.093**	0.0%
Total		**178**	**62.0**	**10.8**	**107**	**1.83**	**0.52**	**360**	**100.0%**
	%of Total	49.4%	17.2%	3.0%	29.7%	0.5%	0.1%	**100.0%**	
By Source - Process + EMR									
Nat. Gas		27.1	36.3	0	0	0.023	0.0065	**63.5**	27.0%
Petroleum		4.94	1.56	0	0	0.32	0.091	**6.91**	2.9%
Coal		55.5	15.4	0	0	0.0030	8.5E-04	**70.9**	30.2%
Hydropower		1.76	0.93	0	0	1.8E-04	5.3E-05	**2.70**	1.1%
Nuclear		8.20	5.83	0	0	0.0011	3.2E-04	**14.0**	6.0%
Wood		75.1	0	0	0	0	0	**75.1**	32.0%
Other		1.11	0.79	0	0	1.6E-04	4.7E-05	**1.91**	0.8%
Total		**174**	**60.8**	**0**	**0**	**0.35**	**0.099**	**235**	**100.0%**
	%of Total	73.9%	25.9%	0.0%	0.0%	0.1%	0.0%	**100.0%**	
By Source - Transp									
Nat. Gas		0.28	0.083	0.72	7.04	0.098	0.028	**8.25**	6.6%
Petroleum		3.92	1.15	9.99	98.4	1.37	0.39	**115**	92.1%
Coal		0.037	0.011	0.093	0.91	0.013	0.0036	**1.07**	0.9%
Hydropower		0.0023	6.7E-04	0.0058	0.057	7.9E-04	2.3E-04	**0.066**	0.1%
Nuclear		0.014	0.0041	0.036	0.35	0.0049	0.0014	**0.41**	0.3%
Wood		0	0	0	0	0	0	**0**	0.0%
Other		0.0020	5.9E-04	0.0051	0.050	7.0E-04	2.0E-04	**0.059**	0.0%
Total		**4.26**	**1.25**	**10.8**	**107**	**1.49**	**0.42**	**125**	**100.0%**
	%of Total	3.4%	1.0%	8.7%	85.4%	1.2%	0.3%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	0	17.5	5.46	**23.0**	
	Usable					5.35	1.67	**7.01**	

Table 3-2-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Unbl Kr
thou lb/ 10,000 pkgs	13.9	1.8
	% recycled content	0

	Box with Unbleached Kraft Paper Dunnage							
	Box	Unbleached Kraft Paper Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process	174	27.8	0	0	0.35	0.052	**202**	65.1%
Transport	4.26	0.56	0.16	101	1.49	0.22	**108**	34.8%
Energy of Material Resource	0.093	0.0082	0	0	0	0	**0.101**	0.0%
Total	**178**	**28.3**	**0.16**	**101**	**1.83**	**0.27**	**310**	**100.0%**
%of Total	57.4%	9.1%	0.1%	32.7%	0.6%	0.1%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	27.1	2.88	0	0	0.023	0.0034	**30.1**	14.9%
Petroleum	4.94	0.81	0	0	0.32	0.048	**6.12**	3.0%
Coal	55.5	6.64	0	0	0.0030	4.4E-04	**62.1**	30.8%
Hydropower	1.76	0.07	0	0	1.8E-04	2.8E-05	**1.83**	0.9%
Nuclear	8.20	0.42	0	0	0.0011	1.7E-04	**8.63**	4.3%
Wood	75.1	16.90	0	0	0	0	**92.0**	45.6%
Other	1.11	0.06	0	0	1.6E-04	2.4E-05	**1.17**	0.6%
Total	**174**	**27.8**	**0**	**0**	**0.35**	**0.052**	**202**	**100.0%**
%of Total	86.1%	13.8%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas	0.28	0.037	0.011	6.68	0.098	0.015	**7.12**	6.6%
Petroleum	3.92	0.52	0.15	93.3	1.37	0.20	**99.5**	92.1%
Coal	0.037	0.0048	0.0014	0.87	0.013	0.0019	**0.92**	0.9%
Hydropower	0.0023	3.0E-04	8.7E-05	0.054	7.9E-04	1.2E-04	**0.057**	0.1%
Nuclear	0.014	0.0018	5.3E-04	0.33	0.0049	7.3E-04	**0.35**	0.3%
Wood	0	0	0	0	0	0	**0**	0.0%
Other	0.0020	2.7E-04	7.7E-05	0.048	7.0E-04	1.0E-04	**0.051**	0.0%
Total	**4.26**	**0.56**	**0.16**	**101**	**1.49**	**0.22**	**108**	**100.0%**
%of Total	3.9%	0.5%	0.2%	93.8%	1.4%	0.2%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	**0**	0	0	0	17.5	2.35	**19.8**	
Usable					5.35	0.72	**6.06**	

Table 3-2-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Newsprint
thou lb/ 10,000 pkgs	13.9	1.7
	% recycled content	10

		Box with Newsprint Dunnage						
	Box	Newsprint Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process	174	32.2	0	0	0.35	0.049	**206**	65.8%
Transport	4.26	0.41	0.13	101	1.49	0.21	**107**	34.2%
Energy of Material Resource	0.093	0	0	0	0	0	**0.093**	0.0%
Total	**178**	**32.7**	**0.13**	**101**	**1.83**	**0.26**	**314**	**100.0%**
%of Total	56.7%	10.4%	0.0%	32.1%	0.6%	0.1%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	27.1	13.3	0	0	0.023	0.0032	**40.5**	19.6%
Petroleum	4.94	1.20	0	0	0.32	0.045	**6.51**	3.2%
Coal	55.5	10.18	0	0	0.0030	4.2E-04	**65.7**	31.8%
Hydropower	1.76	0.60	0	0	1.8E-04	2.6E-05	**2.36**	1.1%
Nuclear	8.20	3.74	0	0	0.0011	1.6E-04	**11.9**	5.8%
Wood	75.1	2.69	0	0	0	0	**77.8**	37.7%
Other	1.11	0.51	0	0	1.6E-04	2.3E-05	**1.62**	0.8%
Total	**174**	**32.2**	**0**	**0**	**0.35**	**0.049**	**206**	**100.0%**
%of Total	84.2%	15.6%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas	0.28	0.027	0.0084	6.65	0.098	0.014	**7.08**	6.6%
Petroleum	3.92	0.38	0.12	92.9	1.37	0.19	**98.9**	92.1%
Coal	0.037	0.0035	0.0011	0.86	0.013	0.0018	**0.92**	0.9%
Hydropower	0.0023	2.2E-04	6.8E-05	0.054	7.9E-04	1.1E-04	**0.057**	0.1%
Nuclear	0.014	0.0014	4.2E-04	0.33	0.0049	6.8E-04	**0.35**	0.3%
Wood	0	0	0	0	0	0	**0**	0.0%
Other	0.0020	1.9E-04	6.0E-05	0.047	7.0E-04	9.8E-05	**0.051**	0.0%
Total	**4.26**	**0.41**	**0.13**	**101**	**1.49**	**0.21**	**107**	**100.0%**
%of Total	4.0%	0.4%	0.1%	94.0%	1.4%	0.2%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	**0**	0	0	0	17.5	2.44	**19.9**	
Usable					5.35	0.75	**6.09**	

Table 3-2-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	1
80% pc box	0

	Box	PC Off Ppr
thou lb/ 10,000 pkgs	13.9	1.5

		Box with Shredded PC Office Paper Dunnage						
		Box	Shredded PC Office Paper Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process		174	0.38	0	0.35	0.043	**174**	62.2%
Transport		4.26	0	100	1.49	0.18	**106**	37.8%
Energy of Material Resource		0.093	0	0	0	0	**0.093**	0.0%
Total		**178**	**0.38**	**100**	**1.83**	**0.23**	**281**	**100.0%**
	%of Total	63.4%	0.1%	35.7%	0.7%	0.1%	**100.0%**	
By Source - Process + EMR								
Nat. Gas		27.1	0.064	0	0.023	0.0029	**27.2**	15.6%
Petroleum		4.94	0.014	0	0.32	0.040	**5.32**	3.0%
Coal		55.5	0.20	0	0.0030	3.7E-04	**55.7**	31.9%
Hydropower		1.76	0.012	0	1.8E-04	2.3E-05	**1.77**	1.0%
Nuclear		8.20	0.076	0	0.0011	1.4E-04	**8.28**	4.7%
Wood		75.1	0	0	0	0	**75.1**	43.0%
Other		1.11	0.010	0	1.6E-04	2.0E-05	**1.13**	0.6%
Total		**174**	**0.38**	**0**	**0.35**	**0.043**	**175**	**100.0%**
	%of Total	99.6%	0.2%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas		0.28	0	6.61	0.098	0.012	**7.00**	6.6%
Petroleum		3.92	0	92.3	1.37	0.17	**98**	92.1%
Coal		0.037	0	0.86	0.013	0.0016	**0.91**	0.9%
Hydropower		0.0023	0	0.053	7.9E-04	9.8E-05	**0.056**	0.1%
Nuclear		0.014	0	0.33	0.0049	6.0E-04	**0.35**	0.3%
Wood		0	0	0	0	0	**0**	0.0%
Other		0.0020	0	0.047	7.0E-04	8.7E-05	**0.050**	0.0%
Total		**4.26**	**0**	**100**	**1.49**	**0.18**	**106**	**100.0%**
	%of Total	4.0%	0.0%	94.4%	1.4%	0.2%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	17.5	1.96	**19.5**	
	Usable				5.35	0.60	**5.94**	

Table 3-2-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	PC Corrug
thou lb/ 10,000 pkgs	13.9	3.2

		Box with Shredded PC Corrugated Dunnage						
		Box	Shredded PC Corrugated Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process		174	0.26	0	0.35	0.091	**174**	61.0%
Transport		4.26	0	105	1.49	0.39	**111**	38.9%
Energy of Material Resource		0.093	0	0	0	0	**0.093**	0.0%
Total		**178**	**0.26**	**105**	**1.83**	**0.48**	**286**	**100.0%**
	%of Total	62.3%	0.1%	36.8%	0.6%	0.2%	**100.0%**	
By Source - Process + EMR								
Nat. Gas		27.1	0.044	0	0.023	0.0060	**27.2**	15.6%
Petroleum		4.94	0.0098	0	0.32	0.084	**5.36**	3.1%
Coal		55.5	0.14	0	0.0030	7.8E-04	**55.6**	31.9%
Hydropower		1.76	0.0082	0	1.8E-04	4.8E-05	**1.77**	1.0%
Nuclear		8.20	0.051	0	0.0011	3.0E-04	**8.26**	4.7%
Wood		75.1	0	0	0	0	**75.1**	43.1%
Other		1.11	0.0070	0	1.6E-04	4.3E-05	**1.12**	0.6%
Total		**174**	**0.26**	**0**	**0.35**	**0.091**	**174**	**100.0%**
	%of Total	99.6%	0.1%	0.0%	0.2%	0.1%	**100.0%**	
By Source - Transp								
Nat. Gas		0.28	0	6.93	0.098	0.026	**7.34**	6.6%
Petroleum		3.92	0	96.9	1.37	0.36	**102.5**	92.1%
Coal		0.037	0	0.90	0.013	0.0033	**0.95**	0.9%
Hydropower		0.0023	0	0.056	7.9E-04	2.1E-04	**0.059**	0.1%
Nuclear		0.014	0	0.34	0.0049	0.0013	**0.36**	0.3%
Wood		0	0	0	0	0	**0**	0.0%
Other		0.0020	0	0.050	7.0E-04	1.8E-04	**0.052**	0.0%
Total		**4.26**	**0**	**105**	**1.49**	**0.39**	**111**	**100.0%**
	%of Total	3.8%	0.0%	94.5%	1.3%	0.3%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	17.5	4.58	**22.1**	
	Usable				5.35	1.40	**6.74**	

Table 3-2-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

		Bl Kr					
thou lb/ 10,000 pkgs		1.4	1.4		1.4		
% recycled content							
		Unpadded Bleached Kraft Bag					
		Bleached Kraft	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)							
By Type							
Process		33.6	0	0	0.040	**33.6**	73.9%
Transport		0.62	1.23	9.84	0.17	**11.9**	26.1%
Energy of Material Resource		0.0098	0	0	0	**0.0098**	0.0%
Total		**34.2**	**1.23**	**9.84**	**0.21**	**45.5**	**100.0%**
	%of Total	75.2%	2.7%	21.6%	0.5%	**100.0%**	
By Source - Process + EMR							
Nat. Gas		4.66	0	0	0.0027	**4.67**	13.9%
Petroleum		4.68	0	0	0.037	**4.72**	14.0%
Coal		7.67	0	0	3.5E-04	**7.67**	22.8%
Hydropower		0.23	0	0	2.1E-05	**0.23**	0.7%
Nuclear		1.42	0	0	1.3E-04	**1.42**	4.2%
Wood		14.7	0	0	0	**14.7**	43.8%
Other		0.19	0	0	1.9E-05	**0.19**	0.6%
Total		**33.6**	**0**	**0**	**0.040**	**33.6**	**100.0%**
	%of Total	99.9%	0.0%	0.0%	0.1%	**100.0%**	
By Source - Transp							
Nat. Gas		0.041	0.081	0.65	0.011	**0.78**	6.6%
Petroleum		0.57	1.13	9.06	0.16	**10.9**	92.1%
Coal		0.0053	0.011	0.084	0.0015	**0.10**	0.9%
Hydropower		3.3E-04	6.5E-04	0.0052	9.1E-05	**0.0063**	0.1%
Nuclear		0.0020	0.0040	0.032	5.6E-04	**0.039**	0.3%
Wood		0	0	0	0	**0**	0.0%
Other		2.9E-04	5.8E-04	0.0046	8.1E-05	**0.0056**	0.0%
Total		**0.62**	**1.23**	**9.84**	**0.17**	**11.9**	**100.0%**
	%of Total	5.2%	10.3%	83.0%	1.5%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	0	0	0	1.83	**1.83**	
	Usable				0.56	**0.56**	

Table 3-2-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr	Unbl Kr			
thou lb/ 10,000 pkgs	1	0.9	1.9	3.8	3.8
% recycled content					

	All-Paper Padded Kraft Bag							
	Bleached Kraft	Unbleached Kraft	Macerated PC Newspaper Padding	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process	24.0	13.9	0.54	0	0	0.11	**38.5**	56.1%
Transport	0.44	0.41	0.60	3.33	24.9	0.47	**30.1**	43.9%
Energy of Material Resource	0.0070	0.0041	0	0	0	0	**0.011**	0.0%
Total	**24.4**	**14.3**	**1.14**	**3.33**	**24.9**	**0.58**	**68.6**	**100.0%**
%of Total	35.6%	20.8%	1.7%	4.9%	36.2%	0.8%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	3.33	1.44	0.088	0	0	0.0072	**4.87**	12.6%
Petroleum	3.34	0.40	0.058	0	0	0.10	**3.91**	10.1%
Coal	5.48	3.32	0.26	0	0	9.4E-04	**9.06**	23.5%
Hydropower	0.16	0.034	0.016	0	0	5.8E-05	**0.21**	0.6%
Nuclear	1.01	0.21	0.10	0	0	3.6E-04	**1.32**	3.4%
Wood	10.5	8.45	0	0	0	0	**19.0**	49.3%
Other	0.14	0.029	0.014	0	0	5.2E-05	**0.18**	0.5%
Total	**24.0**	**13.9**	**0.54**	**0**	**0**	**0.11**	**38.5**	**100.0%**
%of Total	62.3%	36.0%	1.4%	0.0%	0.0%	0.3%	**100.0%**	
By Source - Transp								
Nat. Gas	0.029	0.027	0.039	0.22	1.64	0.031	**1.98**	6.6%
Petroleum	0.41	0.38	0.55	3.07	22.9	0.43	**27.7**	92.1%
Coal	0.0038	0.0036	0.0051	0.029	0.21	0.0040	**0.26**	0.9%
Hydropower	2.3E-04	2.2E-04	3.2E-04	0.0018	0.013	2.5E-04	**0.016**	0.1%
Nuclear	0.0014	0.0014	0.0020	0.011	0.081	0.0015	**0.099**	0.3%
Wood	0	0	0	0	0	0	**0**	0.0%
Other	2.1E-04	2.0E-04	2.8E-04	0.0016	0.012	2.2E-04	**0.014**	0.0%
Total	**0.44**	**0.41**	**0.60**	**3.33**	**24.9**	**0.47**	**30.1**	**100.0%**
%of Total	1.5%	1.4%	2.0%	11.1%	82.6%	1.6%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	0	0	0	0	0	5.22	**5.22**	
Usable						1.59	**1.59**	

Table 3-2-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.86	0.24	0.24	1.34	1.34
% recycled content					

		Bubble Padded Kraft Bag							
		Bleached Kraft	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)									
By Type									
Process		20.6	3.85	3.35	0	0	0.040	**27.9**	53.9%
Transport		0.38	0.32	0.32	1.17	10.2	0.17	**12.6**	24.4%
Energy of Material Resource		0.0060	5.59	5.62	0	0	0	**11.2**	21.7%
Total		**21.0**	**9.77**	**9.28**	**1.17**	**10.2**	**0.21**	**51.7**	**100.0%**
	%of Total	40.7%	18.9%	18.0%	2.3%	19.8%	0.4%	**100.0%**	
By Source - Process + EMR									
Nat. Gas		2.87	6.63	6.51	0	0	0.0026	**16.0**	41.0%
Petroleum		2.88	1.38	1.37	0	0	0.037	**5.65**	14.5%
Coal		4.71	0.96	0.73	0	0	3.4E-04	**6.41**	16.4%
Hydropower		0.14	0.059	0.045	0	0	2.1E-05	**0.24**	0.6%
Nuclear		0.87	0.37	0.28	0	0	1.3E-04	**1.51**	3.9%
Wood		9.06	0	0	0	0	0	**9.06**	23.2%
Other		0.12	0.050	0.038	0	0	1.9E-05	**0.21**	0.5%
Total		**20.6**	**9.45**	**8.97**	**0**	**0**	**0.040**	**39.1**	**100.0%**
	%of Total	52.8%	24.2%	22.9%	0.0%	0.0%	0.1%	**100.0%**	
By Source - Transp									
Nat. Gas		0.025	0.053	0.053	0.077	0.67	0.011	**0.89**	7.1%
Petroleum		0.35	0.26	0.26	1.08	9.43	0.16	**11.5**	91.5%
Coal		0.0033	0.0062	0.0054	0.010	0.088	0.0015	**0.11**	0.9%
Hydropower		2.0E-04	3.8E-04	3.3E-04	6.2E-04	0.0054	9.1E-05	**0.0071**	0.1%
Nuclear		0.0012	0.0023	0.0020	0.0039	0.034	5.6E-04	**0.044**	0.3%
Wood		0	0	0	0	0	0	**0**	0.0%
Other		1.8E-04	3.3E-04	2.8E-04	5.5E-04	0.0048	8.0E-05	**0.0062**	0.0%
Total		**0.38**	**0.32**	**0.32**	**1.17**	**10.2**	**0.17**	**12.6**	**100.0%**
	%of Total	3.0%	2.5%	2.5%	9.3%	81.3%	1.4%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	0	0	0	0	0	2.84	**2.84**	
	Usable						0.87	**0.87**	

Table 3-2-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	LLDPE		
thou lb/ 10,000 pkgs	0.67	0.67	0.67
% recycled content			

		Unpadded LLDPE Film Bag					
		LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)							
By Type							
Process		9.35	0	0	0.021	**9.37**	29.2%
Transport		0.88	1.12	4.92	0.091	**7.02**	21.9%
Energy of Material Resource		15.7	0	0	0	**15.7**	48.9%
Total		**25.9**	**1.12**	**4.92**	**0.11**	**32.1**	**100.0%**
	%of Total	80.8%	3.5%	15.3%	0.4%	**100.0%**	
By Source - Process + EMR							
Nat. Gas		18.2	0	0	0.0014	**18.2**	72.5%
Petroleum		3.81	0	0	0.020	**3.83**	15.3%
Coal		2.05	0	0	1.8E-04	**2.05**	8.2%
Hydropower		0.12	0	0	1.1E-05	**0.12**	0.5%
Nuclear		0.78	0	0	7.0E-05	**0.78**	3.1%
Wood		0	0	0	0	**0**	0.0%
Other		0.11	0	0	1.0E-05	**0.11**	0.4%
Total		**25.0**	**0**	**0**	**0.021**	**25.1**	**100.0%**
	%of Total	99.9%	0.0%	0.0%	0.1%	**100.0%**	
By Source - Transp							
Nat. Gas		0.15	0.074	0.32	0.0060	**0.55**	7.9%
Petroleum		0.71	1.03	4.53	0.084	**6.37**	90.7%
Coal		0.015	0.0096	0.042	7.8E-04	**0.068**	1.0%
Hydropower		9.2E-04	6.0E-04	0.0026	4.8E-05	**0.0042**	0.1%
Nuclear		0.0057	0.0037	0.016	3.0E-04	**0.026**	0.4%
Wood		0	0	0	0	**0**	0.0%
Other		7.9E-04	5.3E-04	0.0023	4.3E-05	**0.0037**	0.1%
Total		**0.88**	**1.12**	**4.92**	**0.091**	**7.02**	**100.0%**
	%of Total	12.6%	16.0%	70.1%	1.3%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	0	0	0	2.41	**2.41**	
	Usable				0.74	**0.74**	

Table 3-2-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.35	0.98	1.33	1.33
% recycled content				

		Bubble Padded LLDPE Bag					
	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)							
By Type							
Process	5.62	13.7	0	0	0.042	**19.3**	30.3%
Transport	0.46	1.29	1.17	10.2	0.18	**13.3**	20.9%
Energy of Material Resource	8.16	23.0	0	0	0	**31.1**	48.8%
Total	**14.2**	**37.9**	**1.17**	**10.2**	**0.22**	**63.8**	**100.0%**
%of Total	22.3%	59.4%	1.8%	16.0%	0.3%	**100.0%**	
By Source - Process + EMR							
Nat. Gas	9.67	26.6	0	0	0.0028	**36.3**	71.9%
Petroleum	2.01	5.57	0	0	0.039	**7.62**	15.1%
Coal	1.41	3.00	0	0	3.6E-04	**4.40**	8.7%
Hydropower	0.085	0.18	0	0	2.3E-05	**0.27**	0.5%
Nuclear	0.53	1.14	0	0	1.4E-04	**1.67**	3.3%
Wood	0	0	0	0	0	**0**	0.0%
Other	0.072	0.15	0	0	2.0E-05	**0.23**	0.4%
Total	**13.8**	**36.6**	**0**	**0**	**0.042**	**50.4**	**100.0%**
%of Total	27.3%	72.6%	0.0%	0.0%	0.1%	**100.0%**	
By Source - Transp							
Nat. Gas	0.077	0.22	0.077	0.67	0.012	**1.06**	7.9%
Petroleum	0.37	1.04	1.07	9.43	0.17	**12.1**	90.6%
Coal	0.0091	0.022	0.010	0.088	0.0015	**0.13**	1.0%
Hydropower	5.5E-04	0.0013	6.2E-04	0.0054	9.6E-05	**0.0080**	0.1%
Nuclear	0.0034	0.0083	0.0038	0.034	5.9E-04	**0.050**	0.4%
Wood	0	0	0	0	0	**0**	0.0%
Other	4.8E-04	0.0012	5.5E-04	0.0048	8.5E-05	**0.0071**	0.1%
Total	**0.46**	**1.29**	**1.17**	**10.2**	**0.18**	**13.3**	**100.0%**
%of Total	3.5%	9.7%	8.7%	76.7%	1.4%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	0	0	0	0	4.78	**4.78**	
Usable					1.46	**1.46**	

Table 3-3-BOX

LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Air Pkt
thou lb/ 10,000 pkgs	13.9	0.84
% recycled content		30

	Box	LDPE Inflated Air Packets	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
	Box with Inflated Air Packets							
Energy (MM Btu/10,000 pkgs)								
By Type								
Process	129	10.9	0	0	0.35	0.027	**140**	54.0%
Transport	4.28	0.96	0.74	98.2	1.49	0.11	**106**	40.7%
Energy of Material Resource	0.074	13.7	0	0	0	0	**13.8**	5.3%
Total	**134**	**25.6**	**0.74**	**98.2**	**1.83**	**0.14**	**260**	**100.0%**
%of Total	51.4%	9.8%	0.3%	37.8%	0.7%	0.1%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	25.6	16.5	0	0	0.023	0.0018	**42.1**	27.3%
Petroleum	4.28	3.43	0	0	0.32	0.025	**8.05**	5.2%
Coal	61.3	3.12	0	0	0.0030	2.3E-04	**64.5**	41.8%
Hydropower	1.52	0.19	0	0	1.8E-04	1.4E-05	**1.71**	1.1%
Nuclear	9.48	1.19	0	0	0.0011	8.8E-05	**10.67**	6.9%
Wood	25.7	0	0	0	0	0	**25.7**	16.7%
Other	1.29	0.16	0	0	1.6E-04	1.3E-05	**1.45**	0.9%
Total	**129**	**24.6**	**0**	**0**	**0.35**	**0.027**	**154**	**100.0%**
%of Total	83.8%	16.0%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas	0.28	0.14	0.049	6.47	0.098	0.0075	**7.05**	6.7%
Petroleum	3.95	0.79	0.68	90.5	1.37	0.11	**97.4**	92.0%
Coal	0.037	0.017	0.0063	0.84	0.013	9.8E-04	**0.91**	0.9%
Hydropower	0.0023	0.0010	3.9E-04	0.052	7.9E-04	6.1E-05	**0.057**	0.1%
Nuclear	0.014	0.0064	0.0024	0.32	0.0049	3.7E-04	**0.35**	0.3%
Wood	0	0	0	0	0	0	**0**	0.0%
Other	0.0020	8.9E-04	3.5E-04	0.046	7.0E-04	5.4E-05	**0.050**	0.0%
Total	**4.28**	**0.96**	**0.74**	**98.2**	**1.49**	**0.11**	**106**	**100.0%**
%of Total	4.1%	0.9%	0.7%	92.8%	1.4%	0.1%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	0	0	0	0	17.5	3.02	**20.5**	
Usable					5.35	0.92	**6.27**	

Table 3-3-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	EPS
thou lb/ 10,000 pkgs	13.9	0.48
% recycled content		30

		Box with EPS Loose Fill							
		Box	EPS Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)									
By Type									
Process		129	13.9	0	0	0.35	0.021	**143**	55.6%
Transport		4.28	1.02	1.94	97.0	1.49	0.089	**106**	41.0%
Energy of Material Resource		0.074	8.57	0	0	0	0	**8.64**	3.3%
Total		**134**	**23.5**	**1.94**	**97.0**	**1.83**	**0.11**	**258**	**100.0%**
	%of Total	51.8%	9.1%	0.8%	37.6%	0.7%	0.0%	**100.0%**	
By Source - Process + EMR									
Nat. Gas		25.6	10.9	0	0	0.023	0.0014	**36.5**	24.0%
Petroleum		4.28	7.27	0	0	0.32	0.020	**11.9**	7.8%
Coal		61.3	2.90	0	0	0.0030	1.8E-04	**64.2**	42.2%
Hydropower		1.52	0.18	0	0	1.8E-04	1.1E-05	**1.70**	1.1%
Nuclear		9.48	1.10	0	0	0.0011	7.0E-05	**10.59**	7.0%
Wood		25.7	0	0	0	0	0	**25.7**	16.9%
Other		1.29	0.15	0	0	1.6E-04	1.0E-05	**1.44**	0.9%
Total		**129**	**22.5**	**0**	**0**	**0.35**	**0.021**	**152**	**100.0%**
	%of Total	85.0%	14.8%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp									
Nat. Gas		0.28	0.085	0.13	6.40	0.098	0.0059	**7.00**	6.6%
Petroleum		3.95	0.90	1.78	89.4	1.37	0.082	**97.5**	92.1%
Coal		0.037	0.024	0.017	0.83	0.013	7.6E-04	**0.92**	0.9%
Hydropower		0.0023	0.0015	0.0010	0.052	7.9E-04	4.7E-05	**0.057**	0.1%
Nuclear		0.014	0.0090	0.0064	0.32	0.0049	2.9E-04	**0.35**	0.3%
Wood		0	0	0	0	0	0	**0**	0.0%
Other		0.0020	0.0013	9.1E-04	0.046	7.0E-04	4.2E-05	**0.051**	0.0%
Total		**4.28**	**1.02**	**1.94**	**97.0**	**1.49**	**0.089**	**106**	**100.0%**
	%of Total	4.0%	1.0%	1.8%	91.7%	1.4%	0.1%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	0	17.5	0.77	**18.3**	
	Usable					5.35	0.24	**5.58**	

Table 3-3-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Cornstarch
thou lb/ 10,000 pkgs	13.9	0.86

	Box with Cornstarch Loose Fill							
	Box	Cornstarch Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process	129	5.63	0	0	0.35	0.0046	**135**	55.5%
Transport	4.28	0.72	3.26	98.3	1.49	0.019	**108**	44.4%
Energy of Material Resource	0.074	0.20	0	0	0	0	**0.28**	0.1%
Total	**134**	**6.55**	**3.26**	**98.3**	**1.83**	**0.023**	**243**	**100.0%**
%of Total	54.8%	2.7%	1.3%	40.4%	0.8%	0.0%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	25.6	1.69	0	0	0.023	3.0E-04	**27.3**	20.2%
Petroleum	4.28	0.37	0	0	0.32	0.0042	**4.97**	3.7%
Coal	61.3	2.58	0	0	0.0030	3.9E-05	**63.9**	47.2%
Hydropower	1.52	0.15	0	0	1.8E-04	2.4E-06	**1.67**	1.2%
Nuclear	9.48	0.92	0	0	0.0011	1.5E-05	**10.40**	7.7%
Wood	25.7	0	0	0	0	0	**25.7**	19.0%
Other	1.29	0.12	0	0	1.6E-04	2.2E-06	**1.41**	1.0%
Total	**129**	**5.83**	**0**	**0**	**0.35**	**0.0046**	**135**	**100.0%**
%of Total	95.4%	4.3%	0.0%	0.0%	0.3%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas	0.28	0.049	0.21	6.48	0.098	0.0012	**7.12**	6.6%
Petroleum	3.95	0.66	3.00	90.5	1.37	0.017	**99.5**	92.1%
Coal	0.037	0.0062	0.028	0.84	0.013	1.6E-04	**0.92**	0.9%
Hydropower	0.0023	3.8E-04	0.0017	0.052	7.9E-04	9.9E-06	**0.057**	0.1%
Nuclear	0.014	0.0024	0.011	0.32	0.0049	6.1E-05	**0.35**	0.3%
Wood	0	0	0	0	0	0	**0**	0.0%
Other	0.0020	3.4E-04	0.0015	0.046	7.0E-04	8.8E-06	**0.051**	0.0%
Total	**4.28**	**0.72**	**3.26**	**98.3**	**1.49**	**0.019**	**108**	**100.0%**
%of Total	4.0%	0.7%	3.0%	91.0%	1.4%	0.0%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	**0**	0	0	0	17.5	0.59	**18.1**	
Usable					5.35	0.18	**5.52**	

Table 3-3-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	0
80% pc box	1

	Box	Mold Pulp
thou lb/ 10,000 pkgs	13.9	3.8

		Box with Molded Pulp Loose Fill							
		Box	Molded Pulp Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)									
By Type									
Process		129	60.8	0	0	0.35	0.099	**190**	60.3%
Transport		4.28	1.25	10.8	107	1.49	0.42	**125**	39.6%
Energy of Material Resource		0.074	0	0	0	0	0	**0.074**	0.0%
Total		**134**	**62.0**	**10.8**	**107**	**1.83**	**0.52**	**316**	**100.0%**
	%of Total	42.3%	19.7%	3.4%	33.9%	0.6%	0.2%	**100.0%**	
By Source - Process + EMR									
Nat. Gas		25.6	36.3	0	0	0.023	0.0065	**61.9**	32.5%
Petroleum		4.28	1.56	0	0	0.32	0.091	**6.25**	3.3%
Coal		61.3	15.4	0	0	0.0030	8.5E-04	**76.7**	40.3%
Hydropower		1.52	0.93	0	0	1.8E-04	5.3E-05	**2.45**	1.3%
Nuclear		9.48	5.83	0	0	0.0011	3.2E-04	**15.3**	8.0%
Wood		25.7	0	0	0	0	0	**25.7**	13.5%
Other		1.29	0.79	0	0	1.6E-04	4.7E-05	**2.08**	1.1%
Total		**129**	**60.8**	**0**	**0**	**0.35**	**0.099**	**190**	**100.0%**
	%of Total	67.8%	31.9%	0.0%	0.0%	0.2%	0.1%	**100.0%**	
By Source - Transp									
Nat. Gas		0.28	0.083	0.72	7.04	0.098	0.028	**8.25**	6.6%
Petroleum		3.95	1.15	9.99	98.4	1.37	0.39	**115**	92.1%
Coal		0.037	0.011	0.093	0.91	0.013	0.0036	**1.07**	0.9%
Hydropower		0.0023	6.7E-04	0.0058	0.057	7.9E-04	2.3E-04	**0.066**	0.1%
Nuclear		0.014	0.0041	0.036	0.35	0.0049	0.0014	**0.41**	0.3%
Wood		0	0	0	0	0	0	**0**	0.0%
Other		0.0020	5.9E-04	0.0051	0.050	7.0E-04	2.0E-04	**0.059**	0.0%
Total		**4.28**	**1.25**	**10.8**	**107**	**1.49**	**0.42**	**125**	**100.0%**
	%of Total	3.4%	1.0%	8.7%	85.4%	1.2%	0.3%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	0	17.5	5.46	**23.0**	
	Usable					5.35	1.67	**7.01**	

Table 3-3-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Unbl Kr
thou lb/ 10,000 pkgs	13.9	1.8
% recycled content		50

	Box with Unbleached Kraft Paper Dunnage							
	Box	Unbleached Kraft Paper Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process	129	19.8	0	0	0.35	0.052	**149**	58.0%
Transport	4.28	0.57	0.16	101	1.49	0.22	**108**	42.0%
Energy of Material Resource	0.074	0.0041	0	0	0	0	**0.078**	0.0%
Total	**134**	**20.3**	**0.16**	**101**	**1.83**	**0.27**	**257**	**100.0%**
%of Total	51.9%	7.9%	0.1%	39.4%	0.7%	0.1%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	25.6	2.51	0	0	0.023	0.0034	**28.1**	18.8%
Petroleum	4.28	0.63	0	0	0.32	0.048	**5.27**	3.5%
Coal	61.3	7.13	0	0	0.0030	4.4E-04	**68.5**	45.8%
Hydropower	1.52	0.13	0	0	1.8E-04	2.8E-05	**1.65**	1.1%
Nuclear	9.48	0.82	0	0	0.0011	1.7E-04	**10.31**	6.9%
Wood	25.7	8.45	0	0	0	0	**34.2**	22.9%
Other	1.29	0.11	0	0	1.6E-04	2.4E-05	**1.40**	0.9%
Total	**129**	**19.8**	**0**	**0**	**0.35**	**0.052**	**149**	**100.0%**
%of Total	86.5%	13.2%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas	0.28	0.038	0.011	6.68	0.098	0.015	**7.12**	6.6%
Petroleum	3.95	0.52	0.15	93.3	1.37	0.20	**99.5**	92.1%
Coal	0.037	0.0049	0.0014	0.87	0.013	0.0019	**0.92**	0.9%
Hydropower	0.0023	3.0E-04	8.7E-05	0.054	7.9E-04	1.2E-04	**0.057**	0.1%
Nuclear	0.014	0.0019	5.3E-04	0.33	0.0049	7.3E-04	**0.35**	0.3%
Wood	0	0	0	0	0	0	**0**	0.0%
Other	0.0020	2.7E-04	7.7E-05	0.048	7.0E-04	1.0E-04	**0.051**	0.0%
Total	**4.28**	**0.57**	**0.16**	**101**	**1.49**	**0.22**	**108**	**100.0%**
%of Total	4.0%	0.5%	0.2%	93.8%	1.4%	0.2%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	**0**	0	0	0	17.5	2.35	**19.8**	
Usable					5.35	0.72	**6.06**	

Table 3-3-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Newsprint
thou lb/ 10,000 pkgs	13.9	1.7
	% recycled content	50

		Box with Newsprint Dunnage							
		Box	Newsprint Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)									
By Type									
Process		129	21.4	0	0	0.35	0.049	**151**	58.4%
Transport		4.28	0.38	0.13	101	1.49	0.21	**107**	41.5%
Energy of Material Resource		0.074	0	0	0	0	0	**0.074**	0.0%
Total		**134**	**21.8**	**0.13**	**101**	**1.83**	**0.26**	**258**	**100.0%**
	%of Total	51.7%	8.4%	0.0%	39.0%	0.7%	0.1%	**100.0%**	
By Source - Process + EMR									
Nat. Gas		25.6	10.0	0	0	0.023	0.0032	**35.7**	23.6%
Petroleum		4.28	0.75	0	0	0.32	0.045	**5.40**	3.6%
Coal		61.3	6.20	0	0	0.0030	4.2E-04	**67.6**	44.7%
Hydropower		1.52	0.37	0	0	1.8E-04	2.6E-05	**1.88**	1.2%
Nuclear		9.48	2.28	0	0	0.0011	1.6E-04	**11.8**	7.8%
Wood		25.7	1.49	0	0	0	0	**27.2**	18.0%
Other		1.29	0.31	0	0	1.6E-04	2.3E-05	**1.60**	1.1%
Total		**129**	**21.4**	**0**	**0**	**0.35**	**0.049**	**151**	**100.0%**
	%of Total	85.5%	14.2%	0.0%	0.0%	0.2%	0.0%	**100.0%**	
By Source - Transp									
Nat. Gas		0.28	0.025	0.0084	6.65	0.098	0.014	**7.07**	6.6%
Petroleum		3.95	0.35	0.12	92.9	1.37	0.19	**98.9**	92.1%
Coal		0.037	0.0033	0.0011	0.86	0.013	0.0018	**0.92**	0.9%
Hydropower		0.0023	2.0E-04	6.8E-05	0.054	7.9E-04	1.1E-04	**0.057**	0.1%
Nuclear		0.014	0.0013	4.2E-04	0.33	0.0049	6.8E-04	**0.35**	0.3%
Wood		0	0	0	0	0	0	**0**	0.0%
Other		0.0020	1.8E-04	6.0E-05	0.047	7.0E-04	9.8E-05	**0.051**	0.0%
Total		**4.28**	**0.38**	**0.13**	**101**	**1.49**	**0.21**	**107**	**100.0%**
	%of Total	4.0%	0.4%	0.1%	94.0%	1.4%	0.2%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	0	17.5	2.44	**19.9**	
	Usable					5.35	0.75	**6.09**	

Table 3-3-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

	select box by entering 1
avg box	0
80% pc box	1

	Box	PC Off Ppr
thou lb/ 10,000 pkgs	13.9	1.5

		Box with Shredded PC Office Paper Dunnage						
		Box	Shredded PC Office Paper Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process		129	0.38	0	0.35	0.043	**130**	55.0%
Transport		4.28	0	100	1.49	0.18	**106**	45.0%
Energy of Material Resource		0.074	0	0	0	0	**0.074**	0.0%
Total		**134**	**0.38**	**100**	**1.83**	**0.23**	**236**	**100.0%**
	%of Total	56.5%	0.2%	42.4%	0.8%	0.1%	**100.0%**	
By Source - Process + EMR								
Nat. Gas		25.6	0.064	0	0.023	0.0029	**25.7**	19.8%
Petroleum		4.28	0.014	0	0.32	0.040	**4.65**	3.6%
Coal		61.3	0.20	0	0.0030	3.7E-04	**61.5**	47.4%
Hydropower		1.52	0.012	0	1.8E-04	2.3E-05	**1.53**	1.2%
Nuclear		9.48	0.076	0	0.0011	1.4E-04	**9.56**	7.4%
Wood		25.7	0	0	0	0	**25.7**	19.8%
Other		1.29	0.010	0	1.6E-04	2.0E-05	**1.30**	1.0%
Total		**129**	**0.38**	**0**	**0.35**	**0.043**	130	**100.0%**
	%of Total	99.4%	0.3%	0.0%	0.3%	0.0%	**100.0%**	
By Source - Transp								
Nat. Gas		0.28	0	6.61	0.098	0.012	**7.00**	6.6%
Petroleum		3.95	0	92.3	1.37	0.17	**98**	92.1%
Coal		0.037	0	0.86	0.013	0.0016	**0.91**	0.9%
Hydropower		0.0023	0	0.053	7.9E-04	9.8E-05	**0.056**	0.1%
Nuclear		0.014	0	0.33	0.0049	6.0E-04	**0.35**	0.3%
Wood		0	0	0	0	0	**0**	0.0%
Other		0.0020	0	0.047	7.0E-04	8.7E-05	**0.050**	0.0%
Total		**4.28**	**0**	**100**	**1.49**	**0.18**	106	**100.0%**
	%of Total	4.0%	0.0%	94.4%	1.4%	0.2%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	17.5	1.96	**19.5**	
	Usable				5.35	0.60	**5.94**	

Table 3-3-BOX
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	PC Corrug
thou lb/ 10,000 pkgs	13.9	3.2

		Box with Shredded PC Corrugated Dunnage						
		Box	Shredded PC Corrugated Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process		129	0.26	0	0.35	0.091	**130**	53.8%
Transport		4.28	0	105	1.49	0.39	**111**	46.1%
Energy of Material Resource		0.074	0	0	0	0	**0.074**	0.0%
Total		**134**	**0.26**	**105**	**1.83**	**0.48**	**241**	**100.0%**
	%of Total	55.3%	0.1%	43.6%	0.8%	0.2%	**100.0%**	
By Source - Process + EMR								
Nat. Gas		25.6	0.044	0	0.023	0.0060	**25.7**	19.8%
Petroleum		4.28	0.0098	0	0.32	0.084	**4.69**	3.6%
Coal		61.3	0.14	0	0.0030	7.8E-04	**61.5**	47.3%
Hydropower		1.52	0.0082	0	1.8E-04	4.8E-05	**1.53**	1.2%
Nuclear		9.48	0.051	0	0.0011	3.0E-04	**9.54**	7.3%
Wood		25.7	0	0	0	0	**25.7**	19.8%
Other		1.29	0.0070	0	1.6E-04	4.3E-05	**1.30**	1.0%
Total		**129**	**0.26**	**0**	**0.35**	**0.091**	**130**	**100.0%**
	%of Total	99.5%	0.2%	0.0%	0.3%	0.1%	**100.0%**	
By Source - Transp								
Nat. Gas		0.28	0	6.93	0.098	0.026	**7.34**	6.6%
Petroleum		3.95	0	96.9	1.37	0.36	**102.6**	92.1%
Coal		0.037	0	0.90	0.013	0.0033	**0.95**	0.9%
Hydropower		0.0023	0	0.056	7.9E-04	2.1E-04	**0.059**	0.1%
Nuclear		0.014	0	0.34	0.0049	0.0013	**0.36**	0.3%
Wood		0	0	0	0	0	**0**	0.0%
Other		0.0020	0	0.050	7.0E-04	1.8E-04	**0.052**	0.0%
Total		**4.28**	**0**	**105**	**1.49**	**0.39**	**111**	**100.0%**
	%of Total	3.8%	0.0%	94.5%	1.3%	0.3%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	**0**	0	0	17.5	4.58	**22.1**	
	Usable				5.35	1.40	**6.74**	

Table 3-3-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr		
thou lb/ 10,000 pkgs	1.4	1.4	1.4
% recycled content	30		

		Unpadded Bleached Kraft Bag					
		Bleached Kraft	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)							
By Type							
Process		26.3	0	0	0.040	**26.3**	69.0%
Transport		0.57	1.23	9.84	0.17	**11.8**	31.0%
Energy of Material Resource		0.0069	0	0	0	**0.0069**	0.0%
Total		**26.8**	**1.23**	**9.84**	**0.21**	**38.1**	**100.0%**
	%of Total	70.4%	3.2%	25.8%	0.6%	**100.0%**	
By Source - Process + EMR							
Nat. Gas		3.76	0	0	0.0027	**3.77**	14.3%
Petroleum		3.38	0	0	0.037	**3.42**	13.0%
Coal		7.15	0	0	3.5E-04	**7.15**	27.2%
Hydropower		0.20	0	0	2.1E-05	**0.20**	0.8%
Nuclear		1.28	0	0	1.3E-04	**1.28**	4.8%
Wood		10.3	0	0	0	**10.3**	39.2%
Other		0.17	0	0	1.9E-05	**0.17**	0.7%
Total		**26.3**	**0**	**0**	**0.040**	**26.3**	**100.0%**
	%of Total	99.8%	0.0%	0.0%	0.2%	**100.0%**	
By Source - Transp							
Nat. Gas		0.037	0.081	0.65	0.011	**0.78**	6.6%
Petroleum		0.52	1.13	9.06	0.16	**10.9**	92.1%
Coal		0.0048	0.011	0.084	0.0015	**0.10**	0.9%
Hydropower		3.0E-04	6.5E-04	0.0052	9.1E-05	**0.0063**	0.1%
Nuclear		0.0019	0.0040	0.032	5.6E-04	**0.039**	0.3%
Wood		0	0	0	0	**0**	0.0%
Other		2.7E-04	5.8E-04	0.0046	8.1E-05	**0.0056**	0.0%
Total		**0.57**	**1.23**	**9.84**	**0.17**	**11.8**	**100.0%**
	%of Total	4.8%	10.4%	83.3%	1.5%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	0	0	0	1.83	**1.83**	
	Usable				0.56	**0.56**	

Table 3-3-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr	Unbl Kr			
thou lb/ 10,000 pkgs	1	0.9	1.9	3.8	3.8
% recycled content	30	30			

All-Paper Padded Kraft Bag

	Bleached Kraft	Unbleached Kraft	Macerated PC Newspaper Padding	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process	18.8	11.5	0.54	0	0	0.11	**30.9**	50.7%
Transport	0.40	0.38	0.60	3.33	24.9	0.47	**30.0**	49.3%
Energy of Material Resource	0.0049	0.0029	0	0	0	0	**0.008**	0.0%
Total	**19.2**	**11.9**	**1.14**	**3.33**	**24.9**	**0.58**	**60.9**	**100.0%**
%of Total	31.5%	19.5%	1.9%	5.5%	40.8%	0.9%	**100.0%**	
By Source - Process + EMR								
Nat. Gas	2.69	1.33	0.088	0	0	0.0072	**4.11**	13.3%
Petroleum	2.42	0.35	0.058	0	0	0.10	**2.92**	9.5%
Coal	5.10	3.47	0.26	0	0	9.4E-04	**8.84**	28.6%
Hydropower	0.15	0.053	0.016	0	0	5.8E-05	**0.22**	0.7%
Nuclear	0.91	0.33	0.10	0	0	3.6E-04	**1.34**	4.3%
Wood	07.4	5.91	0	0	0	0	**13.3**	43.0%
Other	0.12	0.045	0.014	0	0	5.2E-05	**0.18**	0.6%
Total	**18.8**	**11.5**	**0.54**	**0**	**0**	**0.11**	**30.9**	**100.0%**
%of Total	60.7%	37.2%	1.7%	0.0%	0.0%	0.4%	**100.0%**	
By Source - Transp								
Nat. Gas	0.027	0.025	0.039	0.22	1.64	0.031	**1.98**	6.6%
Petroleum	0.37	0.35	0.55	3.07	22.9	0.43	**27.7**	92.1%
Coal	0.0035	0.0032	0.0051	0.029	0.21	0.0040	**0.26**	0.9%
Hydropower	2.2E-04	2.0E-04	3.2E-04	0.0018	0.013	2.5E-04	**0.016**	0.1%
Nuclear	0.0013	0.0012	0.0020	0.011	0.081	0.0015	**0.098**	0.3%
Wood	0	0	0	0	0	0	**0**	0.0%
Other	1.9E-04	1.8E-04	2.8E-04	0.0016	0.012	2.2E-04	**0.014**	0.0%
Total	**0.40**	**0.38**	**0.60**	**3.33**	**24.9**	**0.47**	**30.0**	**100.0%**
%of Total	1.3%	1.3%	2.0%	11.1%	82.8%	1.6%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	0	0	0	0	0	5.22	**5.22**	
Usable						1.59	**1.59**	

Table 3-3-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.86	0.24	0.24	1.34	1.34
% recycled content	30	30	30		

		Bubble Padded Kraft Bag							
		Bleached Kraft	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)									
By Type									
Process		16.1	3.10	2.75	0	0	0.040	**22.0**	52.0%
Transport		0.35	0.28	0.28	1.17	10.2	0.17	**12.5**	29.5%
Energy of Material Resource		0.0042	3.92	3.93	0	0	0	**07.9**	18.5%
Total		**16.5**	**7.30**	**6.96**	**1.17**	**10.2**	**0.21**	**42.4**	**100.0%**
	%of Total	38.9%	17.2%	16.4%	2.8%	24.2%	0.5%	**100.0%**	
By Source - Process + EMR									
Nat. Gas		2.31	4.71	4.63	0	0	0.0026	**11.7**	39.0%
Petroleum		2.08	0.98	0.97	0	0	0.037	**4.07**	13.6%
Coal		4.39	0.89	0.72	0	0	3.4E-04	**6.00**	20.1%
Hydropower		0.13	0.054	0.044	0	0	2.1E-05	**0.22**	0.7%
Nuclear		0.78	0.34	0.27	0	0	1.3E-04	**1.40**	4.7%
Wood		6.34	0	0	0	0	0	**6.34**	21.2%
Other		0.11	0.046	0.037	0	0	1.9E-05	**0.19**	0.6%
Total		**16.1**	**7.02**	**6.68**	**0**	**0**	**0.040**	**29.9**	**100.0%**
	%of Total	54.0%	23.5%	22.4%	0.0%	0.0%	0.1%	**100.0%**	
By Source - Transp									
Nat. Gas		0.023	0.041	0.041	0.077	0.67	0.011	**0.87**	7.0%
Petroleum		0.32	0.23	0.23	1.08	9.43	0.16	**11.5**	91.7%
Coal		0.0030	0.0048	0.0043	0.010	0.088	0.0015	**0.11**	0.9%
Hydropower		1.9E-04	3.0E-04	2.6E-04	6.2E-04	0.0054	9.1E-05	**0.0069**	0.1%
Nuclear		0.0011	0.0018	0.0016	0.0039	0.034	5.6E-04	**0.043**	0.3%
Wood		0	0	0	0	0	0	**0**	0.0%
Other		1.6E-04	2.6E-04	2.3E-04	5.5E-04	0.0048	8.0E-05	**0.0061**	0.0%
Total		**0.35**	**0.28**	**0.28**	**1.17**	**10.2**	**0.17**	**12.5**	**100.0%**
	%of Total	2.8%	2.3%	2.2%	9.4%	82.0%	1.4%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	0	0	0	0	0	2.84	**2.84**	
	Usable						0.87	**0.87**	

Table 3-3-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	LLDPE					
thou lb/ 10,000 pkgs	0.67	0.67		0.67		
% recycled content	30					

	Unpadded LLDPE Film Bag					
	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)						
By Type						
Process	7.67	0	0	0.021	**7.69**	30.0%
Transport	0.78	1.12	4.92	0.091	**6.92**	27.0%
Energy of Material Resource	11.0	0	0	0	**11.0**	42.9%
Total	**19.4**	**1.12**	**4.92**	**0.11**	**25.6**	**100.0%**
%of Total	75.9%	4.4%	19.2%	0.4%	**100.0%**	
By Source - Process + EMR						
Nat. Gas	12.9	0	0	0.0014	**12.9**	69.2%
Petroleum	2.71	0	0	0.020	**2.73**	14.6%
Coal	2.02	0	0	1.8E-04	**2.02**	10.8%
Hydropower	0.12	0	0	1.1E-05	**0.12**	0.7%
Nuclear	0.77	0	0	7.0E-05	**0.77**	4.1%
Wood	0	0	0	0	**0**	0.0%
Other	0.10	0	0	1.0E-05	**0.10**	0.6%
Total	**18.6**	**0**	**0**	**0.021**	**18.7**	**100.0%**
%of Total	99.9%	0.0%	0.0%	0.1%	**100.0%**	
By Source - Transp						
Nat. Gas	0.11	0.074	0.32	0.0060	**0.52**	7.5%
Petroleum	0.65	1.03	4.53	0.084	**6.30**	91.1%
Coal	0.012	0.0096	0.042	7.8E-04	**0.064**	0.9%
Hydropower	7.3E-04	6.0E-04	0.0026	4.8E-05	**0.0040**	0.1%
Nuclear	0.0045	0.0037	0.016	3.0E-04	**0.025**	0.4%
Wood	0	0	0	0	**0**	0.0%
Other	6.3E-04	5.3E-04	0.0023	4.3E-05	**0.0035**	0.1%
Total	**0.78**	**1.12**	**4.92**	**0.091**	**6.92**	**100.0%**
%of Total	11.3%	16.2%	71.2%	1.3%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs) Gross	0	0	0	2.41	**2.41**	
Usable				0.74	**0.74**	

Table 3-3-BAG
LIFE CYCLE ENERGY RESULTS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.35	0.98	1.33	1.33
% recycled content	30	30		

		Bubble Padded LLDPE Bag						
		LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Energy (MM Btu/10,000 pkgs)								
By Type								
Process		4.52	11.2	0	0	0.042	**15.8**	31.1%
Transport		0.41	1.14	1.17	10.2	0.18	**13.1**	25.9%
Energy of Material Resource		5.71	16.1	0	0	0	**21.8**	43.0%
Total		**10.6**	**28.4**	**1.17**	**10.2**	**0.22**	**50.7**	**100.0%**
	%of Total	21.0%	56.1%	2.3%	20.2%	0.4%	**100.0%**	
By Source - Process + EMR								
Nat. Gas		6.87	18.9	0	0	0.0028	**25.8**	68.6%
Petroleum		1.43	3.97	0	0	0.039	**5.44**	14.5%
Coal		1.29	2.96	0	0	3.6E-04	**4.25**	11.3%
Hydropower		0.079	0.18	0	0	2.3E-05	**0.26**	0.7%
Nuclear		0.49	1.12	0	0	1.4E-04	**1.61**	4.3%
Wood		0	0	0	0	0	**0**	0.0%
Other		0.067	0.15	0	0	2.0E-05	**0.22**	0.6%
Total		**10.2**	**27.3**	**0**	**0**	**0.042**	**37.6**	**100.0%**
	%of Total	27.2%	72.6%	0.0%	0.0%	0.1%	**100.0%**	
By Source - Transp								
Nat. Gas		0.060	0.17	0.077	0.67	0.012	**0.99**	7.5%
Petroleum		0.34	0.95	1.07	9.43	0.17	**12.0**	91.1%
Coal		0.0071	0.017	0.010	0.088	0.0015	**0.12**	0.9%
Hydropower		4.3E-04	0.0011	6.2E-04	0.0054	9.6E-05	**0.0076**	0.1%
Nuclear		0.0027	0.0066	0.0038	0.034	5.9E-04	**0.047**	0.4%
Wood		0	0	0	0	0	**0**	0.0%
Other		3.7E-04	0.0009	5.5E-04	0.0048	8.5E-05	**0.0068**	0.1%
Total		**0.41**	**1.14**	**1.17**	**10.2**	**0.18**	**13.1**	**100.0%**
	%of Total	3.1%	8.7%	8.9%	77.9%	1.4%	**100.0%**	
Energy Credit for Waste-to-Energy Incineration of 20% of MSW after Diversion (MM Btu/10,000 pkgs)	Gross	0	0	0	0	4.78	**4.78**	
	Usable					1.46	**1.46**	

Table 3-4-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Air Pkt
thou lb/ 10,000 pkgs	13.9	0.84
	% recycled content	0

	Box with Inflated Air Packets							
	Box	LDPE Inflated Air Packets	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	966	92.4	0	0	0	0	**1,059**	7.5%
Fuel	3,176	187	0.62	82.4	1.54	0.12	**3,448**	24.6%
Postconsumer	0	0	0	0	8,918	605	**9,523**	67.9%
Total	**4,142**	**279**	**0.62**	**82.4**	**8,920**	**605**	**14,029**	**100.0%**
%of Total	29.5%	2.0%	0.0%	0.6%	63.6%	4.3%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	19.3	1.85	0	0	0	0	**21.2**	4.9%
Fuel	63.5	3.74	0.012	1.65	0.031	0.0024	**69.0**	15.9%
Postconsumer	0	0	0	0	319	24.4	**344**	79.2%
Total	**82.8**	**5.59**	**0.012**	**1.65**	**319**	**24.4**	**434**	**100.0%**
%of Total	19.1%	1.3%	0.0%	0.4%	73.6%	5.6%	**100.0%**	

Table 3-4-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	EPS
thou lb/ 10,000 pkgs	13.9	0.48
	% recycled content	0

	Box with EPS Loose Fill							
	Box	EPS Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	966	24.1	0	0	0	0	**990**	7.3%
Fuel	3,176	187	1.24	81.4	1.54	0.092	**3,447**	25.5%
Postconsumer	0	0	0	0	8,918	173	**9,091**	67.2%
Total	**4,142**	**211**	**1.24**	**81.4**	**8,920**	**173**	**13,529**	**100.0%**
%of Total	30.6%	1.6%	0.0%	0.6%	65.9%	1.3%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	19.3	0.48	0	0	0	0	**19.8**	4.6%
Fuel	63.5	3.75	0.025	1.63	0.031	0.0018	**68.9**	16.1%
Postconsumer	0	0	0	0	319	19.4	**339**	79.2%
Total	**82.8**	**4.23**	**0.025**	**1.63**	**319**	**19.4**	**427**	**100.0%**
%of Total	19.4%	1.0%	0.0%	0.4%	74.7%	4.5%	**100.0%**	

Table 3-4-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Cornstarch
thou lb/ 10,000 pkgs	13.9	0.86

	Box with Cornstarch Loose Fill							
	Box	Cornstarch Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	966	39.5	0	0	0	0	**1,006**	7.4%
Fuel	3,176	119	2.73	82.4	1.54	0.020	**3,381**	24.8%
Postconsumer	0	0	0	0	8,918	310	**9,229**	67.8%
Total	**4,142**	**158**	**2.73**	**82.4**	**8,920**	**310**	**13,616**	**100.0%**
%of Total	30.4%	1.2%	0.0%	0.6%	65.5%	2.3%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	19.3	0.79	0	0	0	0	**20.1**	4.9%
Fuel	63.5	2.37	0.055	1.65	0.031	3.9E-04	**67.6**	16.4%
Postconsumer	0	0	0	0	319	4.20	**323**	78.7%
Total	**82.8**	**3.17**	**0.055**	**1.65**	**319**	**4.20**	**411**	**100.0%**
%of Total	20.1%	0.8%	0.0%	0.4%	77.7%	1.0%	**100.0%**	

Table 3-4-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	1
80% pc box	0

	Box	Mold Pulp
thou lb/ 10,000 pkgs	13.9	3.8

	Box with Molded Pulp Loose Fill							
	Box	Molded Pulp Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	966	190	0	0	0	0	**1,156**	6.8%
Fuel	3,176	840	9.10	89.6	1.54	0.44	**4,116**	24.3%
Postconsumer	0	0	0	0	8,918	2,746	**11,664**	68.9%
Total	**4,142**	**1,030**	9.10	**89.6**	**8,920**	**2,746**	**16,937**	**100.0%**
%of Total	24.5%	6.1%	0.1%	0.5%	52.7%	16.2%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	19.3	3.80	0	0	0	0	**23.1**	4.5%
Fuel	63.5	16.8	0.18	1.79	0.031	0.0088	**82.3**	16.0%
Postconsumer	0	0	0	0	319	90.4	**410**	79.5%
Total	**82.8**	**20.6**	0.18	**1.79**	**319**	**90.4**	**515**	**100.0%**
%of Total	16.1%	4.0%	0.0%	0.3%	62.0%	17.5%	**100.0%**	

Table 3-4-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Unbl Kr
thou lb/ 10,000 pkgs	13.9	1.8
	% recycled content	0

	Box	Unbleached Kraft Paper Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
	Box with Unbleached Kraft Paper Dunnage							
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	966	136	0	0	0	0	**1,102**	7.3%
Fuel	3,176	453	0.14	85.0	1.54	0.23	**3,715**	24.7%
Postconsumer	0	0	0	0	8,918	1,299	**10,218**	68.0%
Total	**4,142**	**589**	**0.14**	**85.0**	**8,920**	**1,300**	**15,035**	**100.0%**
%of Total	27.5%	3.9%	0.0%	0.6%	59.3%	8.6%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	19.3	2.72	0	0	0	0	**22.0**	4.8%
Fuel	63.5	9.05	0.0027	1.70	0.031	0.0046	**74.3**	16.1%
Postconsumer	0	0	0	0	319	47.4	**367**	79.2%
Total	**82.8**	**11.8**	**0.0027**	**1.70**	**319**	**47.4**	**463**	**100.0%**
%of Total	17.9%	2.5%	0.0%	0.4%	69.0%	10.2%	**100.0%**	

Table 3-4-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Newsprint
thou lb/ 10,000 pkgs	13.9	1.7
% recycled content		10

	Box	Newsprint Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
	Box with Newsprint Dunnage							
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	966	243	0	0	0	0	**1,209**	8.0%
Fuel	3,176	530	0.11	84.6	1.54	0.22	**3,792**	25.0%
Postconsumer	0	0	0	0	8,918	1,228	**10,147**	67.0%
Total	**4,142**	**773**	**0.11**	**84.6**	**8,920**	**1,229**	**15,148**	**100.0%**
%of Total	27.3%	5.1%	0.0%	0.6%	58.9%	8.1%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	19.3	4.86	0	0	0	0	**24.2**	5.2%
Fuel	63.5	10.60	0.0021	1.69	0.031	0.0043	**75.8**	16.3%
Postconsumer	0	0	0	0	319	44.7	**364**	78.4%
Total	**82.8**	**15.5**	**0.0021**	**1.69**	**319**	**44.8**	**464**	**100.0%**
%of Total	17.9%	3.3%	0.0%	0.4%	68.8%	9.6%	**100.0%**	

Table 3-4-BOX

LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE

LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	PC Off Ppr
thou lb/ 10,000 pkgs	13.9	1.5

	Box with Shredded PC Office Paper Dunnage						
	Box	Shredded PC Office Paper Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes							
By Weight (lb/10,000 pkgs)							
Process	966	0	0	0	0	**966**	6.8%
Fuel	3,176	8.90	84.0	1.54	0.19	**3,271**	23.0%
Postconsumer	0	0	0	8,918	1,083	**10,001**	70.2%
Total	**4,142**	**8.90**	**84.0**	**8,920**	**1,083**	**14,238**	**100.0%**
%of Total	29.1%	0.1%	0.6%	62.6%	7.6%	**100.0%**	
By Volume (cu ft/10,000 pkgs)							
Process	19.3	0	0	0	0	**19.3**	4.4%
Fuel	63.5	0.18	1.68	0.031	0.0038	**65.4**	14.7%
Postconsumer	0	0	0	319	39.5	**359**	80.9%
Total	**82.8**	**0.18**	**1.68**	**319**	**39.5**	**443**	**100.0%**
%of Total	18.7%	0.0%	0.4%	72.0%	8.9%	**100.0%**	

Table 3-4-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	1
80% pc box	0

	Box	PC Corrug
thou lb/ 10,000 pkgs	13.9	3.2

	Box with Shredded PC Corrugated Dunnage						
	Box	Shredded PC Corrugated Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes							
By Weight (lb/10,000 pkgs)							
Process	966	0	0	0	0	**966**	6.2%
Fuel	3,176	6.04	88.2	1.54	0.40	**3,272**	21.1%
Postconsumer	0	0	0	8,918	2,333	**11,252**	72.6%
Total	**4,142**	**6.04**	**88.2**	**8,920**	**2,334**	**15,490**	**100.0%**
%of Total	26.7%	0.0%	0.6%	57.6%	15.1%	**100.0%**	
By Volume (cu ft/10,000 pkgs)							
Process	19.3	0	0	0	0	**19.3**	4.0%
Fuel	63.5	0.12	1.76	0.031	0.0080	**65.4**	13.4%
Postconsumer	0	0	0	319	83.5	**403**	82.6%
Total	**82.8**	**0.12**	**1.76**	**319**	**83.5**	**488**	**100.0%**
%of Total	17.0%	0.0%	0.4%	65.5%	17.1%	**100.0%**	

Table 3-4-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr		
thou lb/ 10,000 pkgs	1.4	1.4	1.4
% recycled content			

	Unpadded Bleached Kraft Bag					
	Bleached Kraft	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes						
By Weight (lb/10,000 pkgs)						
Process	166	0	0	0	**166**	9.9%
Fuel	491	1.03	8.25	0.18	**500**	29.8%
Postconsumer	0	0	0	1,011	**1,011**	60.3%
Total	**656**	**1.03**	**8.25**	**1,011**	**1,676**	**100.0%**
%of Total	39.2%	0.1%	0.5%	60.3%	**100.0%**	
By Volume (cu ft/10,000 pkgs)						
Process	3.31	0	0	0	**3.31**	6.6%
Fuel	9.81	0.021	0.16	0.0036	**10.0**	19.9%
Postconsumer	0	0	0	36.8	**36.8**	73.4%
Total	**13.1**	**0.021**	**0.16**	**36.8**	**50.1**	**100.0%**
%of Total	26.2%	0.0%	0.3%	73.5%	**100.0%**	

Table 3-4-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr	Unbl Kr				
thou lb/ 10,000 pkgs	1	0.9	1.9	3.8		3.8
% recycled content						

	All-Paper Padded Kraft Bag							
	Bleached Kraft	Unbleached Kraft	Macerated PC Newspaper Padding	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	118	68.0	0	0	0	0	**186**	5.3%
Fuel	350	226	12.3	2.79	20.8	0.48	**613**	17.3%
Postconsumer	0	0	0	0	0	2,744	**2,744**	77.4%
Total	**469**	**294**	**12.3**	**2.79**	**20.8**	**2,745**	**3,544**	**100.0%**
%of Total	13.2%	8.3%	0.3%	0.1%	0.6%	77.4%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	2.37	1.36	0	0	0	0	**3.73**	3.2%
Fuel	7.01	4.53	0.25	0.056	0.42	0.0097	**12.3**	10.6%
Postconsumer	0	0	0	0	0	100	**100**	86.2%
Total	**9.38**	**5.89**	**0.25**	**0.056**	**0.42**	**100**	**116**	**100.0%**
%of Total	8.1%	5.1%	0.2%	0.0%	0.4%	86.2%	**100.0%**	

Table 3-4-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.86	0.24	0.24	1.34	1.34
% recycled content					

	Bubble Padded Kraft Bag							
	Bleached Kraft	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	102	24.0	24.6	0	0	0	**150**	9.9%
Fuel	301	53.2	42.5	0.99	8.58	0.18	**407**	26.7%
Postconsumer	0	0	0	0	0	966	**966**	63.4%
Total	**403**	**77.2**	**67.1**	**0.99**	**8.58**	**967**	**1,523**	**100.0%**
%of Total	26.5%	5.1%	4.4%	0.1%	0.6%	63.4%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	2.03	0.48	0.49	0	0	0	**3.01**	6.3%
Fuel	6.03	1.06	0.85	0.020	0.17	0.0035	**8.13**	17.1%
Postconsumer	0	0	0	0	0	36.5	**36.5**	76.6%
Total	**8.06**	**1.54**	**1.34**	**0.020**	**0.17**	**36.5**	**47.6**	**100.0%**
%of Total	16.9%	3.2%	2.8%	0.0%	0.4%	76.6%	**100.0%**	

Table 3-4-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	LLDPE		
thou lb/ 10,000 pkgs	0.67	0.67	0.67
% recycled content			

	Unpadded LLDPE Film Bag					
	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes						
By Weight (lb/10,000 pkgs)						
Process	68.7	0	0	0	**68.7**	10.2%
Fuel	119	0.94	4.13	0.094	**124**	18.3%
Postconsumer	0	0	0	482	**482**	71.5%
Total	**187**	**0.94**	**4.13**	**482**	**675**	**100.0%**
%of Total	27.7%	0.1%	0.6%	71.5%	**100.0%**	
By Volume (cu ft/10,000 pkgs)						
Process	1.37	0	0	0	**1.37**	5.9%
Fuel	2.37	0.019	0.083	0.0019	**2.47**	10.6%
Postconsumer	0	0	0	19.4	**19.4**	83.5%
Total	**3.74**	**0.019**	**0.083**	**19.4**	**23.3**	**100.0%**
%of Total	16.1%	0.1%	0.4%	83.5%	**100.0%**	

Table 3-4-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.35	0.98	1.33	1.33
% recycled content				

	Bubble Padded LLDPE Bag						
	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes							
By Weight (lb/10,000 pkgs)							
Process	35.0	100	0	0	0	**135**	10.0%
Fuel	77.5	173	0.98	8.58	0.19	**261**	19.3%
Postconsumer	0	0	0	0	958	**958**	70.7%
Total	**113**	**274**	**0.98**	**8.58**	**958**	**1,354**	**100.0%**
%of Total	8.3%	20.2%	0.1%	0.6%	70.8%	**100.0%**	
By Volume (cu ft/10,000 pkgs)							
Process	0.70	2.01	0	0	0	**2.71**	5.8%
Fuel	1.55	3.47	0.020	0.17	0.0037	**5.21**	11.2%
Postconsumer	0	0	0	0	38.6	**38.6**	83.0%
Total	**2.25**	**5.48**	**0.020**	**0.17**	**38.6**	**46.5**	**100.0%**
%of Total	4.8%	11.8%	0.0%	0.4%	83.0%	**100.0%**	

Table 3-5-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Air Pkt
thou lb/ 10,000 pkgs	13.9	0.84
% recycled content		30

	Box with Inflated Air Packets							
	Box	LDPE Inflated Air Packets	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	726	97.7	0	0	0	0	**823**	6.1%
Fuel	2,918	164	0.62	82.4	1.54	0.12	**3,167**	23.4%
Postconsumer	0	0	0	0	8,918	605	**9,523**	70.5%
Total	**3,644**	**262**	**0.62**	**82.4**	**8,920**	**605**	**13,514**	**100.0%**
%of Total	27.0%	1.9%	0.0%	0.6%	66.0%	4.5%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	14.5	1.95	0	0	0	0	**16.5**	3.9%
Fuel	58.4	3.29	0.012	1.65	0.031	0.0024	**63.3**	15.0%
Postconsumer	0	0	0	0	319	24.4	**344**	81.2%
Total	**72.9**	**5.24**	**0.012**	**1.65**	**319**	**24.4**	**423**	**100.0%**
%of Total	17.2%	1.2%	0.0%	0.4%	75.4%	5.8%	**100.0%**	

Table 3-5-BOX

LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	EPS
thou lb/ 10,000 pkgs	13.9	0.48
	% recycled content	30

	Box	EPS Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
	Box with EPS Loose Fill							
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	726	31.3	0	0	0	0	**757**	5.8%
Fuel	2,918	170	1.63	81.4	1.54	0.092	**3,173**	24.4%
Postconsumer	0	0	0	0	8,918	173	**9,091**	69.8%
Total	**3,644**	**201**	**1.63**	**81.4**	**8,920**	**173**	**13,021**	**100.0%**
%of Total	28.0%	1.5%	0.0%	0.6%	68.5%	1.3%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	14.5	0.63	0	0	0	0	**15.1**	3.6%
Fuel	58.4	3.40	0.033	1.63	0.031	0.0018	**63.5**	15.2%
Postconsumer	0	0	0	0	319	19.4	**339**	81.2%
Total	**72.9**	**4.03**	**0.033**	**1.63**	**319**	**19.4**	**417**	**100.0%**
%of Total	17.5%	1.0%	0.0%	0.4%	76.5%	4.7%	**100.0%**	

Table 3-5-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	0
80% pc box	1

	Box	Cornstarch
thou lb/ 10,000 pkgs	13.9	0.86

	Box with Cornstarch Loose Fill							
	Box	Cornstarch Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	726	39.5	0	0	0	0	**765**	5.8%
Fuel	2,918	119	2.73	82.4	1.54	0.020	**3,124**	23.8%
Postconsumer	0	0	0	0	8,918	310	**9,229**	70.4%
Total	**3,644**	**158**	**2.73**	**82.4**	**8,920**	**310**	**13,118**	**100.0%**
%of Total	27.8%	1.2%	0.0%	0.6%	68.0%	2.4%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	14.5	0.79	0	0	0	0	**15.3**	3.8%
Fuel	58.4	2.37	0.055	1.65	0.031	3.9E-04	**62.5**	15.6%
Postconsumer	0	0	0	0	319	4.20	**323**	80.6%
Total	**72.9**	**3.17**	**0.055**	**1.65**	**319**	**4.20**	**401**	**100.0%**
%of Total	18.2%	0.8%	0.0%	0.4%	79.6%	1.0%	**100.0%**	

Table 3-5-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	0
80% pc box	1

	Box	Mold Pulp
thou lb/ 10,000 pkgs	13.9	3.8

	Box with Molded Pulp Loose Fill							
	Box	Molded Pulp Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	726	190	0	0	0	0	**916**	5.6%
Fuel	2,918	840	9.10	89.6	1.54	0.44	**3,859**	23.5%
Postconsumer	0	0	0	0	8,918	2,746	**11,664**	71.0%
Total	**3,644**	**1,030**	9.10	**89.6**	**8,920**	**2,746**	**16,439**	**100.0%**
%of Total	22.2%	6.3%	0.1%	0.5%	54.3%	16.7%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	14.5	3.80	0	0	0	0	**18.3**	3.6%
Fuel	58.4	16.8	0.18	1.79	0.031	0.0088	**77.2**	15.3%
Postconsumer	0	0	0	0	319	90.4	**410**	81.1%
Total	**72.9**	**20.6**	0.18	**1.79**	**319**	**90.4**	**505**	**100.0%**
%of Total	14.4%	4.1%	0.0%	0.4%	63.2%	17.9%	**100.0%**	

Table 3-5-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Unbl Kr
thou lb/ 10,000 pkgs	13.9	1.8
	% recycled content	50

	Box	Unbleached Kraft Paper Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	TOTAL	% of Total
	Box with Unbleached Kraft Paper Dunnage							
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	726	124	0	0	0	0	**850**	5.9%
Fuel	2,918	389	0.14	85.0	1.54	0.23	**3,395**	23.5%
Postconsumer	0	0	0	0	8,918	1,299	**10,218**	70.7%
Total	**3,644**	**513**	**0.14**	**85.0**	**8,920**	**1,300**	**14,462**	**100.0%**
%of Total	25.2%	3.6%	0.0%	0.6%	61.7%	9.0%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	14.5	2.48	0	0	0	0	**17.0**	3.8%
Fuel	58.4	7.79	0.0027	1.70	0.031	0.0046	**67.9**	15.0%
Postconsumer	0	0	0	0	319	47.4	**367**	81.2%
Total	**72.9**	**10.3**	**0.0027**	**1.70**	**319**	**47.4**	**452**	**100.0%**
%of Total	16.1%	2.3%	0.0%	0.4%	70.7%	10.5%	**100.0%**	

Table 3-5-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Newsprint
thou lb/ 10,000 pkgs	13.9	1.7
% recycled content		50

	Box with Newsprint Dunnage							
	Box	Newsprint Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	726	279	0	0	0	0	**1,004**	6.9%
Fuel	2,918	331	0.11	84.6	1.54	0.22	**3,336**	23.0%
Postconsumer	0	0	0	0	8,918	1,228	**10,147**	70.0%
Total	**3,644**	**609**	**0.11**	**84.6**	**8,920**	**1,229**	**14,487**	**100.0%**
%of Total	25.2%	4.2%	0.0%	0.6%	61.6%	8.5%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	14.5	5.57	0	0	0	0	**20.1**	4.5%
Fuel	58.4	6.62	0.0021	1.69	0.031	0.0043	**66.7**	14.8%
Postconsumer	0	0	0	0	319	44.7	**364**	80.7%
Total	**72.9**	**12.2**	**0.0021**	**1.69**	**319**	**44.8**	**451**	**100.0%**
%of Total	16.2%	2.7%	0.0%	0.4%	70.8%	9.9%	**100.0%**	

Table 3-5-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

	select box by entering 1	
avg box	0	
80% pc box	1	
	Box	PC Off Ppr
thou lb/ 10,000 pkgs	13.9	1.5

	Box with Shredded PC Office Paper Dunnage						
	Box	Shredded PC Office Paper Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes							
By Weight (lb/10,000 pkgs)							
Process	726	0	0	0	0	**726**	5.3%
Fuel	2,918	8.90	84.0	1.54	0.19	**3,013**	21.9%
Postconsumer	0	0	0	8,918	1,083	**10,001**	72.8%
Total	**3,644**	**8.90**	**84.0**	**8,920**	**1,083**	**13,740**	**100.0%**
%of Total	26.5%	0.1%	0.6%	64.9%	7.9%	**100.0%**	
By Volume (cu ft/10,000 pkgs)							
Process	14.5	0	0	0	0	**14.5**	3.3%
Fuel	58.4	0.18	1.68	0.031	0.0038	**60.3**	13.9%
Postconsumer	0	0	0	319	39.5	**359**	82.8%
Total	**72.9**	**0.18**	**1.68**	**319**	**39.5**	**434**	**100.0%**
%of Total	16.8%	0.0%	0.4%	73.7%	9.1%	**100.0%**	

Table 3-5-BOX
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	0
80% pc box	1

	Box	PC Corrug
thou lb/ 10,000 pkgs	13.9	3.2

	Box with Shredded PC Corrugated Dunnage						
	Box	Shredded PC Corrugated Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Solid Wastes							
By Weight (lb/10,000 pkgs)							
Process	726	0	0	0	0	**726**	4.8%
Fuel	2,918	6.04	88.2	1.54	0.40	**3,015**	20.1%
Postconsumer	0	0	0	8,918	2,333	**11,252**	75.1%
Total	**3,644**	**6.04**	**88.2**	**8,920**	**2,334**	**14,992**	**100.0%**
%of Total	24.3%	0.0%	0.6%	59.5%	15.6%	**100.0%**	
By Volume (cu ft/10,000 pkgs)							
Process	14.5	0	0	0	0	**14.5**	3.0%
Fuel	58.4	0.12	1.76	0.031	0.0080	**60.3**	12.6%
Postconsumer	0	0	0	319	83.5	**403**	84.3%
Total	**72.9**	**0.12**	**1.76**	**319**	**83.5**	**478**	**100.0%**
%of Total	15.3%	0.0%	0.4%	66.9%	17.5%	**100.0%**	

Table 3-5-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr		
thou lb/ 10,000 pkgs	1.4	1.4	1.4
% recycled content	30		

	Unpadded Bleached Kraft Bag					
	Bleached Kraft	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes						
By Weight (lb/10,000 pkgs)						
Process	142	0	0	0	**142**	9.0%
Fuel	420	1.03	8.25	0.18	**429**	27.1%
Postconsumer	0	0	0	1,011	**1,011**	63.9%
Total	**562**	**1.03**	**8.25**	**1,011**	**1,582**	**100.0%**
%of Total	35.5%	0.1%	0.5%	63.9%	**100.0%**	
By Volume (cu ft/10,000 pkgs)						
Process	2.84	0	0	0	**2.84**	5.9%
Fuel	8.39	0.021	0.16	0.0036	**08.6**	17.8%
Postconsumer	0	0	0	36.8	**36.8**	76.3%
Total	**11.2**	**0.021**	**0.16**	**36.8**	**48.3**	**100.0%**
%of Total	23.3%	0.0%	0.3%	76.3%	**100.0%**	

Table 3-5-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr	Unbl Kr			
thou lb/ 10,000 pkgs	1	0.9	1.9	3.8	3.8
% recycled content	30	30			

	All-Paper Padded Kraft Bag							
	Bleached Kraft	Unbleached Kraft	Macerated PC Newspaper Padding	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	101	64.4	0	0	0	0	**166**	4.8%
Fuel	300	207	12.3	2.79	20.8	0.48	**544**	15.7%
Postconsumer	0	0	0	0	0	2,744	**2,744**	79.5%
Total	**401**	**272**	**12.3**	**2.79**	**20.8**	**2,745**	**3,454**	**100.0%**
%of Total	11.6%	7.9%	0.4%	0.1%	0.6%	79.5%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	2.03	1.29	0	0	0	0	**3.32**	2.9%
Fuel	5.99	4.15	0.25	0.056	0.42	0.0097	**10.9**	9.5%
Postconsumer	0	0	0	0	0	100	**100**	87.6%
Total	**8.02**	**5.44**	**0.25**	**0.056**	**0.42**	**100**	**114**	**100.0%**
%of Total	7.0%	4.8%	0.2%	0.0%	0.4%	87.6%	**100.0%**	

Table 3-5-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.86	0.24	0.24	1.34	1.34
% recycled content	30	30	30		

	Bubble Padded Kraft Bag							
	Bleached Kraft	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes								
By Weight (lb/10,000 pkgs)								
Process	87	25.5	25.9	0	0	0	**139**	9.5%
Fuel	258	46.7	39.2	0.99	8.58	0.18	**353**	24.2%
Postconsumer	0	0	0	0	0	966	**966**	66.3%
Total	**345**	**72.2**	**65.2**	**0.99**	**8.58**	**967**	**1,459**	**100.0%**
%of Total	23.7%	5.0%	4.5%	0.1%	0.6%	66.3%	**100.0%**	
By Volume (cu ft/10,000 pkgs)								
Process	1.75	0.51	0.52	0	0	0	**2.77**	6.0%
Fuel	5.15	0.93	0.78	0.020	0.17	0.0035	**7.07**	15.3%
Postconsumer	0	0	0	0	0	36.5	**36.5**	78.7%
Total	**6.90**	**1.44**	**1.30**	**0.020**	**0.17**	**36.5**	**46.3**	**100.0%**
%of Total	14.9%	3.1%	2.8%	0.0%	0.4%	78.7%	**100.0%**	

Table 3-5-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	LLDPE		
thou lb/ 10,000 pkgs	0.67	0.67	0.67
% recycled content	30		

	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	TOTAL	% of Total
	Unpadded LLDPE Film Bag					
Solid Wastes						
By Weight (lb/10,000 pkgs)						
Process	72.4	0	0	0	**72.4**	10.8%
Fuel	110	0.94	4.13	0.094	**115**	17.1%
Postconsumer	0	0	0	482	**482**	72.1%
Total	**182**	**0.94**	**4.13**	**482**	**669**	**100.0%**
%of Total	27.2%	0.1%	0.6%	72.1%	**100.0%**	
By Volume (cu ft/10,000 pkgs)						
Process	1.45	0	0	0	**1.45**	6.2%
Fuel	2.19	0.019	0.083	0.0019	**2.29**	9.9%
Postconsumer	0	0	0	19.4	**19.4**	83.9%
Total	**3.64**	**0.019**	**0.083**	**19.4**	**23.2**	**100.0%**
%of Total	15.7%	0.1%	0.4%	83.9%	**100.0%**	

Table 3-5-BAG
LIFE CYCLE SOLID WASTES FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.35	0.98	1.33	1.33
% recycled content	30	30		

	Bubble Padded LLDPE Bag						
	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Solid Wastes							
By Weight (lb/10,000 pkgs)							
Process	37.2	105.9	0	0	0	**143**	10.7%
Fuel	68.1	160	0.98	8.58	0.19	**238**	17.8%
Postconsumer	0	0	0	0	958	**958**	71.5%
Total	**105**	**266**	**0.98**	**8.58**	**958**	**1,339**	**100.0%**
%of Total	7.9%	19.9%	0.1%	0.6%	71.5%	**100.0%**	
By Volume (cu ft/10,000 pkgs)							
Process	0.74	2.12	0	0	0	**2.86**	6.2%
Fuel	1.36	3.20	0.020	0.17	0.0037	**4.76**	10.3%
Postconsumer	0	0	0	0	38.6	**38.6**	83.5%
Total	**2.11**	**5.32**	**0.020**	**0.17**	**38.6**	**46.2**	**100.0%**
%of Total	4.6%	11.5%	0.0%	0.4%	83.5%	**100.0%**	

Table 3-6-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Air Pkt
thou lb/ 10,000 pkgs	13.9	0.84
	% recycled content	0

	Box with Inflated Air Packets							
	Box	LDPE Inflated Air Packets	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	46.1	1.47	0.15	20.1	0.74	0.057	**68.6**	
Nitrogen Oxides	118	8.17	1.02	134	4.07	0.31	**266**	
Hydrocarbons	18.0	15.2	0.41	54.5	1.17	0.090	**89.4**	
Sulfur Oxides	210	44.7	0.29	38.1	0.71	0.054	**293**	
Carbon Monoxide	187	6.09	1.00	138	3.12	0.24	**336**	
Aldehydes	0.45	0.051	0.028	3.64	0.073	0.0056	**4.25**	
Methane	33.4	9.31	0.019	2.51	0.047	0.0036	**45.3**	
Other Organics	4.84	0.48	0.54	73.4	1.75	0.13	**81.2**	
Odorous Sulfur	0.40	0	0	0	0	0	**0.40**	
Kerosene	0.0018	2.9E-04	4.9E-07	6.5E-05	1.2E-06	9.3E-08	**0.0022**	
Ammonia	0.65	0.0044	1.9E-04	0.025	4.7E-04	3.6E-05	**0.68**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.050	0.0079	1.5E-05	0.0020	3.8E-05	2.9E-06	**0.060**	
Lead	0.010	4.5E-05	6.3E-07	5.3E-04	1.6E-06	1.2E-07	**0.011**	
Mercury	9.1E-04	2.3E-05	1.2E-07	1.6E-05	3.0E-07	2.3E-08	**9.5E-04**	
Chlorine	0.065	6.1E-05	7.2E-06	9.6E-04	1.8E-05	1.4E-06	**0.067**	
HCl	0.36	0.057	1.2E-04	0.015	2.9E-04	2.2E-05	**0.43**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	16,318	1,866	119	15,797	294	22.6	**34,417**	
CO2 (non-fossil)	17,508	0.53	0.028	3.79	0.071	0.0054	**17,512**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	7.14	2.1E-04	1.2E-05	0.0015	2.9E-05	2.2E-06	**7.14**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.3E-05	7.2E-06	1.8E-07	2.4E-05	4.4E-07	3.4E-08	**8.5E-05**	
Arsenic	0.0037	4.3E-05	3.7E-07	4.9E-05	9.1E-07	7.0E-08	**0.0038**	
Beryllium	3.4E-04	5.0E-06	2.6E-08	3.4E-06	6.4E-08	4.9E-09	**3.5E-04**	
Cadmium	9.6E-04	1.6E-05	5.5E-07	7.3E-05	1.4E-06	1.1E-07	**0.0010**	
Chromium	0.0062	6.9E-05	4.2E-07	5.6E-05	1.0E-06	8.0E-08	**0.0063**	
Cobalt	1.5E-04	2.0E-05	5.0E-07	6.7E-05	1.2E-06	9.6E-08	**2.4E-04**	
Manganese	0.085	1.3E-04	5.0E-07	6.7E-05	1.2E-06	9.6E-08	**0.085**	
Nickel	0.0096	2.4E-04	7.8E-06	0.0010	1.9E-05	1.5E-06	**0.011**	
Selenium	5.3E-04	8.2E-05	3.4E-07	4.5E-05	8.4E-07	6.4E-08	**6.6E-04**	
Acreolin	7.2E-05	1.1E-05	2.2E-08	2.9E-06	5.4E-08	4.2E-09	**8.6E-05**	
Nitrous Oxide	0.16	0.0071	1.3E-05	0.0018	3.3E-05	2.5E-06	**0.17**	
Benzene	0.031	1.6E-05	7.0E-08	9.3E-06	1.7E-07	1.3E-08	**0.031**	
Perchloroethylene	6.8E-05	1.1E-05	2.1E-08	2.9E-06	5.4E-08	4.1E-09	**8.2E-05**	
Trichloroethylene	6.8E-05	1.1E-05	2.1E-08	2.7E-06	5.1E-08	3.9E-09	**8.1E-05**	
Methylene Chloride	3.0E-04	4.8E-05	9.6E-08	1.3E-05	2.4E-07	1.8E-08	**3.6E-04**	
Carbon Tetrachloride	1.2E-04	1.8E-05	8.8E-08	1.2E-05	2.2E-07	1.7E-08	**1.5E-04**	
Phenols	0.32	3.4E-05	5.7E-07	7.6E-05	1.4E-06	1.1E-07	**0.32**	
Naphthalene	0.020	8.6E-07	3.3E-08	4.3E-06	8.1E-08	6.2E-09	**0.020**	
Dioxins	3.9E-10	6.2E-11	1.2E-13	1.6E-11	3.0E-13	2.3E-14	**4.7E-10**	
n-nitrosodimethlamine	1.5E-05	2.4E-06	4.6E-09	6.1E-07	1.1E-08	8.8E-10	**1.8E-05**	
Radionuclides	0.0012	1.9E-04	4.1E-07	5.4E-05	1.0E-06	7.8E-08	**0.0015**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	16,318	1,866	119	15,797	294	22.6	**34,417**	96.9%
Methane	769	214	0.43	57.8	1.08	0.083	**1042**	2.9%
Nitrous Oxide	48.4	2.11	0.0039	0.52	0.0098	7.5E-04	**51.1**	0.1%
Total	**17,135**	**2,082**	**119**	**15,855**	**296**	**22.7**	**35,510**	**100.0%**
%of Total	48.3%	5.9%	0.3%	44.6%	0.8%	0.1%	**100.0%**	

Table 3-6-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	1
80% pc box	0

	Box	EPS
thou lb/ 10,000 pkgs	13.9	0.48
% recycled content		0

	Box with EPS Loose Fill							
	Box	EPS Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	46.1	1.28	0.29	19.8	0.74	0.044	**68.3**	
Nitrogen Oxides	118	7.92	2.04	133	4.07	0.24	**265**	
Hydrocarbons	18.0	10.42	0.82	53.9	1.17	0.070	**84.4**	
Sulfur Oxides	210	28.6	0.58	37.7	0.71	0.043	**277**	
Carbon Monoxide	187	4.31	2.01	137	3.12	0.19	**334**	
Aldehydes	0.45	0.060	0.056	3.60	0.073	0.0044	**4.24**	
Methane	33.4	5.98	0.038	2.48	0.047	0.0028	**42.0**	
Other Organics	4.84	0.36	1.09	72.6	1.75	0.10	**80.7**	
Odorous Sulfur	0.40	0	0	0	0	0	**0.40**	
Kerosene	0.0018	2.7E-04	9.7E-07	6.4E-05	1.2E-06	7.3E-08	**0.0022**	
Ammonia	0.65	0.0056	3.8E-04	0.025	4.7E-04	2.8E-05	**0.68**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.050	0.0072	3.0E-05	0.0020	3.8E-05	2.3E-06	**0.059**	
Lead	0.010	6.4E-05	1.3E-06	5.2E-04	1.6E-06	9.4E-08	**0.011**	
Mercury	9.1E-04	2.4E-05	2.4E-07	1.6E-05	3.0E-07	1.8E-08	**9.5E-04**	
Chlorine	0.065	1.2E-04	1.4E-05	9.4E-04	1.8E-05	1.1E-06	**0.067**	
HCl	0.36	0.052	2.3E-04	0.015	2.9E-04	1.7E-05	**0.43**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	16,318	2,181	238	15,609	294	17.7	**34,658**	
CO2 (non-fossil)	17,508	0.58	0.057	3.74	0.071	0.0042	**17,512**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	7.14	2.4E-04	2.3E-05	0.0015	2.9E-05	1.7E-06	**7.14**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.3E-05	1.4E-05	3.6E-07	2.3E-05	4.4E-07	2.6E-08	**9.1E-05**	
Arsenic	0.0037	5.3E-05	7.3E-07	4.8E-05	9.1E-07	5.5E-08	**0.0038**	
Beryllium	3.4E-04	5.4E-06	5.1E-08	3.4E-06	6.4E-08	3.8E-09	**3.5E-04**	
Cadmium	9.6E-04	3.7E-05	1.1E-06	7.2E-05	1.4E-06	8.2E-08	**0.0011**	
Chromium	0.0062	7.9E-05	8.4E-07	5.5E-05	1.0E-06	6.3E-08	**0.0064**	
Cobalt	1.5E-04	3.9E-05	1.0E-06	6.6E-05	1.2E-06	7.5E-08	**2.6E-04**	
Manganese	0.085	1.3E-04	1.0E-06	6.6E-05	1.2E-06	7.5E-08	**0.085**	
Nickel	0.0096	5.4E-04	1.6E-05	0.0010	1.9E-05	1.2E-06	**0.011**	
Selenium	5.3E-04	8.3E-05	6.7E-07	4.4E-05	8.4E-07	5.0E-08	**6.6E-04**	
Acreolin	7.2E-05	1.0E-05	4.4E-08	2.9E-06	5.4E-08	3.3E-09	**8.5E-05**	
Nitrous Oxide	0.16	0.0065	2.7E-05	0.0017	3.3E-05	2.0E-06	**0.17**	
Benzene	0.031	1.5E-05	1.4E-07	9.2E-06	1.7E-07	1.0E-08	**0.031**	
Perchloroethylene	6.8E-05	9.9E-06	4.3E-08	2.8E-06	5.4E-08	3.2E-09	**8.1E-05**	
Trichloroethylene	6.8E-05	9.8E-06	4.1E-08	2.7E-06	5.1E-08	3.1E-09	**8.0E-05**	
Methylene Chloride	3.0E-04	4.4E-05	1.9E-07	1.3E-05	2.4E-07	1.4E-08	**3.6E-04**	
Carbon Tetrachloride	1.2E-04	1.7E-05	1.8E-07	1.2E-05	2.2E-07	1.3E-08	**1.5E-04**	
Phenols	0.32	3.3E-05	1.1E-06	7.5E-05	1.4E-06	8.5E-08	**0.32**	
Naphthalene	0.020	9.0E-07	6.5E-08	4.3E-06	8.1E-08	4.9E-09	**0.020**	
Dioxins	3.9E-10	5.7E-11	2.4E-13	1.6E-11	3.0E-13	1.8E-14	**4.6E-10**	
n-nitrosodimethlamine	1.5E-05	2.2E-06	9.2E-09	6.1E-07	1.1E-08	6.9E-10	**1.8E-05**	
Radionuclides	0.0012	1.8E-04	8.1E-07	5.3E-05	1.0E-06	6.1E-08	**0.0014**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	16,318	2,181	238	15,609	294	17.7	**34,658**	97.2%
Methane	769	138	0.87	57.1	1.08	0.065	**965**	2.7%
Nitrous Oxide	48.4	1.94	0.008	0.52	0.0098	5.9E-04	**50.9**	0.1%
Total	**17,135**	**2,321**	**239**	**15,666**	**296**	**17.7**	**35,674**	**100.0%**
%of Total	48.0%	6.5%	0.7%	43.9%	0.8%	0.0%	**100.0%**	

Table 3-6-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Cornstarch
thou lb/ 10,000 pkgs	13.9	0.86

	Box with Cornstarch Loose Fill							
	Box	Cornstarch Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	46.1	1.68	0.65	20.1	0.74	0.0094	**69.2**	
Nitrogen Oxides	118	3.94	4.51	134	4.07	0.052	**265**	
Hydrocarbons	18.0	1.62	1.81	54.6	1.17	0.015	**77.2**	
Sulfur Oxides	210	7.00	1.28	38.2	0.71	0.0090	**257**	
Carbon Monoxide	187	1.48	4.43	139	3.12	0.039	**335**	
Aldehydes	0.45	0.034	0.12	3.64	0.073	9.2E-04	**4.32**	
Methane	33.4	1.69	0.083	2.51	0.047	6.0E-04	**37.7**	
Other Organics	4.84	0.43	2.40	73.5	1.75	0.022	**82.9**	
Odorous Sulfur	0.40	0	0	0	0	0	**0.40**	
Kerosene	0.0018	2.1E-04	2.1E-06	6.5E-05	1.2E-06	1.5E-08	**0.0021**	
Ammonia	0.65	0.019	8.3E-04	0.025	4.7E-04	5.9E-06	**0.70**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.050	0.0056	6.7E-05	0.0020	3.8E-05	4.8E-07	**0.058**	
Lead	0.010	3.4E-05	2.8E-06	5.3E-04	1.6E-06	2.0E-08	**0.011**	
Mercury	9.1E-04	1.7E-05	5.3E-07	1.6E-05	3.0E-07	3.8E-09	**9.4E-04**	
Chlorine	0.065	1.2E-05	3.2E-05	9.6E-04	1.8E-05	2.3E-07	**0.066**	
HCl	0.36	0.040	5.1E-04	0.015	2.9E-04	3.6E-06	**0.42**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	16,318	884	525	15,807	294	3.74	**33,833**	
CO2 (non-fossil)	17,508	0.56	0.13	3.79	0.071	9.0E-04	**17,512**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	7.14	1.1E-04	5.1E-05	0.0015	2.9E-05	3.7E-07	**7.14**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.3E-05	5.5E-06	7.8E-07	2.4E-05	4.4E-07	5.6E-09	**8.3E-05**	
Arsenic	0.0037	4.4E-05	1.6E-06	4.9E-05	9.1E-07	1.2E-08	**0.0038**	
Beryllium	3.4E-04	5.1E-06	1.1E-07	3.4E-06	6.4E-08	8.1E-10	**3.5E-04**	
Cadmium	9.6E-04	1.6E-05	2.4E-06	7.3E-05	1.4E-06	1.7E-08	**0.0010**	
Chromium	0.0062	7.5E-05	1.9E-06	5.6E-05	1.0E-06	1.3E-08	**0.0064**	
Cobalt	1.5E-04	1.6E-05	2.2E-06	6.7E-05	1.2E-06	1.6E-08	**2.3E-04**	
Manganese	0.085	1.4E-04	2.2E-06	6.7E-05	1.2E-06	1.6E-08	**0.085**	
Nickel	0.0096	2.0E-04	3.5E-05	0.0010	1.9E-05	2.5E-07	**0.011**	
Selenium	5.3E-04	5.9E-05	1.5E-06	4.5E-05	8.4E-07	1.1E-08	**6.4E-04**	
Acreolin	7.2E-05	8.0E-06	9.6E-08	2.9E-06	5.4E-08	6.9E-10	**8.3E-05**	
Nitrous Oxide	0.16	0.0056	5.9E-05	0.0018	3.3E-05	4.2E-07	**0.17**	
Benzene	0.031	1.7E-05	3.1E-07	9.3E-06	1.7E-07	2.2E-09	**0.031**	
Perchloroethylene	6.8E-05	7.6E-06	9.5E-08	2.9E-06	5.4E-08	6.8E-10	**7.9E-05**	
Trichloroethylene	6.8E-05	7.6E-06	9.1E-08	2.7E-06	5.1E-08	6.5E-10	**7.8E-05**	
Methylene Chloride	3.0E-04	3.4E-05	4.3E-07	1.3E-05	2.4E-07	3.0E-09	**3.5E-04**	
Carbon Tetrachloride	1.2E-04	1.2E-05	3.9E-07	1.2E-05	2.2E-07	2.8E-09	**1.4E-04**	
Phenols	0.32	2.2E-05	2.5E-06	7.6E-05	1.4E-06	1.8E-08	**0.32**	
Naphthalene	0.020	5.1E-07	1.4E-07	4.3E-06	8.1E-08	1.0E-09	**0.020**	
Dioxins	3.9E-10	4.4E-11	5.2E-13	1.6E-11	3.0E-13	3.8E-15	**4.5E-10**	
n-nitrosodimethlamine	1.5E-05	1.7E-06	2.0E-08	6.1E-07	1.1E-08	1.5E-10	**1.7E-05**	
Radionuclides	0.0012	1.4E-04	1.8E-06	5.4E-05	1.0E-06	1.3E-08	**0.0014**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	16,318	884	525	15,807	294	3.74	**33,833**	97.4%
Methane	769	38.8	1.92	57.8	1.08	0.014	**868**	2.5%
Nitrous Oxide	48.4	1.66	0.017	0.52	0.0098	1.2E-04	**50.6**	0.1%
Total	**17,135**	**925**	**527**	**15,865**	**296**	**3.76**	**34,752**	**100.0%**
%of Total	49.3%	2.7%	1.5%	45.7%	0.9%	0.0%	**100.0%**	

Table 3-6-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

	select box by entering 1	
avg box	1	
80% pc box	0	
	Box	Mold Pulp
thou lb/ 10,000 pkgs	13.9	3.8

	Box with Molded Pulp Loose Fill							
	Box	Molded Pulp Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	46.1	5.43	2.16	21.8	0.74	0.21	**76.4**	
Nitrogen Oxides	118	28.6	15.0	146	4.07	1.16	**313**	
Hydrocarbons	18.0	18.5	6.04	59.3	1.17	0.33	**103**	
Sulfur Oxides	210	84.3	4.26	41.5	0.71	0.20	**341**	
Carbon Monoxide	187	12.4	14.7	151	3.12	0.89	**369**	
Aldehydes	0.45	0.071	0.41	3.96	0.073	0.021	**4.98**	
Methane	33.4	19.3	0.28	2.73	0.047	0.013	**55.8**	
Other Organics	4.84	1.52	8.00	79.9	1.75	0.50	**96.5**	
Odorous Sulfur	0.40	0	0	0	0	0	**0.40**	
Kerosene	0.0018	0.0013	7.1E-06	7.0E-05	1.2E-06	3.4E-07	**0.0032**	
Ammonia	0.65	0.014	0.0028	0.027	4.7E-04	1.3E-04	**0.69**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.050	0.035	2.2E-04	0.0022	3.8E-05	1.1E-05	**0.088**	
Lead	0.010	1.7E-04	9.3E-06	5.7E-04	1.6E-06	4.5E-07	**0.011**	
Mercury	9.1E-04	9.8E-05	1.8E-06	1.7E-05	3.0E-07	8.5E-08	**0.0010**	
Chlorine	0.065	3.4E-05	1.1E-04	0.0010	1.8E-05	5.1E-06	**0.067**	
HCl	0.36	0.26	0.0017	0.017	2.9E-04	8.2E-05	**0.64**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	16,318	7,805	1,748	17,182	294	83.9	**43,432**	
CO2 (non-fossil)	17,508	2.22	0.42	4.12	0.071	0.020	**17,514**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	7.14	9.1E-04	1.7E-04	0.0017	2.9E-05	8.2E-06	**7.14**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.3E-05	2.5E-05	2.6E-06	2.6E-05	4.4E-07	1.3E-07	**1.1E-04**	
Arsenic	0.0037	1.8E-04	5.4E-06	5.3E-05	9.1E-07	2.6E-07	**0.0039**	
Beryllium	3.4E-04	2.1E-05	3.8E-07	3.7E-06	6.4E-08	1.8E-08	**3.7E-04**	
Cadmium	9.6E-04	4.5E-05	8.1E-06	8.0E-05	1.4E-06	3.9E-07	**0.0011**	
Chromium	0.0062	2.9E-04	6.2E-06	6.1E-05	1.0E-06	3.0E-07	**0.0066**	
Cobalt	1.5E-04	7.0E-05	7.4E-06	7.3E-05	1.2E-06	3.5E-07	**3.0E-04**	
Manganese	0.085	5.8E-04	7.4E-06	7.2E-05	1.2E-06	3.5E-07	**0.085**	
Nickel	0.0096	7.4E-04	1.2E-04	0.0011	1.9E-05	5.5E-06	**0.012**	
Selenium	5.3E-04	3.6E-04	5.0E-06	4.9E-05	8.4E-07	2.4E-07	**9.5E-04**	
Acreolin	7.2E-05	5.1E-05	3.2E-07	3.2E-06	5.4E-08	1.5E-08	**1.3E-04**	
Nitrous Oxide	0.16	0.032	2.0E-04	0.0019	3.3E-05	9.4E-06	**0.20**	
Benzene	0.031	7.3E-05	1.0E-06	1.0E-05	1.7E-07	4.9E-08	**0.031**	
Perchloroethylene	6.8E-05	4.8E-05	3.2E-07	3.1E-06	5.4E-08	1.5E-08	**1.2E-04**	
Trichloroethylene	6.8E-05	4.8E-05	3.0E-07	3.0E-06	5.1E-08	1.5E-08	**1.2E-04**	
Methylene Chloride	3.0E-04	2.2E-04	1.4E-06	1.4E-05	2.4E-07	6.8E-08	**5.3E-04**	
Carbon Tetrachloride	1.2E-04	8.0E-05	1.3E-06	1.3E-05	2.2E-07	6.3E-08	**2.1E-04**	
Phenols	0.32	1.5E-04	8.4E-06	8.3E-05	1.4E-06	4.0E-07	**0.32**	
Naphthalene	0.020	3.7E-06	4.8E-07	4.7E-06	8.1E-08	2.3E-08	**0.020**	
Dioxins	3.9E-10	2.8E-10	1.7E-12	1.7E-11	3.0E-13	8.4E-14	**6.9E-10**	
n-nitrosodimethlamine	1.5E-05	1.1E-05	6.8E-08	6.7E-07	1.1E-08	3.3E-09	**2.7E-05**	
Radionuclides	0.0012	8.6E-04	6.0E-06	5.9E-05	1.0E-06	2.9E-07	**0.0021**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	16,318	7,805	1,748	17,182	294	83.9	**43,432**	97.0%
Methane	769	443	6.39	62.8	1.08	0.31	**1,283**	2.9%
Nitrous Oxide	48.4	9.47	0.058	0.57	0.0098	0.0028	**58.5**	0.1%
Total	**17,135**	**8,258**	**1,754**	**17,245**	**296**	**84.2**	**44,773**	**100.0%**
%of Total	38.3%	18.4%	3.9%	38.5%	0.7%	0.2%	**100.0%**	

Table 3-6-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Unbl Kr
thou lb/ 10,000 pkgs	13.9	1.8
	% recycled content	0

	Box	Unbleached Kraft Paper Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	TOTAL	% of Total
	Box with Unbleached Kraft Paper Dunnage							
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	46.1	5.73	0.032	20.7	0.74	0.11	**73.4**	
Nitrogen Oxides	118	22.6	0.23	139	4.07	0.61	**284**	
Hydrocarbons	18.0	2.14	0.091	56.3	1.17	0.17	**77.8**	
Sulfur Oxides	210	36.7	0.064	39.3	0.71	0.11	**287**	
Carbon Monoxide	187	42.7	0.22	143	3.12	0.46	**377**	
Aldehydes	0.45	0.089	0.0062	3.75	0.073	0.011	**4.38**	
Methane	33.4	3.83	0.0042	2.59	0.047	0.0070	**39.9**	
Other Organics	4.84	0.82	0.12	75.8	1.75	0.26	**83.6**	
Odorous Sulfur	0.40	0	0	0	0	0	**0.40**	
Kerosene	0.0018	9.5E-05	1.1E-07	6.7E-05	1.2E-06	1.8E-07	**0.0020**	
Ammonia	0.65	0.166	4.2E-05	0.026	4.7E-04	6.9E-05	**0.84**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.050	0.0026	3.4E-06	0.0021	3.8E-05	5.6E-06	**0.055**	
Lead	0.010	0.0023	1.4E-07	5.4E-04	1.6E-06	2.3E-07	**0.013**	
Mercury	9.1E-04	2.0E-04	2.7E-08	1.7E-05	3.0E-07	4.5E-08	**0.0011**	
Chlorine	0.065	0.0147	1.6E-06	9.9E-04	1.8E-05	2.7E-06	**0.081**	
HCl	0.36	0.019	2.5E-05	0.016	2.9E-04	4.3E-05	**0.40**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	16,318	1,968	26.3	16,296	294	43.8	**34,948**	
CO2 (non-fossil)	17,508	3,938	0.0063	3.91	0.071	0.011	**21,449**	
Total Reduced Sulfur	0	0.104	0	0	0	0	**0.104**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	7.14	1.61	2.6E-06	0.0016	2.9E-05	4.3E-06	**8.75**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.3E-05	5.4E-06	3.9E-08	2.4E-05	4.4E-07	6.6E-08	**8.3E-05**	
Arsenic	0.0037	6.2E-04	8.1E-08	5.0E-05	9.1E-07	1.4E-07	**0.0043**	
Beryllium	3.4E-04	5.3E-05	5.7E-09	3.5E-06	6.4E-08	9.5E-09	**4.0E-04**	
Cadmium	9.6E-04	1.5E-04	1.2E-07	7.6E-05	1.4E-06	2.0E-07	**0.0012**	
Chromium	0.0062	9.9E-04	9.3E-08	5.8E-05	1.0E-06	1.6E-07	**0.0073**	
Cobalt	1.5E-04	1.5E-05	1.1E-07	6.9E-05	1.2E-06	1.9E-07	**2.3E-04**	
Manganese	0.085	0.0184	1.1E-07	6.9E-05	1.2E-06	1.9E-07	**0.103**	
Nickel	0.0096	0.0018	1.7E-06	0.0011	1.9E-05	2.9E-06	**0.012**	
Selenium	5.3E-04	3.0E-05	7.5E-08	4.6E-05	8.4E-07	1.2E-07	**6.1E-04**	
Acreolin	7.2E-05	3.7E-06	4.8E-09	3.0E-06	5.4E-08	8.1E-09	**7.8E-05**	
Nitrous Oxide	0.16	0.022	2.9E-06	0.0018	3.3E-05	4.9E-06	**0.19**	
Benzene	0.031	0.0069	1.5E-08	9.6E-06	1.7E-07	2.6E-08	**0.038**	
Perchloroethylene	6.8E-05	3.6E-06	4.8E-09	3.0E-06	5.4E-08	8.0E-09	**7.5E-05**	
Trichloroethylene	6.8E-05	3.5E-06	4.6E-09	2.8E-06	5.1E-08	7.6E-09	**7.4E-05**	
Methylene Chloride	3.0E-04	1.6E-05	2.1E-08	1.3E-05	2.4E-07	3.6E-08	**3.3E-04**	
Carbon Tetrachloride	1.2E-04	6.9E-06	2.0E-08	1.2E-05	2.2E-07	3.3E-08	**1.4E-04**	
Phenols	0.32	0.073	1.3E-07	7.8E-05	1.4E-06	2.1E-07	**0.40**	
Naphthalene	0.020	0.0044	7.2E-09	4.5E-06	8.1E-08	1.2E-08	**0.024**	
Dioxins	3.9E-10	2.0E-11	2.6E-14	1.6E-11	3.0E-13	4.4E-14	**4.3E-10**	
n-nitrosodimethlamine	1.5E-05	7.8E-07	1.0E-09	6.3E-07	1.1E-08	1.7E-09	**1.7E-05**	
Radionuclides	0.0012	6.3E-05	9.0E-08	5.6E-05	1.0E-06	1.5E-07	**0.0013**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	16,318	1,968	26.3	16,296	294	43.8	**34,948**	97.3%
Methane	769	88.1	0.096	59.6	1.08	0.16	**918**	2.6%
Nitrous Oxide	48.4	6.40	8.7E-04	0.54	0.0098	0.0015	**55.4**	0.2%
Total	**17,135**	**2,063**	**26.4**	**16,356**	**296**	**44.0**	**35,920**	**100.0%**
%of Total	47.7%	5.7%	0.1%	45.5%	0.8%	0.1%	**100.0%**	

Table 3-6-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	1
80% pc box	0

	Box	Newsprint
thou lb/ 10,000 pkgs	13.9	1.7
% recycled content		10

	Box with Newsprint Dunnage							
	Box	Newsprint Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	46.1	5.85	0.025	20.6	0.74	0.10	**73.4**	
Nitrogen Oxides	118	15.4	0.18	138	4.07	0.57	**276**	
Hydrocarbons	18.0	7.17	0.071	56.0	1.17	0.17	**82.6**	
Sulfur Oxides	210	37.8	0.050	39.2	0.71	0.10	**287**	
Carbon Monoxide	187	8.63	0.17	142	3.12	0.44	**342**	
Aldehydes	0.45	0.055	0.0048	3.74	0.073	0.010	**4.33**	
Methane	33.4	9.12	0.0033	2.58	0.047	0.0066	**45.2**	
Other Organics	4.84	2.06	0.094	75.4	1.75	0.25	**84.4**	
Odorous Sulfur	0.40	0.163	0	0	0	0	**0.56**	
Kerosene	0.0018	8.4E-04	8.4E-08	6.6E-05	1.2E-06	1.7E-07	**0.0027**	
Ammonia	0.65	0.0086	3.2E-05	0.026	4.7E-04	6.6E-05	**0.69**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.050	0.023	2.6E-06	0.0021	3.8E-05	5.3E-06	**0.075**	
Lead	0.010	4.7E-04	1.1E-07	5.4E-04	1.6E-06	2.2E-07	**0.011**	
Mercury	9.1E-04	7.9E-05	2.1E-08	1.6E-05	3.0E-07	4.2E-08	**1.0E-03**	
Chlorine	0.065	0.0024	1.2E-06	9.8E-04	1.8E-05	2.5E-06	**0.069**	
HCl	0.36	0.16	2.0E-05	0.016	2.9E-04	4.0E-05	**0.54**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	16,318	3,907	20.6	16,218	294	41.4	**36,800**	
CO2 (non-fossil)	17,508	627	0.0049	3.89	0.071	0.010	**18,139**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0.0063	0	0	0	0	**0.0063**	
Metals	7.14	0.26	2.0E-06	0.0016	2.9E-05	4.1E-06	**7.40**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.3E-05	1.8E-05	3.1E-08	2.4E-05	4.4E-07	6.2E-08	**9.6E-05**	
Arsenic	0.0037	1.7E-04	6.3E-08	5.0E-05	9.1E-07	1.3E-07	**0.0039**	
Beryllium	3.4E-04	1.7E-05	4.4E-09	3.5E-06	6.4E-08	9.0E-09	**3.6E-04**	
Cadmium	9.6E-04	4.3E-05	9.5E-08	7.5E-05	1.4E-06	1.9E-07	**0.0011**	
Chromium	0.0062	2.6E-04	7.2E-08	5.7E-05	1.0E-06	1.5E-07	**0.0065**	
Cobalt	1.5E-04	5.0E-05	8.7E-08	6.8E-05	1.2E-06	1.8E-07	**2.7E-04**	
Manganese	0.085	0.0031	8.7E-08	6.8E-05	1.2E-06	1.7E-07	**0.088**	
Nickel	0.0096	7.6E-04	1.4E-06	0.0011	1.9E-05	2.7E-06	**0.011**	
Selenium	5.3E-04	2.3E-04	5.8E-08	4.6E-05	8.4E-07	1.2E-07	**8.1E-04**	
Acreolin	7.2E-05	3.3E-05	3.8E-09	3.0E-06	5.4E-08	7.6E-09	**1.1E-04**	
Nitrous Oxide	0.16	0.022	2.3E-06	0.0018	3.3E-05	4.6E-06	**0.19**	
Benzene	0.031	1.1E-03	1.2E-08	9.5E-06	1.7E-07	2.4E-08	**0.032**	
Perchloroethylene	6.8E-05	3.1E-05	3.7E-09	2.9E-06	5.4E-08	7.5E-09	**1.0E-04**	
Trichloroethylene	6.8E-05	3.1E-05	3.6E-09	2.8E-06	5.1E-08	7.2E-09	**1.0E-04**	
Methylene Chloride	3.0E-04	1.4E-04	1.7E-08	1.3E-05	2.4E-07	3.4E-08	**4.5E-04**	
Carbon Tetrachloride	1.2E-04	5.1E-05	1.5E-08	1.2E-05	2.2E-07	3.1E-08	**1.8E-04**	
Phenols	0.32	0.0116	9.9E-08	7.8E-05	1.4E-06	2.0E-07	**0.33**	
Naphthalene	0.020	7.0E-04	5.6E-09	4.5E-06	8.1E-08	1.1E-08	**0.020**	
Dioxins	3.9E-10	1.8E-10	2.1E-14	1.6E-11	3.0E-13	4.2E-14	**5.9E-10**	
n-nitrosodimethlamine	1.5E-05	6.9E-06	8.0E-10	6.3E-07	1.1E-08	1.6E-09	**2.3E-05**	
Radionuclides	0.0012	5.5E-04	7.0E-08	5.6E-05	1.0E-06	1.4E-07	**0.0018**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	16,318	3,907	20.6	16,218	294	41.4	**36,800**	97.1%
Methane	769	210	0.075	59.3	1.08	0.15	**1039**	2.7%
Nitrous Oxide	48.4	6.40	6.8E-04	0.54	0.0098	0.0014	**55.4**	0.1%
Total	**17,135**	**4,123**	**20.6**	**16,278**	**296**	**41.6**	**37,895**	**100.0%**
%of Total	45.2%	10.9%	0.1%	43.0%	0.8%	0.1%	**100.0%**	

Table 3-6-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	PC Off Ppr
thou lb/ 10,000 pkgs	13.9	1.5

	Box with Shredded PC Office Paper Dunnage						
	Box	Shredded PC Office Paper Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related							
Particulates	46.1	0.059	20.5	0.74	0.092	**67.4**	
Nitrogen Oxides	118	0.18	137	4.07	0.50	**260**	
Hydrocarbons	18.0	0.036	55.7	1.17	0.15	**75.0**	
Sulfur Oxides	210	0.36	38.9	0.71	0.088	**250**	
Carbon Monoxide	187	0.026	141	3.12	0.39	**332**	
Aldehydes	0.45	1.3E-04	3.71	0.073	0.0090	**4.24**	
Methane	33.4	0.11	2.56	0.047	0.0058	**36.1**	
Other Organics	4.84	1.9E-04	74.9	1.75	0.22	**81.8**	
Odorous Sulfur	0.40	0	0	0	0	**0.40**	
Kerosene	0.0018	1.7E-05	6.6E-05	1.2E-06	1.5E-07	**0.0019**	
Ammonia	0.65	1.7E-04	0.025	4.7E-04	5.8E-05	**0.68**	
Ethylene Oxide	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.050	4.6E-04	0.0021	3.8E-05	4.7E-06	**0.052**	
Lead	0.010	2.2E-06	5.4E-04	1.6E-06	1.9E-07	**0.011**	
Mercury	9.1E-04	1.3E-06	1.6E-05	3.0E-07	3.7E-08	**9.3E-04**	
Chlorine	0.065	2.0E-07	0.0010	1.8E-05	2.2E-06	**0.066**	
HCl	0.36	0.0033	0.016	2.9E-04	3.6E-05	**0.38**	
Phosphorus	0	0	0	0	0	**0**	
CO2 (fossil)	16,318	51.1	16,120	294	36.5	**32,821**	
CO2 (non-fossil)	17,508	0.018	3.87	0.071	0.0088	**17,512**	
Total Reduced Sulfur	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	**0**	
Metals	7.14	7.5E-06	0.0016	2.9E-05	3.6E-06	**7.14**	
Mercaptan	0	0	0	0	0	**0**	
Antimony	5.3E-05	2.9E-07	2.4E-05	4.4E-07	5.5E-08	**7.8E-05**	
Arsenic	0.0037	2.3E-06	5.0E-05	9.1E-07	1.1E-07	**0.0037**	
Beryllium	3.4E-04	2.7E-07	3.5E-06	6.4E-08	7.9E-09	**3.5E-04**	
Cadmium	9.6E-04	4.8E-07	7.5E-05	1.4E-06	1.7E-07	**0.0010**	
Chromium	0.0062	3.7E-06	5.7E-05	1.0E-06	1.3E-07	**0.0063**	
Cobalt	1.5E-04	8.2E-07	6.8E-05	1.2E-06	1.5E-07	**2.2E-04**	
Manganese	0.085	7.4E-06	6.8E-05	1.2E-06	1.5E-07	**0.085**	
Nickel	0.0096	8.1E-06	0.0011	1.9E-05	2.4E-06	**0.011**	
Selenium	5.3E-04	4.7E-06	4.6E-05	8.4E-07	1.0E-07	**5.8E-04**	
Acreolin	7.2E-05	6.6E-07	3.0E-06	5.4E-08	6.7E-09	**7.5E-05**	
Nitrous Oxide	0.16	4.1E-04	0.0018	3.3E-05	4.1E-06	**0.17**	
Benzene	0.031	9.3E-07	9.5E-06	1.7E-07	2.2E-08	**0.031**	
Perchloroethylene	6.8E-05	6.3E-07	2.9E-06	5.4E-08	6.6E-09	**7.2E-05**	
Trichloroethylene	6.8E-05	6.2E-07	2.8E-06	5.1E-08	6.4E-09	**7.1E-05**	
Methylene Chloride	3.0E-04	2.8E-06	1.3E-05	2.4E-07	3.0E-08	**3.2E-04**	
Carbon Tetrachloride	1.2E-04	1.0E-06	1.2E-05	2.2E-07	2.7E-08	**1.3E-04**	
Phenols	0.32	1.7E-06	7.8E-05	1.4E-06	1.8E-07	**0.32**	
Naphthalene	0.020	3.6E-08	4.4E-06	8.1E-08	1.0E-08	**0.020**	
Dioxins	3.9E-10	3.6E-12	1.6E-11	3.0E-13	3.7E-14	**4.1E-10**	
n-nitrosodimethlamine	1.5E-05	1.4E-07	6.2E-07	1.1E-08	1.4E-09	**1.6E-05**	
Radionuclides	0.0012	1.1E-05	5.5E-05	1.0E-06	1.3E-07	**0.0013**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)							
Fossil CO2	16,318	51.1	16,120	294	36.5	**32,821**	97.4%
Methane	769	2.58	59.0	1.08	0.13	**831**	2.5%
Nitrous Oxide	48.4	0.12	0.53	0.0098	0.0012	**49.1**	0.1%
Total	**17,135**	**53.8**	**16,180**	**296**	**36.7**	**33,701**	**100.0%**
%of Total	50.8%	0.2%	48.0%	0.9%	0.1%	**100.0%**	

Table 3-6-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	PC Corrug
thou lb/ 10,000 pkgs	13.9	3.2

	Box with Shredded PC Corrugated Dunnage						
	Box	Shredded PC Corrugated Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related							
Particulates	46.1	0.040	21.5	0.74	0.19	**68.5**	
Nitrogen Oxides	118	0.13	144	4.07	1.06	**267**	
Hydrocarbons	18.0	0.025	58.4	1.17	0.31	**77.9**	
Sulfur Oxides	210	0.24	40.8	0.71	0.19	**252**	
Carbon Monoxide	187	0.018	148	3.12	0.82	**340**	
Aldehydes	0.45	8.7E-05	3.90	0.073	0.019	**4.44**	
Methane	33.4	0.076	2.69	0.047	0.012	**36.2**	
Other Organics	4.84	1.3E-04	78.6	1.75	0.46	**85.7**	
Odorous Sulfur	0.40	0	0	0	0	**0.40**	
Kerosene	0.0018	1.2E-05	6.9E-05	1.2E-06	3.2E-07	**0.0019**	
Ammonia	0.65	1.2E-04	0.027	4.7E-04	1.2E-04	**0.68**	
Ethylene Oxide	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.050	3.1E-04	0.0022	3.8E-05	9.9E-06	**0.052**	
Lead	0.010	1.5E-06	5.6E-04	1.6E-06	4.1E-07	**0.011**	
Mercury	9.1E-04	8.5E-07	1.7E-05	3.0E-07	7.8E-08	**9.3E-04**	
Chlorine	0.065	1.4E-07	1.0E-03	1.8E-05	4.7E-06	**0.067**	
HCl	0.36	0.0023	0.016	2.9E-04	7.5E-05	**0.38**	
Phosphorus	0	0	0	0	0	**0**	
CO2 (fossil)	16,318	34.7	16,916	294	77.0	**33,641**	
CO2 (non-fossil)	17,508	0.012	4.06	0.071	0.019	**17,512**	
Total Reduced Sulfur	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	**0**	
Metals	7.14	5.1E-06	0.0017	2.9E-05	7.6E-06	**7.14**	
Mercaptan	0	0	0	0	0	**0**	
Antimony	5.3E-05	2.0E-07	2.5E-05	4.4E-07	1.2E-07	**7.9E-05**	
Arsenic	0.0037	1.6E-06	5.2E-05	9.1E-07	2.4E-07	**0.0037**	
Beryllium	3.4E-04	1.9E-07	3.6E-06	6.4E-08	1.7E-08	**3.5E-04**	
Cadmium	9.6E-04	3.2E-07	7.8E-05	1.4E-06	3.6E-07	**0.0010**	
Chromium	0.0062	2.5E-06	6.0E-05	1.0E-06	2.7E-07	**0.0063**	
Cobalt	1.5E-04	5.5E-07	7.1E-05	1.2E-06	3.3E-07	**2.2E-04**	
Manganese	0.085	5.0E-06	7.1E-05	1.2E-06	3.3E-07	**0.085**	
Nickel	0.0096	5.5E-06	0.0011	1.9E-05	5.1E-06	**0.011**	
Selenium	5.3E-04	3.2E-06	4.8E-05	8.4E-07	2.2E-07	**5.8E-04**	
Acreolin	7.2E-05	4.5E-07	3.1E-06	5.4E-08	1.4E-08	**7.5E-05**	
Nitrous Oxide	0.16	2.8E-04	0.0019	3.3E-05	8.6E-06	**0.17**	
Benzene	0.031	6.3E-07	1.0E-05	1.7E-07	4.5E-08	**0.031**	
Perchloroethylene	6.8E-05	4.3E-07	3.1E-06	5.4E-08	1.4E-08	**7.2E-05**	
Trichloroethylene	6.8E-05	4.2E-07	2.9E-06	5.1E-08	1.3E-08	**7.1E-05**	
Methylene Chloride	3.0E-04	1.9E-06	1.4E-05	2.4E-07	6.3E-08	**3.2E-04**	
Carbon Tetrachloride	1.2E-04	6.9E-07	1.3E-05	2.2E-07	5.7E-08	**1.3E-04**	
Phenols	0.32	1.2E-06	8.1E-05	1.4E-06	3.7E-07	**0.32**	
Naphthalene	0.020	2.5E-08	4.6E-06	8.1E-08	2.1E-08	**0.020**	
Dioxins	3.9E-10	2.4E-12	1.7E-11	3.0E-13	7.7E-14	**4.1E-10**	
n-nitrosodimethlamine	1.5E-05	9.4E-08	6.6E-07	1.1E-08	3.0E-09	**1.6E-05**	
Radionuclides	0.0012	7.6E-06	5.8E-05	1.0E-06	2.6E-07	**0.0013**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)							
Fossil CO2	16,318	34.7	16,916	294	77.0	**33,641**	97.4%
Methane	769	1.75	61.9	1.08	0.28	**834**	2.4%
Nitrous Oxide	48.4	0.083	0.56	0.0098	0.0026	**49.1**	0.1%
Total	**17,135**	**36.5**	**16,979**	**296**	**77.3**	**34,524**	**100.0%**
%of Total	49.6%	0.1%	49.2%	0.9%	0.2%	**100.0%**	

Table 3-6-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr		
thou lb/ 10,000 pkgs	1.4	1.4	1.4
% recycled content			

	Unpadded Bleached Kraft Bag					
	Bleached Kraft	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related						
Particulates	5.13	0.24	2.01	0.086	**7.47**	
Nitrogen Oxides	20.6	1.70	13.4	0.47	**36.2**	
Hydrocarbons	4.16	0.68	5.46	0.14	**10.4**	
Sulfur Oxides	29.2	0.48	3.82	0.082	**33.5**	
Carbon Monoxide	26.6	1.67	13.9	0.36	**42.5**	
Aldehydes	0.070	0.046	0.36	0.0084	**0.49**	
Methane	4.97	0.031	0.25	0.0054	**5.26**	
Other Organics	0.96	0.91	7.35	0.20	**9.42**	
Odorous Sulfur	0.028	0	0	0	**0.028**	
Kerosene	3.2E-04	8.1E-07	6.5E-06	1.4E-07	**3.3E-04**	
Ammonia	0.061	3.1E-04	0.0025	5.4E-05	**0.064**	
Ethylene Oxide	0	0	0	0	**0**	
Hydrogen Fluoride	0.0086	2.5E-05	2.0E-04	4.4E-06	**0.0089**	
Lead	0.0022	1.1E-06	5.3E-05	1.8E-07	**0.0023**	
Mercury	9.2E-05	2.0E-07	1.6E-06	3.5E-08	**9.4E-05**	
Chlorine	0.034	1.2E-05	9.6E-05	2.1E-06	**0.034**	
HCl	0.063	1.9E-04	0.0015	3.3E-05	**0.064**	
Phosphorus	0	0	0	0	**0**	
CO2 (fossil)	3,049	198	1,582	34.1	**4,863**	
CO2 (non-fossil)	3,437	0.047	0.38	0.0082	**3,437**	
Total Reduced Sulfur	0.56	0	0	0	**0.56**	
Chlorine Dioxide	0	0	0	0	**0**	
Metals	1.40	1.9E-05	1.5E-04	3.3E-06	**1.40**	
Mercaptan	0	0	0	0	**0**	
Antimony	7.6E-05	3.0E-07	2.4E-06	5.1E-08	**7.9E-05**	
Arsenic	6.3E-04	6.1E-07	4.9E-06	1.1E-07	**6.3E-04**	
Beryllium	5.0E-05	4.3E-08	3.4E-07	7.4E-09	**5.0E-05**	
Cadmium	3.4E-04	9.2E-07	7.3E-06	1.6E-07	**3.4E-04**	
Chromium	9.2E-04	7.0E-07	5.6E-06	1.2E-07	**9.3E-04**	
Cobalt	2.2E-04	8.3E-07	6.7E-06	1.4E-07	**2.2E-04**	
Manganese	0.016	8.3E-07	6.7E-06	1.4E-07	**0.016**	
Nickel	0.0046	1.3E-05	1.0E-04	2.3E-06	**0.0047**	
Selenium	1.6E-04	5.6E-07	4.5E-06	9.7E-08	**1.7E-04**	
Acreolin	1.2E-05	3.6E-08	2.9E-07	6.3E-09	**1.3E-05**	
Nitrous Oxide	0.022	2.2E-05	1.8E-04	3.8E-06	**0.022**	
Benzene	0.0060	1.2E-07	9.3E-07	2.0E-08	**0.0060**	
Perchloroethylene	1.2E-05	3.6E-08	2.9E-07	6.2E-09	**1.2E-05**	
Trichloroethylene	1.2E-05	3.4E-08	2.7E-07	5.9E-09	**1.2E-05**	
Methylene Chloride	5.2E-05	1.6E-07	1.3E-06	2.8E-08	**5.4E-05**	
Carbon Tetrachloride	2.0E-05	1.5E-07	1.2E-06	2.5E-08	**2.2E-05**	
Phenols	0.063	9.5E-07	7.6E-06	1.6E-07	**0.063**	
Naphthalene	0.0038	5.4E-08	4.3E-07	9.4E-09	**0.0038**	
Dioxins	6.8E-11	2.0E-13	1.6E-12	3.4E-14	**6.9E-11**	
n-nitrosodimethlamine	2.6E-06	7.7E-09	6.1E-08	1.3E-09	**2.7E-06**	
Radionuclides	2.1E-04	6.8E-07	5.4E-06	1.2E-07	**2.2E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)						
Fossil CO2	3,049	198	1,582	34.1	**4,863**	97.4%
Methane	114	0.72	5.79	0.13	**121**	2.4%
Nitrous Oxide	6.39	0.0065	0.052	0.0011	**6.45**	0.1%
Total	**3,170**	**198**	**1,588**	**34.2**	**4,991**	**100.0%**
%of Total	63.5%	4.0%	31.8%	0.7%	**100.0%**	

Table 3-6-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr	Unbl Kr			
thou lb/ 10,000 pkgs	1	0.9	1.9	3.8	3.8
% recycled content					

	All-Paper Padded Kraft Bag							
	Bleached Kraft	Unbleached Kraft	Macerated PC Newspaper Padding	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	3.67	2.89	0.35	0.66	5.08	0.23	**12.9**	
Nitrogen Oxides	14.7	11.5	1.58	4.61	34.0	1.28	**67.7**	
Hydrocarbons	2.97	1.14	0.47	1.85	13.8	0.37	**20.6**	
Sulfur Oxides	20.8	18.4	0.73	1.31	9.65	0.22	**51.1**	
Carbon Monoxide	19.0	21.5	1.22	4.53	35.0	0.98	**82.3**	
Aldehydes	0.050	0.049	0.025	0.13	0.92	0.023	**1.19**	
Methane	3.55	1.92	0.16	0.085	0.64	0.015	**6.37**	
Other Organics	0.68	0.51	0.70	2.46	18.6	0.55	**23.5**	
Odorous Sulfur	0.020	0	0	0	0	0	**0.020**	
Kerosene	2.3E-04	4.8E-05	2.3E-05	2.2E-06	1.6E-05	3.8E-07	**3.2E-04**	
Ammonia	0.043	0.083	3.9E-04	8.5E-04	0.0063	1.5E-04	**0.13**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.0062	0.0013	6.2E-04	6.9E-05	5.1E-04	1.2E-05	**0.0087**	
Lead	0.0016	0.0011	3.4E-06	2.9E-06	1.3E-04	4.9E-07	**0.0029**	
Mercury	6.6E-05	1.0E-04	1.8E-06	5.4E-07	4.1E-06	9.4E-08	**1.7E-04**	
Chlorine	0.024	0.0074	6.5E-06	3.2E-05	2.4E-04	5.6E-06	**0.032**	
HCl	0.045	0.0094	0.0045	5.2E-04	0.0039	9.0E-05	**0.063**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	2,178	1,006	170	537	3,998	92.6	**7,981**	
CO2 (non-fossil)	2,455	1,969	0.049	0.13	0.96	0.022	**4,425**	
Total Reduced Sulfur	0.40	0.052	0	0	0	0	**0.45**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	1.00	0.80	2.0E-05	5.2E-05	3.9E-04	9.1E-06	**1.80**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.4E-05	2.7E-06	5.4E-07	8.0E-07	6.0E-06	1.4E-07	**6.5E-05**	
Arsenic	4.5E-04	3.1E-04	3.3E-06	1.7E-06	1.2E-05	2.9E-07	**7.7E-04**	
Beryllium	3.6E-05	2.6E-05	3.8E-07	1.2E-07	8.6E-07	2.0E-08	**6.3E-05**	
Cadmium	2.4E-04	7.6E-05	1.1E-06	2.5E-06	1.9E-05	4.3E-07	**3.4E-04**	
Chromium	6.6E-04	5.0E-04	5.3E-06	1.9E-06	1.4E-05	3.3E-07	**0.0012**	
Cobalt	1.5E-04	7.7E-06	1.5E-06	2.3E-06	1.7E-05	3.9E-07	**1.8E-04**	
Manganese	0.011	0.0092	1.0E-05	2.3E-06	1.7E-05	3.9E-07	**0.021**	
Nickel	0.0033	8.8E-04	1.8E-05	3.5E-05	2.6E-04	6.1E-06	**0.0045**	
Selenium	1.2E-04	1.5E-05	6.4E-06	1.5E-06	1.1E-05	2.6E-07	**1.5E-04**	
Acreolin	8.8E-06	1.9E-06	8.9E-07	9.8E-08	7.3E-07	1.7E-08	**1.2E-05**	
Nitrous Oxide	0.015	0.011	5.6E-04	6.0E-05	4.5E-04	1.0E-05	**0.027**	
Benzene	0.0043	0.0035	1.3E-06	3.2E-07	2.4E-06	5.5E-08	**0.0078**	
Perchloroethylene	8.4E-06	1.8E-06	8.5E-07	9.7E-08	7.2E-07	1.7E-08	**1.2E-05**	
Trichloroethylene	8.3E-06	1.8E-06	8.4E-07	9.3E-08	6.9E-07	1.6E-08	**1.2E-05**	
Methylene Chloride	3.7E-05	7.9E-06	3.8E-06	4.4E-07	3.2E-06	7.5E-08	**5.3E-05**	
Carbon Tetrachloride	1.5E-05	3.5E-06	1.4E-06	4.0E-07	3.0E-06	6.9E-08	**2.3E-05**	
Phenols	0.045	0.036	2.8E-06	2.6E-06	1.9E-05	4.5E-07	**0.082**	
Naphthalene	0.0027	0.0022	7.6E-08	1.5E-07	1.1E-06	2.6E-08	**0.0049**	
Dioxins	4.8E-11	1.0E-11	4.9E-12	5.4E-13	4.0E-12	9.3E-14	**6.8E-11**	
n-nitrosodimethlamine	1.9E-06	3.9E-07	1.9E-07	2.1E-08	1.5E-07	3.6E-09	**2.6E-06**	
Radionuclides	1.5E-04	3.2E-05	1.5E-05	1.8E-06	1.4E-05	3.2E-07	**2.1E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	2,178	1,006	170	537	3,998	92.6	**7,981**	98.1%
Methane	81.7	44.1	3.78	1.96	14.6	0.34	**147**	1.8%
Nitrous Oxide	4.57	3.20	0.17	0.018	0.13	0.0031	**8.09**	0.1%
Total	**2,264**	**1,053**	**174**	**539**	**4,012**	**93.0**	**8,135**	**100.0%**
%of Total	27.8%	12.9%	2.1%	6.6%	49.3%	1.1%	**100.0%**	

Table 3-6-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.86	0.24	0.24	1.34	1.34
% recycled content					

	Bleached Kraft	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	TOTAL	% of Total
	Bubble Padded Kraft Bag							
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	3.15	0.42	0.36	0.23	2.09	0.085	**6.35**	
Nitrogen Oxides	12.6	2.34	2.10	1.62	14.0	0.47	**33.2**	
Hydrocarbons	2.55	4.35	3.77	0.65	5.68	0.13	**17.1**	
Sulfur Oxides	17.9	12.8	12.2	0.46	3.97	0.081	**47.4**	
Carbon Monoxide	16.3	1.75	1.71	1.60	14.4	0.36	**36.2**	
Aldehydes	0.043	0.015	0.015	0.044	0.38	0.0083	**0.51**	
Methane	3.05	2.66	2.51	0.030	0.26	0.0054	**8.52**	
Other Organics	0.59	0.14	0.14	0.87	7.65	0.20	**9.59**	
Odorous Sulfur	0.017	0	0	0	0	0	**0.017**	
Kerosene	2.0E-04	8.3E-05	6.3E-05	7.7E-07	6.7E-06	1.4E-07	**3.5E-04**	
Ammonia	0.037	0.0012	0.0010	3.0E-04	0.0026	5.4E-05	**0.043**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.0053	0.0022	0.0017	2.4E-05	2.1E-04	4.3E-06	**0.0095**	
Lead	0.0014	1.3E-05	1.0E-05	1.0E-06	5.5E-05	1.8E-07	**0.0014**	
Mercury	5.7E-05	6.4E-06	5.0E-06	1.9E-07	1.7E-06	3.4E-08	**7.0E-05**	
Chlorine	0.021	1.7E-05	1.7E-05	1.1E-05	1.0E-04	2.0E-06	**0.021**	
HCl	0.038	0.016	0.012	1.8E-04	0.0016	3.3E-05	**0.069**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	1,873	533	465	189	1,646	33.8	**4,741**	
CO2 (non-fossil)	2,111	0.15	0.13	0.045	0.39	0.0081	**2,112**	
Total Reduced Sulfur	0.34	0	0	0	0	0	**0.34**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	0.86	6.1E-05	5.2E-05	1.8E-05	1.6E-04	3.3E-06	**0.86**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	4.7E-05	2.1E-06	1.7E-06	2.8E-07	2.5E-06	5.1E-08	**5.3E-05**	
Arsenic	3.9E-04	1.2E-05	9.7E-06	5.8E-07	5.1E-06	1.0E-07	**4.1E-04**	
Beryllium	3.1E-05	1.4E-06	1.1E-06	4.1E-08	3.6E-07	7.3E-09	**3.4E-05**	
Cadmium	2.1E-04	4.4E-06	3.9E-06	8.8E-07	7.6E-06	1.6E-07	**2.2E-04**	
Chromium	5.7E-04	2.0E-05	1.5E-05	6.7E-07	5.8E-06	1.2E-07	**6.1E-04**	
Cobalt	1.3E-04	5.8E-06	4.8E-06	8.0E-07	7.0E-06	1.4E-07	**1.5E-04**	
Manganese	0.0098	3.7E-05	2.9E-05	8.0E-07	6.9E-06	1.4E-07	**0.010**	
Nickel	0.0028	6.9E-05	5.9E-05	1.2E-05	1.1E-04	2.2E-06	**0.0031**	
Selenium	1.0E-04	2.3E-05	1.8E-05	5.4E-07	4.7E-06	9.6E-08	**1.5E-04**	
Acreolin	7.6E-06	3.2E-06	2.4E-06	3.5E-08	3.0E-07	6.2E-09	**1.4E-05**	
Nitrous Oxide	0.013	0.0020	0.0015	2.1E-05	1.8E-04	3.8E-06	**0.017**	
Benzene	0.0037	4.6E-06	3.5E-06	1.1E-07	9.7E-07	2.0E-08	**0.0037**	
Perchloroethylene	7.2E-06	3.1E-06	2.3E-06	3.4E-08	3.0E-07	6.1E-09	**1.3E-05**	
Trichloroethylene	7.2E-06	3.0E-06	2.3E-06	3.3E-08	2.9E-07	5.9E-09	**1.3E-05**	
Methylene Chloride	3.2E-05	1.4E-05	1.0E-05	1.5E-07	1.3E-06	2.7E-08	**5.8E-05**	
Carbon Tetrachloride	1.2E-05	5.1E-06	3.9E-06	1.4E-07	1.2E-06	2.5E-08	**2.3E-05**	
Phenols	0.039	9.5E-06	7.5E-06	9.1E-07	7.9E-06	1.6E-07	**0.039**	
Naphthalene	0.0024	2.5E-07	2.0E-07	5.2E-08	4.5E-07	9.3E-09	**0.0024**	
Dioxins	4.1E-11	1.8E-11	1.3E-11	1.9E-13	1.6E-12	3.4E-14	**7.4E-11**	
n-nitrosodimethlamine	1.6E-06	6.8E-07	5.2E-07	7.3E-09	6.4E-08	1.3E-09	**2.9E-06**	
Radionuclides	1.3E-04	5.5E-05	4.2E-05	6.5E-07	5.6E-06	1.2E-07	**2.3E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	1,873	533	465	189	1,646	33.8	**4,741**	95.9%
Methane	70.2	61.1	57.7	0.69	6.02	0.12	**196**	4.0%
Nitrous Oxide	3.93	0.60	0.46	0.0063	0.055	0.0011	**5.05**	0.1%
Total	**1,947**	**595**	**524**	**190**	**1,652**	**33.9**	**4,942**	**100.0%**
%of Total	39.4%	12.0%	10.6%	3.8%	33.4%	0.7%	**100.0%**	

Table 3-6-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	LLDPE			
thou lb/ 10,000 pkgs	0.67	0.67		0.67
% recycled content				

	Unpadded LLDPE Film Bag					
	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related						
Particulates	1.02	0.19	1.01	0.046	**2.26**	
Nitrogen Oxides	5.87	1.14	6.73	0.25	**14.0**	
Hydrocarbons	10.5	0.53	2.73	0.072	**13.9**	
Sulfur Oxides	34.2	0.43	1.91	0.043	**36.6**	
Carbon Monoxide	4.76	0.91	6.94	0.19	**12.8**	
Aldehydes	0.042	0.041	0.18	0.0044	**0.27**	
Methane	7.01	0.029	0.13	0.0029	**7.17**	
Other Organics	0.40	0.49	3.68	0.11	**4.68**	
Odorous Sulfur	0	0	0	0	**0**	
Kerosene	1.8E-04	7.4E-07	3.2E-06	7.4E-08	**1.8E-04**	
Ammonia	0.0029	2.9E-04	0.0013	2.9E-05	**0.0045**	
Ethylene Oxide	0	0	0	0	**0**	
Hydrogen Fluoride	0.0048	2.3E-05	1.0E-04	2.3E-06	**0.0049**	
Lead	2.8E-05	9.6E-07	2.6E-05	9.6E-08	**5.6E-05**	
Mercury	1.4E-05	1.8E-07	8.0E-07	1.8E-08	**1.5E-05**	
Chlorine	4.8E-05	1.1E-05	4.8E-05	1.1E-06	**1.1E-04**	
HCl	0.034	1.8E-04	7.7E-04	1.8E-05	**0.035**	
Phosphorus	0	0	0	0	**0**	
CO2 (fossil)	1,299	183	792	18.1	**2,292**	
CO2 (non-fossil)	0.35	0.043	0.19	0.0043	**0.59**	
Total Reduced Sulfur	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	**0**	
Metals	1.4E-04	1.8E-05	7.7E-05	1.8E-06	**2.4E-04**	
Mercaptan	0	0	0	0	**0**	
Antimony	4.8E-06	2.7E-07	1.2E-06	2.7E-08	**6.3E-06**	
Arsenic	2.7E-05	5.6E-07	2.4E-06	5.6E-08	**3.0E-05**	
Beryllium	3.1E-06	3.9E-08	1.7E-07	3.9E-09	**3.3E-06**	
Cadmium	1.1E-05	8.4E-07	3.7E-06	8.4E-08	**1.5E-05**	
Chromium	4.3E-05	6.4E-07	2.8E-06	6.4E-08	**4.6E-05**	
Cobalt	1.3E-05	7.6E-07	3.3E-06	7.6E-08	**1.8E-05**	
Manganese	8.0E-05	7.6E-07	3.3E-06	7.6E-08	**8.4E-05**	
Nickel	1.6E-04	1.2E-05	5.2E-05	1.2E-06	**2.3E-04**	
Selenium	5.0E-05	5.1E-07	2.2E-06	5.1E-08	**5.3E-05**	
Acreolin	6.8E-06	3.3E-08	1.5E-07	3.3E-09	**7.0E-06**	
Nitrous Oxide	0.0043	2.0E-05	8.9E-05	2.0E-06	**0.0044**	
Benzene	9.9E-06	1.1E-07	4.7E-07	1.1E-08	**1.0E-05**	
Perchloroethylene	6.5E-06	3.3E-08	1.4E-07	3.3E-09	**6.7E-06**	
Trichloroethylene	6.4E-06	3.1E-08	1.4E-07	3.1E-09	**6.6E-06**	
Methylene Chloride	2.9E-05	1.5E-07	6.4E-07	1.5E-08	**3.0E-05**	
Carbon Tetrachloride	1.1E-05	1.3E-07	5.9E-07	1.3E-08	**1.2E-05**	
Phenols	2.1E-05	8.7E-07	3.8E-06	8.7E-08	**2.6E-05**	
Naphthalene	5.6E-07	5.0E-08	2.2E-07	5.0E-09	**8.3E-07**	
Dioxins	3.7E-11	1.8E-13	7.9E-13	1.8E-14	**3.8E-11**	
n-nitrosodimethlamine	1.4E-06	7.0E-09	3.1E-08	7.0E-10	**1.5E-06**	
Radionuclides	1.2E-04	6.2E-07	2.7E-06	6.2E-08	**1.2E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)						
Fossil CO2	1,299	183	792	18.1	**2,292**	93.2%
Methane	161	0.66	2.90	0.066	**165**	6.7%
Nitrous Oxide	1.28	0.0060	0.026	6.0E-04	**1.31**	0.1%
Total	**1,462**	**183**	**795**	**18.1**	**2,458**	**100.0%**
%of Total	59.5%	7.5%	32.3%	0.7%	**100.0%**	

Table 3-6-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.35	0.98	1.33	1.33
% recycled content				

	Bubble Padded LLDPE Bag						
	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related							
Particulates	0.61	1.49	0.23	2.09	0.090	**4.52**	
Nitrogen Oxides	3.41	8.58	1.61	14.0	0.49	**28.1**	
Hydrocarbons	6.35	15.4	0.65	5.68	0.14	**28.2**	
Sulfur Oxides	18.6	50.0	0.46	3.97	0.086	**73.1**	
Carbon Monoxide	2.55	6.97	1.58	14.4	0.38	**25.9**	
Aldehydes	0.022	0.061	0.044	0.38	0.0088	**0.51**	
Methane	3.88	10.3	0.030	0.26	0.0057	**14.4**	
Other Organics	0.21	0.58	0.86	7.65	0.21	**9.52**	
Odorous Sulfur	0	0	0	0	0	**0**	
Kerosene	1.2E-04	2.6E-04	7.7E-07	6.7E-06	1.5E-07	**3.8E-04**	
Ammonia	0.0018	0.0043	3.0E-04	0.0026	5.7E-05	**0.0090**	
Ethylene Oxide	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.0033	0.0070	2.4E-05	2.1E-04	4.6E-06	**0.010**	
Lead	1.8E-05	4.1E-05	1.0E-06	5.5E-05	1.9E-07	**1.2E-04**	
Mercury	9.4E-06	2.0E-05	1.9E-07	1.7E-06	3.7E-08	**3.2E-05**	
Chlorine	2.5E-05	7.0E-05	1.1E-05	1.0E-04	2.2E-06	**2.1E-04**	
HCl	0.024	0.050	1.8E-04	0.0016	3.5E-05	**0.076**	
Phosphorus	0	0	0	0	0	**0**	
CO2 (fossil)	777	1,900	188	1,646	35.8	**4,547**	
CO2 (non-fossil)	0.22	0.52	0.045	0.39	0.0086	**1.19**	
Total Reduced Sulfur	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	**0**	
Metals	8.9E-05	2.1E-04	1.8E-05	1.6E-04	3.5E-06	**4.8E-04**	
Mercaptan	0	0	0	0	0	**0**	
Antimony	3.0E-06	7.0E-06	2.8E-07	2.5E-06	5.4E-08	**1.3E-05**	
Arsenic	1.8E-05	4.0E-05	5.8E-07	5.1E-06	1.1E-07	**6.3E-05**	
Beryllium	2.1E-06	4.5E-06	4.0E-08	3.6E-07	7.7E-09	**6.9E-06**	
Cadmium	6.5E-06	1.6E-05	8.7E-07	7.6E-06	1.7E-07	**3.1E-05**	
Chromium	2.9E-05	6.2E-05	6.6E-07	5.8E-06	1.3E-07	**9.7E-05**	
Cobalt	8.4E-06	2.0E-05	7.9E-07	7.0E-06	1.5E-07	**3.6E-05**	
Manganese	5.4E-05	1.2E-04	7.9E-07	6.9E-06	1.5E-07	**1.8E-04**	
Nickel	1.0E-04	2.4E-04	1.2E-05	1.1E-04	2.4E-06	**4.6E-04**	
Selenium	3.4E-05	7.3E-05	5.3E-07	4.7E-06	1.0E-07	**1.1E-04**	
Acreolin	4.7E-06	1.0E-05	3.4E-08	3.0E-07	6.6E-09	**1.5E-05**	
Nitrous Oxide	0.0030	0.0063	2.1E-05	1.8E-04	4.0E-06	**0.0095**	
Benzene	6.7E-06	1.4E-05	1.1E-07	9.7E-07	2.1E-08	**2.2E-05**	
Perchloroethylene	4.5E-06	9.5E-06	3.4E-08	3.0E-07	6.5E-09	**1.4E-05**	
Trichloroethylene	4.4E-06	9.4E-06	3.3E-08	2.9E-07	6.2E-09	**1.4E-05**	
Methylene Chloride	2.0E-05	4.2E-05	1.5E-07	1.3E-06	2.9E-08	**6.4E-05**	
Carbon Tetrachloride	7.4E-06	1.6E-05	1.4E-07	1.2E-06	2.7E-08	**2.5E-05**	
Phenols	1.4E-05	3.1E-05	9.0E-07	7.9E-06	1.7E-07	**5.4E-05**	
Naphthalene	3.6E-07	8.2E-07	5.2E-08	4.5E-07	9.9E-09	**1.7E-06**	
Dioxins	2.6E-11	5.4E-11	1.9E-13	1.6E-12	3.6E-14	**8.2E-11**	
n-nitrosodimethlamine	9.9E-07	2.1E-06	7.3E-09	6.4E-08	1.4E-09	**3.2E-06**	
Radionuclides	8.0E-05	1.7E-04	6.4E-07	5.6E-06	1.2E-07	**2.6E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)							
Fossil CO2	777	1,900	188	1,646	35.8	**4,547**	93.1%
Methane	89.1	236	0.69	6.02	0.13	**332**	6.8%
Nitrous Oxide	0.87	1.87	0.0062	0.055	0.0012	**2.80**	0.1%
Total	**867**	**2,138**	**189**	**1,652**	**36.0**	**4,882**	**100.0%**
%of Total	17.8%	43.8%	3.9%	33.8%	0.7%	**100.0%**	

Table 3-7-BOX

LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Air Pkt
thou lb/ 10,000 pkgs	13.9	0.84
	% recycled content	30

	Box with Inflated Air Packets							
	Box	LDPE Inflated Air Packets	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	39.1	1.32	0.15	20.1	0.74	0.057	**61.4**	
Nitrogen Oxides	81	6.78	1.02	134	4.07	0.31	**228**	
Hydrocarbons	16.7	10.9	0.41	54.5	1.17	0.090	**83.9**	
Sulfur Oxides	165	32.7	0.29	38.1	0.71	0.054	**237**	
Carbon Monoxide	79	4.72	1.00	138	3.12	0.24	**226**	
Aldehydes	0.31	0.044	0.028	3.64	0.073	0.0056	**4.10**	
Methane	35.5	6.95	0.019	2.51	0.047	0.0036	**45.0**	
Other Organics	4.05	0.55	0.54	73.4	1.75	0.13	**80.5**	
Odorous Sulfur	0.16	0	0	0	0	0	**0.16**	
Kerosene	0.0021	2.7E-04	4.9E-07	6.5E-05	1.2E-06	9.3E-08	**0.0025**	
Ammonia	0.28	0.0037	1.9E-04	0.025	4.7E-04	3.6E-05	**0.31**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.058	0.0072	1.5E-05	0.0020	3.8E-05	2.9E-06	**0.067**	
Lead	0.004	3.9E-05	6.3E-07	5.3E-04	1.6E-06	1.2E-07	**0.005**	
Mercury	5.2E-04	2.1E-05	1.2E-07	1.6E-05	3.0E-07	2.3E-08	**5.5E-04**	
Chlorine	0.022	4.5E-05	7.2E-06	9.6E-04	1.8E-05	1.4E-06	**0.023**	
HCl	0.42	0.052	1.2E-04	0.015	2.9E-04	2.2E-05	**0.49**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	17,223	1,532	119	15,797	294	22.6	**34,987**	
CO2 (non-fossil)	5,995	0.45	0.028	3.79	0.071	0.0054	**6,000**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	2.44	1.8E-04	1.2E-05	0.0015	2.9E-05	2.2E-06	**2.45**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.4E-05	6.2E-06	1.8E-07	2.4E-05	4.4E-07	3.4E-08	**8.5E-05**	
Arsenic	0.0034	3.9E-05	3.7E-07	4.9E-05	9.1E-07	7.0E-08	**0.0035**	
Beryllium	3.7E-04	4.5E-06	2.6E-08	3.4E-06	6.4E-08	4.9E-09	**3.8E-04**	
Cadmium	1.0E-03	1.3E-05	5.5E-07	7.3E-05	1.4E-06	1.1E-07	**0.0011**	
Chromium	0.0064	6.2E-05	4.2E-07	5.6E-05	1.0E-06	8.0E-08	**0.0065**	
Cobalt	1.5E-04	1.7E-05	5.0E-07	6.7E-05	1.2E-06	9.6E-08	**2.4E-04**	
Manganese	0.036	1.2E-04	5.0E-07	6.7E-05	1.2E-06	9.6E-08	**0.036**	
Nickel	0.0067	2.0E-04	7.8E-06	0.0010	1.9E-05	1.5E-06	**0.008**	
Selenium	6.0E-04	7.5E-05	3.4E-07	4.5E-05	8.4E-07	6.4E-08	**7.3E-04**	
Acreolin	8.3E-05	1.0E-05	2.2E-08	2.9E-06	5.4E-08	4.2E-09	**9.6E-05**	
Nitrous Oxide	0.18	0.0065	1.3E-05	0.0018	3.3E-05	2.5E-06	**0.19**	
Benzene	0.012	1.5E-05	7.0E-08	9.3E-06	1.7E-07	1.3E-08	**0.012**	
Perchloroethylene	7.9E-05	9.9E-06	2.1E-08	2.9E-06	5.4E-08	4.1E-09	**9.2E-05**	
Trichloroethylene	7.8E-05	9.8E-06	2.1E-08	2.7E-06	5.1E-08	3.9E-09	**9.1E-05**	
Methylene Chloride	3.5E-04	4.4E-05	9.6E-08	1.3E-05	2.4E-07	1.8E-08	**4.1E-04**	
Carbon Tetrachloride	1.4E-04	1.6E-05	8.8E-08	1.2E-05	2.2E-07	1.7E-08	**1.6E-04**	
Phenols	0.11	3.0E-05	5.7E-07	7.6E-05	1.4E-06	1.1E-07	**0.11**	
Naphthalene	0.007	7.5E-07	3.3E-08	4.3E-06	8.1E-08	6.2E-09	**0.007**	
Dioxins	4.5E-10	5.7E-11	1.2E-13	1.6E-11	3.0E-13	2.3E-14	**5.2E-10**	
n-nitrosodimethlamine	1.7E-05	2.2E-06	4.6E-09	6.1E-07	1.1E-08	8.8E-10	**2.0E-05**	
Radionuclides	0.0014	1.8E-04	4.1E-07	5.4E-05	1.0E-06	7.8E-08	**0.0016**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	17,223	1,532	119	15,797	294	22.6	**34,987**	97.0%
Methane	816	160	0.43	57.8	1.08	0.083	**1035**	2.9%
Nitrous Oxide	53.0	1.94	0.0039	0.52	0.0098	7.5E-04	**55.5**	0.2%
Total	**18,092**	**1,694**	**119**	**15,855**	**296**	**22.7**	**36,078**	**100.0%**
%of Total	50.1%	4.7%	0.3%	43.9%	0.8%	0.1%	**100.0%**	

Table 3-7-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	EPS
thou lb/ 10,000 pkgs	13.9	0.48
	% recycled content	30

	Box	EPS Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
	Box with EPS Loose Fill							
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	39.1	1.25	0.39	19.8	0.74	0.044	**61.3**	
Nitrogen Oxides	81	7.30	2.68	133	4.07	0.24	**228**	
Hydrocarbons	16.7	8.36	1.08	53.9	1.17	0.070	**81.3**	
Sulfur Oxides	165	23.7	0.76	37.7	0.71	0.043	**228**	
Carbon Monoxide	79	3.98	2.63	137	3.12	0.19	**226**	
Aldehydes	0.31	0.056	0.073	3.60	0.073	0.0044	**4.11**	
Methane	35.5	5.02	0.050	2.48	0.047	0.0028	**43.1**	
Other Organics	4.05	0.56	1.43	72.6	1.75	0.10	**80.5**	
Odorous Sulfur	0.16	0	0	0	0	0	**0.16**	
Kerosene	0.0021	2.5E-04	1.3E-06	6.4E-05	1.2E-06	7.3E-08	**0.0024**	
Ammonia	0.28	0.0046	4.9E-04	0.025	4.7E-04	2.8E-05	**0.31**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.058	0.0067	4.0E-05	0.0020	3.8E-05	2.3E-06	**0.067**	
Lead	0.004	5.3E-05	1.7E-06	5.2E-04	1.6E-06	9.4E-08	**0.005**	
Mercury	5.2E-04	2.2E-05	3.2E-07	1.6E-05	3.0E-07	1.8E-08	**5.5E-04**	
Chlorine	0.022	8.7E-05	1.9E-05	9.4E-04	1.8E-05	1.1E-06	**0.024**	
HCl	0.42	0.049	3.0E-04	0.015	2.9E-04	1.7E-05	**0.48**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	17,223	1,914	312	15,609	294	17.7	**35,369**	
CO2 (non-fossil)	5,995	0.51	0.075	3.74	0.071	0.0042	**6,000**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	2.44	2.1E-04	3.0E-05	0.0015	2.9E-05	1.7E-06	**2.45**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.4E-05	1.1E-05	4.7E-07	2.3E-05	4.4E-07	2.6E-08	**8.9E-05**	
Arsenic	0.0034	4.6E-05	9.6E-07	4.8E-05	9.1E-07	5.5E-08	**0.0035**	
Beryllium	3.7E-04	4.8E-06	6.7E-08	3.4E-06	6.4E-08	3.8E-09	**3.8E-04**	
Cadmium	1.0E-03	2.8E-05	1.4E-06	7.2E-05	1.4E-06	8.2E-08	**0.0011**	
Chromium	0.0064	6.9E-05	1.1E-06	5.5E-05	1.0E-06	6.3E-08	**0.0065**	
Cobalt	1.5E-04	3.0E-05	1.3E-06	6.6E-05	1.2E-06	7.5E-08	**2.5E-04**	
Manganese	0.036	1.2E-04	1.3E-06	6.6E-05	1.2E-06	7.5E-08	**0.036**	
Nickel	0.0067	4.1E-04	2.1E-05	0.0010	1.9E-05	1.2E-06	**0.008**	
Selenium	6.0E-04	7.5E-05	8.9E-07	4.4E-05	8.4E-07	5.0E-08	**7.3E-04**	
Acreolin	8.3E-05	9.7E-06	5.7E-08	2.9E-06	5.4E-08	3.3E-09	**9.5E-05**	
Nitrous Oxide	0.18	0.0061	3.5E-05	0.0017	3.3E-05	2.0E-06	**0.19**	
Benzene	0.012	1.4E-05	1.8E-07	9.2E-06	1.7E-07	1.0E-08	**0.012**	
Perchloroethylene	7.9E-05	9.2E-06	5.7E-08	2.8E-06	5.4E-08	3.2E-09	**9.1E-05**	
Trichloroethylene	7.8E-05	9.1E-06	5.4E-08	2.7E-06	5.1E-08	3.1E-09	**9.0E-05**	
Methylene Chloride	3.5E-04	4.1E-05	2.5E-07	1.3E-05	2.4E-07	1.4E-08	**4.1E-04**	
Carbon Tetrachloride	1.4E-04	1.6E-05	2.3E-07	1.2E-05	2.2E-07	1.3E-08	**1.6E-04**	
Phenols	0.11	3.0E-05	1.5E-06	7.5E-05	1.4E-06	8.5E-08	**0.11**	
Naphthalene	0.007	8.1E-07	8.6E-08	4.3E-06	8.1E-08	4.9E-09	**0.007**	
Dioxins	4.5E-10	5.3E-11	3.1E-13	1.6E-11	3.0E-13	1.8E-14	**5.2E-10**	
n-nitrosodimethlamine	1.7E-05	2.0E-06	1.2E-08	6.1E-07	1.1E-08	6.9E-10	**2.0E-05**	
Radionuclides	0.0014	1.6E-04	1.1E-06	5.3E-05	1.0E-06	6.1E-08	**0.0016**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	17,223	1,914	312	15,609	294	17.7	**35,369**	97.1%
Methane	816	116	1.14	57.1	1.08	0.065	**991**	2.7%
Nitrous Oxide	53.0	1.81	0.010	0.52	0.0098	5.9E-04	**55.4**	0.2%
Total	**18,092**	**2,031**	**313**	**15,666**	**296**	**17.7**	**36,415**	**100.0%**
%of Total	49.7%	5.6%	0.9%	43.0%	0.8%	0.0%	**100.0%**	

Table 3-7-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Cornstarch
thou lb/ 10,000 pkgs	13.9	0.86

	Box with Cornstarch Loose Fill							
	Box	Cornstarch Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	39.1	1.68	0.65	20.1	0.74	0.0094	**62.3**	
Nitrogen Oxides	81	3.94	4.51	134	4.07	0.052	**228**	
Hydrocarbons	16.7	1.62	1.81	54.6	1.17	0.015	**75.9**	
Sulfur Oxides	165	7.00	1.28	38.2	0.71	0.0090	**212**	
Carbon Monoxide	79	1.48	4.43	139	3.12	0.039	**227**	
Aldehydes	0.31	0.034	0.12	3.64	0.073	9.2E-04	**4.18**	
Methane	35.5	1.69	0.083	2.51	0.047	6.0E-04	**39.8**	
Other Organics	4.05	0.43	2.40	73.5	1.75	0.022	**82.1**	
Odorous Sulfur	0.16	0	0	0	0	0	**0.16**	
Kerosene	0.0021	2.1E-04	2.1E-06	6.5E-05	1.2E-06	1.5E-08	**0.0024**	
Ammonia	0.28	0.019	8.3E-04	0.025	4.7E-04	5.9E-06	**0.32**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.058	0.0056	6.7E-05	0.0020	3.8E-05	4.8E-07	**0.065**	
Lead	0.004	3.4E-05	2.8E-06	5.3E-04	1.6E-06	2.0E-08	**0.005**	
Mercury	5.2E-04	1.7E-05	5.3E-07	1.6E-05	3.0E-07	3.8E-09	**5.5E-04**	
Chlorine	0.022	1.2E-05	3.2E-05	9.6E-04	1.8E-05	2.3E-07	**0.023**	
HCl	0.42	0.040	5.1E-04	0.015	2.9E-04	3.6E-06	**0.47**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	17,223	884	525	15,807	294	3.74	**34,738**	
CO2 (non-fossil)	5,995	0.56	0.13	3.79	0.071	9.0E-04	**6,000**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	2.44	1.1E-04	5.1E-05	0.0015	2.9E-05	3.7E-07	**2.45**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.4E-05	5.5E-06	7.8E-07	2.4E-05	4.4E-07	5.6E-09	**8.5E-05**	
Arsenic	0.0034	4.4E-05	1.6E-06	4.9E-05	9.1E-07	1.2E-08	**0.0035**	
Beryllium	3.7E-04	5.1E-06	1.1E-07	3.4E-06	6.4E-08	8.1E-10	**3.8E-04**	
Cadmium	1.0E-03	1.6E-05	2.4E-06	7.3E-05	1.4E-06	1.7E-08	**0.0011**	
Chromium	0.0064	7.5E-05	1.9E-06	5.6E-05	1.0E-06	1.3E-08	**0.0065**	
Cobalt	1.5E-04	1.6E-05	2.2E-06	6.7E-05	1.2E-06	1.6E-08	**2.4E-04**	
Manganese	0.036	1.4E-04	2.2E-06	6.7E-05	1.2E-06	1.6E-08	**0.036**	
Nickel	0.0067	2.0E-04	3.5E-05	0.0010	1.9E-05	2.5E-07	**0.008**	
Selenium	6.0E-04	5.9E-05	1.5E-06	4.5E-05	8.4E-07	1.1E-08	**7.1E-04**	
Acreolin	8.3E-05	8.0E-06	9.6E-08	2.9E-06	5.4E-08	6.9E-10	**9.4E-05**	
Nitrous Oxide	0.18	0.0056	5.9E-05	0.0018	3.3E-05	4.2E-07	**0.19**	
Benzene	0.012	1.7E-05	3.1E-07	9.3E-06	1.7E-07	2.2E-09	**0.012**	
Perchloroethylene	7.9E-05	7.6E-06	9.5E-08	2.9E-06	5.4E-08	6.8E-10	**9.0E-05**	
Trichloroethylene	7.8E-05	7.6E-06	9.1E-08	2.7E-06	5.1E-08	6.5E-10	**8.9E-05**	
Methylene Chloride	3.5E-04	3.4E-05	4.3E-07	1.3E-05	2.4E-07	3.0E-09	**4.0E-04**	
Carbon Tetrachloride	1.4E-04	1.2E-05	3.9E-07	1.2E-05	2.2E-07	2.8E-09	**1.6E-04**	
Phenols	0.11	2.2E-05	2.5E-06	7.6E-05	1.4E-06	1.8E-08	**0.11**	
Naphthalene	0.007	5.1E-07	1.4E-07	4.3E-06	8.1E-08	1.0E-09	**0.007**	
Dioxins	4.5E-10	4.4E-11	5.2E-13	1.6E-11	3.0E-13	3.8E-15	**5.1E-10**	
n-nitrosodimethlamine	1.7E-05	1.7E-06	2.0E-08	6.1E-07	1.1E-08	1.5E-10	**2.0E-05**	
Radionuclides	0.0014	1.4E-04	1.8E-06	5.4E-05	1.0E-06	1.3E-08	**0.0016**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	17,223	884	525	15,807	294	3.74	**34,738**	97.3%
Methane	816	38.8	1.92	57.8	1.08	0.014	**915**	2.6%
Nitrous Oxide	53.0	1.66	0.017	0.52	0.0098	1.2E-04	**55.2**	0.2%
Total	**18,092**	**925**	**527**	**15,865**	**296**	**3.76**	**35,708**	**100.0%**
%of Total	50.7%	2.6%	1.5%	44.4%	0.8%	0.0%	**100.0%**	

Table 3-7-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Mold Pulp
thou lb/ 10,000 pkgs	13.9	3.8

	Box	Molded Pulp Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
	Box with Molded Pulp Loose Fill							
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	39.1	5.43	2.16	21.8	0.74	0.21	**69.5**	
Nitrogen Oxides	81.4	28.6	15.0	146	4.07	1.16	**276**	
Hydrocarbons	16.7	18.5	6.04	59.3	1.17	0.33	**102**	
Sulfur Oxides	165	84.3	4.26	41.5	0.71	0.20	**296**	
Carbon Monoxide	79.0	12.4	14.7	151	3.12	0.89	**261**	
Aldehydes	0.31	0.071	0.41	3.96	0.073	0.021	**4.84**	
Methane	35.5	19.3	0.28	2.73	0.047	0.013	**57.8**	
Other Organics	4.05	1.52	8.00	79.9	1.75	0.50	**95.7**	
Odorous Sulfur	0.16	0	0	0	0	0	**0.16**	
Kerosene	0.0021	0.0013	7.1E-06	7.0E-05	1.2E-06	3.4E-07	**0.0035**	
Ammonia	0.28	0.014	0.0028	0.027	4.7E-04	1.3E-04	**0.32**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.058	0.035	2.2E-04	0.0022	3.8E-05	1.1E-05	**0.096**	
Lead	0.0040	1.7E-04	9.3E-06	5.7E-04	1.6E-06	4.5E-07	**0.0047**	
Mercury	5.2E-04	9.8E-05	1.8E-06	1.7E-05	3.0E-07	8.5E-08	**6.3E-04**	
Chlorine	0.022	3.4E-05	1.1E-04	0.0010	1.8E-05	5.1E-06	**0.024**	
HCl	0.42	0.26	0.0017	0.017	2.9E-04	8.2E-05	**0.69**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	17,223	7,805	1,748	17,182	294	83.9	**44,336**	
CO2 (non-fossil)	5,995	2.22	0.42	4.12	0.071	0.020	**6,002**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	2.44	9.1E-04	1.7E-04	0.0017	2.9E-05	8.2E-06	**2.45**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.4E-05	2.5E-05	2.6E-06	2.6E-05	4.4E-07	1.3E-07	**1.1E-04**	
Arsenic	0.0034	1.8E-04	5.4E-06	5.3E-05	9.1E-07	2.6E-07	**0.0036**	
Beryllium	3.7E-04	2.1E-05	3.8E-07	3.7E-06	6.4E-08	1.8E-08	**4.0E-04**	
Cadmium	0.0010	4.5E-05	8.1E-06	8.0E-05	1.4E-06	3.9E-07	**0.0011**	
Chromium	0.0064	2.9E-04	6.2E-06	6.1E-05	1.0E-06	3.0E-07	**0.0068**	
Cobalt	1.5E-04	7.0E-05	7.4E-06	7.3E-05	1.2E-06	3.5E-07	**3.0E-04**	
Manganese	0.036	5.8E-04	7.4E-06	7.2E-05	1.2E-06	3.5E-07	**0.037**	
Nickel	0.0067	7.4E-04	1.2E-04	0.0011	1.9E-05	5.5E-06	**0.0087**	
Selenium	6.0E-04	3.6E-04	5.0E-06	4.9E-05	8.4E-07	2.4E-07	**0.0010**	
Acreolin	8.3E-05	5.1E-05	3.2E-07	3.2E-06	5.4E-08	1.5E-08	**1.4E-04**	
Nitrous Oxide	0.18	0.032	2.0E-04	0.0019	3.3E-05	9.4E-06	**0.21**	
Benzene	0.012	7.3E-05	1.0E-06	1.0E-05	1.7E-07	4.9E-08	**0.012**	
Perchloroethylene	7.9E-05	4.8E-05	3.2E-07	3.1E-06	5.4E-08	1.5E-08	**1.3E-04**	
Trichloroethylene	7.8E-05	4.8E-05	3.0E-07	3.0E-06	5.1E-08	1.5E-08	**1.3E-04**	
Methylene Chloride	3.5E-04	2.2E-04	1.4E-06	1.4E-05	2.4E-07	6.8E-08	**5.8E-04**	
Carbon Tetrachloride	1.4E-04	8.0E-05	1.3E-06	1.3E-05	2.2E-07	6.3E-08	**2.3E-04**	
Phenols	0.11	1.5E-04	8.4E-06	8.3E-05	1.4E-06	4.0E-07	**0.11**	
Naphthalene	0.0067	3.7E-06	4.8E-07	4.7E-06	8.1E-08	2.3E-08	**0.0067**	
Dioxins	4.5E-10	2.8E-10	1.7E-12	1.7E-11	3.0E-13	8.4E-14	**7.5E-10**	
n-nitrosodimethlamine	1.7E-05	1.1E-05	6.8E-08	6.7E-07	1.1E-08	3.3E-09	**2.9E-05**	
Radionuclides	0.0014	8.6E-04	6.0E-06	5.9E-05	1.0E-06	2.9E-07	**0.0023**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	17,223	7,805	1,748	17,182	294	83.9	**44,336**	97.0%
Methane	816	443	6.39	62.8	1.08	0.31	**1,330**	2.9%
Nitrous Oxide	53.0	9.47	0.058	0.57	0.0098	0.0028	**63.1**	0.1%
Total	**18,092**	**8,258**	**1,754**	**17,245**	**296**	**84.2**	**45,729**	**100.0%**
%of Total	39.6%	18.1%	3.8%	37.7%	0.6%	0.2%	**100.0%**	

Table 3-7-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Unbl Kr
thou lb/ 10,000 pkgs	13.9	1.8
	% recycled content	50

	Box with Unbleached Kraft Paper Dunnage							
	Box	Unbleached Kraft Paper Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	39.1	4.04	0.032	20.7	0.74	0.11	**64.7**	
Nitrogen Oxides	81	14.7	0.23	139	4.07	0.61	**240**	
Hydrocarbons	16.7	1.85	0.091	56.3	1.17	0.17	**76.3**	
Sulfur Oxides	165	25.6	0.064	39.3	0.71	0.11	**231**	
Carbon Monoxide	79	22.3	0.22	143	3.12	0.46	**248**	
Aldehydes	0.31	0.059	0.0062	3.75	0.073	0.011	**4.21**	
Methane	35.5	3.95	0.0042	2.59	0.047	0.0070	**42.1**	
Other Organics	4.05	0.64	0.12	75.8	1.75	0.26	**82.6**	
Odorous Sulfur	0.16	0	0	0	0	0	**0.16**	
Kerosene	0.0021	1.8E-04	1.1E-07	6.7E-05	1.2E-06	1.8E-07	**0.0024**	
Ammonia	0.28	0.084	4.2E-05	0.026	4.7E-04	6.9E-05	**0.39**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.058	0.0050	3.4E-06	0.0021	3.8E-05	5.6E-06	**0.065**	
Lead	0.004	0.0012	1.4E-07	5.4E-04	1.6E-06	2.3E-07	**0.006**	
Mercury	5.2E-04	1.2E-04	2.7E-08	1.7E-05	3.0E-07	4.5E-08	**0.0006**	
Chlorine	0.022	0.0074	1.6E-06	9.9E-04	1.8E-05	2.7E-06	**0.031**	
HCl	0.42	0.036	2.5E-05	0.016	2.9E-04	4.3E-05	**0.47**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	17,223	1,990	26.3	16,296	294	43.8	**35,873**	
CO2 (non-fossil)	5,995	1,969	0.0063	3.91	0.071	0.011	**7,968**	
Total Reduced Sulfur	0	0.052	0	0	0	0	**0.052**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	2.44	0.80	2.6E-06	0.0016	2.9E-05	4.3E-06	**3.25**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.4E-05	5.9E-06	3.9E-08	2.4E-05	4.4E-07	6.6E-08	**8.5E-05**	
Arsenic	0.0034	5.0E-04	8.1E-08	5.0E-05	9.1E-07	1.4E-07	**0.0040**	
Beryllium	3.7E-04	4.9E-05	5.7E-09	3.5E-06	6.4E-08	9.5E-09	**4.2E-04**	
Cadmium	1.0E-03	1.4E-04	1.2E-07	7.6E-05	1.4E-06	2.0E-07	**0.0012**	
Chromium	0.0064	8.8E-04	9.3E-08	5.8E-05	1.0E-06	1.6E-07	**0.0074**	
Cobalt	1.5E-04	1.7E-05	1.1E-07	6.9E-05	1.2E-06	1.9E-07	**2.4E-04**	
Manganese	0.036	0.0098	1.1E-07	6.9E-05	1.2E-06	1.9E-07	**0.046**	
Nickel	0.0067	0.0012	1.7E-06	0.0011	1.9E-05	2.9E-06	**0.009**	
Selenium	6.0E-04	5.4E-05	7.5E-08	4.6E-05	8.4E-07	1.2E-07	**7.1E-04**	
Acreolin	8.3E-05	7.2E-06	4.8E-09	3.0E-06	5.4E-08	8.1E-09	**9.3E-05**	
Nitrous Oxide	0.18	0.022	2.9E-06	0.0018	3.3E-05	4.9E-06	**0.20**	
Benzene	0.012	0.0035	1.5E-08	9.6E-06	1.7E-07	2.6E-08	**0.015**	
Perchloroethylene	7.9E-05	6.8E-06	4.8E-09	3.0E-06	5.4E-08	8.0E-09	**8.9E-05**	
Trichloroethylene	7.8E-05	6.8E-06	4.6E-09	2.8E-06	5.1E-08	7.6E-09	**8.8E-05**	
Methylene Chloride	3.5E-04	3.0E-05	2.1E-08	1.3E-05	2.4E-07	3.6E-08	**3.9E-04**	
Carbon Tetrachloride	1.4E-04	1.2E-05	2.0E-08	1.2E-05	2.2E-07	3.3E-08	**1.6E-04**	
Phenols	0.11	0.036	1.3E-07	7.8E-05	1.4E-06	2.1E-07	**0.15**	
Naphthalene	0.007	0.0022	7.2E-09	4.5E-06	8.1E-08	1.2E-08	**0.009**	
Dioxins	4.5E-10	3.9E-11	2.6E-14	1.6E-11	3.0E-13	4.4E-14	**5.1E-10**	
n-nitrosodimethlamine	1.7E-05	1.5E-06	1.0E-09	6.3E-07	1.1E-08	1.7E-09	**2.0E-05**	
Radionuclides	0.0014	1.2E-04	9.0E-08	5.6E-05	1.0E-06	1.5E-07	**0.0016**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	17,223	1,990	26.3	16,296	294	43.8	**35,873**	97.2%
Methane	816	90.8	0.096	59.6	1.08	0.16	**967**	2.6%
Nitrous Oxide	53.0	6.48	8.7E-04	0.54	0.0098	0.0015	**60.1**	0.2%
Total	**18,092**	**2,087**	**26.4**	**16,356**	**296**	**44.0**	**36,901**	**100.0%**
%of Total	49.0%	5.7%	0.1%	44.3%	0.8%	0.1%	**100.0%**	

Table 3-7-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Newsprint
thou lb/ 10,000 pkgs	13.9	1.7
% recycled content		50

	Box with Newsprint Dunnage							
	Box	Newsprint Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	39.1	4.24	0.025	20.6	0.74	0.10	**64.8**	
Nitrogen Oxides	81	10.3	0.18	138	4.07	0.57	**234**	
Hydrocarbons	16.7	5.35	0.071	56.0	1.17	0.17	**79.5**	
Sulfur Oxides	165	26.4	0.050	39.2	0.71	0.10	**231**	
Carbon Monoxide	79	5.73	0.17	142	3.12	0.44	**231**	
Aldehydes	0.31	0.038	0.0048	3.74	0.073	0.010	**4.17**	
Methane	35.5	6.21	0.0033	2.58	0.047	0.0066	**44.3**	
Other Organics	4.05	2.03	0.094	75.4	1.75	0.25	**83.6**	
Odorous Sulfur	0.16	0.090	0	0	0	0	**0.25**	
Kerosene	0.0021	5.1E-04	8.4E-08	6.6E-05	1.2E-06	1.7E-07	**0.0027**	
Ammonia	0.28	0.0053	3.2E-05	0.026	4.7E-04	6.6E-05	**0.31**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.058	0.014	2.6E-06	0.0021	3.8E-05	5.3E-06	**0.074**	
Lead	0.004	2.7E-04	1.1E-07	5.4E-04	1.6E-06	2.2E-07	**0.005**	
Mercury	5.2E-04	4.8E-05	2.1E-08	1.6E-05	3.0E-07	4.2E-08	**5.8E-04**	
Chlorine	0.022	0.0013	1.2E-06	9.8E-04	1.8E-05	2.5E-06	**0.025**	
HCl	0.42	0.10	2.0E-05	0.016	2.9E-04	4.0E-05	**0.53**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	17,223	2,624	20.6	16,218	294	41.4	**36,422**	
CO2 (non-fossil)	5,995	349	0.0049	3.89	0.071	0.010	**6,348**	
Total Reduced Sulfur	0	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0.0035	0	0	0	0	**0.0035**	
Metals	2.44	0.14	2.0E-06	0.0016	2.9E-05	4.1E-06	**2.59**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	5.4E-05	1.1E-05	3.1E-08	2.4E-05	4.4E-07	6.2E-08	**9.0E-05**	
Arsenic	0.0034	1.0E-04	6.3E-08	5.0E-05	9.1E-07	1.3E-07	**0.0036**	
Beryllium	3.7E-04	1.0E-05	4.4E-09	3.5E-06	6.4E-08	9.0E-09	**3.9E-04**	
Cadmium	1.0E-03	2.6E-05	9.5E-08	7.5E-05	1.4E-06	1.9E-07	**0.0011**	
Chromium	0.0064	1.5E-04	7.2E-08	5.7E-05	1.0E-06	1.5E-07	**0.0066**	
Cobalt	1.5E-04	3.1E-05	8.7E-08	6.8E-05	1.2E-06	1.8E-07	**2.5E-04**	
Manganese	0.036	0.0018	8.7E-08	6.8E-05	1.2E-06	1.7E-07	**0.038**	
Nickel	0.0067	4.5E-04	1.4E-06	0.0011	1.9E-05	2.7E-06	**0.008**	
Selenium	6.0E-04	1.4E-04	5.8E-08	4.6E-05	8.4E-07	1.2E-07	**8.0E-04**	
Acreolin	8.3E-05	2.0E-05	3.8E-09	3.0E-06	5.4E-08	7.6E-09	**1.1E-04**	
Nitrous Oxide	0.18	0.013	2.3E-06	0.0018	3.3E-05	4.6E-06	**0.19**	
Benzene	0.012	6.3E-04	1.2E-08	9.5E-06	1.7E-07	2.4E-08	**0.012**	
Perchloroethylene	7.9E-05	1.9E-05	3.7E-09	2.9E-06	5.4E-08	7.5E-09	**1.0E-04**	
Trichloroethylene	7.8E-05	1.9E-05	3.6E-09	2.8E-06	5.1E-08	7.2E-09	**1.0E-04**	
Methylene Chloride	3.5E-04	8.4E-05	1.7E-08	1.3E-05	2.4E-07	3.4E-08	**4.5E-04**	
Carbon Tetrachloride	1.4E-04	3.1E-05	1.5E-08	1.2E-05	2.2E-07	3.1E-08	**1.8E-04**	
Phenols	0.11	0.0065	9.9E-08	7.8E-05	1.4E-06	2.0E-07	**0.12**	
Naphthalene	0.007	3.9E-04	5.6E-09	4.5E-06	8.1E-08	1.1E-08	**0.007**	
Dioxins	4.5E-10	1.1E-10	2.1E-14	1.6E-11	3.0E-13	4.2E-14	**5.8E-10**	
n-nitrosodimethlamine	1.7E-05	4.2E-06	8.0E-10	6.3E-07	1.1E-08	1.6E-09	**2.2E-05**	
Radionuclides	0.0014	3.4E-04	7.0E-08	5.6E-05	1.0E-06	1.4E-07	**0.0018**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	17,223	2,624	20.6	16,218	294	41.4	**36,422**	97.1%
Methane	816	143	0.075	59.3	1.08	0.15	**1019**	2.7%
Nitrous Oxide	53.0	3.90	6.8E-04	0.54	0.0098	0.0014	**57.5**	0.2%
Total	**18,092**	**2,771**	**20.6**	**16,278**	**296**	**41.6**	**37,499**	**100.0%**
%of Total	48.2%	7.4%	0.1%	43.4%	0.8%	0.1%	**100.0%**	

Table 3-7-BOX

LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

	select box by entering 1	
avg box	0	
80% pc box	1	
	Box	PC Off Ppr
thou lb/ 10,000 pkgs	13.9	1.5

	Box with Shredded PC Office Paper Dunnage						
	Box	Shredded PC Office Paper Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related							
Particulates	39.1	0.059	20.5	0.74	0.092	**60.5**	
Nitrogen Oxides	81	0.18	137	4.07	0.50	**223**	
Hydrocarbons	16.7	0.036	55.7	1.17	0.15	**73.7**	
Sulfur Oxides	165	0.36	38.9	0.71	0.088	**205**	
Carbon Monoxide	79	0.026	141	3.12	0.39	**224**	
Aldehydes	0.31	1.3E-04	3.71	0.073	0.0090	**4.11**	
Methane	35.5	0.11	2.56	0.047	0.0058	**38.2**	
Other Organics	4.05	1.9E-04	74.9	1.75	0.22	**81.0**	
Odorous Sulfur	0.16	0	0	0	0	**0.16**	
Kerosene	0.0021	1.7E-05	6.6E-05	1.2E-06	1.5E-07	**0.0022**	
Ammonia	0.28	1.7E-04	0.025	4.7E-04	5.8E-05	**0.30**	
Ethylene Oxide	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.058	4.6E-04	0.0021	3.8E-05	4.7E-06	**0.060**	
Lead	0.004	2.2E-06	5.4E-04	1.6E-06	1.9E-07	**0.005**	
Mercury	5.2E-04	1.3E-06	1.6E-05	3.0E-07	3.7E-08	**5.3E-04**	
Chlorine	0.022	2.0E-07	0.0010	1.8E-05	2.2E-06	**0.023**	
HCl	0.42	0.0033	0.016	2.9E-04	3.6E-05	**0.44**	
Phosphorus	0	0	0	0	0	**0**	
CO2 (fossil)	17,223	51.1	16,120	294	36.5	**33,725**	
CO2 (non-fossil)	5,995	0.018	3.87	0.071	0.0088	**5,999**	
Total Reduced Sulfur	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	**0**	
Metals	2.44	7.5E-06	0.0016	2.9E-05	3.6E-06	**2.45**	
Mercaptan	0	0	0	0	0	**0**	
Antimony	5.4E-05	2.9E-07	2.4E-05	4.4E-07	5.5E-08	**7.9E-05**	
Arsenic	0.0034	2.3E-06	5.0E-05	9.1E-07	1.1E-07	**0.0035**	
Beryllium	3.7E-04	2.7E-07	3.5E-06	6.4E-08	7.9E-09	**3.8E-04**	
Cadmium	1.0E-03	4.8E-07	7.5E-05	1.4E-06	1.7E-07	**0.0011**	
Chromium	0.0064	3.7E-06	5.7E-05	1.0E-06	1.3E-07	**0.0065**	
Cobalt	1.5E-04	8.2E-07	6.8E-05	1.2E-06	1.5E-07	**2.2E-04**	
Manganese	0.036	7.4E-06	6.8E-05	1.2E-06	1.5E-07	**0.036**	
Nickel	0.0067	8.1E-06	0.0011	1.9E-05	2.4E-06	**0.008**	
Selenium	6.0E-04	4.7E-06	4.6E-05	8.4E-07	1.0E-07	**6.6E-04**	
Acreolin	8.3E-05	6.6E-07	3.0E-06	5.4E-08	6.7E-09	**8.6E-05**	
Nitrous Oxide	0.18	4.1E-04	0.0018	3.3E-05	4.1E-06	**0.18**	
Benzene	0.012	9.3E-07	9.5E-06	1.7E-07	2.2E-08	**0.012**	
Perchloroethylene	7.9E-05	6.3E-07	2.9E-06	5.4E-08	6.6E-09	**8.3E-05**	
Trichloroethylene	7.8E-05	6.2E-07	2.8E-06	5.1E-08	6.4E-09	**8.2E-05**	
Methylene Chloride	3.5E-04	2.8E-06	1.3E-05	2.4E-07	3.0E-08	**3.7E-04**	
Carbon Tetrachloride	1.4E-04	1.0E-06	1.2E-05	2.2E-07	2.7E-08	**1.5E-04**	
Phenols	0.11	1.7E-06	7.8E-05	1.4E-06	1.8E-07	**0.11**	
Naphthalene	0.007	3.6E-08	4.4E-06	8.1E-08	1.0E-08	**0.007**	
Dioxins	4.5E-10	3.6E-12	1.6E-11	3.0E-13	3.7E-14	**4.7E-10**	
n-nitrosodimethlamine	1.7E-05	1.4E-07	6.2E-07	1.1E-08	1.4E-09	**1.8E-05**	
Radionuclides	0.0014	1.1E-05	5.5E-05	1.0E-06	1.3E-07	**0.0015**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)							
Fossil CO2	17,223	51.1	16,120	294	36.5	**33,725**	97.3%
Methane	816	2.58	59.0	1.08	0.13	**878**	2.5%
Nitrous Oxide	53.0	0.12	0.53	0.0098	0.0012	**53.7**	0.2%
Total	**18,092**	**53.8**	**16,180**	**296**	**36.7**	**34,657**	**100.0%**
%of Total	52.2%	0.2%	46.7%	0.9%	0.1%	**100.0%**	

Table 3-7-BOX
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	PC Corrug
thou lb/ 10,000 pkgs	13.9	3.2

	Box with Shredded PC Corrugated Dunnage						
	Box	Shredded PC Corrugated Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related							
Particulates	39.1	0.040	21.5	0.74	0.19	**61.6**	
Nitrogen Oxides	81	0.13	144	4.07	1.06	**230**	
Hydrocarbons	16.7	0.025	58.4	1.17	0.31	**76.6**	
Sulfur Oxides	165	0.24	40.8	0.71	0.19	**207**	
Carbon Monoxide	79	0.018	148	3.12	0.82	**231**	
Aldehydes	0.31	8.7E-05	3.90	0.073	0.019	**4.30**	
Methane	35.5	0.076	2.69	0.047	0.012	**38.3**	
Other Organics	4.05	1.3E-04	78.6	1.75	0.46	**84.9**	
Odorous Sulfur	0.16	0	0	0	0	**0.16**	
Kerosene	0.0021	1.2E-05	6.9E-05	1.2E-06	3.2E-07	**0.0022**	
Ammonia	0.28	1.2E-04	0.027	4.7E-04	1.2E-04	**0.31**	
Ethylene Oxide	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.058	3.1E-04	0.0022	3.8E-05	9.9E-06	**0.060**	
Lead	0.004	1.5E-06	5.6E-04	1.6E-06	4.1E-07	**0.005**	
Mercury	5.2E-04	8.5E-07	1.7E-05	3.0E-07	7.8E-08	**5.3E-04**	
Chlorine	0.022	1.4E-07	1.0E-03	1.8E-05	4.7E-06	**0.024**	
HCl	0.42	0.0023	0.016	2.9E-04	7.5E-05	**0.44**	
Phosphorus	0	0	0	0	0	**0**	
CO2 (fossil)	17,223	34.7	16,916	294	77.0	**34,545**	
CO2 (non-fossil)	5,995	0.012	4.06	0.071	0.019	**6,000**	
Total Reduced Sulfur	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	**0**	
Metals	2.44	5.1E-06	0.0017	2.9E-05	7.6E-06	**2.45**	
Mercaptan	0	0	0	0	0	**0**	
Antimony	5.4E-05	2.0E-07	2.5E-05	4.4E-07	1.2E-07	**8.0E-05**	
Arsenic	0.0034	1.6E-06	5.2E-05	9.1E-07	2.4E-07	**0.0035**	
Beryllium	3.7E-04	1.9E-07	3.6E-06	6.4E-08	1.7E-08	**3.8E-04**	
Cadmium	1.0E-03	3.2E-07	7.8E-05	1.4E-06	3.6E-07	**0.0011**	
Chromium	0.0064	2.5E-06	6.0E-05	1.0E-06	2.7E-07	**0.0065**	
Cobalt	1.5E-04	5.5E-07	7.1E-05	1.2E-06	3.3E-07	**2.3E-04**	
Manganese	0.036	5.0E-06	7.1E-05	1.2E-06	3.3E-07	**0.036**	
Nickel	0.0067	5.5E-06	0.0011	1.9E-05	5.1E-06	**0.008**	
Selenium	6.0E-04	3.2E-06	4.8E-05	8.4E-07	2.2E-07	**6.6E-04**	
Acreolin	8.3E-05	4.5E-07	3.1E-06	5.4E-08	1.4E-08	**8.6E-05**	
Nitrous Oxide	0.18	2.8E-04	0.0019	3.3E-05	8.6E-06	**0.18**	
Benzene	0.012	6.3E-07	1.0E-05	1.7E-07	4.5E-08	**0.012**	
Perchloroethylene	7.9E-05	4.3E-07	3.1E-06	5.4E-08	1.4E-08	**8.3E-05**	
Trichloroethylene	7.8E-05	4.2E-07	2.9E-06	5.1E-08	1.3E-08	**8.2E-05**	
Methylene Chloride	3.5E-04	1.9E-06	1.4E-05	2.4E-07	6.3E-08	**3.7E-04**	
Carbon Tetrachloride	1.4E-04	6.9E-07	1.3E-05	2.2E-07	5.7E-08	**1.5E-04**	
Phenols	0.11	1.2E-06	8.1E-05	1.4E-06	3.7E-07	**0.11**	
Naphthalene	0.007	2.5E-08	4.6E-06	8.1E-08	2.1E-08	**0.007**	
Dioxins	4.5E-10	2.4E-12	1.7E-11	3.0E-13	7.7E-14	**4.7E-10**	
n-nitrosodimethlamine	1.7E-05	9.4E-08	6.6E-07	1.1E-08	3.0E-09	**1.8E-05**	
Radionuclides	0.0014	7.6E-06	5.8E-05	1.0E-06	2.6E-07	**0.0015**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)							
Fossil CO2	17,223	34.7	16,916	294	77.0	**34,545**	97.4%
Methane	816	1.75	61.9	1.08	0.28	**881**	2.5%
Nitrous Oxide	53.0	0.083	0.56	0.0098	0.0026	**53.7**	0.2%
Total	**18,092**	**36.5**	**16,979**	**296**	**77.3**	**35,480**	**100.0%**
%of Total	51.0%	0.1%	47.9%	0.8%	0.2%	**100.0%**	

Table 3-7-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr					
thou lb/ 10,000 pkgs	1.4	1.4		1.4		
% recycled content	30					

	Unpadded Bleached Kraft Bag					
	Bleached Kraft	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related						
Particulates	4.14	0.24	2.01	0.086	**6.48**	
Nitrogen Oxides	16.0	1.70	13.4	0.47	**31.6**	
Hydrocarbons	3.27	0.68	5.46	0.14	**09.6**	
Sulfur Oxides	23.8	0.48	3.82	0.082	**28.2**	
Carbon Monoxide	19.1	1.67	13.9	0.36	**35.0**	
Aldehydes	0.056	0.046	0.36	0.0084	**0.48**	
Methane	4.43	0.031	0.25	0.0054	**4.72**	
Other Organics	0.78	0.91	7.35	0.20	**9.24**	
Odorous Sulfur	0.020	0	0	0	**0.020**	
Kerosene	2.9E-04	8.1E-07	6.5E-06	1.4E-07	**2.9E-04**	
Ammonia	0.043	3.1E-04	0.0025	5.4E-05	**0.046**	
Ethylene Oxide	0	0	0	0	**0**	
Hydrogen Fluoride	0.0078	2.5E-05	2.0E-04	4.4E-06	**0.0080**	
Lead	0.0016	1.1E-06	5.3E-05	1.8E-07	**0.0016**	
Mercury	7.2E-05	2.0E-07	1.6E-06	3.5E-08	**7.3E-05**	
Chlorine	0.024	1.2E-05	9.6E-05	2.1E-06	**0.024**	
HCl	0.056	1.9E-04	0.0015	3.3E-05	**0.058**	
Phosphorus	0	0	0	0	**0**	
CO2 (fossil)	2,604	198	1,582	34.1	**4,418**	
CO2 (non-fossil)	2,406	0.047	0.38	0.0082	**2,406**	
Total Reduced Sulfur	0.39	0	0	0	**0.39**	
Chlorine Dioxide	0	0	0	0	**0**	
Metals	0.98	1.9E-05	1.5E-04	3.3E-06	**0.98**	
Mercaptan	0	0	0	0	**0**	
Antimony	5.5E-05	3.0E-07	2.4E-06	5.1E-08	**5.8E-05**	
Arsenic	5.3E-04	6.1E-07	4.9E-06	1.1E-07	**5.4E-04**	
Beryllium	4.6E-05	4.3E-08	3.4E-07	7.4E-09	**4.6E-05**	
Cadmium	2.6E-04	9.2E-07	7.3E-06	1.6E-07	**2.7E-04**	
Chromium	8.2E-04	7.0E-07	5.6E-06	1.2E-07	**8.3E-04**	
Cobalt	1.6E-04	8.3E-07	6.7E-06	1.4E-07	**1.6E-04**	
Manganese	0.012	8.3E-07	6.7E-06	1.4E-07	**0.012**	
Nickel	0.0034	1.3E-05	1.0E-04	2.3E-06	**0.0035**	
Selenium	1.3E-04	5.6E-07	4.5E-06	9.7E-08	**1.4E-04**	
Acreolin	1.1E-05	3.6E-08	2.9E-07	6.3E-09	**1.1E-05**	
Nitrous Oxide	0.020	2.2E-05	1.8E-04	3.8E-06	**0.020**	
Benzene	0.0043	1.2E-07	9.3E-07	2.0E-08	**0.0043**	
Perchloroethylene	1.1E-05	3.6E-08	2.9E-07	6.2E-09	**1.1E-05**	
Trichloroethylene	1.1E-05	3.4E-08	2.7E-07	5.9E-09	**1.1E-05**	
Methylene Chloride	4.7E-05	1.6E-07	1.3E-06	2.8E-08	**4.9E-05**	
Carbon Tetrachloride	1.8E-05	1.5E-07	1.2E-06	2.5E-08	**2.0E-05**	
Phenols	0.044	9.5E-07	7.6E-06	1.6E-07	**0.044**	
Naphthalene	0.0027	5.4E-08	4.3E-07	9.4E-09	**0.0027**	
Dioxins	6.1E-11	2.0E-13	1.6E-12	3.4E-14	**6.3E-11**	
n-nitrosodimethlamine	2.4E-06	7.7E-09	6.1E-08	1.3E-09	**2.4E-06**	
Radionuclides	1.9E-04	6.8E-07	5.4E-06	1.2E-07	**2.0E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)						
Fossil CO2	2,604	198	1,582	34.1	**4,418**	97.5%
Methane	102	0.72	5.79	0.13	**108**	2.4%
Nitrous Oxide	6.00	0.0065	0.052	0.0011	**6.06**	0.1%
Total	**2,712**	**198**	**1,588**	**34.2**	4,532	**100.0%**
%of Total	59.8%	4.4%	35.0%	0.8%	**100.0%**	

Table 3-7-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr	Unbl Kr						
thou lb/ 10,000 pkgs	1	0.9	1.9	3.8		3.8		
% recycled content	30	30						
	All-Paper Padded Kraft Bag							
	Bleached Kraft	Unbleached Kraft	Macerated PC Newspaper Padding	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	2.96	2.38	0.35	0.66	5.08	0.23	**11.7**	
Nitrogen Oxides	11.4	09.1	1.58	4.61	34.0	1.28	**61.9**	
Hydrocarbons	2.34	1.03	0.47	1.85	13.8	0.37	**19.9**	
Sulfur Oxides	17.0	15.0	0.73	1.31	9.65	0.22	**44.0**	
Carbon Monoxide	13.6	15.4	1.22	4.53	35.0	0.98	**70.7**	
Aldehydes	0.040	0.039	0.025	0.13	0.92	0.023	**1.17**	
Methane	3.16	1.95	0.16	0.085	0.64	0.015	**6.02**	
Other Organics	0.56	0.43	0.70	2.46	18.6	0.55	**23.3**	
Odorous Sulfur	0.014	0	0	0	0	0	**0.014**	
Kerosene	2.0E-04	7.4E-05	2.3E-05	2.2E-06	1.6E-05	3.8E-07	**3.2E-04**	
Ammonia	0.031	0.059	3.9E-04	8.5E-04	0.0063	1.5E-04	**0.10**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.0055	0.0020	6.2E-04	6.9E-05	5.1E-04	1.2E-05	**0.0088**	
Lead	0.0011	0.0008	3.4E-06	2.9E-06	1.3E-04	4.9E-07	**0.0021**	
Mercury	5.1E-05	7.5E-05	1.8E-06	5.4E-07	4.1E-06	9.4E-08	**1.3E-04**	
Chlorine	0.017	0.0052	6.5E-06	3.2E-05	2.4E-04	5.6E-06	**0.022**	
HCl	0.040	0.0146	0.0045	5.2E-04	0.0039	9.0E-05	**0.064**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	1,860	1,006	170	537	3,998	92.6	**7,663**	
CO2 (non-fossil)	1,718	1,378	0.049	0.13	0.96	0.022	**3,098**	
Total Reduced Sulfur	0.28	0.037	0	0	0	0	**0.32**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	0.70	0.56	2.0E-05	5.2E-05	3.9E-04	9.1E-06	**1.26**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	3.9E-05	2.9E-06	5.4E-07	8.0E-07	6.0E-06	1.4E-07	**5.0E-05**	
Arsenic	3.8E-04	2.7E-04	3.3E-06	1.7E-06	1.2E-05	2.9E-07	**6.7E-04**	
Beryllium	3.3E-05	2.5E-05	3.8E-07	1.2E-07	8.6E-07	2.0E-08	**5.9E-05**	
Cadmium	1.9E-04	7.1E-05	1.1E-06	2.5E-06	1.9E-05	4.3E-07	**2.8E-04**	
Chromium	5.9E-04	4.6E-04	5.3E-06	1.9E-06	1.4E-05	3.3E-07	**0.0011**	
Cobalt	1.1E-04	8.1E-06	1.5E-06	2.3E-06	1.7E-05	3.9E-07	**1.4E-04**	
Manganese	0.008	0.0066	1.0E-05	2.3E-06	1.7E-05	3.9E-07	**0.015**	
Nickel	0.0024	7.1E-04	1.8E-05	3.5E-05	2.6E-04	6.1E-06	**0.0034**	
Selenium	9.5E-05	2.2E-05	6.4E-06	1.5E-06	1.1E-05	2.6E-07	**1.4E-04**	
Acreolin	8.0E-06	2.9E-06	8.9E-07	9.8E-08	7.3E-07	1.7E-08	**1.3E-05**	
Nitrous Oxide	0.014	0.011	5.6E-04	6.0E-05	4.5E-04	1.0E-05	**0.026**	
Benzene	0.0030	0.0025	1.3E-06	3.2E-07	2.4E-06	5.5E-08	**0.0055**	
Perchloroethylene	7.6E-06	2.8E-06	8.5E-07	9.7E-08	7.2E-07	1.7E-08	**1.2E-05**	
Trichloroethylene	7.5E-06	2.7E-06	8.4E-07	9.3E-08	6.9E-07	1.6E-08	**1.2E-05**	
Methylene Chloride	3.4E-05	1.2E-05	3.8E-06	4.4E-07	3.2E-06	7.5E-08	**5.4E-05**	
Carbon Tetrachloride	1.3E-05	5.0E-06	1.4E-06	4.0E-07	3.0E-06	6.9E-08	**2.3E-05**	
Phenols	0.032	0.025	2.8E-06	2.6E-06	1.9E-05	4.5E-07	**0.057**	
Naphthalene	0.0019	0.0015	7.6E-08	1.5E-07	1.1E-06	2.6E-08	**0.0035**	
Dioxins	4.3E-11	1.6E-11	4.9E-12	5.4E-13	4.0E-12	9.3E-14	**6.9E-11**	
n-nitrosodimethlamine	1.7E-06	6.1E-07	1.9E-07	2.1E-08	1.5E-07	3.6E-09	**2.7E-06**	
Radionuclides	1.4E-04	4.9E-05	1.5E-05	1.8E-06	1.4E-05	3.2E-07	**2.2E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	1,860	1,006	170	537	3,998	92.6	**7,663**	98.1%
Methane	72.7	44.9	3.78	1.96	14.6	0.34	**138**	1.8%
Nitrous Oxide	4.29	3.22	0.17	0.018	0.13	0.0031	**7.83**	0.1%
Total	**1,937**	**1,054**	**174**	**539**	**4,012**	**93.0**	**7,809**	**100.0%**
%of Total	24.8%	13.5%	2.2%	6.9%	51.4%	1.2%	**100.0%**	

Table 3-7-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.86	0.24	0.24	1.34	1.34
% recycled content	30	30	30		

	Bubble Padded Kraft Bag							
	Bleached Kraft	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related								
Particulates	2.54	0.38	0.34	0.23	2.09	0.085	**5.67**	
Nitrogen Oxides	09.8	1.94	1.77	1.62	14.0	0.47	**29.6**	
Hydrocarbons	2.01	3.12	2.71	0.65	5.68	0.13	**14.3**	
Sulfur Oxides	14.6	09.3	09.0	0.46	3.97	0.081	**37.5**	
Carbon Monoxide	11.7	1.36	1.32	1.60	14.4	0.36	**30.8**	
Aldehydes	0.034	0.013	0.013	0.044	0.38	0.0083	**0.49**	
Methane	2.72	1.98	1.88	0.030	0.26	0.0054	**6.88**	
Other Organics	0.48	0.16	0.16	0.87	7.65	0.20	**9.52**	
Odorous Sulfur	0.012	0	0	0	0	0	**0.012**	
Kerosene	1.8E-04	7.6E-05	6.2E-05	7.7E-07	6.7E-06	1.4E-07	**3.2E-04**	
Ammonia	0.027	0.0011	0.0009	3.0E-04	0.0026	5.4E-05	**0.032**	
Ethylene Oxide	0	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.0048	0.0021	0.0017	2.4E-05	2.1E-04	4.3E-06	**0.0087**	
Lead	0.0010	1.1E-05	9.4E-06	1.0E-06	5.5E-05	1.8E-07	**0.0010**	
Mercury	4.4E-05	5.8E-06	4.8E-06	1.9E-07	1.7E-06	3.4E-08	**5.7E-05**	
Chlorine	0.015	1.3E-05	1.3E-05	1.1E-05	1.0E-04	2.0E-06	**0.015**	
HCl	0.035	0.015	0.012	1.8E-04	0.0016	3.3E-05	**0.063**	
Phosphorus	0	0	0	0	0	0	**0**	
CO2 (fossil)	1,600	437	390	189	1,646	33.8	**4,296**	
CO2 (non-fossil)	1,478	0.13	0.11	0.045	0.39	0.0081	**1,478**	
Total Reduced Sulfur	0.24	0	0	0	0	0	**0.24**	
Chlorine Dioxide	0	0	0	0	0	0	**0**	
Metals	0.60	5.2E-05	4.5E-05	1.8E-05	1.6E-04	3.3E-06	**0.60**	
Mercaptan	0	0	0	0	0	0	**0**	
Antimony	3.4E-05	1.8E-06	1.5E-06	2.8E-07	2.5E-06	5.1E-08	**4.0E-05**	
Arsenic	3.3E-04	1.1E-05	9.2E-06	5.8E-07	5.1E-06	1.0E-07	**3.5E-04**	
Beryllium	2.8E-05	1.3E-06	1.1E-06	4.1E-08	3.6E-07	7.3E-09	**3.1E-05**	
Cadmium	1.6E-04	3.6E-06	3.3E-06	8.8E-07	7.6E-06	1.6E-07	**1.8E-04**	
Chromium	5.1E-04	1.8E-05	1.5E-05	6.7E-07	5.8E-06	1.2E-07	**5.5E-04**	
Cobalt	9.5E-05	5.0E-06	4.3E-06	8.0E-07	7.0E-06	1.4E-07	**1.1E-04**	
Manganese	0.0071	3.4E-05	2.8E-05	8.0E-07	6.9E-06	1.4E-07	**0.007**	
Nickel	0.0021	5.7E-05	5.1E-05	1.2E-05	1.1E-04	2.2E-06	**0.0023**	
Selenium	8.2E-05	2.1E-05	1.8E-05	5.4E-07	4.7E-06	9.6E-08	**1.3E-04**	
Acreolin	6.8E-06	2.9E-06	2.4E-06	3.5E-08	3.0E-07	6.2E-09	**1.3E-05**	
Nitrous Oxide	0.012	0.0019	0.0015	2.1E-05	1.8E-04	3.8E-06	**0.016**	
Benzene	0.0026	4.2E-06	3.5E-06	1.1E-07	9.7E-07	2.0E-08	**0.0026**	
Perchloroethylene	6.5E-06	2.8E-06	2.3E-06	3.4E-08	3.0E-07	6.1E-09	**1.2E-05**	
Trichloroethylene	6.5E-06	2.8E-06	2.3E-06	3.3E-08	2.9E-07	5.9E-09	**1.2E-05**	
Methylene Chloride	2.9E-05	1.2E-05	1.0E-05	1.5E-07	1.3E-06	2.7E-08	**5.3E-05**	
Carbon Tetrachloride	1.1E-05	4.7E-06	3.8E-06	1.4E-07	1.2E-06	2.5E-08	**2.1E-05**	
Phenols	0.027	8.6E-06	7.1E-06	9.1E-07	7.9E-06	1.6E-07	**0.027**	
Naphthalene	0.0016	2.1E-07	1.8E-07	5.2E-08	4.5E-07	9.3E-09	**0.0017**	
Dioxins	3.7E-11	1.6E-11	1.3E-11	1.9E-13	1.6E-12	3.4E-14	**6.8E-11**	
n-nitrosodimethlamine	1.4E-06	6.2E-07	5.1E-07	7.3E-09	6.4E-08	1.3E-09	**2.6E-06**	
Radionuclides	1.2E-04	5.0E-05	4.1E-05	6.5E-07	5.6E-06	1.2E-07	**2.1E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)								
Fossil CO2	1,600	437	390	189	1,646	33.8	**4,296**	96.3%
Methane	62.6	45.6	43.2	0.69	6.02	0.12	**158**	3.5%
Nitrous Oxide	3.69	0.55	0.45	0.0063	0.055	0.0011	**4.75**	0.1%
Total	**1,666**	**483**	**433**	**190**	**1,652**	**33.9**	**4,459**	**100.0%**
%of Total	37.4%	10.8%	9.7%	4.3%	37.1%	0.8%	**100.0%**	

Table 3-7-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	LLDPE					
thou lb/ 10,000 pkgs	0.67	0.67		0.67		
% recycled content	30					

	Unpadded LLDPE Film Bag					
	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related						
Particulates	0.95	0.19	1.01	0.046	**2.19**	
Nitrogen Oxides	4.95	1.14	6.73	0.25	**13.1**	
Hydrocarbons	07.6	0.53	2.73	0.072	**10.9**	
Sulfur Oxides	25.1	0.43	1.91	0.043	**27.5**	
Carbon Monoxide	3.70	0.91	6.94	0.19	**11.7**	
Aldehydes	0.036	0.041	0.18	0.0044	**0.26**	
Methane	5.25	0.029	0.13	0.0029	**5.40**	
Other Organics	0.45	0.49	3.68	0.11	**4.72**	
Odorous Sulfur	0	0	0	0	**0**	
Kerosene	1.7E-04	7.4E-07	3.2E-06	7.4E-08	**1.8E-04**	
Ammonia	0.0026	2.9E-04	0.0013	2.9E-05	**0.0042**	
Ethylene Oxide	0	0	0	0	**0**	
Hydrogen Fluoride	0.0047	2.3E-05	1.0E-04	2.3E-06	**0.0048**	
Lead	2.6E-05	9.6E-07	2.6E-05	9.6E-08	**5.4E-05**	
Mercury	1.3E-05	1.8E-07	8.0E-07	1.8E-08	**1.4E-05**	
Chlorine	3.6E-05	1.1E-05	4.8E-05	1.1E-06	**9.6E-05**	
HCl	0.034	1.8E-04	7.7E-04	1.8E-05	**0.035**	
Phosphorus	0	0	0	0	**0**	
CO2 (fossil)	1,088	183	792	18.1	**2,081**	
CO2 (non-fossil)	0.31	0.043	0.19	0.0043	**0.55**	
Total Reduced Sulfur	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	**0**	
Metals	1.3E-04	1.8E-05	7.7E-05	1.8E-06	**2.2E-04**	
Mercaptan	0	0	0	0	**0**	
Antimony	4.3E-06	2.7E-07	1.2E-06	2.7E-08	**5.7E-06**	
Arsenic	2.6E-05	5.6E-07	2.4E-06	5.6E-08	**2.9E-05**	
Beryllium	3.0E-06	3.9E-08	1.7E-07	3.9E-09	**3.2E-06**	
Cadmium	9.1E-06	8.4E-07	3.7E-06	8.4E-08	**1.4E-05**	
Chromium	4.1E-05	6.4E-07	2.8E-06	6.4E-08	**4.4E-05**	
Cobalt	1.2E-05	7.6E-07	3.3E-06	7.6E-08	**1.6E-05**	
Manganese	7.8E-05	7.6E-07	3.3E-06	7.6E-08	**8.2E-05**	
Nickel	1.4E-04	1.2E-05	5.2E-05	1.2E-06	**2.1E-04**	
Selenium	4.9E-05	5.1E-07	2.2E-06	5.1E-08	**5.2E-05**	
Acreolin	6.7E-06	3.3E-08	1.5E-07	3.3E-09	**6.9E-06**	
Nitrous Oxide	0.0042	2.0E-05	8.9E-05	2.0E-06	**0.0044**	
Benzene	9.7E-06	1.1E-07	4.7E-07	1.1E-08	**1.0E-05**	
Perchloroethylene	6.4E-06	3.3E-08	1.4E-07	3.3E-09	**6.6E-06**	
Trichloroethylene	6.4E-06	3.1E-08	1.4E-07	3.1E-09	**6.5E-06**	
Methylene Chloride	2.8E-05	1.5E-07	6.4E-07	1.5E-08	**2.9E-05**	
Carbon Tetrachloride	1.1E-05	1.3E-07	5.9E-07	1.3E-08	**1.1E-05**	
Phenols	2.0E-05	8.7E-07	3.8E-06	8.7E-08	**2.5E-05**	
Naphthalene	5.1E-07	5.0E-08	2.2E-07	5.0E-09	**7.8E-07**	
Dioxins	3.7E-11	1.8E-13	7.9E-13	1.8E-14	**3.8E-11**	
n-nitrosodimethlamine	1.4E-06	7.0E-09	3.1E-08	7.0E-10	**1.5E-06**	
Radionuclides	1.1E-04	6.2E-07	2.7E-06	6.2E-08	**1.2E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)						
Fossil CO2	1,088	183	792	18.1	**2,081**	94.3%
Methane	121	0.66	2.90	0.066	**124**	5.6%
Nitrous Oxide	1.26	0.0060	0.026	6.0E-04	**1.29**	0.1%
Total	**1,210**	**183**	**795**	**18.1**	**2,206**	**100.0%**
%of Total	54.8%	8.3%	36.0%	0.8%	**100.0%**	

Table 3-7-BAG
LIFE CYCLE ATMOSPHERIC EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.35	0.98	1.33	1.33
% recycled content	30	30		

	Bubble Padded LLDPE Bag						
	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**	% of Total
Atmospheric Emissions (lb/10,000 pkgs) - Process + Fuel-Related							
Particulates	0.55	1.38	0.23	2.09	0.090	**4.35**	
Nitrogen Oxides	2.83	7.24	1.61	14.0	0.49	**26.2**	
Hydrocarbons	4.55	11.1	0.65	5.68	0.14	**22.1**	
Sulfur Oxides	13.6	36.7	0.46	3.97	0.086	**54.8**	
Carbon Monoxide	1.98	5.41	1.58	14.4	0.38	**23.8**	
Aldehydes	0.019	0.052	0.044	0.38	0.0088	**0.50**	
Methane	2.89	07.7	0.030	0.26	0.0057	**10.9**	
Other Organics	0.23	0.65	0.86	7.65	0.21	**9.61**	
Odorous Sulfur	0	0	0	0	0	**0**	
Kerosene	1.1E-04	2.5E-04	7.7E-07	6.7E-06	1.5E-07	**3.7E-04**	
Ammonia	0.0016	0.0038	3.0E-04	0.0026	5.7E-05	**0.0083**	
Ethylene Oxide	0	0	0	0	0	**0**	
Hydrogen Fluoride	0.0030	0.0069	2.4E-05	2.1E-04	4.6E-06	**0.010**	
Lead	1.6E-05	3.9E-05	1.0E-06	5.5E-05	1.9E-07	**1.1E-04**	
Mercury	8.5E-06	2.0E-05	1.9E-07	1.7E-06	3.7E-08	**3.0E-05**	
Chlorine	1.9E-05	5.3E-05	1.1E-05	1.0E-04	2.2E-06	**1.8E-04**	
HCl	0.022	0.050	1.8E-04	0.0016	3.5E-05	**0.073**	
Phosphorus	0	0	0	0	0	**0**	
CO2 (fossil)	638	1,592	188	1,646	35.8	**4,099**	
CO2 (non-fossil)	0.18	0.45	0.045	0.39	0.0086	**1.09**	
Total Reduced Sulfur	0	0	0	0	0	**0**	
Chlorine Dioxide	0	0	0	0	0	**0**	
Metals	7.5E-05	1.8E-04	1.8E-05	1.6E-04	3.5E-06	**4.4E-04**	
Mercaptan	0	0	0	0	0	**0**	
Antimony	2.6E-06	6.2E-06	2.8E-07	2.5E-06	5.4E-08	**1.2E-05**	
Arsenic	1.6E-05	3.8E-05	5.8E-07	5.1E-06	1.1E-07	**6.0E-05**	
Beryllium	1.9E-06	4.3E-06	4.0E-08	3.6E-07	7.7E-09	**6.6E-06**	
Cadmium	5.3E-06	1.3E-05	8.7E-07	7.6E-06	1.7E-07	**2.7E-05**	
Chromium	2.6E-05	6.0E-05	6.6E-07	5.8E-06	1.3E-07	**9.2E-05**	
Cobalt	7.2E-06	1.7E-05	7.9E-07	7.0E-06	1.5E-07	**3.3E-05**	
Manganese	5.0E-05	1.1E-04	7.9E-07	6.9E-06	1.5E-07	**1.7E-04**	
Nickel	8.3E-05	2.1E-04	1.2E-05	1.1E-04	2.4E-06	**4.1E-04**	
Selenium	3.1E-05	7.2E-05	5.3E-07	4.7E-06	1.0E-07	**1.1E-04**	
Acreolin	4.3E-06	9.8E-06	3.4E-08	3.0E-07	6.6E-09	**1.4E-05**	
Nitrous Oxide	0.0027	0.0062	2.1E-05	1.8E-04	4.0E-06	**0.0091**	
Benzene	6.2E-06	1.4E-05	1.1E-07	9.7E-07	2.1E-08	**2.1E-05**	
Perchloroethylene	4.1E-06	9.4E-06	3.4E-08	3.0E-07	6.5E-09	**1.4E-05**	
Trichloroethylene	4.1E-06	9.3E-06	3.3E-08	2.9E-07	6.2E-09	**1.4E-05**	
Methylene Chloride	1.8E-05	4.2E-05	1.5E-07	1.3E-06	2.9E-08	**6.1E-05**	
Carbon Tetrachloride	6.8E-06	1.6E-05	1.4E-07	1.2E-06	2.7E-08	**2.4E-05**	
Phenols	1.2E-05	2.9E-05	9.0E-07	7.9E-06	1.7E-07	**5.1E-05**	
Naphthalene	3.1E-07	7.4E-07	5.2E-08	4.5E-07	9.9E-09	**1.6E-06**	
Dioxins	2.3E-11	5.4E-11	1.9E-13	1.6E-12	3.6E-14	**7.9E-11**	
n-nitrosodimethlamine	9.1E-07	2.1E-06	7.3E-09	6.4E-08	1.4E-09	**3.1E-06**	
Radionuclides	7.3E-05	1.7E-04	6.4E-07	5.6E-06	1.2E-07	**2.5E-04**	
GHG Summary (lb CO2 Equivalents/10,000 pkgs)							
Fossil CO2	638	1,592	188	1,646	35.8	**4,099**	94.2%
Methane	66.5	176	0.69	6.02	0.13	**250**	5.7%
Nitrous Oxide	0.80	1.84	0.0062	0.055	0.0012	**2.70**	0.1%
Total	**705**	**1,770**	**189**	**1,652**	**36.0**	**4,352**	**100.0%**
%of Total	16.2%	40.7%	4.3%	38.0%	0.8%	**100.0%**	

Table 3-8-BOX

LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Air Pkt
thou lb/ 10,000 pkgs	13.9	0.84
	% recycled content	0

	Box with Inflated Air Packets						
	Box	LDPE Inflated Air Packets	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.20	0.111	3.9E-08	5.2E-06	9.7E-08	7.5E-09	**0.31**
Metal Ion	0.010	0.0068	8.3E-04	0.11	0.0021	1.6E-04	**0.13**
Fluorides	0.0073	0.0012	1.9E-06	2.6E-04	4.8E-06	3.7E-07	**0.0088**
Dissolved Solids	76.6	62.2	0.16	21.6	0.40	0.031	**161**
Suspended Solids	51.4	1.19	0.0037	0.49	0.0092	7.1E-04	**53.1**
BOD	34.1	0.27	6.1E-04	0.081	0.0015	1.2E-04	**34.4**
COD	129	1.24	0.0041	0.54	0.010	7.8E-04	**131**
Phenol	0.012	2.2E-05	2.7E-06	3.6E-04	6.7E-06	5.1E-07	**0.012**
Sulfides	1.00	0.050	0	0	0	0	**1.05**
Oil	2.32	1.12	0.0038	0.51	0.0095	7.3E-04	**3.96**
Sulfuric Acid	0.12	0.0078	3.2E-05	0.0043	8.0E-05	6.2E-06	**0.13**
Iron	1.65	0.045	8.8E-05	0.012	2.2E-04	1.7E-05	**1.70**
Cyanide	6.3E-06	4.2E-06	8.7E-09	1.1E-06	2.2E-08	1.7E-09	**1.2E-05**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0034	0.0028	6.1E-06	8.1E-04	1.5E-05	1.2E-06	**0.0071**
Aluminum	1.25	0	0	0	0	0	**1.25**
Nickel	2.0E-08	0	0	0	0	0	**2.0E-08**
Mercury	2.9E-07	2.2E-07	4.6E-10	6.0E-08	1.1E-09	8.8E-11	**5.7E-07**
Lead	8.9E-07	5.6E-07	6.9E-08	9.2E-06	1.7E-07	1.3E-08	**1.1E-05**
Phosphates	1.11	0.0095	1.6E-05	0.0022	4.0E-05	3.1E-06	**1.12**
Phosphorus	0.44	0	0	0	0	0	**0.44**
Nitrogen	0.47	0	0	0	0	0	**0.47**
Zinc	0.015	0.0019	3.0E-06	4.0E-04	7.5E-06	5.8E-07	**0.017**
Ammonia	0.33	0.0013	6.6E-05	0.0088	1.6E-04	1.3E-05	**0.34**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.43	2.87	0.0060	0.79	0.015	0.0011	**7.12**
Cadmium	0.0034	0.0028	5.9E-06	7.8E-04	1.5E-05	1.1E-06	**0.0070**
Organic Carbon	0	0.118	0	0	0	0	**0.118**
Sulfates	3.52	2.34	0.0048	0.64	0.012	9.2E-04	**6.52**
Sodium	0.0029	4.6E-04	7.7E-07	1.0E-04	1.9E-06	1.5E-07	**0.0035**
Calcium	0.0016	2.5E-04	4.2E-07	5.6E-05	1.0E-06	8.0E-08	**0.0019**
Manganese	0.40	0.026	4.3E-05	0.0057	1.1E-04	8.2E-06	**0.43**
Nitrates	0.017	1.1E-04	1.8E-07	2.4E-05	4.5E-07	3.5E-08	**0.017**
Boron	0.47	0.031	1.3E-04	0.017	3.2E-04	2.5E-05	**0.52**
Other Organics	0.30	0.069	4.0E-04	0.053	9.9E-04	7.6E-05	**0.42**
Chromates	1.0E-04	1.3E-05	4.6E-07	5.9E-05	1.1E-06	8.7E-08	**1.8E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-8-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	EPS
thou lb/ 10,000 pkgs	13.9	0.48
% recycled content		0

	Box with EPS Loose Fill						
	Box	EPS Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.20	0.018	7.8E-08	5.1E-06	9.7E-08	5.8E-09	**0.21**
Metal Ion	0.010	0.0133	0.0017	0.11	0.0021	1.2E-04	**0.14**
Fluorides	0.0073	0.0011	3.9E-06	2.5E-04	4.8E-06	2.9E-07	**0.0087**
Dissolved Solids	76.6	37.1	0.33	21.4	0.40	0.024	**136**
Suspended Solids	51.4	1.15	0.0074	0.49	0.0092	5.5E-04	**53.0**
BOD	34.1	0.32	0.0012	0.080	0.0015	9.1E-05	**34.5**
COD	129	0.93	0.008	0.54	0.010	6.1E-04	**130**
Phenol	0.012	4.3E-05	5.4E-06	3.5E-04	6.7E-06	4.0E-07	**0.012**
Sulfides	1.00	0.0094	0	0	0	0	**1.01**
Oil	2.32	0.68	0.008	0.50	0.0095	5.7E-04	**3.51**
Sulfuric Acid	0.12	0.0079	6.5E-05	0.0042	8.0E-05	4.8E-06	**0.13**
Iron	1.65	0.042	1.8E-04	0.012	2.2E-04	1.3E-05	**1.70**
Cyanide	6.3E-06	2.4E-06	1.7E-08	1.1E-06	2.2E-08	1.3E-09	**9.9E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0034	0.0017	1.2E-05	8.0E-04	1.5E-05	9.1E-07	**0.0059**
Aluminum	1.25	0	0	0	0	0	**1.25**
Nickel	2.0E-08	0	0	0	0	0	**2.0E-08**
Mercury	2.9E-07	1.3E-07	9.2E-10	5.9E-08	1.1E-09	6.8E-11	**4.8E-07**
Lead	8.9E-07	1.1E-06	1.4E-07	9.1E-06	1.7E-07	1.0E-08	**1.1E-05**
Phosphates	1.11	0.0049	3.2E-05	0.0021	4.0E-05	2.4E-06	**1.11**
Phosphorus	0.44	0	0	0	0	0	**0.44**
Nitrogen	0.47	0	0	0	0	0	**0.47**
Zinc	0.015	7.4E-04	6.1E-06	4.0E-04	7.5E-06	4.5E-07	**0.016**
Ammonia	0.33	0.0019	1.3E-04	0.0087	1.6E-04	9.9E-06	**0.34**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0.048	0	0	0	0	**0.048**
Chlorides	3.43	1.68	0.012	0.79	0.015	8.9E-04	**5.92**
Cadmium	0.0034	0.0017	1.2E-05	7.7E-04	1.5E-05	8.9E-07	**0.0059**
Organic Carbon	0	0.022	0	0	0	0	**0.022**
Sulfates	3.52	1.42	0.010	0.63	0.012	7.2E-04	**5.60**
Sodium	0.0029	4.2E-04	1.5E-06	1.0E-04	1.9E-06	1.1E-07	**0.0034**
Calcium	0.0016	2.3E-04	8.4E-07	5.5E-05	1.0E-06	6.2E-08	**0.0019**
Manganese	0.40	0.024	8.6E-05	0.0056	1.1E-04	6.4E-06	**0.43**
Nitrates	0.017	1.0E-04	3.7E-07	2.4E-05	4.5E-07	2.7E-08	**0.017**
Boron	0.47	0.032	2.6E-04	0.017	3.2E-04	1.9E-05	**0.52**
Other Organics	0.30	0.089	0.0008	0.052	9.9E-04	5.9E-05	**0.44**
Chromates	1.0E-04	3.1E-05	9.1E-07	5.9E-05	1.1E-06	6.8E-08	**1.9E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-8-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	1
80% pc box	0

	Box	Cornstarch
thou lb/ 10,000 pkgs	13.9	0.86

	Box with Cornstarch Loose Fill						
	Box	Cornstarch Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.20	0.087	1.7E-07	5.2E-06	9.7E-08	1.2E-09	**0.28**
Metal Ion	0.010	0.0012	0.0037	0.11	0.0021	2.6E-05	**0.13**
Fluorides	0.0073	8.2E-04	8.5E-06	2.6E-04	4.8E-06	6.1E-08	**0.0084**
Dissolved Solids	76.6	7.11	0.72	21.7	0.40	0.0051	**106**
Suspended Solids	51.4	10.0	0.016	0.49	0.0092	1.2E-04	**61.9**
BOD	34.1	1.06	0.0027	0.081	0.0015	1.9E-05	**35.2**
COD	129	1.74	0.018	0.54	0.010	1.3E-04	**131**
Phenol	0.012	5.6E-06	1.2E-05	3.6E-04	6.7E-06	8.5E-08	**0.012**
Sulfides	1.00	0	0	0	0	0	**1.00**
Oil	2.32	0.077	0.017	0.51	0.0095	1.2E-04	**2.93**
Sulfuric Acid	0.12	0.0059	1.4E-04	0.0043	8.0E-05	1.0E-06	**0.13**
Iron	1.65	0.034	3.9E-04	0.012	2.2E-04	2.8E-06	**1.69**
Cyanide	6.3E-06	3.5E-06	3.8E-08	1.1E-06	2.2E-08	2.8E-10	**1.1E-05**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0034	1.9E-04	2.7E-05	8.1E-04	1.5E-05	1.9E-07	**0.0044**
Aluminum	1.25	0	0	0	0	0	**1.25**
Nickel	2.0E-08	0	0	0	0	0	**2.0E-08**
Mercury	2.9E-07	1.5E-08	2.0E-09	6.0E-08	1.1E-09	1.4E-11	**3.7E-07**
Lead	8.9E-07	1.0E-07	3.1E-07	9.2E-06	1.7E-07	2.2E-09	**1.1E-05**
Phosphates	1.11	0.26	7.1E-05	0.0022	4.0E-05	5.1E-07	**1.37**
Phosphorus	0.44	0	0	0	0	0	**0.44**
Nitrogen	0.47	1.11	0	0	0	0	**1.58**
Zinc	0.015	6.6E-05	1.3E-05	4.0E-04	7.5E-06	9.6E-08	**0.016**
Ammonia	0.33	0.0015	2.9E-04	0.0088	1.6E-04	2.1E-06	**0.34**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.43	0.19	0.026	0.80	0.015	1.9E-04	**4.46**
Cadmium	0.0034	1.9E-04	2.6E-05	7.8E-04	1.5E-05	1.9E-07	**0.0044**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	3.52	0.25	0.021	0.64	0.012	1.5E-04	**4.45**
Sodium	0.0029	3.3E-04	3.4E-06	1.0E-04	1.9E-06	2.4E-08	**0.0034**
Calcium	0.0016	1.8E-04	1.8E-06	5.6E-05	1.0E-06	1.3E-08	**0.0018**
Manganese	0.40	0.020	1.9E-04	0.0057	1.1E-04	1.4E-06	**0.43**
Nitrates	0.017	7.7E-05	8.1E-07	2.4E-05	4.5E-07	5.8E-09	**0.017**
Boron	0.47	0.024	5.7E-04	0.017	3.2E-04	4.1E-06	**0.51**
Other Organics	0.30	0.016	0.0018	0.053	9.9E-04	1.3E-05	**0.37**
Chromates	1.0E-04	1.0E-05	2.0E-06	6.0E-05	1.1E-06	1.4E-08	**1.8E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-8-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	1
80% pc box	0

	Box	Mold Pulp
thou lb/ 10,000 pkgs	13.9	3.8

	Box with Molded Pulp Loose Fill						
	Box	Molded Pulp Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.20	1.4E-07	5.8E-07	5.7E-06	9.7E-08	2.8E-08	**0.20**
Metal Ion	0.010	0.0031	0.012	0.12	0.0021	5.9E-04	**0.15**
Fluorides	0.0073	0.0052	2.8E-05	2.8E-04	4.8E-06	1.4E-06	**0.013**
Dissolved Solids	76.6	98.8	2.39	23.5	0.40	0.12	**202**
Suspended Solids	51.4	4.03	0.054	0.54	0.0092	0.0026	**56.0**
BOD	34.1	0.098	0.0089	0.088	0.0015	4.3E-04	**34.3**
COD	129	1.38	0.060	0.59	0.010	0.0029	**131**
Phenol	0.012	9.9E-06	3.9E-05	3.9E-04	6.7E-06	1.9E-06	**0.012**
Sulfides	1.00	0	0	0	0	0	**1.00**
Oil	2.32	1.74	0.056	0.55	0.0095	0.0027	**4.68**
Sulfuric Acid	0.12	0.034	4.8E-04	0.0047	8.0E-05	2.3E-05	**0.16**
Iron	1.65	0.20	0.0013	0.013	2.2E-04	6.3E-05	**1.87**
Cyanide	6.3E-06	6.6E-06	1.3E-07	1.2E-06	2.2E-08	6.2E-09	**1.4E-05**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0034	0.0045	9.0E-05	8.8E-04	1.5E-05	4.3E-06	**0.0089**
Aluminum	1.25	0	0	0	0	0	**1.25**
Nickel	2.0E-08	0	0	0	0	0	**2.0E-08**
Mercury	2.9E-07	3.5E-07	6.7E-09	6.5E-08	1.1E-09	3.2E-10	**7.1E-07**
Lead	8.9E-07	2.6E-07	1.0E-06	1.0E-05	1.7E-07	4.9E-08	**1.2E-05**
Phosphates	1.11	0.017	2.4E-04	0.0023	4.0E-05	1.1E-05	**1.13**
Phosphorus	0.44	0	0	0	0	0	**0.44**
Nitrogen	0.47	0	0	0	0	0	**0.47**
Zinc	0.015	0.0015	4.5E-05	4.4E-04	7.5E-06	2.1E-06	**0.017**
Ammonia	0.33	0.0040	9.7E-04	0.0096	1.6E-04	4.7E-05	**0.34**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.43	4.52	0.088	0.86	0.015	0.0042	**8.93**
Cadmium	0.0034	0.0045	8.8E-05	8.5E-04	1.5E-05	4.2E-06	**0.0088**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	3.52	4.12	0.071	0.70	0.012	0.0034	**8.43**
Sodium	0.0029	0.0021	1.1E-05	1.1E-04	1.9E-06	5.4E-07	**0.0051**
Calcium	0.0016	0.0011	6.1E-06	6.0E-05	1.0E-06	3.0E-07	**0.0028**
Manganese	0.40	0.12	6.3E-04	0.0062	1.1E-04	3.0E-05	**0.53**
Nitrates	0.017	4.9E-04	2.7E-06	2.6E-05	4.5E-07	1.3E-07	**0.018**
Boron	0.47	0.14	0.0019	0.019	3.2E-04	9.2E-05	**0.63**
Other Organics	0.30	0.31	0.0058	0.057	9.9E-04	2.8E-04	**0.67**
Chromates	1.0E-04	3.9E-05	6.7E-06	6.5E-05	1.1E-06	3.2E-07	**2.1E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-8-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Unbl Kr
thou lb/ 10,000 pkgs	13.9	1.8
	% recycled content	0

	Box with Unbleached Kraft Paper Dunnage						
	Box	Unbleached Kraft Paper Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.20	0.045	8.7E-09	5.4E-06	9.7E-08	1.4E-08	**0.24**
Metal Ion	0.010	0.0016	1.8E-04	0.11	0.0021	3.1E-04	**0.13**
Fluorides	0.0073	3.8E-04	4.3E-07	2.7E-04	4.8E-06	7.2E-07	**0.0080**
Dissolved Solids	76.6	8.07	0.036	22.3	0.40	0.060	**107**
Suspended Solids	51.4	4.60	8.2E-04	0.51	0.0092	0.0014	**56.5**
BOD	34.1	2.37	1.3E-04	0.083	0.0015	2.3E-04	**36.5**
COD	129	23.6	9.0E-04	0.56	0.010	0.0015	**153**
Phenol	0.012	0.0000	5.9E-07	3.7E-04	6.7E-06	9.9E-07	**0.012**
Sulfides	1.00	0.00	0	0	0	0	**1.00**
Oil	2.32	0.14	8.4E-04	0.52	0.0095	0.0014	**3.00**
Sulfuric Acid	0.12	0.014	7.1E-06	0.0044	8.0E-05	1.2E-05	**0.14**
Iron	1.65	0.07	2.0E-05	0.012	2.2E-04	3.3E-05	**1.73**
Cyanide	6.3E-06	6.5E-07	1.9E-09	1.2E-06	2.2E-08	3.2E-09	**8.2E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0034	3.6E-04	1.4E-06	8.4E-04	1.5E-05	2.3E-06	**0.0046**
Aluminum	1.25	0.20	0	0	0	0	**1.45**
Nickel	2.0E-08	2.1E-09	0	0	0	0	**2.2E-08**
Mercury	2.9E-07	3.1E-08	1.0E-10	6.2E-08	1.1E-09	1.7E-10	**3.8E-07**
Lead	8.9E-07	1.3E-07	1.5E-08	9.5E-06	1.7E-07	2.6E-08	**1.1E-05**
Phosphates	1.11	0.18	3.6E-06	0.0022	4.0E-05	6.0E-06	**1.29**
Phosphorus	0.44	0.117	0	0	0	0	**0.56**
Nitrogen	0.47	0.042	0	0	0	0	**0.52**
Zinc	0.015	0.0001	6.7E-07	4.2E-04	7.5E-06	1.1E-06	**0.016**
Ammonia	0.33	0.078	1.5E-05	0.0091	1.6E-04	2.4E-05	**0.41**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.43	0.37	0.0013	0.82	0.015	0.0022	**4.64**
Cadmium	0.0034	3.6E-04	1.3E-06	8.0E-04	1.5E-05	2.2E-06	**0.0046**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	3.52	0.32	0.0011	0.66	0.012	0.0018	**4.52**
Sodium	0.0029	1.5E-04	1.7E-07	1.1E-04	1.9E-06	2.8E-07	**0.0032**
Calcium	0.0016	8.2E-05	9.2E-08	5.7E-05	1.0E-06	1.5E-07	**0.0017**
Manganese	0.40	0.047	9.5E-06	0.0059	1.1E-04	1.6E-05	**0.46**
Nitrates	0.017	0.0044	4.0E-08	2.5E-05	4.5E-07	6.8E-08	**0.021**
Boron	0.47	0.055	2.9E-05	0.018	3.2E-04	4.8E-05	**0.54**
Other Organics	0.30	0.033	8.8E-05	0.054	9.9E-04	1.5E-04	**0.39**
Chromates	1.0E-04	1.2E-05	1.0E-07	6.1E-05	1.1E-06	1.7E-07	**1.8E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-8-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	Newsprint
thou lb/ 10,000 pkgs	13.9	1.7
% recycled content		10

	Box with Newsprint Dunnage						
	Box	Newsprint Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.20	8.5E-08	6.8E-09	5.3E-06	9.7E-08	1.4E-08	**0.20**
Metal Ion	0.010	0.0018	1.4E-04	0.11	0.0021	2.9E-04	**0.13**
Fluorides	0.0073	0.0033	3.3E-07	2.6E-04	4.8E-06	6.8E-07	**0.0109**
Dissolved Solids	76.6	36.5	0.028	22.2	0.40	0.057	**136**
Suspended Solids	51.4	11.5	6.4E-04	0.51	0.0092	0.0013	**63.4**
BOD	34.1	9.18	1.1E-04	0.083	0.0015	2.1E-04	**43.4**
COD	129	6.69	7.1E-04	0.56	0.010	0.0014	**136**
Phenol	0.012	6.3E-06	4.6E-07	3.7E-04	6.7E-06	9.4E-07	**0.012**
Sulfides	1.00	4.1E-06	0	0	0	0	**1.00**
Oil	2.32	0.64	6.6E-04	0.52	0.0095	0.0013	**3.49**
Sulfuric Acid	0.12	0.023	5.6E-06	0.0044	8.0E-05	1.1E-05	**0.14**
Iron	1.65	0.134	1.5E-05	0.012	2.2E-04	3.1E-05	**1.79**
Cyanide	6.3E-06	2.4E-06	1.5E-09	1.2E-06	2.2E-08	3.0E-09	**1.0E-05**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0034	0.0017	1.1E-06	8.4E-04	1.5E-05	2.1E-06	**0.0059**
Aluminum	1.25	0	0	0	0	0	**1.25**
Nickel	2.0E-08	3.0E-08	0	0	0	0	**5.0E-08**
Mercury	2.9E-07	1.7E-07	7.9E-11	6.1E-08	1.1E-09	1.6E-10	**5.2E-07**
Lead	8.9E-07	2.3E-06	1.2E-08	9.5E-06	1.7E-07	2.4E-08	**1.3E-05**
Phosphates	1.11	0.0115	2.8E-06	0.0022	4.0E-05	5.7E-06	**1.12**
Phosphorus	0.44	0	0	0	0	0	**0.44**
Nitrogen	0.47	0	0	0	0	0	**0.47**
Zinc	0.015	8.3E-04	5.2E-07	4.1E-04	7.5E-06	1.1E-06	**0.016**
Ammonia	0.33	0.0021	1.1E-05	0.0090	1.6E-04	2.3E-05	**0.34**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.43	1.67	0.0010	0.82	0.015	0.0021	**5.93**
Cadmium	0.0034	0.0017	1.0E-06	8.0E-04	1.5E-05	2.1E-06	**0.0059**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	3.52	1.69	8.3E-04	0.66	0.012	0.0017	**5.89**
Sodium	0.0029	1.3E-03	1.3E-07	1.1E-04	1.9E-06	2.7E-07	**0.0044**
Calcium	0.0016	7.2E-04	7.2E-08	5.7E-05	1.0E-06	1.5E-07	**0.0024**
Manganese	0.40	0.077	7.4E-06	0.0058	1.1E-04	1.5E-05	**0.49**
Nitrates	0.017	3.1E-04	3.2E-08	2.5E-05	4.5E-07	6.4E-08	**0.017**
Boron	0.47	0.092	2.2E-05	0.018	3.2E-04	4.5E-05	**0.58**
Other Organics	0.30	0.121	6.9E-05	0.054	9.9E-04	1.4E-04	**0.48**
Chromates	1.0E-04	3.0E-05	7.9E-08	6.1E-05	1.1E-06	1.6E-07	**1.9E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0.021	0	0	0	0	**0.021**

Table 3-8-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	1	
80% pc box	0	
	Box	PC Off Ppr
thou lb/ 10,000 pkgs	13.9	1.5

	Box with Shredded PC Office Paper Dunnage					
	Box	Shredded PC Office Paper Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related						
Acid	0.20	7.3E-10	5.3E-06	9.7E-08	1.2E-08	**0.20**
Metal Ion	0.010	1.6E-05	0.11	0.0021	2.6E-04	**0.13**
Fluorides	0.0073	6.7E-05	2.6E-04	4.8E-06	6.0E-07	**0.0077**
Dissolved Solids	76.6	0.18	22.1	0.40	0.050	**99**
Suspended Solids	51.4	0.033	0.50	0.0092	0.0011	**51.9**
BOD	34.1	1.8E-04	0.083	0.0015	1.9E-04	**34.2**
COD	129	0.0025	0.55	0.010	0.0013	**129**
Phenol	0.012	5.0E-08	3.6E-04	6.7E-06	8.3E-07	**0.012**
Sulfides	1.00	0	0	0	0	**1.00**
Oil	2.32	0.0031	0.52	0.0095	0.0012	**2.85**
Sulfuric Acid	0.12	4.4E-04	0.0044	8.0E-05	1.0E-05	**0.12**
Iron	1.65	0.0026	0.012	2.2E-04	2.7E-05	**1.66**
Cyanide	6.3E-06	1.2E-08	1.2E-06	2.2E-08	2.7E-09	**7.5E-06**
Alkalinity	0	0	0	0	0	**0**
Chromium	0.0034	8.0E-06	8.3E-04	1.5E-05	1.9E-06	**0.0042**
Aluminum	1.25	0	0	0	0	**1.25**
Nickel	2.0E-08	0	0	0	0	**2.0E-08**
Mercury	2.9E-07	6.2E-10	6.1E-08	1.1E-09	1.4E-10	**3.5E-07**
Lead	8.9E-07	1.3E-09	9.4E-06	1.7E-07	2.1E-08	**1.0E-05**
Phosphates	1.11	2.2E-04	0.0022	4.0E-05	5.0E-06	**1.11**
Phosphorus	0.44	0	0	0	0	**0.44**
Nitrogen	0.47	0	0	0	0	**0.47**
Zinc	0.015	2.7E-06	4.1E-04	7.5E-06	9.4E-07	**0.016**
Ammonia	0.33	3.0E-05	0.0090	1.6E-04	2.0E-05	**0.34**
Pesticides	0.012	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	**0**
Chlorides	3.43	0.0082	0.81	0.015	0.0018	**4.27**
Cadmium	0.0034	8.0E-06	7.9E-04	1.5E-05	1.8E-06	**0.0042**
Organic Carbon	0	0	0	0	0	**0**
Sulfates	3.52	0.015	0.66	0.012	0.0015	**4.21**
Sodium	0.0029	2.7E-05	1.0E-04	1.9E-06	2.4E-07	**0.0031**
Calcium	0.0016	1.5E-05	5.7E-05	1.0E-06	1.3E-07	**0.0017**
Manganese	0.40	0.0015	0.0058	1.1E-04	1.3E-05	**0.41**
Nitrates	0.017	6.4E-06	2.5E-05	4.5E-07	5.6E-08	**0.017**
Boron	0.47	0.0018	0.018	3.2E-04	4.0E-05	**0.49**
Other Organics	0.30	8.4E-04	0.054	9.9E-04	1.2E-04	**0.36**
Chromates	1.0E-04	4.2E-07	6.1E-05	1.1E-06	1.4E-07	**1.6E-04**
Sodium Dichromate	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	**0**

Table 3-8-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
LOWER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	1
80% pc box	0

	Box	PC Corrug
thou lb/ 10,000 pkgs	13.9	3.2

	Box with Shredded PC Corrugated Dunnage					
	Box	Shredded PC Corrugated Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related						
Acid	0.20	5.0E-10	5.6E-06	9.7E-08	2.5E-08	**0.20**
Metal Ion	0.010	1.1E-05	0.12	0.0021	5.4E-04	**0.13**
Fluorides	0.0073	4.6E-05	2.8E-04	4.8E-06	1.3E-06	**0.0077**
Dissolved Solids	76.6	0.12	23.2	0.40	0.11	**100.4**
Suspended Solids	51.4	0.022	0.53	0.0092	0.0024	**52.0**
BOD	34.1	1.2E-04	0.087	0.0015	4.0E-04	**34.2**
COD	129	0.0017	0.58	0.010	0.0027	**129**
Phenol	0.012	3.4E-08	3.8E-04	6.7E-06	1.7E-06	**0.012**
Sulfides	1.00	0	0	0	0	**1.00**
Oil	2.32	0.0021	0.54	0.0095	0.0025	**2.88**
Sulfuric Acid	0.12	3.0E-04	0.0046	8.0E-05	2.1E-05	**0.12**
Iron	1.65	0.0018	0.013	2.2E-04	5.8E-05	**1.66**
Cyanide	6.3E-06	8.0E-09	1.2E-06	2.2E-08	5.7E-09	**7.6E-06**
Alkalinity	0	0	0	0	0	**0**
Chromium	0.0034	5.4E-06	8.7E-04	1.5E-05	4.0E-06	**0.0043**
Aluminum	1.25	0	0	0	0	**1.25**
Nickel	2.0E-08	0	0	0	0	**2.0E-08**
Mercury	2.9E-07	4.2E-10	6.4E-08	1.1E-09	3.0E-10	**3.5E-07**
Lead	8.9E-07	8.8E-10	9.9E-06	1.7E-07	4.5E-08	**1.1E-05**
Phosphates	1.11	1.5E-04	0.0023	4.0E-05	1.1E-05	**1.11**
Phosphorus	0.44	0	0	0	0	**0.44**
Nitrogen	0.47	0	0	0	0	**0.47**
Zinc	0.015	1.9E-06	4.3E-04	7.5E-06	2.0E-06	**0.016**
Ammonia	0.33	2.0E-05	0.0094	1.6E-04	4.3E-05	**0.34**
Pesticides	0.012	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	**0**
Chlorides	3.43	0.0056	0.85	0.015	0.0039	**4.31**
Cadmium	0.0034	5.4E-06	8.3E-04	1.5E-05	3.9E-06	**0.0042**
Organic Carbon	0	0	0	0	0	**0**
Sulfates	3.52	0.010	0.69	0.012	0.0031	**4.24**
Sodium	0.0029	1.8E-05	1.1E-04	1.9E-06	5.0E-07	**0.0030**
Calcium	0.0016	9.9E-06	6.0E-05	1.0E-06	2.7E-07	**0.0017**
Manganese	0.40	0.0010	0.0061	1.1E-04	2.8E-05	**0.41**
Nitrates	0.017	4.3E-06	2.6E-05	4.5E-07	1.2E-07	**0.017**
Boron	0.47	0.0012	0.018	3.2E-04	8.4E-05	**0.49**
Other Organics	0.30	5.7E-04	0.057	9.9E-04	2.6E-04	**0.36**
Chromates	1.0E-04	2.9E-07	6.4E-05	1.1E-06	3.0E-07	**1.7E-04**
Sodium Dichromate	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	**0**

Table 3-8-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr		
thou lb/ 10,000 pkgs	1.4	1.4	1.4
% recycled content			

	Unpadded Bleached Kraft Bag				
	Bleached Kraft	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related					
Acid	0.0042	6.5E-08	5.2E-07	1.1E-08	**0.0042**
Metal Ion	0.0064	0.0014	0.011	2.4E-04	**0.019**
Fluorides	0.0013	3.2E-06	2.6E-05	5.6E-07	**0.0013**
Dissolved Solids	13.4	0.27	2.17	0.047	**15.9**
Suspended Solids	10.0	0.0062	0.049	0.0011	**10.1**
BOD	3.97	0.0010	0.0081	1.8E-04	**3.98**
COD	6.30	0.0068	0.054	0.0012	**6.36**
Phenol	2.1E-05	4.5E-06	3.6E-05	7.7E-07	**6.2E-05**
Sulfides	7.3E-06	0	0	0	**7.3E-06**
Oil	0.24	0.0063	0.051	0.0011	**0.29**
Sulfuric Acid	0.024	5.4E-05	4.3E-04	9.3E-06	**0.024**
Iron	0.092	1.5E-04	0.0012	2.5E-05	**0.093**
Cyanide	1.0E-06	1.4E-08	1.1E-07	2.5E-09	**1.1E-06**
Alkalinity	0	0	0	0	**0**
Chromium	5.8E-04	1.0E-05	8.1E-05	1.8E-06	**6.8E-04**
Aluminum	0	0	0	0	**0**
Nickel	5.4E-08	0	0	0	**5.4E-08**
Mercury	1.2E-07	7.6E-10	6.0E-09	1.3E-10	**1.3E-07**
Lead	5.9E-07	1.2E-07	9.2E-07	2.0E-08	**1.6E-06**
Phosphates	0.094	2.7E-05	2.2E-04	4.7E-06	**0.095**
Phosphorus	0.14	0	0	0	**0.14**
Nitrogen	0.054	0	0	0	**0.054**
Zinc	2.0E-04	5.0E-06	4.0E-05	8.7E-07	**2.5E-04**
Ammonia	0.39	1.1E-04	8.8E-04	1.9E-05	**0.39**
Pesticides	0	0	0	0	**0**
Other Chemicals	0	0	0	0	**0**
Herbicides	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	**0**
Chlorides	0.59	0.010	0.080	0.0017	**0.68**
Cadmium	5.8E-04	9.9E-06	7.8E-05	1.7E-06	**6.7E-04**
Organic Carbon	0	0	0	0	**0**
Sulfates	0.61	0.0080	0.064	0.0014	**0.68**
Sodium	5.0E-04	1.3E-06	1.0E-05	2.2E-07	**5.2E-04**
Calcium	2.7E-04	7.0E-07	5.6E-06	1.2E-07	**2.8E-04**
Manganese	0.056	7.1E-05	5.7E-04	1.2E-05	**0.057**
Nitrates	1.2E-04	3.0E-07	2.4E-06	5.3E-08	**1.2E-04**
Boron	0.095	2.2E-04	0.0017	3.7E-05	**0.097**
Other Organics	0.055	6.6E-04	0.0053	1.1E-04	**0.061**
Chromates	1.9E-04	7.6E-07	6.0E-06	1.3E-07	**2.0E-04**
Sodium Dichromate	4.8E-06	0	0	0	**4.8E-06**
Methanol	0	0	0	0	**0**

Table 3-8-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr	Unbl Kr			
thou lb/ 10,000 pkgs	1	0.9	1.9	3.8	3.8
% recycled content					

	All-Paper Padded Kraft Bag						
	Bleached Kraft	Unbleached Kraft	Macerated PC Newspaper Padding	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.0030	0.022	3.5E-08	1.8E-07	1.3E-06	3.1E-08	**0.025**
Metal Ion	0.0045	9.4E-04	7.4E-04	0.0037	0.028	6.5E-04	**0.039**
Fluorides	9.0E-04	1.9E-04	9.1E-05	8.7E-06	6.5E-05	1.5E-06	**0.0013**
Dissolved Solids	9.55	4.07	0.37	0.73	5.48	0.13	**20.3**
Suspended Solids	7.15	2.30	0.046	0.017	0.12	0.0029	**9.64**
BOD	2.84	1.19	7.6E-04	0.0027	0.020	4.8E-04	**4.05**
COD	4.50	11.8	0.0068	0.018	0.14	0.0032	**16.5**
Phenol	1.5E-05	3.1E-06	2.4E-06	1.2E-05	9.0E-05	2.1E-06	**1.2E-04**
Sulfides	5.2E-06	1.4E-07	0	0	0	0	**5.4E-06**
Oil	0.17	0.071	0.0074	0.017	0.13	0.0030	**0.40**
Sulfuric Acid	0.017	0.0069	6.1E-04	1.5E-04	0.0011	2.5E-05	**0.026**
Iron	0.066	0.037	0.0036	4.0E-04	0.0030	6.9E-05	**0.11**
Cyanide	7.2E-07	3.3E-07	2.3E-08	3.9E-08	2.9E-07	6.8E-09	**1.4E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	4.2E-04	1.8E-04	1.6E-05	2.8E-05	2.1E-04	4.8E-06	**8.5E-04**
Aluminum	0	0.10	0	0	0	0	**0.10**
Nickel	3.8E-08	1.0E-09	0	0	0	0	**3.9E-08**
Mercury	8.6E-08	1.5E-08	1.2E-09	2.1E-09	1.5E-08	3.6E-10	**1.2E-07**
Lead	4.2E-07	8.0E-08	6.2E-08	3.1E-07	2.3E-06	5.4E-08	**3.3E-06**
Phosphates	0.067	0.089	3.1E-04	7.3E-05	5.4E-04	1.3E-05	**0.16**
Phosphorus	0.10	0.059	0	0	0	0	**0.16**
Nitrogen	0.039	0.021	0	0	0	0	**0.060**
Zinc	1.5E-04	6.3E-05	6.2E-06	1.4E-05	1.0E-04	2.4E-06	**3.3E-04**
Ammonia	0.28	0.039	9.7E-05	3.0E-04	0.0022	5.2E-05	**0.32**
Pesticides	0	0	0	0	0	0	**0**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	0.42	0.18	0.016	0.027	0.20	0.0047	**0.85**
Cadmium	4.2E-04	1.8E-04	1.6E-05	2.7E-05	2.0E-04	4.7E-06	**8.4E-04**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	0.43	0.16	0.023	0.022	0.16	0.0038	**0.81**
Sodium	3.6E-04	7.6E-05	3.6E-05	3.5E-06	2.6E-05	6.0E-07	**5.0E-04**
Calcium	2.0E-04	4.1E-05	2.0E-05	1.9E-06	1.4E-05	3.3E-07	**2.7E-04**
Manganese	0.040	0.024	0.0020	1.9E-04	0.0014	3.3E-05	**0.067**
Nitrates	8.5E-05	0.0022	8.6E-06	8.2E-07	6.1E-06	1.4E-07	**0.0023**
Boron	0.068	0.028	0.0025	5.8E-04	0.0044	1.0E-04	**0.10**
Other Organics	0.039	0.017	0.0015	0.0018	0.013	3.1E-04	**0.073**
Chromates	1.4E-04	6.2E-06	9.5E-07	2.1E-06	1.5E-05	3.6E-07	**1.6E-04**
Sodium Dichromate	3.4E-06	0	0	0	0	0	**3.4E-06**
Methanol	0	0	0	0	0	0	**0**

Table 3-8-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	Bl Kr	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.86	0.24	0.24	1.34	1.34
% recycled content					

	Bubble Padded Kraft Bag						
	Bleached Kraft	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.0026	0.032	0.032	6.2E-08	5.4E-07	1.1E-08	**0.066**
Metal Ion	0.0039	0.0019	0.0019	0.0013	0.011	2.4E-04	**0.021**
Fluorides	7.8E-04	3.3E-04	2.5E-04	3.1E-06	2.7E-05	5.5E-07	**0.0014**
Dissolved Solids	8.21	17.8	17.4	0.26	2.25	0.046	**46.0**
Suspended Solids	6.15	0.34	0.24	0.0059	0.051	0.0011	**6.79**
BOD	2.44	0.077	0.029	9.7E-04	0.0084	1.7E-04	**2.56**
COD	3.87	0.35	0.22	0.0065	0.057	0.0012	**4.51**
Phenol	1.3E-05	6.3E-06	6.3E-06	4.3E-06	3.7E-05	7.7E-07	**6.8E-05**
Sulfides	4.5E-06	0.014	0.014	0	0	0	**0.029**
Oil	0.14	0.32	0.31	0.0061	0.053	0.0011	**0.84**
Sulfuric Acid	0.015	0.0022	0.0017	5.1E-05	4.5E-04	9.2E-06	**0.019**
Iron	0.056	0.013	0.0098	1.4E-04	0.0012	2.5E-05	**0.080**
Cyanide	6.2E-07	1.2E-06	1.2E-06	1.4E-08	1.2E-07	2.5E-09	**3.1E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	3.6E-04	8.1E-04	8.0E-04	9.7E-06	8.5E-05	1.7E-06	**0.0021**
Aluminum	0	0	0	0	0	0	**0**
Nickel	3.3E-08	0	0	0	0	0	**3.3E-08**
Mercury	7.4E-08	6.3E-08	6.2E-08	7.3E-10	6.2E-09	1.3E-10	**2.1E-07**
Lead	3.6E-07	1.6E-07	1.6E-07	1.1E-07	9.6E-07	2.0E-08	**1.8E-06**
Phosphates	0.058	0.0027	0.0025	2.6E-05	2.2E-04	4.6E-06	**0.063**
Phosphorus	0.086	0	0	0	0	0	**0.086**
Nitrogen	0.033	0	0	0	0	0	**0.033**
Zinc	1.3E-04	5.5E-04	5.4E-04	4.8E-06	4.2E-05	8.7E-07	**0.0013**
Ammonia	0.24	3.8E-04	3.5E-04	1.1E-04	9.2E-04	1.9E-05	**0.24**
Pesticides	0	0	0	0	0	0	**0**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	0.36	0.82	0.80	0.0095	0.083	0.0017	**2.08**
Cadmium	3.6E-04	8.1E-04	8.0E-04	9.5E-06	8.1E-05	1.7E-06	**0.0021**
Organic Carbon	0	0.034	0.034	0	0	0	**0.068**
Sulfates	0.37	0.67	0.65	0.0077	0.067	0.0014	**1.76**
Sodium	3.1E-04	1.3E-04	1.0E-04	1.2E-06	1.1E-05	2.2E-07	**5.5E-04**
Calcium	1.7E-04	7.1E-05	5.4E-05	6.7E-07	5.8E-06	1.2E-07	**3.0E-04**
Manganese	0.034	0.0074	0.0056	6.8E-05	5.9E-04	1.2E-05	**0.048**
Nitrates	7.3E-05	3.1E-05	2.4E-05	2.9E-07	2.5E-06	5.2E-08	**1.3E-04**
Boron	0.059	0.0089	0.0068	2.1E-04	0.0018	3.7E-05	**0.076**
Other Organics	0.034	0.020	0.018	6.3E-04	0.0055	1.1E-04	**0.078**
Chromates	1.2E-04	3.7E-06	3.2E-06	7.3E-07	6.2E-06	1.3E-07	**1.3E-04**
Sodium Dichromate	2.9E-06	0	0	0	0	0	**2.9E-06**
Methanol	0	0	0	0	0	0	**0**

Table 3-8-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	LLDPE		
thou lb/ 10,000 pkgs	0.67	0.67	0.67
% recycled content			

	Unpadded LLDPE Film Bag				
	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related					
Acid	0.089	6.0E-08	2.6E-07	6.0E-09	**0.089**
Metal Ion	0.0054	0.0013	0.0055	1.3E-04	**0.012**
Fluorides	7.0E-04	3.0E-06	1.3E-05	2.9E-07	**7.1E-04**
Dissolved Solids	48.7	0.25	1.08	0.025	**50.0**
Suspended Solids	0.68	0.0057	0.025	5.6E-04	**0.71**
BOD	0.080	9.3E-04	0.0041	9.3E-05	**0.085**
COD	0.62	0.0062	0.027	6.2E-04	**0.65**
Phenol	1.7E-05	4.1E-06	1.8E-05	4.1E-07	**4.0E-05**
Sulfides	0.040	0	0	0	**0.040**
Oil	0.88	0.0058	0.025	5.8E-04	**0.91**
Sulfuric Acid	0.0048	4.9E-05	2.2E-04	4.9E-06	**0.0050**
Iron	0.027	1.3E-04	5.9E-04	1.3E-05	**0.028**
Cyanide	3.3E-06	1.3E-08	5.7E-08	1.3E-09	**3.3E-06**
Alkalinity	0	0	0	0	**0**
Chromium	0.0022	9.3E-06	4.1E-05	9.3E-07	**0.0023**
Aluminum	0	0	0	0	**0**
Nickel	0	0	0	0	**0**
Mercury	1.7E-07	7.0E-10	3.0E-09	7.0E-11	**1.8E-07**
Lead	4.5E-07	1.1E-07	4.6E-07	1.1E-08	**1.0E-06**
Phosphates	0.0069	2.5E-05	1.1E-04	2.5E-06	**0.0070**
Phosphorus	0	0	0	0	**0**
Nitrogen	0	0	0	0	**0**
Zinc	0.0015	4.6E-06	2.0E-05	4.6E-07	**0.0015**
Ammonia	9.7E-04	1.0E-04	4.4E-04	1.0E-05	**0.0015**
Pesticides	0	0	0	0	**0**
Other Chemicals	0	0	0	0	**0**
Herbicides	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	**0**
Chlorides	2.24	0.0091	0.040	9.1E-04	**2.29**
Cadmium	0.0022	9.1E-06	3.9E-05	9.1E-07	**0.0023**
Organic Carbon	0.095	0	0	0	**0.095**
Sulfates	1.81	0.0074	0.032	7.4E-04	**1.85**
Sodium	2.8E-04	1.2E-06	5.1E-06	1.2E-07	**2.8E-04**
Calcium	1.5E-04	6.4E-07	2.8E-06	6.4E-08	**1.5E-04**
Manganese	0.016	6.5E-05	2.9E-04	6.5E-06	**0.016**
Nitrates	6.6E-05	2.8E-07	1.2E-06	2.8E-08	**6.7E-05**
Boron	0.019	2.0E-04	8.6E-04	2.0E-05	**0.020**
Other Organics	0.050	6.1E-04	0.0026	6.0E-05	**0.054**
Chromates	9.1E-06	7.0E-07	3.0E-06	6.9E-08	**1.3E-05**
Sodium Dichromate	0	0	0	0	**0**
Methanol	0	0	0	0	**0**

Table 3-8-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
LOWER RECYCLED CONTENT OPTIONS

	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.35	0.98	1.33	1.33
% recycled content				

	Bubble Padded LLDPE Bag					
	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related						
Acid	0.046	0.13	6.2E-08	5.4E-07	1.2E-08	**0.18**
Metal Ion	0.0028	0.0079	0.0013	0.011	2.5E-04	**0.024**
Fluorides	4.8E-04	0.0010	3.1E-06	2.7E-05	5.9E-07	**0.0015**
Dissolved Solids	25.9	71.2	0.26	2.25	0.049	**99.7**
Suspended Solids	0.49	0.99	0.0059	0.051	0.0011	**1.54**
BOD	0.11	0.12	9.6E-04	0.0084	1.8E-04	**0.24**
COD	0.52	0.91	0.0064	0.057	0.0012	**1.49**
Phenol	9.2E-06	2.6E-05	4.2E-06	3.7E-05	8.1E-07	**7.7E-05**
Sulfides	0.021	0.059	0	0	0	**0.080**
Oil	0.47	1.29	0.0060	0.053	0.0012	**1.81**
Sulfuric Acid	0.0032	0.0070	5.1E-05	4.5E-04	9.8E-06	**0.011**
Iron	0.019	0.040	1.4E-04	0.0012	2.7E-05	**0.060**
Cyanide	1.7E-06	4.8E-06	1.4E-08	1.2E-07	2.6E-09	**6.6E-06**
Alkalinity	0	0	0	0	0	**0**
Chromium	0.0012	0.0033	9.7E-06	8.5E-05	1.9E-06	**0.0045**
Aluminum	0	0	0	0	0	**0**
Nickel	0	0	0	0	0	**0**
Mercury	9.2E-08	2.5E-07	7.2E-10	6.2E-09	1.4E-10	**3.5E-07**
Lead	2.4E-07	6.6E-07	1.1E-07	9.6E-07	2.1E-08	**2.0E-06**
Phosphates	0.0040	0.010	2.6E-05	2.2E-04	4.9E-06	**0.014**
Phosphorus	0	0	0	0	0	**0**
Nitrogen	0	0	0	0	0	**0**
Zinc	8.0E-04	0.0022	4.8E-06	4.2E-05	9.2E-07	**0.0031**
Ammonia	5.6E-04	0.0014	1.0E-04	9.2E-04	2.0E-05	**0.0030**
Pesticides	0	0	0	0	0	**0**
Other Chemicals	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	**0**
Chlorides	1.19	3.28	0.0094	0.083	0.0018	**4.57**
Cadmium	0.0012	0.0033	9.4E-06	8.1E-05	1.8E-06	**0.0045**
Organic Carbon	0.049	0.14	0	0	0	**0.19**
Sulfates	0.98	2.64	0.0076	0.067	0.0015	**3.69**
Sodium	1.9E-04	4.1E-04	1.2E-06	1.1E-05	2.3E-07	**6.1E-04**
Calcium	1.0E-04	2.2E-04	6.6E-07	5.8E-06	1.3E-07	**3.3E-04**
Manganese	0.011	0.023	6.8E-05	5.9E-04	1.3E-05	**0.034**
Nitrates	4.5E-05	9.6E-05	2.9E-07	2.5E-06	5.5E-08	**1.4E-04**
Boron	0.013	0.028	2.0E-04	0.0018	3.9E-05	**0.043**
Other Organics	0.029	0.074	6.3E-04	0.0055	1.2E-04	**0.11**
Chromates	5.5E-06	1.3E-05	7.2E-07	6.2E-06	1.4E-07	**2.6E-05**
Sodium Dichromate	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	**0**

Table 3-9-BOX

LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Air Pkt
thou lb/ 10,000 pkgs	13.9	0.84
% recycled content		30

	Box with Inflated Air Packets						
	Box	LDPE Inflated Air Packets	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.09	0.078	3.9E-08	5.2E-06	9.7E-08	7.5E-09	**0.17**
Metal Ion	0.009	0.0050	8.3E-04	0.11	0.0021	1.6E-04	**0.13**
Fluorides	0.0085	0.0011	1.9E-06	2.6E-04	4.8E-06	3.7E-07	**0.0098**
Dissolved Solids	73.9	44.3	0.16	21.6	0.40	0.031	**140**
Suspended Solids	53.3	0.96	0.0037	0.49	0.0092	7.1E-04	**54.7**
BOD	39.1	0.19	6.1E-04	0.081	0.0015	1.2E-04	**39.4**
COD	92	0.88	0.0041	0.54	0.010	7.8E-04	**93**
Phenol	0.027	1.6E-05	2.7E-06	3.6E-04	6.7E-06	5.1E-07	**0.027**
Sulfides	2.24	0.035	0	0	0	0	**2.27**
Oil	3.48	0.80	0.0038	0.51	0.0095	7.3E-04	**4.80**
Sulfuric Acid	0.13	0.0071	3.2E-05	0.0043	8.0E-05	6.2E-06	**0.14**
Iron	2.96	0.042	8.8E-05	0.012	2.2E-04	1.7E-05	**3.01**
Cyanide	5.8E-06	3.0E-06	8.7E-09	1.1E-06	2.2E-08	1.7E-09	**9.9E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0032	0.0020	6.1E-06	8.1E-04	1.5E-05	1.2E-06	**0.0061**
Aluminum	1.42	0	0	0	0	0	**1.42**
Nickel	4.8E-09	0	0	0	0	0	**4.8E-09**
Mercury	2.5E-07	1.6E-07	4.6E-10	6.0E-08	1.1E-09	8.8E-11	**4.7E-07**
Lead	8.0E-07	4.2E-07	6.9E-08	9.2E-06	1.7E-07	1.3E-08	**1.1E-05**
Phosphates	1.12	0.0075	1.6E-05	0.0022	4.0E-05	3.1E-06	**1.13**
Phosphorus	0.18	0	0	0	0	0	**0.18**
Nitrogen	0.38	0	0	0	0	0	**0.38**
Zinc	0.032	0.0014	3.0E-06	4.0E-04	7.5E-06	5.8E-07	**0.034**
Ammonia	0.18	0.0011	6.6E-05	0.0088	1.6E-04	1.3E-05	**0.19**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.25	2.04	0.0060	0.79	0.015	0.0011	**6.10**
Cadmium	0.0032	0.0020	5.9E-06	7.8E-04	1.5E-05	1.1E-06	**0.0060**
Organic Carbon	0	0.083	0	0	0	0	**0.083**
Sulfates	3.52	1.70	0.0048	0.64	0.012	9.2E-04	**5.88**
Sodium	0.0034	4.2E-04	7.7E-07	1.0E-04	1.9E-06	1.5E-07	**0.0039**
Calcium	0.0018	2.3E-04	4.2E-07	5.6E-05	1.0E-06	8.0E-08	**0.0021**
Manganese	0.45	0.024	4.3E-05	0.0057	1.1E-04	8.2E-06	**0.47**
Nitrates	0.007	1.0E-04	1.8E-07	2.4E-05	4.5E-07	3.5E-08	**0.007**
Boron	0.52	0.029	1.3E-04	0.017	3.2E-04	2.5E-05	**0.56**
Other Organics	0.30	0.051	4.0E-04	0.053	9.9E-04	7.6E-05	**0.40**
Chromates	1.0E-04	1.1E-05	4.6E-07	5.9E-05	1.1E-06	8.7E-08	**1.7E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-9-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	EPS
thou lb/ 10,000 pkgs	13.9	0.48
% recycled content		30

	Box with EPS Loose Fill						
	Box	EPS Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.09	0.013	1.0E-07	5.1E-06	9.7E-08	5.8E-09	**0.11**
Metal Ion	0.009	0.0097	0.0022	0.11	0.0021	1.2E-04	**0.13**
Fluorides	0.0085	0.0010	5.1E-06	2.5E-04	4.8E-06	2.9E-07	**0.0097**
Dissolved Solids	73.9	30.0	0.43	21.4	0.40	0.024	**126**
Suspended Solids	53.3	0.98	0.0097	0.49	0.0092	5.5E-04	**54.7**
BOD	39.1	0.23	0.0016	0.080	0.0015	9.1E-05	**39.4**
COD	92	0.71	0.011	0.54	0.010	6.1E-04	**93**
Phenol	0.027	3.2E-05	7.1E-06	3.5E-04	6.7E-06	4.0E-07	**0.027**
Sulfides	2.24	0.0066	0	0	0	0	**2.24**
Oil	3.48	0.55	0.010	0.50	0.0095	5.7E-04	**4.55**
Sulfuric Acid	0.13	0.0072	8.5E-05	0.0042	8.0E-05	4.8E-06	**0.14**
Iron	2.96	0.039	2.3E-04	0.012	2.2E-04	1.3E-05	**3.01**
Cyanide	5.8E-06	2.0E-06	2.3E-08	1.1E-06	2.2E-08	1.3E-09	**8.9E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0032	0.0014	1.6E-05	8.0E-04	1.5E-05	9.1E-07	**0.0054**
Aluminum	1.42	0	0	0	0	0	**1.42**
Nickel	4.8E-09	0	0	0	0	0	**4.8E-09**
Mercury	2.5E-07	1.0E-07	1.2E-09	5.9E-08	1.1E-09	6.8E-11	**4.2E-07**
Lead	8.0E-07	8.1E-07	1.8E-07	9.1E-06	1.7E-07	1.0E-08	**1.1E-05**
Phosphates	1.12	0.0042	4.2E-05	0.0021	4.0E-05	2.4E-06	**1.13**
Phosphorus	0.18	0	0	0	0	0	**0.18**
Nitrogen	0.38	0	0	0	0	0	**0.38**
Zinc	0.032	5.8E-04	8.0E-06	4.0E-04	7.5E-06	4.5E-07	**0.033**
Ammonia	0.18	0.0016	1.7E-04	0.0087	1.6E-04	9.9E-06	**0.19**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0.034	0	0	0	0	**0.034**
Chlorides	3.25	1.36	0.016	0.79	0.015	8.9E-04	**5.42**
Cadmium	0.0032	0.0014	1.6E-05	7.7E-04	1.5E-05	8.9E-07	**0.0054**
Organic Carbon	0	0.015	0	0	0	0	**0.015**
Sulfates	3.52	1.17	0.013	0.63	0.012	7.2E-04	**5.35**
Sodium	0.0034	3.9E-04	2.0E-06	1.0E-04	1.9E-06	1.1E-07	**0.0039**
Calcium	0.0018	2.1E-04	1.1E-06	5.5E-05	1.0E-06	6.2E-08	**0.0021**
Manganese	0.45	0.022	1.1E-04	0.0056	1.1E-04	6.4E-06	**0.47**
Nitrates	0.007	9.3E-05	4.8E-07	2.4E-05	4.5E-07	2.7E-08	**0.007**
Boron	0.52	0.029	3.4E-04	0.017	3.2E-04	1.9E-05	**0.56**
Other Organics	0.30	0.075	0.0010	0.052	9.9E-04	5.9E-05	**0.43**
Chromates	1.0E-04	2.3E-05	1.2E-06	5.9E-05	1.1E-06	6.8E-08	**1.8E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-9-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Cornstarch
thou lb/ 10,000 pkgs	13.9	0.86

	Box with Cornstarch Loose Fill						
	Box	Cornstarch Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.09	0.087	1.7E-07	5.2E-06	9.7E-08	1.2E-09	**0.18**
Metal Ion	0.009	0.0012	0.0037	0.11	0.0021	2.6E-05	**0.13**
Fluorides	0.0085	8.2E-04	8.5E-06	2.6E-04	4.8E-06	6.1E-08	**0.0096**
Dissolved Solids	73.9	7.11	0.72	21.7	0.40	0.0051	**104**
Suspended Solids	53.3	10.0	0.016	0.49	0.0092	1.2E-04	**63.8**
BOD	39.1	1.06	0.0027	0.081	0.0015	1.9E-05	**40.3**
COD	92	1.74	0.018	0.54	0.010	1.3E-04	**94**
Phenol	0.027	5.6E-06	1.2E-05	3.6E-04	6.7E-06	8.5E-08	**0.027**
Sulfides	2.24	0	0	0	0	0	**2.24**
Oil	3.48	0.077	0.017	0.51	0.0095	1.2E-04	**4.09**
Sulfuric Acid	0.13	0.0059	1.4E-04	0.0043	8.0E-05	1.0E-06	**0.14**
Iron	2.96	0.034	3.9E-04	0.012	2.2E-04	2.8E-06	**3.00**
Cyanide	5.8E-06	3.5E-06	3.8E-08	1.1E-06	2.2E-08	2.8E-10	**1.1E-05**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0032	1.9E-04	2.7E-05	8.1E-04	1.5E-05	1.9E-07	**0.0042**
Aluminum	1.42	0	0	0	0	0	**1.42**
Nickel	4.8E-09	0	0	0	0	0	**4.8E-09**
Mercury	2.5E-07	1.5E-08	2.0E-09	6.0E-08	1.1E-09	1.4E-11	**3.3E-07**
Lead	8.0E-07	1.0E-07	3.1E-07	9.2E-06	1.7E-07	2.2E-09	**1.1E-05**
Phosphates	1.12	0.26	7.1E-05	0.0022	4.0E-05	5.1E-07	**1.38**
Phosphorus	0.18	0	0	0	0	0	**0.18**
Nitrogen	0.38	1.11	0	0	0	0	**1.49**
Zinc	0.032	6.6E-05	1.3E-05	4.0E-04	7.5E-06	9.6E-08	**0.033**
Ammonia	0.18	0.0015	2.9E-04	0.0088	1.6E-04	2.1E-06	**0.19**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.25	0.19	0.026	0.80	0.015	1.9E-04	**4.28**
Cadmium	0.0032	1.9E-04	2.6E-05	7.8E-04	1.5E-05	1.9E-07	**0.0042**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	3.52	0.25	0.021	0.64	0.012	1.5E-04	**4.44**
Sodium	0.0034	3.3E-04	3.4E-06	1.0E-04	1.9E-06	2.4E-08	**0.0038**
Calcium	0.0018	1.8E-04	1.8E-06	5.6E-05	1.0E-06	1.3E-08	**0.0021**
Manganese	0.45	0.020	1.9E-04	0.0057	1.1E-04	1.4E-06	**0.47**
Nitrates	0.007	7.7E-05	8.1E-07	2.4E-05	4.5E-07	5.8E-09	**0.007**
Boron	0.52	0.024	5.7E-04	0.017	3.2E-04	4.1E-06	**0.56**
Other Organics	0.30	0.016	0.0018	0.053	9.9E-04	1.3E-05	**0.37**
Chromates	1.0E-04	1.0E-05	2.0E-06	6.0E-05	1.1E-06	1.4E-08	**1.7E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-9-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	0
80% pc box	1

	Box	Mold Pulp
thou lb/ 10,000 pkgs	13.9	3.8

	Box with Molded Pulp Loose Fill						
	Box	Molded Pulp Loose Fill	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.094	1.4E-07	5.8E-07	5.7E-06	9.7E-08	2.8E-08	**0.094**
Metal Ion	0.0095	0.0031	0.012	0.12	0.0021	5.9E-04	**0.15**
Fluorides	0.0085	0.0052	2.8E-05	2.8E-04	4.8E-06	1.4E-06	**0.014**
Dissolved Solids	73.9	98.8	2.39	23.5	0.40	0.12	**199**
Suspended Solids	53.3	4.03	0.054	0.54	0.0092	0.0026	**57.9**
BOD	39.1	0.098	0.0089	0.088	0.0015	4.3E-04	**39.3**
COD	92.0	1.38	0.060	0.59	0.010	0.0029	**94.0**
Phenol	0.027	9.9E-06	3.9E-05	3.9E-04	6.7E-06	1.9E-06	**0.027**
Sulfides	2.24	0	0	0	0	0	**2.24**
Oil	3.48	1.74	0.056	0.55	0.0095	0.0027	**5.84**
Sulfuric Acid	0.13	0.034	4.8E-04	0.0047	8.0E-05	2.3E-05	**0.17**
Iron	2.96	0.20	0.0013	0.013	2.2E-04	6.3E-05	**3.18**
Cyanide	5.8E-06	6.6E-06	1.3E-07	1.2E-06	2.2E-08	6.2E-09	**1.4E-05**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0032	0.0045	9.0E-05	8.8E-04	1.5E-05	4.3E-06	**0.0087**
Aluminum	1.42	0	0	0	0	0	**1.42**
Nickel	4.8E-09	0	0	0	0	0	**4.8E-09**
Mercury	2.5E-07	3.5E-07	6.7E-09	6.5E-08	1.1E-09	3.2E-10	**6.7E-07**
Lead	8.0E-07	2.6E-07	1.0E-06	1.0E-05	1.7E-07	4.9E-08	**1.2E-05**
Phosphates	1.12	0.017	2.4E-04	0.0023	4.0E-05	1.1E-05	**1.14**
Phosphorus	0.18	0	0	0	0	0	**0.18**
Nitrogen	0.38	0	0	0	0	0	**0.38**
Zinc	0.032	0.0015	4.5E-05	4.4E-04	7.5E-06	2.1E-06	**0.034**
Ammonia	0.18	0.0040	9.7E-04	0.0096	1.6E-04	4.7E-05	**0.20**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.25	4.52	0.088	0.86	0.015	0.0042	**8.74**
Cadmium	0.0032	0.0045	8.8E-05	8.5E-04	1.5E-05	4.2E-06	**0.0087**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	3.52	4.12	0.071	0.70	0.012	0.0034	**8.42**
Sodium	0.0034	0.0021	1.1E-05	1.1E-04	1.9E-06	5.4E-07	**0.0056**
Calcium	0.0018	0.0011	6.1E-06	6.0E-05	1.0E-06	3.0E-07	**0.0030**
Manganese	0.45	0.12	6.3E-04	0.0062	1.1E-04	3.0E-05	**0.57**
Nitrates	0.0074	4.9E-04	2.7E-06	2.6E-05	4.5E-07	1.3E-07	**0.0079**
Boron	0.52	0.14	0.0019	0.019	3.2E-04	9.2E-05	**0.68**
Other Organics	0.30	0.31	0.0058	0.057	9.9E-04	2.8E-04	**0.67**
Chromates	1.0E-04	3.9E-05	6.7E-06	6.5E-05	1.1E-06	3.2E-07	**2.1E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-9-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	Unbl Kr
thou lb/ 10,000 pkgs	13.9	1.8
% recycled content		50

	Box with Unbleached Kraft Paper Dunnage						
	Box	Unbleached Kraft Paper Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	TOTAL
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.09	0.022	8.7E-09	5.4E-06	9.7E-08	1.4E-08	**0.12**
Metal Ion	0.009	0.0013	1.8E-04	0.11	0.0021	3.1E-04	**0.13**
Fluorides	0.0085	7.3E-04	4.3E-07	2.7E-04	4.8E-06	7.2E-07	**0.0095**
Dissolved Solids	73.9	7.28	0.036	22.3	0.40	0.060	**104**
Suspended Solids	53.3	5.60	8.2E-04	0.51	0.0092	0.0014	**59.4**
BOD	39.1	3.92	1.3E-04	0.083	0.0015	2.3E-04	**43.1**
COD	92	16.1	9.0E-04	0.56	0.010	0.0015	**109**
Phenol	0.027	0.0022	5.9E-07	3.7E-04	6.7E-06	9.9E-07	**0.029**
Sulfides	2.24	0.18	0	0	0	0	**2.42**
Oil	3.48	0.30	8.4E-04	0.52	0.0095	0.0014	**4.32**
Sulfuric Acid	0.13	0.015	7.1E-06	0.0044	8.0E-05	1.2E-05	**0.15**
Iron	2.96	0.26	2.0E-05	0.012	2.2E-04	3.3E-05	**3.23**
Cyanide	5.8E-06	5.2E-07	1.9E-09	1.2E-06	2.2E-08	3.2E-09	**7.5E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0032	3.2E-04	1.4E-06	8.4E-04	1.5E-05	2.3E-06	**0.0044**
Aluminum	1.42	0.19	0	0	0	0	**1.61**
Nickel	4.8E-09	1.0E-09	0	0	0	0	**5.8E-09**
Mercury	2.5E-07	2.6E-08	1.0E-10	6.2E-08	1.1E-09	1.7E-10	**3.4E-07**
Lead	8.0E-07	1.1E-07	1.5E-08	9.5E-06	1.7E-07	2.6E-08	**1.1E-05**
Phosphates	1.12	0.15	3.6E-06	0.0022	4.0E-05	6.0E-06	**1.28**
Phosphorus	0.18	0.059	0	0	0	0	**0.24**
Nitrogen	0.38	0.021	0	0	0	0	**0.40**
Zinc	0.032	0.0026	6.7E-07	4.2E-04	7.5E-06	1.1E-06	**0.035**
Ammonia	0.18	0.044	1.5E-05	0.0091	1.6E-04	2.4E-05	**0.23**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.25	0.32	0.0013	0.82	0.015	0.0022	**4.41**
Cadmium	0.0032	3.2E-04	1.3E-06	8.0E-04	1.5E-05	2.2E-06	**0.0043**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	3.52	0.33	0.0011	0.66	0.012	0.0018	**4.53**
Sodium	0.0034	2.9E-04	1.7E-07	1.1E-04	1.9E-06	2.8E-07	**0.0038**
Calcium	0.0018	1.6E-04	9.2E-08	5.7E-05	1.0E-06	1.5E-07	**0.0020**
Manganese	0.45	0.051	9.5E-06	0.0059	1.1E-04	1.6E-05	**0.50**
Nitrates	0.007	0.0022	4.0E-08	2.5E-05	4.5E-07	6.8E-08	**0.010**
Boron	0.52	0.060	2.9E-05	0.018	3.2E-04	4.8E-05	**0.59**
Other Organics	0.30	0.031	8.8E-05	0.054	9.9E-04	1.5E-04	**0.39**
Chromates	1.0E-04	1.2E-05	1.0E-07	6.1E-05	1.1E-06	1.7E-07	**1.7E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	0	**0**

Table 3-9-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1	
avg box	0
80% pc box	1

	Box	Newsprint
thou lb/ 10,000 pkgs	13.9	1.7
% recycled content		50

	Box with Newsprint Dunnage						
	Box	Newsprint Dunnage	Transp of Dunnage to Retail Order Ctr	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.09	6.0E-08	6.8E-09	5.3E-06	9.7E-08	1.4E-08	**0.09**
Metal Ion	0.009	0.0013	1.4E-04	0.11	0.0021	2.9E-04	**0.13**
Fluorides	0.0085	0.0020	3.3E-07	2.6E-04	4.8E-06	6.8E-07	**0.0108**
Dissolved Solids	73.9	27.4	0.028	22.2	0.40	0.057	**124**
Suspended Solids	53.3	10.4	6.4E-04	0.51	0.0092	0.0013	**64.2**
BOD	39.1	7.39	1.1E-04	0.083	0.0015	2.1E-04	**46.6**
COD	92	3.81	7.1E-04	0.56	0.010	0.0014	**96**
Phenol	0.027	4.4E-06	4.6E-07	3.7E-04	6.7E-06	9.4E-07	**0.027**
Sulfides	2.24	2.3E-06	0	0	0	0	**2.24**
Oil	3.48	0.48	6.6E-04	0.52	0.0095	0.0013	**4.50**
Sulfuric Acid	0.13	0.014	5.6E-06	0.0044	8.0E-05	1.1E-05	**0.15**
Iron	2.96	0.081	1.5E-05	0.012	2.2E-04	3.1E-05	**3.05**
Cyanide	5.8E-06	1.8E-06	1.5E-09	1.2E-06	2.2E-08	3.0E-09	**8.8E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	0.0032	0.0012	1.1E-06	8.4E-04	1.5E-05	2.1E-06	**0.0053**
Aluminum	1.42	0	0	0	0	0	**1.42**
Nickel	4.8E-09	1.7E-08	0	0	0	0	**2.2E-08**
Mercury	2.5E-07	1.2E-07	7.9E-11	6.1E-08	1.1E-09	1.6E-10	**4.3E-07**
Lead	8.0E-07	1.3E-06	1.2E-08	9.5E-06	1.7E-07	2.4E-08	**1.2E-05**
Phosphates	1.12	0.0070	2.8E-06	0.0022	4.0E-05	5.7E-06	**1.13**
Phosphorus	0.18	0	0	0	0	0	**0.18**
Nitrogen	0.38	0	0	0	0	0	**0.38**
Zinc	0.032	5.7E-04	5.2E-07	4.1E-04	7.5E-06	1.1E-06	**0.033**
Ammonia	0.18	0.0014	1.1E-05	0.0090	1.6E-04	2.3E-05	**0.19**
Pesticides	0.012	0	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	3.25	1.25	0.0010	0.82	0.015	0.0021	**5.34**
Cadmium	0.0032	0.0012	1.0E-06	8.0E-04	1.5E-05	2.1E-06	**0.0053**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	3.52	1.21	8.3E-04	0.66	0.012	0.0017	**5.41**
Sodium	0.0034	8.1E-04	1.3E-07	1.1E-04	1.9E-06	2.7E-07	**0.0043**
Calcium	0.0018	4.4E-04	7.2E-08	5.7E-05	1.0E-06	1.5E-07	**0.0023**
Manganese	0.45	0.047	7.4E-06	0.0058	1.1E-04	1.5E-05	**0.50**
Nitrates	0.007	1.9E-04	3.2E-08	2.5E-05	4.5E-07	6.4E-08	**0.008**
Boron	0.52	0.056	2.2E-05	0.018	3.2E-04	4.5E-05	**0.59**
Other Organics	0.30	0.089	6.9E-05	0.054	9.9E-04	1.4E-04	**0.44**
Chromates	1.0E-04	1.8E-05	7.9E-08	6.1E-05	1.1E-06	1.6E-07	**1.8E-04**
Sodium Dichromate	0	0	0	0	0	0	**0**
Methanol	0	0.012	0	0	0	0	**0.012**

Table 3-9-BOX

LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	PC Off Ppr
thou lb/ 10,000 pkgs	13.9	1.5

	Box with Shredded PC Office Paper Dunnage					
	Box	Shredded PC Office Paper Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related						
Acid	0.09	7.3E-10	5.3E-06	9.7E-08	1.2E-08	**0.09**
Metal Ion	0.009	1.6E-05	0.11	0.0021	2.6E-04	**0.12**
Fluorides	0.0085	6.7E-05	2.6E-04	4.8E-06	6.0E-07	**0.0088**
Dissolved Solids	73.9	0.18	22.1	0.40	0.050	**97**
Suspended Solids	53.3	0.033	0.50	0.0092	0.0011	**53.8**
BOD	39.1	1.8E-04	0.083	0.0015	1.9E-04	**39.2**
COD	92	0.0025	0.55	0.010	0.0013	**93**
Phenol	0.027	5.0E-08	3.6E-04	6.7E-06	8.3E-07	**0.027**
Sulfides	2.24	0	0	0	0	**2.24**
Oil	3.48	0.0031	0.52	0.0095	0.0012	**4.01**
Sulfuric Acid	0.13	4.4E-04	0.0044	8.0E-05	1.0E-05	**0.13**
Iron	2.96	0.0026	0.012	2.2E-04	2.7E-05	**2.97**
Cyanide	5.8E-06	1.2E-08	1.2E-06	2.2E-08	2.7E-09	**7.0E-06**
Alkalinity	0	0	0	0	0	**0**
Chromium	0.0032	8.0E-06	8.3E-04	1.5E-05	1.9E-06	**0.0041**
Aluminum	1.42	0	0	0	0	**1.42**
Nickel	4.8E-09	0	0	0	0	**4.8E-09**
Mercury	2.5E-07	6.2E-10	6.1E-08	1.1E-09	1.4E-10	**3.2E-07**
Lead	8.0E-07	1.3E-09	9.4E-06	1.7E-07	2.1E-08	**1.0E-05**
Phosphates	1.12	2.2E-04	0.0022	4.0E-05	5.0E-06	**1.13**
Phosphorus	0.18	0	0	0	0	**0.18**
Nitrogen	0.38	0	0	0	0	**0.38**
Zinc	0.032	2.7E-06	4.1E-04	7.5E-06	9.4E-07	**0.033**
Ammonia	0.18	3.0E-05	0.0090	1.6E-04	2.0E-05	**0.19**
Pesticides	0.012	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	**0**
Chlorides	3.25	0.0082	0.81	0.015	0.0018	**4.08**
Cadmium	0.0032	8.0E-06	7.9E-04	1.5E-05	1.8E-06	**0.0040**
Organic Carbon	0	0	0	0	0	**0**
Sulfates	3.52	0.015	0.66	0.012	0.0015	**4.20**
Sodium	0.0034	2.7E-05	1.0E-04	1.9E-06	2.4E-07	**0.0035**
Calcium	0.0018	1.5E-05	5.7E-05	1.0E-06	1.3E-07	**0.0019**
Manganese	0.45	0.0015	0.0058	1.1E-04	1.3E-05	**0.45**
Nitrates	0.007	6.4E-06	2.5E-05	4.5E-07	5.6E-08	**0.007**
Boron	0.52	0.0018	0.018	3.2E-04	4.0E-05	**0.54**
Other Organics	0.30	8.4E-04	0.054	9.9E-04	1.2E-04	**0.36**
Chromates	1.0E-04	4.2E-07	6.1E-05	1.1E-06	1.4E-07	**1.6E-04**
Sodium Dichromate	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	**0**

Table 3-9-BOX
LIFE CYCLE WATERBORNE WASTES FOR 10,000 PACKAGES USING CORRUGATED BOX AND DUNNAGE
HIGHER RECYCLED CONTENT OPTIONS

select box by entering 1		
avg box	0	
80% pc box	1	
	Box	PC Corrug
thou lb/ 10,000 pkgs	13.9	3.2

	Box with Shredded PC Corrugated Dunnage					
	Box	Shredded PC Corrugated Dunnage	Transp to Customer	End of Life Disposal of Box	End of Life Disposal of Dunnage	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related						
Acid	0.09	5.0E-10	5.6E-06	9.7E-08	2.5E-08	**0.09**
Metal Ion	0.009	1.1E-05	0.12	0.0021	5.4E-04	**0.13**
Fluorides	0.0085	4.6E-05	2.8E-04	4.8E-06	1.3E-06	**0.0088**
Dissolved Solids	73.9	0.12	23.2	0.40	0.11	**97.7**
Suspended Solids	53.3	0.022	0.53	0.0092	0.0024	**53.8**
BOD	39.1	1.2E-04	0.087	0.0015	4.0E-04	**39.2**
COD	92	0.0017	0.58	0.010	0.0027	**93**
Phenol	0.027	3.4E-08	3.8E-04	6.7E-06	1.7E-06	**0.027**
Sulfides	2.24	0	0	0	0	**2.24**
Oil	3.48	0.0021	0.54	0.0095	0.0025	**4.04**
Sulfuric Acid	0.13	3.0E-04	0.0046	8.0E-05	2.1E-05	**0.13**
Iron	2.96	0.0018	0.013	2.2E-04	5.8E-05	**2.97**
Cyanide	5.8E-06	8.0E-09	1.2E-06	2.2E-08	5.7E-09	**7.0E-06**
Alkalinity	0	0	0	0	0	**0**
Chromium	0.0032	5.4E-06	8.7E-04	1.5E-05	4.0E-06	**0.0041**
Aluminum	1.42	0	0	0	0	**1.42**
Nickel	4.8E-09	0	0	0	0	**4.8E-09**
Mercury	2.5E-07	4.2E-10	6.4E-08	1.1E-09	3.0E-10	**3.2E-07**
Lead	8.0E-07	8.8E-10	9.9E-06	1.7E-07	4.5E-08	**1.1E-05**
Phosphates	1.12	1.5E-04	0.0023	4.0E-05	1.1E-05	**1.13**
Phosphorus	0.18	0	0	0	0	**0.18**
Nitrogen	0.38	0	0	0	0	**0.38**
Zinc	0.032	1.9E-06	4.3E-04	7.5E-06	2.0E-06	**0.033**
Ammonia	0.18	2.0E-05	0.0094	1.6E-04	4.3E-05	**0.19**
Pesticides	0.012	0	0	0	0	**0.012**
Other Chemicals	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	**0**
Chlorides	3.25	0.0056	0.85	0.015	0.0039	**4.12**
Cadmium	0.0032	5.4E-06	8.3E-04	1.5E-05	3.9E-06	**0.0041**
Organic Carbon	0	0	0	0	0	**0**
Sulfates	3.52	0.010	0.69	0.012	0.0031	**4.23**
Sodium	0.0034	1.8E-05	1.1E-04	1.9E-06	5.0E-07	**0.0035**
Calcium	0.0018	9.9E-06	6.0E-05	1.0E-06	2.7E-07	**0.0019**
Manganese	0.45	0.0010	0.0061	1.1E-04	2.8E-05	**0.45**
Nitrates	0.007	4.3E-06	2.6E-05	4.5E-07	1.2E-07	**0.007**
Boron	0.52	0.0012	0.018	3.2E-04	8.4E-05	**0.54**
Other Organics	0.30	5.7E-04	0.057	9.9E-04	2.6E-04	**0.36**
Chromates	1.0E-04	2.9E-07	6.4E-05	1.1E-06	3.0E-07	**1.7E-04**
Sodium Dichromate	0	0	0	0	0	**0**

Table 3-9-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr				
thou lb/ 10,000 pkgs	1.4	1.4		1.4	
% recycled content	30				

	Unpadded Bleached Kraft Bag				
	Bleached Kraft	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related					
Acid	0.0030	6.5E-08	5.2E-07	1.1E-08	**0.0030**
Metal Ion	0.0047	0.0014	0.011	2.4E-04	**0.017**
Fluorides	0.0011	3.2E-06	2.6E-05	5.6E-07	**0.0012**
Dissolved Solids	10.9	0.27	2.17	0.047	**13.4**
Suspended Solids	08.5	0.0062	0.049	0.0011	**08.6**
BOD	4.06	0.0010	0.0081	1.8E-04	**4.06**
COD	6.43	0.0068	0.054	0.0012	**6.49**
Phenol	1.0E-03	4.5E-06	3.6E-05	7.7E-07	**1.1E-03**
Sulfides	8.4E-02	0	0	0	**8.4E-02**
Oil	0.27	0.0063	0.051	0.0011	**0.33**
Sulfuric Acid	0.020	5.4E-05	4.3E-04	9.3E-06	**0.021**
Iron	0.169	1.5E-04	0.0012	2.5E-05	**0.171**
Cyanide	8.0E-07	1.4E-08	1.1E-07	2.5E-09	**9.3E-07**
Alkalinity	0	0	0	0	**0**
Chromium	4.7E-04	1.0E-05	8.1E-05	1.8E-06	**5.6E-04**
Aluminum	0	0	0	0	**0**
Nickel	3.8E-08	0	0	0	**3.8E-08**
Mercury	8.9E-08	7.6E-10	6.0E-09	1.3E-10	**9.6E-08**
Lead	4.3E-07	1.2E-07	9.2E-07	2.0E-08	**1.5E-06**
Phosphates	0.095	2.7E-05	2.2E-04	4.7E-06	**0.095**
Phosphorus	0.10	0	0	0	**0.10**
Nitrogen	0.038	0	0	0	**0.038**
Zinc	1.3E-03	5.0E-06	4.0E-05	8.7E-07	**1.4E-03**
Ammonia	0.28	1.1E-04	8.8E-04	1.9E-05	**0.28**
Pesticides	0	0	0	0	**0**
Other Chemicals	0	0	0	0	**0**
Herbicides	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	**0**
Chlorides	0.48	0.010	0.080	0.0017	**0.57**
Cadmium	4.7E-04	9.9E-06	7.8E-05	1.7E-06	**5.6E-04**
Organic Carbon	0	0	0	0	**0**
Sulfates	0.50	0.0080	0.064	0.0014	**0.58**
Sodium	4.5E-04	1.3E-06	1.0E-05	2.2E-07	**4.6E-04**
Calcium	2.5E-04	7.0E-07	5.6E-06	1.2E-07	**2.5E-04**
Manganese	0.052	7.1E-05	5.7E-04	1.2E-05	**0.053**
Nitrates	1.1E-04	3.0E-07	2.4E-06	5.3E-08	**1.1E-04**
Boron	0.082	2.2E-04	0.0017	3.7E-05	**0.084**
Other Organics	0.045	6.6E-04	0.0053	1.1E-04	**0.051**
Chromates	1.4E-04	7.6E-07	6.0E-06	1.3E-07	**1.5E-04**
Sodium Dichromate	3.3E-06	0	0	0	**3.3E-06**
Methanol	0	0	0	0	**0**

Table 3-9-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr	Unbl Kr					
thou lb/ 10,000 pkgs	1	0.9	1.9	3.8		3.8	
% recycled content	30	30					

	All-Paper Padded Kraft Bag						
	Bleached Kraft	Unbleached Kraft	Macerated PC Newspaper Padding	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.0021	0.016	3.5E-08	1.8E-07	1.3E-06	3.1E-08	**0.018**
Metal Ion	0.0034	8.2E-04	7.4E-04	0.0037	0.028	6.5E-04	**0.037**
Fluorides	8.1E-04	3.0E-04	9.1E-05	8.7E-06	6.5E-05	1.5E-06	**0.0013**
Dissolved Solids	7.77	3.82	0.37	0.73	5.48	0.13	**18.3**
Suspended Solids	6.11	2.60	0.046	0.017	0.12	0.0029	**8.90**
BOD	2.90	1.65	7.6E-04	0.0027	0.020	4.8E-04	**4.57**
COD	4.59	09.6	0.0068	0.018	0.14	0.0032	**14.3**
Phenol	7.3E-04	6.5E-04	2.4E-06	1.2E-05	9.0E-05	2.1E-06	**1.5E-03**
Sulfides	6.0E-02	5.4E-02	0	0	0	0	**1.1E-01**
Oil	0.20	0.120	0.0074	0.017	0.13	0.0030	**0.47**
Sulfuric Acid	0.015	0.0072	6.1E-04	1.5E-04	0.0011	2.5E-05	**0.024**
Iron	0.121	0.093	0.0036	4.0E-04	0.0030	6.9E-05	**0.22**
Cyanide	5.7E-07	2.9E-07	2.3E-08	3.9E-08	2.9E-07	6.8E-09	**1.2E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	3.4E-04	1.7E-04	1.6E-05	2.8E-05	2.1E-04	4.8E-06	**7.6E-04**
Aluminum	0	0.10	0	0	0	0	**0.13**
Nickel	2.7E-08	7.2E-10	0	0	0	0	**2.8E-08**
Mercury	6.3E-08	1.4E-08	1.2E-09	2.1E-09	1.5E-08	3.6E-10	**9.6E-08**
Lead	3.1E-07	7.0E-08	6.2E-08	3.1E-07	2.3E-06	5.4E-08	**3.1E-06**
Phosphates	0.068	0.081	3.1E-04	7.3E-05	5.4E-04	1.3E-05	**0.15**
Phosphorus	0.07	0.041	0	0	0	0	**0.11**
Nitrogen	0.027	0.015	0	0	0	0	**0.042**
Zinc	9.6E-04	8.1E-04	6.2E-06	1.4E-05	1.0E-04	2.4E-06	**1.9E-03**
Ammonia	0.20	0.029	9.7E-05	3.0E-04	0.0022	5.2E-05	**0.23**
Pesticides	0	0	0	0	0	0	**0**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	0.34	0.17	0.016	0.027	0.20	0.0047	**0.76**
Cadmium	3.4E-04	1.7E-04	1.6E-05	2.7E-05	2.0E-04	4.7E-06	**7.5E-04**
Organic Carbon	0	0	0	0	0	0	**0**
Sulfates	0.36	0.17	0.023	0.022	0.16	0.0038	**0.74**
Sodium	3.2E-04	1.2E-04	3.6E-05	3.5E-06	2.6E-05	6.0E-07	**5.1E-04**
Calcium	1.8E-04	6.4E-05	2.0E-05	1.9E-06	1.4E-05	3.3E-07	**2.8E-04**
Manganese	0.037	0.025	0.0020	1.9E-04	0.0014	3.3E-05	**0.066**
Nitrates	7.7E-05	0.0015	8.6E-06	8.2E-07	6.1E-06	1.4E-07	**0.0016**
Boron	0.058	0.029	0.0025	5.8E-04	0.0044	1.0E-04	**0.09**
Other Organics	0.032	0.016	0.0015	0.0018	0.013	3.1E-04	**0.065**
Chromates	9.9E-05	6.1E-06	9.5E-07	2.1E-06	1.5E-05	3.6E-07	**1.2E-04**
Sodium Dichromate	2.4E-06	0	0	0	0	0	**2.4E-06**
Methanol	0	0	0	0	0	0	**0**

Table 3-9-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	Bl Kr	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.86	0.24	0.24	1.34	1.34
% recycled content	30	30	30		

	Bubble Padded Kraft Bag						
	Bleached Kraft	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related							
Acid	0.0018	0.022	0.022	6.2E-08	5.4E-07	1.1E-08	**0.046**
Metal Ion	0.0029	0.0014	0.0014	0.0013	0.011	2.4E-04	**0.019**
Fluorides	7.0E-04	3.0E-04	2.5E-04	3.1E-06	2.7E-05	5.5E-07	**0.0013**
Dissolved Solids	6.68	12.7	12.4	0.26	2.25	0.046	**34.3**
Suspended Solids	5.25	0.27	0.20	0.0059	0.051	0.0011	**5.79**
BOD	2.49	0.054	0.020	9.7E-04	0.0084	1.7E-04	**2.58**
COD	3.95	0.25	0.16	0.0065	0.057	0.0012	**4.42**
Phenol	6.3E-04	4.7E-06	4.7E-06	4.3E-06	3.7E-05	7.7E-07	**6.8E-04**
Sulfides	5.2E-02	0.010	0.010	0	0	0	**0.072**
Oil	0.17	0.23	0.22	0.0061	0.053	0.0011	**0.68**
Sulfuric Acid	0.013	0.0020	0.0017	5.1E-05	4.5E-04	9.2E-06	**0.017**
Iron	0.104	0.012	0.0096	1.4E-04	0.0012	2.5E-05	**0.127**
Cyanide	4.9E-07	8.5E-07	8.3E-07	1.4E-08	1.2E-07	2.5E-09	**2.3E-06**
Alkalinity	0	0	0	0	0	0	**0**
Chromium	2.9E-04	5.8E-04	5.7E-04	9.7E-06	8.5E-05	1.7E-06	**0.0015**
Aluminum	0	0	0	0	0	0	**0**
Nickel	2.3E-08	0	0	0	0	0	**2.3E-08**
Mercury	5.5E-08	4.5E-08	4.4E-08	7.3E-10	6.2E-09	1.3E-10	**1.5E-07**
Lead	2.7E-07	1.2E-07	1.2E-07	1.1E-07	9.6E-07	2.0E-08	**1.6E-06**
Phosphates	0.058	0.0021	0.0020	2.6E-05	2.2E-04	4.6E-06	**0.063**
Phosphorus	0.060	0	0	0	0	0	**0.060**
Nitrogen	0.023	0	0	0	0	0	**0.023**
Zinc	8.2E-04	3.9E-04	3.8E-04	4.8E-06	4.2E-05	8.7E-07	**0.0016**
Ammonia	0.17	3.1E-04	2.8E-04	1.1E-04	9.2E-04	1.9E-05	**0.17**
Pesticides	0	0	0	0	0	0	**0**
Other Chemicals	0	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	0	**0**
Chlorides	0.29	0.58	0.57	0.0095	0.083	0.0017	**1.54**
Cadmium	2.9E-04	5.8E-04	5.7E-04	9.5E-06	8.1E-05	1.7E-06	**0.0015**
Organic Carbon	0	0.024	0.024	0	0	0	**0.047**
Sulfates	0.31	0.48	0.47	0.0077	0.067	0.0014	**1.34**
Sodium	2.8E-04	1.2E-04	9.8E-05	1.2E-06	1.1E-05	2.2E-07	**5.1E-04**
Calcium	1.5E-04	6.5E-05	5.3E-05	6.7E-07	5.8E-06	1.2E-07	**2.8E-04**
Manganese	0.032	0.0068	0.0056	6.8E-05	5.9E-04	1.2E-05	**0.045**
Nitrates	6.6E-05	2.8E-05	2.3E-05	2.9E-07	2.5E-06	5.2E-08	**1.2E-04**
Boron	0.050	0.0081	0.0067	2.1E-04	0.0018	3.7E-05	**0.067**
Other Organics	0.028	0.015	0.014	6.3E-04	0.0055	1.1E-04	**0.062**
Chromates	8.5E-05	3.1E-06	2.8E-06	7.3E-07	6.2E-06	1.3E-07	**9.8E-05**
Sodium Dichromate	2.1E-06	0	0	0	0	0	**2.1E-06**
Methanol	0	0	0	0	0	0	**0**

Table 3-9-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	LLDPE		
thou lb/ 10,000 pkgs	0.67	0.67	0.67
% recycled content	30		

	Unpadded LLDPE Film Bag				
	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related					
Acid	0.062	6.0E-08	2.6E-07	6.0E-09	**0.062**
Metal Ion	0.0040	0.0013	0.0055	1.3E-04	**0.011**
Fluorides	6.9E-04	3.0E-06	1.3E-05	2.9E-07	**7.1E-04**
Dissolved Solids	34.7	0.25	1.08	0.025	**36.0**
Suspended Solids	0.57	0.0057	0.025	5.6E-04	**0.60**
BOD	0.057	9.3E-04	0.0041	9.3E-05	**0.062**
COD	0.44	0.0062	0.027	6.2E-04	**0.48**
Phenol	1.3E-05	4.1E-06	1.8E-05	4.1E-07	**3.5E-05**
Sulfides	0.028	0	0	0	**0.028**
Oil	0.63	0.0058	0.025	5.8E-04	**0.66**
Sulfuric Acid	0.0047	4.9E-05	2.2E-04	4.9E-06	**0.0049**
Iron	0.027	1.3E-04	5.9E-04	1.3E-05	**0.028**
Cyanide	2.3E-06	1.3E-08	5.7E-08	1.3E-09	**2.4E-06**
Alkalinity	0	0	0	0	**0**
Chromium	0.0016	9.3E-06	4.1E-05	9.3E-07	**0.0016**
Aluminum	0	0	0	0	**0**
Nickel	0	0	0	0	**0**
Mercury	1.2E-07	7.0E-10	3.0E-09	7.0E-11	**1.3E-07**
Lead	3.3E-07	1.1E-07	4.6E-07	1.1E-08	**9.1E-07**
Phosphates	0.0055	2.5E-05	1.1E-04	2.5E-06	**0.0056**
Phosphorus	0	0	0	0	**0**
Nitrogen	0	0	0	0	**0**
Zinc	0.0011	4.6E-06	2.0E-05	4.6E-07	**0.0011**
Ammonia	7.8E-04	1.0E-04	4.4E-04	1.0E-05	**0.0013**
Pesticides	0	0	0	0	**0**
Other Chemicals	0	0	0	0	**0**
Herbicides	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	**0**
Chlorides	1.60	0.0091	0.040	9.1E-04	**1.65**
Cadmium	0.0016	9.1E-06	3.9E-05	9.1E-07	**0.0016**
Organic Carbon	0.066	0	0	0	**0.066**
Sulfates	1.31	0.0074	0.032	7.4E-04	**1.35**
Sodium	2.7E-04	1.2E-06	5.1E-06	1.2E-07	**2.8E-04**
Calcium	1.5E-04	6.4E-07	2.8E-06	6.4E-08	**1.5E-04**
Manganese	0.016	6.5E-05	2.9E-04	6.5E-06	**0.016**
Nitrates	6.5E-05	2.8E-07	1.2E-06	2.8E-08	**6.7E-05**
Boron	0.019	2.0E-04	8.6E-04	2.0E-05	**0.020**
Other Organics	0.038	6.1E-04	0.0026	6.0E-05	**0.041**
Chromates	7.7E-06	7.0E-07	3.0E-06	6.9E-08	**1.1E-05**
Sodium Dichromate	0	0	0	0	**0**
Methanol	0	0	0	0	**0**

Table 3-9-BAG
LIFE CYCLE WATERBORNE EMISSIONS FOR 10,000 PACKAGES USING SHIPPING BAGS
HIGHER RECYCLED CONTENT OPTIONS

	LDPE	LLDPE		
thou lb/ 10,000 pkgs	0.35	0.98	1.33	1.33
% recycled content	30	30		

	Bubble Padded LLDPE Bag					
	LDPE Film	LLDPE Film	Transp of Bag to Retail Order Ctr	Transp to Customer	End of Life Disposal of Bag	**TOTAL**
Waterborne Wastes (lb/10,000 pkgs) - Process + Fuel-Related						
Acid	0.032	0.09	6.2E-08	5.4E-07	1.2E-08	**0.12**
Metal Ion	0.0021	0.0059	0.0013	0.011	2.5E-04	**0.021**
Fluorides	4.4E-04	0.0010	3.1E-06	2.7E-05	5.9E-07	**0.0015**
Dissolved Solids	18.4	50.7	0.26	2.25	0.049	**71.7**
Suspended Solids	0.40	0.84	0.0059	0.051	0.0011	**1.29**
BOD	0.08	0.08	9.6E-04	0.0084	1.8E-04	**0.17**
COD	0.37	0.65	0.0064	0.057	0.0012	**1.08**
Phenol	6.8E-06	1.9E-05	4.2E-06	3.7E-05	8.1E-07	**6.8E-05**
Sulfides	0.015	0.041	0	0	0	**0.056**
Oil	0.33	0.91	0.0060	0.053	0.0012	**1.31**
Sulfuric Acid	0.0030	0.0068	5.1E-05	4.5E-04	9.8E-06	**0.010**
Iron	0.017	0.039	1.4E-04	0.0012	2.7E-05	**0.058**
Cyanide	1.2E-06	3.4E-06	1.4E-08	1.2E-07	2.6E-09	**4.8E-06**
Alkalinity	0	0	0	0	0	**0**
Chromium	0.0008	0.0023	9.7E-06	8.5E-05	1.9E-06	**0.0033**
Aluminum	0	0	0	0	0	**0**
Nickel	0	0	0	0	0	**0**
Mercury	6.6E-08	1.8E-07	7.2E-10	6.2E-09	1.4E-10	**2.5E-07**
Lead	1.8E-07	4.9E-07	1.1E-07	9.6E-07	2.1E-08	**1.8E-06**
Phosphates	0.0031	0.008	2.6E-05	2.2E-04	4.9E-06	**0.011**
Phosphorus	0	0	0	0	0	**0**
Nitrogen	0	0	0	0	0	**0**
Zinc	5.6E-04	0.0016	4.8E-06	4.2E-05	9.2E-07	**0.0022**
Ammonia	4.5E-04	0.0011	1.0E-04	9.2E-04	2.0E-05	**0.0026**
Pesticides	0	0	0	0	0	**0**
Other Chemicals	0	0	0	0	0	**0**
Herbicides	0	0	0	0	0	**0**
Hydrocarbons	0	0	0	0	0	**0**
Chlorides	0.85	2.33	0.0094	0.083	0.0018	**3.28**
Cadmium	0.0008	0.0023	9.4E-06	8.1E-05	1.8E-06	**0.0032**
Organic Carbon	0.034	0.10	0	0	0	**0.13**
Sulfates	0.71	1.92	0.0076	0.067	0.0015	**2.70**
Sodium	1.8E-04	4.0E-04	1.2E-06	1.1E-05	2.3E-07	**5.9E-04**
Calcium	9.5E-05	2.2E-04	6.6E-07	5.8E-06	1.3E-07	**3.2E-04**
Manganese	0.010	0.023	6.8E-05	5.9E-04	1.3E-05	**0.033**
Nitrates	4.2E-05	9.5E-05	2.9E-07	2.5E-06	5.5E-08	**1.4E-04**
Boron	0.012	0.027	2.0E-04	0.0018	3.9E-05	**0.041**
Other Organics	0.021	0.056	6.3E-04	0.0055	1.2E-04	**0.08**
Chromates	4.5E-06	1.1E-05	7.2E-07	6.2E-06	1.4E-07	**2.3E-05**
Sodium Dichromate	0	0	0	0	0	**0**
Methanol	0	0	0	0	0	**0**

CHAPTER 4

CONSIDERATIONS FOR INTERPRETATION OF DATA AND RESULTS

INTRODUCTION

An important issue with LCI results is whether two numbers are really different from one another. For example, if one product has a total system requirement of 100 energy units, is it really different from another product system that requires 110 energy units? If the error or variability in the data is sufficiently large, it cannot be concluded that the two numbers are actually different.

STATISTICAL CONSIDERATIONS

A statistical analysis that yields clear numerical answers would be ideal, but unfortunately LCI data are not amenable to this. The data are not (1) random samples from (2) large populations that result in (3) "normal curve" distributions. LCI data meet none of these requirements for statistical analysis. LCI data for a given sub-process (such as potato production, roundwood harvesting, or caustic soda manufacture, for example) are generally selected to be representative of a process or industry, and are typically calculated as an average of two to five data points. In statistical terminology, these are not random samples, but "judgment samples," selected so as to reduce the possible errors incurred by limited sampling or limited population sizes. Formal statistics cannot be applied to judgment samples; however, a hypothetical data framework can be constructed to help assess in a general sense the reliability of LCI results.

The first step in this assessment is reporting standard deviation values from LCI data, calculated by:

$$s = \sqrt{\frac{\sum (x_1 - x_{mean})^2}{n-1}},$$

where x_i is a measured value in the data set and x_{mean} is the average of n values. An analysis of sub-process data from Franklin Associates, Ltd. files shows that, for a typical sub-process with two to five different companies supplying information, the standard deviation of the sample is about 30 percent of the sample average.

In a typical LCI study, the total energy of a product system consists of the sum of many sub-processes. For the moment, consider an example of adding only two numbers. If both numbers are independent of each other and are an average of measurements which have a sample standard deviation, s, of 30, the standard deviation of the sum is obtained by adding the variances of each term to form the sum of the variances, then taking the square root. Variances are calculated by squaring the standard deviation, s^2, so the sum of the variances is $30^2 + 30^2 = 900 + 900 = 1800$. The new standard deviation of the sum is the square root of the sum of the variances, or $\sqrt{1800}$ = 42.4. In this example, suppose both average values are 100, with a sum of 200. If reported as a percent of the sum, the new standard deviation is 42.4/200 = 21.3% of the sum. Another way of obtaining this value is to use the formula $s_{\%} = \frac{s/x_{mean}}{\sqrt{n}}$, where the term $s_{\%}$ is defined as the standard deviation of n data points, expressed as a % of the average, where each entry has approximately the same standard deviation, s. For the example, then, $s_{\%} = \frac{30\%}{\sqrt{2}} = 21.3\%$.

Going back to a hypothetical LCI example, consider a common product system consisting of a sum of approximately 40 subsystems. First, a special hypothetical case is examined where *all of the values are approximately the same size, and all have a standard deviation of 30%*. The standard deviation in the result is $s_{\%} = \frac{30\%}{\sqrt{40}} = 4.7\%$. The act of summing reduces the standard deviation of the result with respect to the standard deviation of each entry because of the assumption that errors are randomly distributed, and by combining values there is some cancellation of total error because some data values in each component system are higher than the true values and some are lower.

The point of this analysis, however, is to compare two results, e.g., the energy totals for two different product systems, and decide if the difference between them is significant or not. To test a hypothetical data set it will be assumed that two product systems consist of a sum of 40 values, and that the standard deviation, $s_{\%}$, is 4.7% for each product system.

If there is statistical knowledge of the sample only, and not of the populations from which they were drawn, "t" statistics can be used to find if the two product totals are different or not. The expression selected is:
$\mu 1 - \mu 2 = x1 - x2 +/- t_{.025} s' \sqrt{\frac{1}{n1} + \frac{1}{n2}}$, where $\mu 1 - \mu 2$. is the difference in population means, x_1-x_2 is the difference in sample means, and s' is a pooled standard deviation of the two samples. For the hypothetical case, where it is assumed that the standard deviation of the two samples is the same, the pooled value is simply replaced with the standard deviation of the samples.

The goal is to find an expression that compares our sample means to "true," or population, means. A new quantity is defined:
$\Delta = (\mu 1 - \mu 2) - (x1 - x2)$, and the sample sizes are assumed to be the same (i.e., n_1=n_2). The result is $\Delta = t_{.025} s' \sqrt{\frac{2}{n}}$, where Δ is the minimum difference corresponding to a 95%

confidence level, s' is the standard deviation of the sum of n values, and $t_{.025}$ is a t statistic for 95% confidence levels. The values for t are a function of n and are found in tables. This expression can be converted to percent notation by dividing both sides by the average of the sample means, which results in $\Delta\% = t_{.025} s'\% \sqrt{\frac{2}{n}}$, where $\Delta\%$ is now the percent difference corresponding to a 95% confidence level, and s'% is the standard deviation expressed as a percent of the average of the sample means. This formula can be simplified for the example calculation by remembering that $s'\% = \frac{s\%}{\sqrt{n}}$, where s% is the standard deviation of each energy entry for a product system. Now the equation becomes $\Delta\% = t_{.025} s\% \frac{\sqrt{2}}{n}$. For the example, t = 2.0, s = 30%, and n = 40, so that $\Delta\%$ = 2.1%. This means that if the two product system energy totals differ by more than 2.1%, there is a 95% confidence level that the difference is significant. That is, if 100 independent studies were conducted (in which new data samples were drawn from the same population and the study was conducted in the identical manner), then 95 of these studies would find the energy values for the two product systems to differ by more than 2.1%.

The previous discussion applies only to a hypothetical and highly idealized framework to which statistical mathematics apply. LCI data differ from this in some important ways. One is that the 40 or so numbers that are added together for a final energy value of a product system are of widely varying size and have different variances. The importance of this is that large numbers contribute more to the total variance of the result. For example, if 20 energy units and 2,000 energy units are added, the sum is 2,020 energy units. If the standard deviation of the smaller value is 30% (or 6 units), the variance is 6^2 = 36. If the standard deviation of the larger number is 10% (or 200), the variance is 200^2 = 40,000. The total variance of the sum is 36 + 40,000 = 40,036, leading to a standard deviation in the sum of $\frac{\sqrt{(40036)}}{2020}$ = 9.9%. Clearly, the variance in the result is much more greatly influenced by larger numbers. In a set of LCI energy data, standard deviations may range from 10% to 60%. If a large number has a large percentage standard deviation, then the sum will also be more uncertain. If the variance of the large number is small, the answer will be more certain. To offset the potential problem of a large variance, Franklin Associates goes to great lengths to increase the reliability of the larger numbers, but there may simply be inherent variability in some numbers which is beyond the researchers' control.

If only a few numbers contribute most of the total energy in a system, the value of $\Delta\%$ goes up. This can be illustrated by going back to the formula for $\Delta\%$ and calculating examples for n = 5 and 10. From statistical tables, the values for $t_{.025}$ are 2.78 for n = 5, and 2.26 for n = 10. Referring back to the hypothetical two-product data set with s% = 30% *for each entry*, the corresponding values for $\Delta\%$ are 24% for n = 5 and 9.6% for n = 10. Thus, if only 5 numbers out of 40 contribute most of the energy, the percent *difference* in the two product system energy values must increase to 24% to achieve the 95% confidence level that the two values are different. The minimum difference decreases to 9.6% if there are 10 major contributors out of the 40 energy numbers in a product system.

CONCLUSIONS

The discussion above highlights the importance of sample size, and of the variability of the sample. However, once again it must be emphasized that the statistical analysis does not apply to LCI data. It only serves to illustrate the important issues. Valid standard deviations cannot be calculated because of the failure of the data to meet the required statistical formula assumptions. Nevertheless, it is important to achieve a maximum sample size with minimum variability in the data. Franklin Associates examines the data, identifies the large values contributing to a sum, then conducts more intensive analysis of those values. This has the effect of increasing the number of data points, and therefore decreasing the "standard deviation." Even though a calculated standard deviation of 30% may be typical for Franklin Associates' LCI data, the actual confidence level is much higher for the large values that control the variability of the data than for the small values. However, none of this can be quantified to the satisfaction of a statistician who draws conclusions based upon random sampling. In the case of LCI data, it comes down to a matter of professional judgment and experience. The increase in confidence level resulting from judgment and experience is not measurable.

It is the professional judgment of Franklin Associates, based upon over 25 years of experience in analyzing LCI data, that a 10% rule is a reasonable value for $\Delta\%$ for stating results of product system energy totals. That is, if the energy of one system is 10% different from another, it can be concluded that the difference is significant. It is clear that this convention is a matter of judgment. This is not claimed to be a highly accurate statement; however, the statistical arguments with hypothetical, but similar, data lend plausibility to this convention.

We also conclude that the weight of postconsumer solid waste data can be analyzed in a similar way. These data are at least as accurate as the energy data, perhaps with even less uncertainty in the results. Therefore, the 10% rule applies to postconsumer solid waste weight. However, we apply a 25% rule to the solid waste volume data because of greater potential variability in the volume conversion factors.

Air and water pollution and industrial solid waste data are not included in the 10% rule. Their variability is much higher. Data reported by similar plants may differ by a factor of two, or even a factor of ten or higher in some cases. Standard deviations may be as high as 150%, although 75% is typical. This translates to a hypothetical standard deviation in a final result of 12%, or a difference of at least 25% being required for a 95% confidence of two totals being different if 10 subsystems are major contributors to the final results. However, this rule applies only to single emission categories, and cannot be extended to general statements about environmental emissions resulting from a single product system. The interpretation of environmental emission data is further complicated by the fact that not all plants report the same emission categories, and that there is not an accepted method of evaluating the relative importance of various emissions.

It is the intent of this appendix to convey an explanation of Franklin Associates' 10% and 25% rules and establish their plausibility. **Franklin Associates' policy is to consider product system totals for energy and weight of postconsumer solid waste weight to be different if there is at least a 10% difference in the totals. Otherwise, the difference is considered to be insignificant. In the detailed tables of this report there are many specific pollutant categories that are variable between systems. For the air and waterborne emissions, industrial solid waste, and postconsumer solid waste volume, the 25% rule should be applied.** The formula used to calculate the difference between two systems is:

$$\% \text{ Diff} = \left(\frac{x-y}{\frac{x+y}{2}} \right) \text{ X } 100,$$

where x and y are the summed totals of energy or waste for two product systems. The denominator of this expression is the average of the two values.

ADDENDUM: PEER REVIEW PANEL REPORT AND CONSULTANT RESPONSES

Life Cycle Inventory Of Packaging Options For Shipment Of Retail Mail-Order Soft Goods: Final Draft Report And Final Appendix, December, 2003

Peer Review Comments Submitted February 17, 2004 And Consultant Responses

April 2004

Peer Review Team: Gregory Keoleian
University of Michigan
Center for Sustainable Systems

Joyce Cooper
University of Washington
Department of Mechanical Engineering

Mary Ann Curran, Review Team Chair
US Environmental Protection Agency
National Risk Management Research Laboratory

Study Commissioned By: Oregon Department of Environmental Quality (DEQ)

Analysis Conducted By: Franklin Associates, A Division of ERG
Prairie Village, KS

Process for Review

Peer review team members were provided copies of the draft final report and appendices (dated December, 2003) and an Excel file containing the results of the life cycle inventory. Individual members of the team shared their comments on these documents and the overall study with each other. After discussion of these individual comments, the Chair of the Review Team synthesized them into the following peer review report. Note: the Reviewers were unable to review each individual data point and how data were combined (i.e. data calculation and computational structure) in detail.

Review Summary

This Life Cycle Inventory (LCI) of soft goods packaging was, for the most part, well-constructed and developed in accordance with ISO 14040/14041 documents on life cycle goal and scoping and inventory. The mail-order soft goods packaging systems, corrugated boxes with various types of dunnage and shipping bags, are well defined. Package logistics were modeled for a ground-delivered package shipped from an order fulfillment center in western Oregon to a customer in central Missouri. An overview of the assumptions, data source and data analysis methods, is provided, however, the transparency of the report can be improved. This study is supported by a comprehensive set of Appendices that describe an extensive life cycle inventory database. The conclusions drawn from this study are consistent with the results for both packaging systems. Recommendations for improving the report are indicated below. For example, data categories for environmental emissions should be more explicitly defined. Other recommendations related mainly to clarifying limitations and assumptions of the study and the inventory data presented in the Appendix. The inventory should be more transparent to enable tracking of data sources in each module. It's unclear how data quality for model parameters are translated to the overall quality of the final results, i.e. how data with poor quality influence the uncertainty of the results. Gravity, uncertainty and sensitivity could be better highlighted in the discussion.

MAJOR RECOMMENDATIONS (NOT RANKED)

1. Define data categories for environmental emissions more explicitly, i.e., list the pollutants tracked.

Response: A full list of atmospheric emissions can be found in results tables 2-6, 2-7, 3-6, and 3-7. The list of waterborne emissions is shown in results tables 2-8, 2-9, 3-8, and 3-9. This has been stated in the Executive Summary.

2. It would be useful to model airfreight in addition to ground-based logistics but this would require additional modeling. Additionally, consider a sensitivity analysis that explores changes in distribution distance.

Response: It is agreed that it would be useful to model airfreight, but this was beyond the scope and budget of the project. A section providing guidance for readers on how to estimate the burdens for different distribution distances by road has been added to the end of Chapter 3 of the report. Readers interested in understanding the importance of the ground freight component relative to other life cycle steps will find that transportation to consumer is shown as a separate category in Chapter 3 figures.

3. It does not appear that fabrication scrap losses are accounted for. Plastic fabrication losses are often small; is this also the case for the paper-based products?

Response: For most packaging components, fabrication data (including scrap rates) were either collected specifically for this study or taken from Franklin Associates' LCI database. Data were not available for the fabrication of shipping bags from their component materials. This limitation is clearly stated in the report results chapters. A section has also been added to Chapter 1 under System Components Not Included. Finally, a section has been added to the end of Chapter 3 providing guidance on using the material production data modules to estimate the effect of different fabrication scrap rates.

4. An overview of the Appendix should be provided that indicates the overall age of the data and processes modeled.

Response: The Franklin Associates LCI database has been developed over many years. Individual process/material data sets contributing to material process trees are continuously updated as new LCI projects involving these unit processes are conducted or as new or updated public data sources become available. Thus, for any packaging product modeled, the sources and ages of individual contributing unit process data sets within the model varies, making it difficult to concisely describe the age of the overall dataset. In Chapter 1, an overview of the age and source of the final material production and fabrication data sets for each packaging material has been added in the section Process Data (subsection Sources), and a general description of the age of the fuels and energy database has been added to Chapter 1 in the section Fuel Data.

5. Limit the claim of following ISO standard to goal and scope definition and inventory analysis.

Response: Agreed that this is appropriate, since this report is limited to a life cycle inventory and does not include impact assessment. Text has been added to the Introduction of Chapter 1 to clarify this.

6. Clarify how data quality affects the overall quality of the final results.

Response: An additional chapter has been added to the report to address this issue in greater detail. Chapter 4 provides an explanation of Franklin Associates' criteria for meaningful differences in LCI results, supported by statistical arguments with hypothetical data and taking into account representative standard deviations, variances, and "t" statistics for desired confidence levels.

7. Clarify the recycling allocation method that was used, per comment #10 below.

Response: This comment is believed to refer to the question regarding solid waste allocation (Item 9 under **Executive Summary** comments). Text has been added to the report to clarify the methodology used.

8. The discussion on data accuracy versus data quality should be expanded and clarified (see point 9, Body of Report, below).

Response: Revisions have made to text to address the suggestions and comments in Item 9 under **Body of Report** comments.

EXECUTIVE SUMMARY

1. Table ES-1: It would be helpful to add a subtitle to clarify this table for the reader. Definition of Packaging Options. Two corrugated box options (1 and 2) and eight dunnage options including a no dunnage option.

Response: The purpose of this table is to define the weights and compositions of the individual packaging components that are analyzed in various combinations in the study. The study does not evaluate a "no dunnage" box option. The table title has been modified: "Definition of individual packaging components modeled in the study (Study models corrugated boxes used in combination with various dunnage options.)" The titles of the corresponding Tables 2-1 and 3-1 have also been changed.

2. ES-4; Scope and Boundaries; third bullet: "Glues, adhesives, and other inputs accounting for less than one percent of the weight of product were not included." If several components each with individual weights slightly less than one percent are excluded the impact on the results might be significant. In addition while the energy burden may be negligible for these elements their environmental emissions may be significant. What percentage by weight of the total product system is inventoried?

Response: In Chapter 1, section Miscellaneous Materials and Additives, under System Components Not Included, it is noted that cornstarch loose fill contains greater than one percent proprietary plasticizers that could not be modeled since the composition of the proprietary constituents was unknown; thus the cornstarch loose fill was modeled as 100% cornstarch. Because the identity of the proprietary materials is unknown, their potential impact on results cannot be estimated. The scope of the study did not include detailed compositional analysis of all packaging components. Based on the general compositional data available on other packaging materials, no other materials were knowingly excluded from the analysis.

3. "Data were not available for the fabrication of shipping envelopes from their component materials; thus, the burdens for shipping bags are understated by an unknown amount." How significant is this lack of data? should it be noted more often than it is? especially under "limitations?"

Response: See response to Item 3 under **Major Recommendations** comments.

4. ES-4: the word "envelope" is used in discussing the shipping bag system but it is not explained how the envelope is different from the bag.

Response: The terms were used interchangeably. For clarification, the report has been revised to use only the term "shipping bag."

5. Space conditioning was not included in the scope of the analysis but this process can be significant. DOE data for the industrial sector indicates that non-process energy use including HVAC and lighting accounts for 10 -15 percent of the total end use fuel energy consumption in the case of electricity and natural gas. (http://www.eia.doe.gov/emeu/mecs/mecs98/datatables/d98n6_4.htm)

Response: Space conditioning was not explicitly included in the scope of the study; however, primary LCI data are often based on overall facility utility use and may include some space conditioning data. In addition, based on the practitioner's experience, HVAC and lighting may account for a significant percentage of total electricity and natural gas use for facilities where relatively low-energy processes such as assembly processes are conducted, but they are generally an insignificant percentage of total energy use for facilities where higher-energy processes such as chemical processing or fabrication processes take place. The space conditioning section of Chapter 1 has been revised to better describe this issue, including adding reference to the DOE website.

6. Transport of packaging items from the manufacturer to the order fulfillment center was inventoried but secondary and tertiary packaging components were not apparently inventoried. These components can potentially have a significant burden depending on their mass and composition. Was any attempt made to examine these components?

Response: Inclusion of secondary and tertiary packaging used to deliver packaging items to the order fulfillment center was not within the scope of this study. This is noted in Chapter 1, section Secondary Packaging, under System Components Not Included. The types of secondary packaging used in bulk shipments of packaging materials (e.g., steel or reinforced plastic strapping, plastic bags or film, etc.) are generally small in mass relative to the mass of the packaging delivered, or are reusable and commonly reused many times (pallets, plastic boxes, etc.) such that the burdens per delivery of packaging are small.

7. The study defined a representative customer in central Missouri for modeling purposes. Given that customers are distributed across the country it would be helpful to conduct a sensitivity analysis on the transportation distance from the distribution center to the customer.

Response: See response to Item 2 under **Major Recommendations** comments.

8. Solid Waste ES-8: Indicate in this section that the transport of packaged product has a negligible contribution to the total solid waste. White bar in figure ES-2 is not visible presumably because its magnitude is too small.

Response: Text has been added to explain that the only solid waste from transport of packaged product is fuel-related waste, which is too small relative to other life cycle stages to show up on the results figure ES-2.

9. Solid waste credit is made for the recycled content of the package. This statement is unclear and seems to conflict with the recycling allocation method described in the Methodology of Chapter 1. Which recycling allocation rule was used? Chapter 1 suggests that the EPA LCI Guidance Manual (1993) allocation method 2 was used but the solid waste credit wouldn't be assigned to the packaging system. This method indicates that if the original product is recycled the solid waste burden for that product is reduced by the amount of waste diverted from the disposal phase. The product system that uses the recycled material picks up the burdens for

processing of the secondary material but avoids virgin material production burdens.

Response: For postconsumer recycled content of packaging in this study, the initial product system generating the material is assigned all of the burdens for material production and none of the disposal burdens, while the system using the postconsumer material is assigned none of the material production burdens and all of the disposal burdens for packaging that is not recycled or reused. The solid waste credit shown in Figure ES-3 is assigned to the initial system that produced the postconsumer material used in the packaging. Figure ES-4 thus shows the net solid waste benefit, i.e., how using postconsumer material produced by the initial system (thus diverting it from solid waste) offsets packaging disposal burdens for the packaging systems utilizing postconsumer recycled content. Text has been added to the report for clarification.

10. It would be helpful to provide a list of environmental emissions (data categories) that are inventoried.

Response: See response to Item 1 under **Major Recommendations** comments.

11. Emissions from combustion of packaging wastes were not modeled. This exclusion is understandable given the lack of material specific emissions data. Carbon dioxide emissions, however, could be estimated with reasonable certainty by assuming complete oxidation of the carbon content in each material.

Response: This is discussed in Chapter 1, under System Components Not Included, section Emissions from Combustion and Landfilling of Postconsumer Waste. This section notes that complete oxidation of the carbon content may not be an accurate representation of mixed MSW combustion (which often contains wet wastes and is burned with very low efficiency under less than ideal conditions for complete combustion to carbon dioxide). Because of the uncertainty in emissions data for MSW combustion, as well as for other end-of-life disposal options such as decomposition in landfills, it was decided not to include end-of-life atmospheric emissions in the analysis.

12. Overall Conclusions - General rule: any box system that is more than four times as heavy as a shipping bag will require more cradle to production energy than the shipping bag. This factor is two times for solid waste and greenhouse gas emissions. Energy and greenhouse gas emissions generally correlate well. Can you explain the difference between the factor four and factor two?

Response: The overall energy includes the energy of material resource, that is, the energy content of fuel resources used as material inputs to plastic products. This represents an energy content that does not result in combustion emissions. An explanation has been added to the comparative factor discussion in the Executive Summary and Chapter 3 of the report.

BODY OF REPORT

1. 1-1 (revised): Insert the phrase “shared allocation approach” somewhere here (the term is used on the next page without being defined).

Response: The term “shared allocation approach” has been inserted in the third sentence of the first paragraph of the Recycling section of Chapter 1.

2. Figure 1-1: The product recycling on this diagram should be labeled closed loop recycling and/or another arrow could be added to represent open loop recycling.

Response: The return lines on the figure labeled “Product Recycling” apply to both types of recycling; the difference between open-loop and closed-loop recycling is the number of cycles before the material is disposed. Wording has been added to the diagram to clarify this.

3. The functional unit should be specified with more detail. Packaging required to deliver 10,000 packages of mail-order soft goods to customers does not by itself indicate a well-defined system. Soft goods can range in size from heavy wool blankets to tee shirts. The package size and weight parameters, which are defined in the Appendix, should be summarized here (i.e. sooner in the report). The location of the distribution center and customer and the delivery distance should be indicated here as well as mass and volume of the product being delivered. ISO14040 1997 (E) defines the functional unit as a measure of the performance of the functional outputs of a product system. Specification of the functional unit consists of the magnitude and duration of service, including the product's life span. The purpose of the functional unit is to provide a reference to which the inventory data are related to ensure alternatives are compared on a common basis. For each product system or alternative being assessed, the amount of product necessary per functional unit is known as the reference flow (International Standards Organization 1998). Definition of the reference flows must include the type and quantity of materials and energy linked to the functional unit and the number of times materials must be replaced during the analysis lifetime. From Cooper, J.S. "Specifying Functional Units and Reference Flows for Comparable Alternatives," recently published in the IJLCA.

Response: Wording has been added to the Functional Unit section of Chapter 3 to clearly define the mass and volume of the representative soft goods order shipped as well as the locations of the order fulfillment center and customer and the shipping distance. While all chapters contain a Functional Unit section, Chapter 3 is the appropriate place to add the detailed functional unit description because this chapter is where the functional unit is applied (i.e., to weight the data modules developed in Chapter 2, using the LCI methodology described in Chapter 1).

Specify the base year.

Response: Added as requested, in Chapter 3 Functional Unit section.

4. 1-4: W is capitalized in “kwh”; should read kWh.

Response: Corrected.

5. Precombustion energy is not a common term used in energy analysis. Life cycle energy literature often uses the term “upstream energy” to refer to extraction, processing, and distribution. It may be useful to also include this term as a parenthetical note: (precombustion energy is also referred to in the literature as upstream energy).

Response: Suggested parenthetical note has been added at the first text reference to precombustion energy (Chapter 1, second paragraph in section **Energy Requirements**).

6. Energy embodied in wood is not inventoried. This convention was recommended in the US EPA LCI Guidance Manual. Alternatively, this energy source can be tracked separately and reported as a renewable energy.

Response: Chapter 1 clearly explains the reasoning why energy embodied in wood is not included in the inventory. In the United States, wood’s predominant use is as a material input to wood and paper products. The use of wood as a material input does not result in a depletion of finite fuel resources; thus Franklin Associates’ methodological approach does not include inventorying the embodied energy of wood-based products. However, wood-derived energy used in the production of paper products in included in the inventory, and the energy recovered through waste-to-energy incineration of disposed paper packaging is included in the net energy results.

7. Particulate matter - The analysts recognize the difficulty in obtaining particulate emissions data categorized by size range. The analysts should also indicate that PM 2.5 is now considered the size range of most concern for human health effects. A note of caution could be provided here stating that assessing environmental consequences of unclassified particulate emissions is challenging for several reasons.

Response: Because this analysis is limited to an inventory and does not include impact assessment, the issues of health and environmental consequences are beyond the scope of the report. However, some additional wording has been added for informational purposes.

8. Inclusion of Inputs and Outputs - “Any material less than one percent of the mass in the system is generally considered negligible.” Clarify this rule. Exclusion of many smaller components by mass could result in a significant oversimplification and underestimation of the system burden. A cautionary note should also be provided indicating that the use of mass exclusion criteria could result in oversight of minor constituents that are highly toxic.

Response: Text has been added to this section to clarify.

9. Data quality – while we would like to some day be able to say something about accuracy, the methodology is not there yet. "In a complex study with literally thousands of numbers, the accuracy of the data and how it affects conclusions is truly a complex subject, and one that does not lend itself to standard error analysis techniques." This is true but techniques such as Monte Carlo analysis can be used to study uncertainty. The greatest challenge is the lack of uncertainty data or probability distributions for key parameters, which are often only available as single point estimates.

   "Each number by itself contributes little to the total, so the accuracy of each number by itself has a small effect on the overall accuracy of the total. " This is a bit overstated. Should reword: "by itself [may] contribute little to the total" It depends on the magnitude of the uncertainty for each parameter and the sensitivity of the final result to changes in each parameter.

   "It is assumed that with careful scrutiny of the data, any errors will be random. That is, some numbers will be a little high due to errors, and some will be slightly low, but in the summing process these errors cancel out." Such errors do not cancel out completely and will contribute to the overall uncertainty in the results.

Response: Revisions have made to text to address above suggestions and comments.

10. 1-11: While this introduces <u>some</u> subjectivity into the uncertainty analysis" Drop "some"

Response: Change made as suggested.

11. The DQI approach is the best available means for characterizing uncertainty given the scarcity of uncertainty data. Data quality indicators were reported with inventory modules presented in the appendix. It is not clear how the data quality indicators are used to create a stochastic model and how the output is a distribution of values.

Response: Because stochastic modeling was outside of the scope of this study, the data quality indicator discussion in this section was for informational purposes only and does not apply to the modeling approach used in this analysis. The text discussion of DQIs has thus been removed from Chapter 1 to avoid confusion.

12. The LCI traces energy and environmental emissions. Mineral resource extraction measured as the mass of ore mined is not inventoried. Available datasets often don't include minerals extracted and therefore the inclusion of this data category is not possible. While this might be the case, this limitation should be indicated.

Response: Individual unit process data sets in the full appendix document submitted to the peer reviewers include resource use (such as wood, ore, etc.) associated with the output product of each specific unit process. However, there was not a “rolled-up” weighted summary of upstream resource use based on each unit process’ contribution to the final output of packaging material. A public version of the appendices prepared under this project does include a “rolled-up” cradle-to-production table for each packaging material showing resource use per output of packaging material. (Note: The public appendices were prepared concurrently with the peer review and thus were not available to the peer reviewers; however, they contain no information that was not provided to the peer reviewers. The cradle-to-production tables are developed from the individual unit process data sets and material flow diagrams examined by the peer reviewers.)

13. Energy of Material Resources, already discussed above.

Response: See response to Item 6 under **Body of Report** comments.

14. 1- 12: “Critical review is specified in ISO standard 14040 as an optional component for LCA/LCI studies.” However, 14040 goes on to say that “a critical review shall be conducted for LCA studies used to make a comparative assertion that is disclosed to the public…”
    ISO 42 and 43 are for Impact Assessment and Interpretation, not dealing with Inventory.

Response: As suggested earlier, clarification has been made that this study complies with ISO standards for Life Cycle Inventory. While ISO 14040 does not specifically require peer review for LCIs, because this study will be publicly released the sponsor of the study wished to have the study peer reviewed in order to ensure that the study used a valid, ISO-compliant life cycle methodology. Wording has been added for clarification.

15. 1-17: It is acknowledged that this assumption may introduce some error.” Change to “will likely introduce error.”

Response: Changed as suggested.

16. Comparisons of LCA databases have shown that airborne and waterborne pollutant emissions for a particular material production inventory can easily vary by 200%. Energy and solid waste values are generally more agreeable between databases.

Response: Text has been added to the second paragraph of the Environmental Emissions section of Chapter 1. There is also a similar statement in the last paragraph on page 4 of Chapter 4.

17. “Half of the unpadded LLDPE area assumed to be produced overseas and imported to the West Coast” Indicate source for assumption.

Response: Of the two companies selling unpadded plastic shipping bags that provided data for this study, one produced bags domestically and one provided bags produced overseas. Text added to report.

18. Electricity - "Users of electricity, in general, cannot specify the fuels used to produce their share of the electric power grid." This is changing with deregulation and users can purchase green power with a defined fuel mix. I do support the use of the average grid in modeling, given the often lack of data about fuel mixes.

No response required.

19. Emissions from combustion - "Theoretical carbon dioxide ….., however, this may not be an accurate representation of the results of mixed MSW combustion." The carbon balance would expected to be reasonably accurate particularly in comparison to other data inputs.

Response: See response to Item 11 under **Executive Summary** comments.

20. Space conditioning is discussed in the Executive Summary section.

Response: See response to Item 5 under **Executive Summary** comments.

21. Secondary Packaging is discussed in the Executive Summary section. Exclusion can be significant as stated above.

Response: See response to Item 6 under **Executive Summary** comments.

22. 2-6: "fabrication scrap losses can have a significant effect on results." This is certainly true, were they modeled here?

Response: See response to Item 3 under **Major Recommendations** comments.

23. Energy Results - Based on the uncertainty in the energy data, energy differences between systems are not considered significant unless the percent difference is greater than 10 percent. This is based on the judgment of the analysts but was not a calculated criterion. This should be stated as such.

Response: Wording has been added to clarify. Also, Chapter 4 has been added to the report to provide further background on Franklin Associates' criteria for meaningful differences in LCI results, supported by statistical arguments.

24. 2-11: "Natural gas …in the generation of electricity" is repeated.

Response: The discussion in the first paragraph (heading "Energy Profiles") describes all the different ways in which natural gas, petroleum, and coal contribute to energy results.

Subsequent statements refer to how these resources contribute to energy reported for specific packaging systems (e.g., paper-based and plastic).

25. 2-12: Solid Waste - Differences in solid waste results between systems are not considered significant unless the percent difference is greater than 25 percent. This is based on the judgment of the analysts but was not a calculated criterion. This should be stated as such.

Response: See response to Item 23 above.

26. Environmental Emissions - The analysts state clearly the large expected uncertainty associated with emissions results.

No response required.

27. No valid impact assessment methodology exists. TRACI is an impact assessment tool developed by US EPA which seems to contradict this statement.

Response: Many detailed impact assessment methodologies exist, including TRACI. However, there are inherent problems with using the output of LCIs as input for impact modeling. The output of an LCI is an aggregated summary of the total quantity of substances released over the life cycle of a product system. These emissions occur at different geographic locations, over different time periods, at different concentrations, with different human exposures, into different bodies of water, etc., and thus are inherently lacking the specificity necessary for a true evaluation of impacts on human health and the environment. This is not a criticism of any impact assessment methodology, but rather an acknowledgement of the limitations. Wording has been revised to reflect this.

28. 3-3 (revised): Omit the discussion on CO2 being part of the natural carbon cycle and a net contributor to global warming. It really goes beyond the scope of this study, which is an inventory analysis (and this is an impact-related conclusion), but also, it is repeated later on page3-6 (which is more appropriate being in the conclusions section).

Response: The detailed emissions tables (Tables 2-6 and 2-7, Tables 3-6 and 3-7) report fossil and non-fossil CO_2 separately. For consistency with the EPA, natural carbon cycle CO_2 (non-fossil) is not included in greenhouse gas calculations, but fossil CO_2 is included. It is this practitioner's position that greenhouse gas calculations using IPCC global warming potentials are another inventory calculation and do not fall under the category of impact since no projections are made regarding actual global warming effects associated with emissions from packaging systems. The discussion of the shift from wood-derived CO_2 to fossil fuel-derived CO_2 with increased recycled content of paper(board) systems has been removed from the main emissions results section and retained in the conclusions section.

29. 3-6: Insert recycle content between lower and box in the last line of the first paragraph.

Response: Done.

30. 3-26: Chlorine and sulfur emissions were highest for the bag system, what process(es) might be accounting for these differences?

Response: These are associated with virgin bleached kraft production. An explanatory sentence has been added to this paragraph.

APPENDICES

In general the Appendices are well documented. References are clearly identified for each inventory module presented.

Appendix A

1. It would be helpful in Appendix A to provide a section that describes the temporal boundaries for modeling the energy systems. The range in years over which the energy systems and technologies are modeled and then specific information about key systems such as the fuel mix for the US grid.

Response: An initial overview statement has been added to the Appendix A Introduction: This version of Appendix A was last completely updated in 1998 using the most current data sources that were available at that time. Most of the public data sources for fuel use and emissions were 1995-1997 publications. Combustion energy values are 1995 values. Average fuel use for electricity generation is 1996 data. Crude oil production data are 1994 values, while refinery data are 1993 values. Specific sources of data on the production and combustion of each fuel and for electricity generation are clearly referenced in the text and tables, with full source information (including age) provided in the References section at the end of the appendix. Note to reviewers: At the same time that this packaging study was being conducted in 2003, Franklin Associates was updating our fuels and energy database; however, this update was not completed in time to use it for the packaging study.

2. The Scope section could also provide an overview of the data categories inventoried. Each inventory module presents environmental emissions but it is not clear how comprehensive the analysis was. Without a description, the reader can assume three possible cases for specific pollutants not listed: zero emissions, negligible emissions, or not reported due to lack of data.

Response: The level of completeness in emissions reporting is certainly a major area of uncertainty in LCIs, for exactly those reasons identified by the reviewer. Unfortunately, emissions data sources generally do not provide the information necessary to determine completeness of reporting. The practitioner can only work with the information that is available. However, as each unit process is analyzed, the data analyst researches the process and looks for obvious omissions in reporting or suspect data and follows up accordingly. These issues are discussed to some extent in Chapter 1 of the report, in the sections **Environmental Emissions, Methodology for [Process Data] Collection/Verification**, and **Data Accuracy**.

3. A clear definition for the solid waste data category would also be useful. What wastes are included here (e.g., hazardous solid wastes, industrial wastes, mining wastes excluding overburden?, municipal solid waste)

Response: Except for classifying wastes as hazardous, the reporting of process solid wastes may include any or all of these types of waste, depending on what is relevant for each unit process. Each unit process description writeup in the appendices provides a description of the types of solid waste that are associated with that process.

4. A-10: Method for allocating burdens to co-products from petroleum refining should be described.

Response: Allocation approach is described in the last paragraph of the Petroleum Refining section.

5. A-20: W is capitalized in "kwh"; should read kWh

Response: Corrected throughout appendices.

6. Minor correction 3413 should be changed to 3412 Btu/kWh

Response: Conversion factor can vary slightly depending on the source conversion table used. No change made.

7. A-23: Other renewables currently make up 2.1% of the net generation in the US for 2001 http://www.eia.doe.gov/neic/brochure/elecinfocard.html

Response: This appendix was based on 1997 data sources for fuel use for electricity generation, as can be seen from the Appendix A references for electricity.

8. A-23: I recommend changing "unconventional" energy sources to "renewable" energy sources.

Response: Text has been changed to read: Renewable energy sources other than hydroelectricity, such as geothermal energy, solar energy for steam generation, and biomass energy, produced less than one percent of the total electricity generated in the U.S. in 1996.

9. Non-utility generated electricity is currently about 11 percent of the total US electricity generation. Need to change “currently” to the year “199x” these data are applicable. The 2001 non-utility fraction is 30%.

Response: Text has been changed to read: In 1996, non-utility generated electricity was about 11 percent of the total ...

10. Glossary: Biomass definition. I recommend substituting the EIA definition: Biomass (as an energy source): Organic non-fossil material of biological origin constituting a renewable energy source.

Response: EIA definition added to original definition.

11. Glossary: Particulate Matter definition from EPA glossary (http://www.epa.gov/OCEPAterms/pterms.html)

PM-10/PM-2.5: PM 10 is measure of particles in the atmosphere with a diameter of less than ten or equal to a nominal 10 micrometers. PM-2.5 is a measure of smaller particles in the air. PM-10 has been the pollutant particulate level standard against which EPA has been measuring Clean Air Act compliance. On the basis of newer scientific findings, the Agency is considering regulations that will make PM-2.5 the new "standard".

Note: The NAAQS for PM2.5 were established in 1997.

Response: Glossary definition has been revised to include PM 2.5 information. Information is often not available to report LCI particulate emissions by particle size classification.

Appendix B

1. B-12: “While Pactiv would not divulge the exact composition of the bubble material, a representative did state that the nylon represents less than 5% of the material, by weight. Preliminary comparison of the burdens of nylon and polyethylene by Franklin Associates showed that modeling the bubble material as a LDPE/LLDPE/nylon blend would not yield significantly different results than modeling the bubble material without the nylon but would increase study costs.” This statement should be qualified since the material production inventories for LDPE and nylon are quite different. These differences become less significant when the nylon inventory is weighted for a 5% mass fraction.

Response: Text has been revised to clarify the material compositions modeled and to clarify that the statement is based on composition-weighted averages of the LCI burdens for the respective materials.

2. B-14: Couldn’t the product of 17.5 x 12 inches fit in the Stock #6 box? Was extra space provided for protection?

Response: It is assumed that this comment refers to the Stock #6 bag shown on the referenced page B-14. According to the study sponsor, while the length and width of the packaged product were within the #6 bag dimensions, the product height did not allow use of this bag.

3. B-18: Box void volume seems excessive but if that is the industry standard then model is valid. This could be a real opportunity for source reduction.

Response: Void volumes reflect packaging practices of experienced order fulfillment packaging staff and thus represent actual current industry practices. It is agreed that this could be an important opportunity for source reduction.

Appendix C

1. It is not clear whether the inventory modeling considered scrap from the fabrication of packaging. It is expected that scrap rates would be very low and in many cases less than one percent.

Response: See response to Item 3 under **Major Recommendations** comments

2. It would be useful to provide an inventory module that summarizes the cradle to gate environmental burdens for each packaging material. This would facilitate the comparison of results from this study with other material databases such as APME.

Response: See response to Item 12 under **Body of Report** comments.

3. C-37: Pesticides were not included in the inventory. Pesticide use in corn production can lead to significant environmental burdens. For example, atrizine used in corn production is a major contaminate of groundwater and surface water. A statement to this effect would be appropriate.

Response: Added.

Appendix D

1. D 16: This study focuses on the ground delivery of parcels. It is expected that many parcels are shipped by air. It would be interesting to explore the implications for the overall study results of shipping by air rather than ground.

Response: See response to Item 2 under **Major Recommendations** comments.

2. D19: The modeling of the allocation of transportation burdens needs to be more transparent. The source for the results presented in Table D-2 is clear but the next steps in determining the energy and environmental emissions should be described.

Response: Wording has been added to this section indicating that, based on the results in Table D-2, fuel use and emissions for transportation of packaged product were modeled based on the fuel economy for a volume-loaded vehicle rather than a fully weight-loaded vehicle.

Appendix E

1. The end of life system is very complex. This method presented is clear. A more comprehensive model of EOL was developed by RTI and involved Franklin Associates.

No response required.

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Ms. Curran directs the System Analysis Branch's Life Cycle Assessment (LCA) research program which includes the development of LCA methodology, the performance of life-cycle case studies, life-cycle workshops and conferences, and the development of a life cycle data directory website (www.epa.gov/ORD/NRMRL/lcaccess). As an expert in LCA, she provides technical support to several EPA offices in developing policy and regulations including guidelines for the federal procurement of environmentally-preferable products.

Ms. Curran also provides technical review and assistance to outside groups on clean product design and development. She has participated in the technical peer review of industry-sponsored life-cycle studies, including electricity, diapers, cleaners, plastics, coal ash, and building products. She represents the Agency in two international activities for establishing LCA-based guidance: the International Standards Organisation (ISO) LCA subcommittee and the Canadian Standards Association (CSA) life-cycle design committee. Ms. Curran works closely with the Society of Environmental Toxicology and Chemistry (SETAC), which has been instrumental in advancing LCA awareness, and serving on the advisory committee for the development of a North American database. She also serves on the editorial boards of the *International Journal of Life Cycle Assessment* and *Environmental Progress,* as well as on the Executive Committee for the American Center for Life Cycle Assessment.

Since 1990, Ms. Curran has authored and co-authored numerous papers which address LCA concepts and applications. She has presented EPA's activities in LCA-related research at technical meetings across the U.S. and in Europe. She co-authored and edited a book entitled "Environmental Life Cycle Assessment" which was published by McGraw-Hill in July 1996.

Ms. Curran has been with the EPA's Office of Research and Development since 1980. She holds a Masters degree in Environmental Management and Policy from the International Institute for Industrial Environmental Economics (IIIEE) at Lund University, Lund, Sweden (1996) and a Bachelor of Science degree in Chemical Engineering, from the University of Cincinnati, Cincinnati, Ohio (1980).

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Dr. Cooper has been a key researcher in Life Cycle Assessment as well as a faculty member of the University of Washington. She has developed LCA curriculum for University level courses. Curriculum development focuses on the use of LCA in an interdisciplinary Design for the Environment course for seniors and graduate students. She has also been a key participant in the establishment of ACLCA (American Center for Life Cycle Assessment).

Dr. Cooper's LCA experience includes methodological advances focusing on specification of functional units and reference flows for comparable alternatives, integration of LCA into the product design process, and process and materials selection.

Her case study experience has focused on emerging technologies such as advanced aircraft and automotive materials and fuel cells.

In addition, Dr. Cooper has achieved excellent teaching effectiveness ratings including courses in sustainability and design for the environment.

Her publications include 12 refereed archival journal publications, 8 refereed conference papers and articles, and 8 project reports, most of which are LCAs. In addition, she is an advocate of the use of LCA in design and of a structured LCA peer review process.

Prior to joining the University of Washington faculty she worked in the private sector for Battelle Memorial Institute, Research Triangle Institute, University of Tennessee Center for Clean Products, Polaroid Corporation, and E-Systems.

Dr. Cooper holds a BS in Mechanical Engineering from Rensselaer Polytechnic Institute (1987), an MS in Environmental Engineering from Duke University (1991), and a PhD in Environmental Engineering from Duke University (1996).

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Dr. Keoleian as Co-Director of the Center for Sustainable Systems is directly involved in the primary mission of the Center which is to organize and lead interdisciplinary research and education on the application of life cycle based models and sustainability metrics.

He has been involved in teaching and research at the University of Michigan for over 20 years, and has an impressive list of accomplishments in Life Cycle Inventory (LCI)/Life Cycle Assessment (LCA) and related fields. He has been principal investigator on 29 funded research projects totaling over $3 million since 1989. Nine of these projects involved LCI/LCA projects, and the balance are in related areas such as design for the environment, pollution prevention, and industrial ecology. In addition, Dr. Keoleian has authored or co-authored more than 100 articles and papers for professional journals, peer reviewed technical reports, technical papers, plus presentations at conferences and workshops. Finally, he has authored or co-authored books or chapters in books on the subject of Life Cycle Assessment, industrial ecology, and pollution prevention. In short, he has been a leader in the fields of LCA, pollution prevention, and industrial technology.

Dr. Keoleian has also been a peer reviewer for a number of LCI/LCA reports.

Dr. Keoleian has BS degrees in Chemical Engineering and Chemistry (1980), a MS degree in chemical engineering (1982), and a PhD in Chemical Engineering (1987) all from the University of Michigan.

FINAL PEER-REVIEWED APPENDIX TO
LIFE CYCLE INVENTORY
OF PACKAGING OPTIONS FOR SHIPMENT
OF RETAIL MAIL-ORDER SOFT GOODS

Prepared for

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY (DEQ)
And
U.S. EPA ENVIRONMENTALLY PREFERABLE PURCHASING PROGRAM

By

FRANKLIN ASSOCIATES, A DIVISION OF ERG
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April 2004

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APPENDIX A

ENERGY REQUIREMENTS AND ENVIRONMENTAL EMISSIONS FOR FUEL CONSUMPTION

INTRODUCTION

This appendix provides detailed information about energy requirements and environmental emissions associated with production and use of various types of fuels and energy sources. Specifically, this appendix describes production of fuels and generation of electrical power, and is presented in terms of precombustion and combustion components. Precombustion components include the resources consumed, energy used, and environmental emissions as a result of mining, refining, and transporting fuels, and includes all steps up to, but not including, their end use, or consumption. The combustion components are the energy and the environmental releases due to combustion of fuels for heat, process energy, and electricity generation. In addition, fuels used to generate electricity in the U.S. are evaluated in this appendix, and a standard method for relating electricity consumption to actual fuel usage is developed.

This version of Appendix A was last completely updated in 1998 using the most current data sources that were available at that time. Most of the public data sources for fuel use and emissions were 1995-1997 publications. Combustion energy values are 1995 values. Average fuel use for electricity generation is 1996 data. Crude oil production data are 1994 values, while refinery data are 1993 values. Specific sources of data on the production and combustion of each fuel and for electricity generation are clearly referenced in the text and tables, with full source information (including age) provided in the References section at the end of the appendix.

The energy and environmental emissions data developed here can be used in the evaluation of products or processes using a life cycle approach. For example, if it is known that a particular manufacturing process requires the use of a certain amount of electricity, the data presented in this appendix can be used to allocate the fuel usage and the environmental emissions for generating this amount of electricity. In addition, the data in this appendix can be used to calculate the fuel usage and environmental emissions for producing the fuels used to generate this electricity. In this way, the total amount of fuel consumed as well as all of the environmental emissions that result from electricity being used in a particular manufacturing process can be accounted for. Fuel usage by other processes in the manufacture of a product under investigation can be evaluated in a similar manner using the data developed in this appendix.

While determination of the energy and environmental emissions is logically straightforward, it is complicated by the iterative nature of some of the calculations. For this reason, a roadmap is included for the discussion that follows.

The two main topics in this appendix are a) primary fuel production, and b) primary fuel combustion.

Primary Fuel Production

Primary fuels are the fuels used to produce electricity, to generate heat and power, and to provide energy for transportation of materials and fuels. They include coal, natural gas, residual and distillate fuel oil, and uranium.

The objective is to know both: a) the energy (in terms of electricity and primary fuels) required to deliver these fuels to a customer; and b) the environmental emissions resulting from the delivery of these fuels to a customer. (Use of these fuels by a customer is discussed in the section on primary fuel combustion.)

The energy requirements and environmental emissions, starting from the extraction of raw materials from the earth, and ending with the delivery of the processed and refined primary fuels to the customer, are known as **precombustion energy** and **precombustion emissions**. The energy and emissions due to the combustion of these primary fuels by the customer, to produce electricity, to generate heat and power for industrial processes, or to provide energy for transportation are called **combustion energy** and **combustion emissions**.

The energy requirements for the production and processing of primary fuels can be found from industry sources, government surveys, or in the published and unpublished literature. They typically are given in terms of electricity, coal, natural gas, and fuel oil (residual and distillate).

The environmental emissions can be divided into two sources:

a) the emissions due to the combustion of fuels used in the production of primary fuels. This includes emissions from such sources as motor vehicles used in the transportation steps, or natural gas compressor engines used to move natural gas through pipelines. These emissions are called **fuel-related precombustion emissions**.

b) the process-related emissions *not* due to the combustion of fuel, which include such sources as fugitive dust, natural gas vented at the wellhead, waste rock from coal cleaning, etc. These emissions are called **precombustion process emissions**.

Transportation occurs at several stages along the path to delivering primary fuels for consumption, and must be included in the precombustion components. Coal, for example, is moved from the mine to the utility plant primarily by railroad and barge; oil is transported from the well to the refinery to the customer primarily by pipeline; uranium is transported from the mine to the mill to the enrichment facility to the power plant primarily by truck; and so on.

Data needed are, therefore: a) the fuels used by various modes of transportation (assuming that the modes and distances involved are known), and b) the fuel-related emissions put out by the transportation steps involved in the stages along the path of delivering primary fuels for consumption.

The fuels used in transportation of fuels for consumption are included in the **precombustion (process) energy** requirements. The fuel-related transportation emissions are included in the **precombustion fuel-related emissions** reported in this appendix.

The production of primary fuels requires electricity and fuels, which in turn require electricity and fuels for their production. Similarly, the fuels used to produce the fuels used to produce the primary fuels also require electricity and fuels for their production. Theoretically, an infinite set of iterations is necessary to account for the electricity and fuels required to deliver the primary fuels for use by a customer.

To account accurately for the fuels used in production and processing of primary fuels, the fuel mix for electricity production in the U.S. must be known, that is, how much coal, natural gas, fuel oil, and uranium are needed to produce one kilowatt-hour of electricity. This is called the composite kilowatt-hour. Knowing the composite kilowatt-hour, the fuels used to generate electricity used in the production of primary fuels can be determined. Then, the total amount of fuels needed to produce the primary fuels can be calculated by an iterative process.

Emissions to the environment occur whenever fuel is combusted. These **fuel-related precombustion emissions** occur during the production of primary fuels and are determined only after the total fuel requirements for the production of primary fuels have been determined.

Primary Fuel Combustion

The energy and emissions released when fuels are burned are only one part of the energy and emissions associated with the use of a fuel. This part is known as the **combustion components** (i.e., the **combustion energy** and the **combustion emissions**). There are many steps in the production and processing of a fuel before it is usable, and the energy and emissions resulting from these production steps are known as the **precombustion components** (i.e., **precombustion energy** and **precombustion (fuel-related** and **process) emissions)**.

When accounting for the energy and emissions released when fuels are burned, the precombustion components must be added to the combustion components, in order to account for the full environmental burdens associated with the use of the fuels.

The list of emissions reported and level of speciation (e.g., in categories such as acid and metal ion) reported in these appendix tables is limited by the published data sources that are available and may vary for different fuels and combustion source. Combustion emissions for a given primary fuel will vary according to how it is combusted; for example, coal burned in utility boilers will have different emission factors from coal burned in industrial boilers. Different types of boilers and engines vary in completeness of combustion, resulting in different emissions of carbon dioxide, carbon monoxide, and methane for the same type of fuel. The types and efficiencies of emission control systems used with various combustion sources also vary, affecting the quantities of controlled emissions that are reported in these tables. Major types of combustion sources for the primary fuels, both stationary and mobile, are included in this appendix.

To summarize, the topics included in this appendix are:

- Primary fuel production (precombustion process energy requirements and precombustion process emissions data)
    - Coal
    - Natural gas
    - Petroleum fuels
    - Nuclear fuel
- Energy for transportation
- Fuels consumed for electricity generation
    - Calculation of the composite kilowatt-hour
- Precombustion energy and precombustion process and fuel-related emissions
    - Coal
    - Natural gas
    - Petroleum fuels
    - Nuclear fuel
- Primary fuel combustion

  Energy content of fuels

  Environmental emissions (precombustion and combustion)
    - Coal
        - Utility boilers
        - Industrial boilers
    - Residual fuel oil
        - Utility boilers
        - Industrial boilers
    - Distillate fuel oil - Industrial boilers
    - Natural gas
        - Utility boilers
        - Industrial boilers
        - Industrial equipment
    - Diesel fuel - Industrial equipment
    - Gasoline - Industrial equipment
    - Liquefied petroleum gases (LPG) - Industrial equipment
    - Uranium
    - Wood wastes
    - Mobile sources
        - Truck
        - Locomotive
        - Barges and ocean freighters

Data Quality Indicators

Life Cycle Inventories (LCIs) are an attempt to determine all of the inputs (in terms of energy and natural resource use) and all of the outputs (in terms of products, co-products, and environmental emissions to the air, water, and soil) over the entire life of a product or service. Thousands of data points are needed in a typical LCI, including values for the extraction of raw materials, the manufacturing of intermediate materials, the fabrication of the product, the use/reuse/maintenance of the product, and the ultimate disposal or recycling of the product.

In the best of possible worlds, we could use classical statistics to determine the uncertainties in Life Cycle Inventories. Classical statistics, however, requires that the data conform to several restrictive assumptions such as independence, randomness, and representativeness.

In LCIs, as in many areas of complex assessments, data often do not meet the stringent requirements of classical statistics. There may be no option to control the representativeness of samples, the number of data points, or the randomness of the data collected. In that case, expert judgment becomes important. Recent research has shown that expert judgment can be translated into quantifiable statements about data quality and uncertainty with high reproducibility. While this introduces some subjectivity into the uncertainty analysis, it is presently the best available methodology. It brings to LCI assessments valuable information that has historically been missing. It has the potential of greatly increasing the credibility of comparative LCI results, and making the database in a research project as sound as possible.

Franklin Associates has developed methodologies to deal with the issues of uncertainty and data quality in Life Cycle Analysis. In traditional LCIs, single point estimates of input variables (such as fuel requirements) are used to determine single point estimates for the output variables (such as total energy used or solid waste generated). These point estimates contain no information about the uncertainty of the data; therefore they give a false sense of precision.

The Franklin Associates methodology involves the assignment of data quality indicators (DQIs) to the variables used as inputs to our computer models. This allows the determination of a distribution of input values, rather than a single point estimate. This distribution more accurately reflects the level of confidence in the values. The deterministic model is therefore changed into a stochastic model. This means that the output of the model is also a distribution of values, rather than a single point estimate. It is then easier to judge, for example, whether two values for total solid waste are the same or different. This approach requires considerable additional modeling time and expense, however, and is outside the scope of this project. Data quality indicators are reported here for informational purposes only.

A DQI of A is given to data that is of the highest quality possible. It may represent recent industrial data collected by experts, based on verified measurements, on a comprehensive sample of the specific process or product under study.

A DQI of B would be assigned to data of very good quality. A DQI of B is based on verified data, partly based on assumptions, or non-verified data based on measurements. It would be data based on a representative, but smaller, sample of specific processes or products under study.

A DQI of C is assigned to data that is of average quality. It may be based on non-verified data based partly on assumptions, and may be from a representative sample of similar processes of products under study.

A DQI of D is given to data of fair quality. This may be a qualified estimate by an industry representative, and be representative of a small number of processes or products related to those under study.

A DQI of E is assigned to data of poor quality. This would be a non-qualified estimate from a sample that is incomplete or whose representativeness is unknown. It would be based on old data and only on related processes or products.

PRIMARY FUEL PRODUCTION

Precombustion Energy and Process Emissions

The fuel production section of this appendix describes the precombustion process and transportation energy requirements and the precombustion process emissions for the production and processing (extraction, beneficiation, refining, and transportation) of the various primary fuels. These fuels are used to generate electricity, to provide direct process energy, or to provide energy for transportation. These precombustion process energy requirements include the use of electricity and primary fuels to provide heat and/or power for industrial processes.

Precombustion process emissions include all environmental emissions that are released as a direct result of activities associated with producing the primary fuels. The process emissions listed in this fuel production section do not, however, include emissions from the combustion of fuels used to produce process energy. These fuel-related process emissions are calculated and presented in a different section of this appendix. The energy values presented in Tables A-1 through A-4 are the basis for these fuel-related precombustion emissions calculations.

Coal

Coal is used as a fuel for electric power generation and industrial heating and steam generation. Energy is required and environmental consequences are incurred in acquiring coal for fuel. Table A-1 presents the energy requirements and the process-related environmental emissions involved in mining and preparing coal for fuel consumption.

Coal Mining. Coal may be obtained by surface mining of outcrops or seams that are near the earth's surface or by underground mining of deeper deposits. In surface mining, also called strip mining, the overburden (soil and rock covering the ore) is removed from shallow seams, the deposit is broken up, and the coal is loaded for transport. The overburden is generally returned to the mine (eventually) and is not considered as a solid waste in this appendix. Underground mining is done primarily by one of two methods—room-and-pillar mining or longwall mining. Underground mining is a complex undertaking, and is much more labor and energy intensive than surface mining. The data in Table A-1 are based on the portion of coal mined by surface and underground methods in the U.S. in 1994.

Coal Production. After the coal is mined, it goes through various preparation processes before it is used as fuel. These processes vary depending on the quality of the coal and the use for which it is intended. Coal preparation usually involves some type of size reduction, such as crushing and screening, and the removal of extraneous material introduced during mining. In addition, coal is often cleaned to upgrade the quality and heating value of the coal by removing or reducing the sulfur, clay, rock, and other ash-producing materials (Reference A-18).

The coal industry depends heavily on the transportation network for delivering coal to domestic customers. The flow of coal is carried by railroads, barges, ships, trucks, conveyors, and a slurry pipeline. Coal deliveries are usually handled by a combination of transportation modes before finally reaching the consumer.

Natural Gas

Natural gas is a widely used energy resource, since it is a relatively clean, efficient, and versatile fuel. The major component of natural gas is methane (CH_4). Other components of natural gas include ethane, propane, butane, and other heavier hydrocarbons, as well as water vapor, carbon dioxide, nitrogen and hydrogen sulfides. Table A-2 contains the combined energy requirements and environmental emissions for producing, processing, and transporting natural gas used as a fuel. The data are based on the portion of natural gas extracted on-shore and off-shore in 1994.

Natural Gas Production. Natural gas is extracted from deep underground wells and is frequently co-produced with crude oil. Because of its gaseous nature, natural gas flows quite freely from wells, which produce primarily natural gas, but some energy is required to pump natural gas and crude oil mixtures to the surface.

Atmospheric emissions from natural gas production result primarily from unflared venting. The waterborne wastes result from brines that occur when natural gas is produced in combination with oil.

Natural Gas Processing. Once the raw natural gas is extracted, it is processed to yield a marketable product. First, the heavier hydrocarbons such as ethane, butane and propane are removed and marketed as liquefied petroleum gas (LPG). Then the water vapor, carbon dioxide, and nitrogen are removed to increase the quality and heating value of the natural gas. If the natural gas has a high hydrogen sulfide content, it is considered "sour."

Before it is used, hydrogen sulfide is removed by adsorption in an amine solution—a process known as "sweetening."

Atmospheric emissions result from gas sweetening plants if the acid waste gas is flared or incinerated.

Table A-1

DATA FOR MINING AND PROCESSING 1,000 POUNDS OF COAL

Energy Usage			**DQI**
Process Energy			
Electricity	9.6	kwh	B
Natural Gas	0.79	cubic feet	B
Residual Oil	0.028	gal	C
Distillate Oil	0.30	gal	C
Gasoline	0.024	gal	C
Coal	0.48	lb	B
Transportation Energy			
Combination Truck	2.0	ton-miles	C
Diesel	0.020	gal	C
Rail	200	ton-miles	C
Diesel	0.56	gal	C
Barge	20	ton-miles	D
Diesel	0.040	gal	D
Residual Oil	0.016	gal	D
Pipeline-coal slurry	1.4	ton-miles	C
Electricity	0.32	kwh	C
Process Atmospheric Emissions			
Particulates	2.5	lb	D
Methane	4.7	lb	B
Process Waterborne Emissions			
Suspended Solids	1.4	lb	E
Manganese	0.078	lb	E
Iron	0.12	lb	E
Process Solid Wastes	342	lbs	C

References: A-2, A-6, A-9, A-19, A-21, A-22, A-23, A-40, A-41, and A-54 through A-57

Source: Franklin Associates, Ltd.

Table A-2

DATA FOR THE PRODUCTION AND PROCESSING OF 1,000 CUBIC FEET OF NATURAL GAS

Energy Usage			**DQI**
Process Energy			
Electricity	0.82	kwh	B
Natural Gas	51.0	cubic feet	B
Residual Oil	0.013	gallons	B
Distillate Oil	0.011	gallons	B
Gasoline	0.046	gallons	B
Transportation Energy			
Natural Gas Pipeline	17.3	ton-miles	C
Natural Gas	39.9	cu ft	C
Combination Truck	0.64	ton-miles	C
Diesel	0.0064	gallons	C
Rail	1.93	ton-miles	C
Diesel	0.0054	gallons	C
Barge	0.64	ton-miles	C
Diesel	0.0013	gallons	C
Residual Oil	5.2E-04	gallons	C
Process Atmospheric Emissions			
Methane	0.35	lb	B
Hydrocarbons (other than methane)	0.46	lb	B
Sulfur Oxides	1.80	lb	B
Process Waterborne Emissions			
Dissolved Solids	2.8	lb	D
Suspended Solids	0.0014	lb	D
BOD	0.0025	lb	D
COD	0.016	lb	D
Oil/grease	0.05	lb	E
Chromium	1.3E-04	lb	E
Zinc	4.40E-05	lb	E
Chlorides	0.13	lb	E
Sulfates	0.10	lb	E
Cyanide	1.9E-07	lb	E
Mercury	1.0E-08	lb	E
Cadmium	1.3E-04	lb	E
Other Organics	0.0081	lb	E
Process Solid Waste	5.1	lb	C

References: A-2, A-6, A-9, A-20, A-21, A-24 through A-30, A-51, A-52, A-54, and A-57.

Source: Franklin Associates, Ltd.

Natural gas is transported primarily by pipeline. Sometimes it is compressed and transported by insulated railcars and tankers.

Petroleum Fuels

Petroleum Production. Oil is produced by drilling into porous rock structures located several thousand feet underground. Once an oil deposit is located, numerous holes are drilled and lined with steel casing. Some oil is brought to the surface by natural pressure in the rock structure, but most oil requires some energy to drive pumps that lift oil to the surface. Once oil is on the surface, it is stored in tanks to await transportation to a refinery. In some cases, it is immediately transferred to a pipeline, which transports the oil to a larger terminal.

The American Petroleum Institute identifies three categories of oil extraction wastes: produced water, drilling waste, and associated waste.

The water that is extracted with crude oil is called the “oil field brine”. The brine goes through a separator at or near the wellhead in order to remove the oil from the water. According to the American Petroleum Institute (API), it is estimated that 17.9 billion barrels of brine water were produced from crude oil production in 1995. This quantity of water equates to a ratio of 3.3 barrels of water for each barrel of oil. The majority of this water (85 percent) is injected into separate wells specifically designed to accept production-related waters. This represents all waters produced by onshore oil production facilities, which are not permitted to discharge “oil field brine” to surface waters (Reference A-29). The remainder of the produced water is from offshore oil production facilities and is assumed to be discharged to the ocean. Therefore, the waterborne wastes represent the brine wastes present in this 15 percent of brine water (Reference A-50). Because crude oil is frequently produced along with natural gas, a portion of the waterborne waste is allocated to natural gas production (Reference A-20).

The second type of oil extraction waste is drilling waste. Drilling waste includes the rock cuttings and fluids produced from drilling a wellbore. Drilling mud, a viscous fluid, is a particular kind of drilling fluid that is commonly used for drilling wellbores.

The third source of waste is associated waste, which is a broad category of small volume wastes. Associated wastes include atmospheric emissions, which are primarily hydrocarbons. These atmospheric emissions originate from the natural gas produced from combination wells and result in line losses and unflared venting.

Petroleum Refining. A petroleum refinery processes crude oil into thousands of products using physical and/or chemical processing technology. Gasoline is the primary output from refineries; however, other major products include kerosene, aviation fuel, diesel fuel, fuel oils, lubricating oil, and feedstocks for the petrochemical industry.

A petroleum refinery receives crude oil, which is comprised of mixtures of many hydrocarbon compounds and uses distillation processes to separate out pure product streams. Because the crude oil is contaminated (to variable degrees) with compounds of sulfur, nitrogen, oxygen, and metals, cleaning operations are common in all refineries. Also, the natural hydrocarbon components that comprise the crude oil are often chemically changed to give products for which there is higher demand. These processes, such as polymerization, alkylation, reforming, and visbreaking, are utilized to convert light or heavy crude oil fractions into intermediate weight products, which are more easily handled and utilized as fuels and/or feedstocks (Reference A-8).

Air pollution is caused by various petroleum refining processes, including: vacuum distillation, catalytic cracking, thermal cracking processes, and sulfur recovery. Fugitive emissions are also significant contributors to air emissions. These may be leaks from valves, seals, flanges, and drains, as well as leaks escaping from storage tanks or during transfer operations. The wastewater treatment plant for a refinery is also a source of fugitive emissions (Reference A-6).

The energy and emissions data for crude oil exploration and drilling are combined with refinery operations to present total precombustion energy for refined products in Tables A-3a through A-3d. The same refinery data are used for each petroleum fuel and allocation of energy emissions to the different refinery products is done on a mass basis. Differences in these values for different refinery products shown in Tables A-3a through A-3d are the result of converting from pounds of product to gallons using the specific gravity for each type of product.

Nuclear Fuel

As with other fuels used for the generation of electricity, uranium ore must undergo a series of processing and refining steps before being used in utility plants. These steps include mining, milling, conversion, enrichment, and fuel fabrication. The following sections describe the operations required to process fuel grade uranium for use by the U.S. nuclear power industry, as well as describing the power generation process itself.

Mining. Uranium ore can be extracted from the earth by either open-pit or underground mining; these methods are referred to as “conventional” mining. In addition, significant amounts of concentrated uranium ore can be produced by “nonconventional” methods such as solution mining (in-situ leaching), and recovery as a byproduct of phosphate, copper, and beryllium production. Since 1993, no conventional mining of uranium ore has occurred in the United States; all of the domestic uranium concentrate has come from nonconventional methods.

Milling. Uranium ore is processed in mills where uranium oxide (U_3O_8, also known as yellowcake) is extracted from the ore by a series of crushing, grinding, and concentration operations. Uranium mills are located near uranium mines due to the large quantities of ore that must be milled to produce concentrated uranium oxide. The most significant waste stream from the milling operations is called “tailings.” Tailings are liquid sludge from the concentration operations. The solids portion of the tailings is separated from the liquid and usually returned to the earth. Unlike overburden from mining operations, tailing solids are reported as in Table A-4 as solid wastes because they result from ore processing operations.

Table A-3a

DATA FOR THE PRODUCTION AND PROCESSING OF 1,000 GALLONS OF RESIDUAL FUEL OIL

Energy Usage			**DQI**
Process Energy			
Electricity	199	kwh	B
Natural Gas	8,969	cu ft	B
Residual Oil	11.5	gal	B
Distillate Oil	1.67	gal	B
Gasoline	0.74	gal	B
LPG	1.33	gal	B
Transportation Energy			
Combination Truck	79.2	ton-miles	C
Diesel	0.79	gal	C
Ocean Freighter	16,065	ton-miles	C
Diesel	1.61	gal	C
Residual Oil	28.9	gal	C
Petroleum Pipeline	1,125	ton-miles	C
Electricity	24.8	kwh	C
Process Atmospheric Emissions			
Particulates	0.47	lb	B
Hydrocarbons (other than methane)	48.1	lb	B
Sulfur Oxides	1.58	lb	B
Aldehydes	0.32	lb	D
Ammonia	0.041	lb	D
Lead	1.1E-05	lb	C
Chlorine	0.0016	lb	D
Hydrochloric Acid	0.0012	lb	D
Process Waterborne Emissions			
Acid	9.0E-06	lb	E
Metal Ion	0.19	lb	E
Dissolved Solids	7.38	lb	D
Suspended Solids	0.10	lb	D
BOD	0.11	lb	D
COD	0.52	lb	D
Phenol	6.2E-04	lb	E
Oil	0.35	lb	E
Iron	0.0033	lb	E
Ammonia	0.014	lb	E
Chromium	3.6E-05	lb	E
Lead	1.6E-05	lb	E
Zinc	2.3E-04	lb	E
Process Solid Waste	31.2	lb	C

References: A-6, A-8, A-11, A-20, A-25 through A-28, A-32 through A-36, A-38, A-42 through A-48, and A-53.

Source: Franklin Associates, Ltd.

Table A-3b

DATA FOR THE PRODUCTION AND PROCESSING OF 1,000 GALLONS OF DISTILLATE OIL

Energy Usage			**DQI**
Process Energy			
Electricity	183	kwh	B
Natural Gas	8,235	cu ft	B
Residual Oil	10.6	gal	B
Distillate Oil	1.53	gal	B
Gasoline	0.68	gal	B
LPG	1.23	gal	B
Transportation Energy			
Combination Truck	72.7	ton-miles	C
Diesel	0.72	gal	C
Ocean Freighter	14,750	ton-miles	C
Diesel	1.48	gal	C
Residual Oil	26.6	gal	C
Petroleum Pipeline	1,033	ton-miles	C
Electricity	22.7	kwh	C
Process Atmospheric Emissions			
Particulates	0.43	lb	B
Hydrocarbons (other than methane)	44.2	lb	B
Sulfur Oxides	1.45	lb	B
Aldehydes	0.29	lb	D
Ammonia	0.038	lb	D
Lead	1.0E-05	lb	C
Chlorine	0.0015	lb	D
Hydrochloric Acid	0.0011	lb	D
Process Waterborne Emissions			
Acid	8.2E-06	lb	E
Metal Ion	0.17	lb	E
Dissolved Solids	6.78	lb	D
Suspended Solids	0.092	lb	D
BOD	0.10	lb	D
COD	0.48	lb	D
Phenol	5.7E-04	lb	E
Oil	0.32	lb	E
Iron	0.0030	lb	E
Ammonia	0.013	lb	E
Chromium	3.3E-05	lb	E
Lead	1.5E-05	lb	E
Zinc	2.1E-04	lb	E
Process Solid Waste	28.7	lb	C

References: A-6, A-8, A-11, A-20, A-25 through A-28, A-32 through A-36, A-38, A-42 through A-48, and A-53.

Source: Franklin Associates, Ltd.

Table A-3c

DATA FOR THE PRODUCTION AND PROCESSING OF 1,000 GALLONS OF GASOLINE

Energy Usage			**DQI**
Process Energy			
Electricity	156	kwh	B
Natural Gas	7,017	cu ft	B
Residual Oil	9.00	gal	B
Distillate Oil	1.30	gal	B
Gasoline	0.58	gal	B
LPG	1.04	gal	B
Transportation Energy			
Combination Truck	62.0	ton-miles	C
Diesel	0.61	gal	C
Ocean Freighter	12,569	ton-miles	C
Diesel	1.26	gal	C
Residual Oil	22.6	gal	C
Petroleum Pipeline	880	ton-miles	C
Electricity	19.4	kwh	C
Process Atmospheric Emissions			
Particulates	0.37	lb	B
Hydrocarbons (other than methane)	37.7	lb	B
Sulfur Oxides	1.23	lb	B
Aldehydes	0.25	lb	D
Ammonia	0.032	lb	D
Lead	8.9E-06	lb	C
Chlorine	0.0013	lb	D
Hydrochloric Acid	9.5E-04	lb	D
Process Waterborne Emissions			
Acid	7.0E-06	lb	E
Metal Ion	0.15	lb	E
Dissolved Solids	5.78	lb	D
Suspended Solids	0.079	lb	D
BOD	0.086	lb	D
COD	0.41	lb	D
Phenol	4.8E-04	lb	E
Oil	0.27	lb	E
Iron	0.0026	lb	E
Ammonia	0.011	lb	E
Chromium	2.8E-05	lb	E
Lead	1.2E-05	lb	E
Zinc	1.8E-04	lb	E
Process Solid Waste	24.4	lb	C

References: A-6, A-8, A-11, A-20, A-25 through A-28, A-32 thourgh A-36, A-38, A-42 through A-48, and A-53.

Source: Franklin Associates, Ltd.

Table A-3d

DATA FOR THE PRODUCTION AND PROCESSING OF 1,000 GALLONS OF LIQUEFIED PETROLEUM GAS (LPG)

			DQI
Energy Usage			
Process Energy			
Electricity	114	kwh	B
Natural Gas	5,148	cu ft	B
Residual Oil	6.60	gal	B
Distillate Oil	0.95	gal	B
Gasoline	0.43	gal	B
LPG	0.77	gal	B
Transportation Energy			
Combination Truck	45.5	ton-miles	C
Diesel	0.45	gal	C
Ocean Freighter	9,221	ton-miles	C
Diesel	0.92	gal	C
Residual Oil	16.6	gal	C
Petroleum Pipeline	646	ton-miles	C
Electricity	14.2	kwh	C
Process Atmospheric Emissions			
Particulates	0.27	lb	B
Hydrocarbons (other than methane)	27.6	lb	B
Sulfur Oxides	0.90	lb	B
Aldehydes	0.18	lb	D
Ammonia	0.024	lb	D
Lead	6.5E-06	lb	D
Chlorine	9.3E-04	lb	D
Hydrochloric Acid	7.0E-04	lb	D
Process Waterborne Emissions			
Acid	5.2E-06	lb	E
Metal Ion	0.11	lb	E
Dissolved Solids	4.24	lb	D
Suspended Solids	0.058	lb	D
BOD	0.063	lb	D
COD	0.30	lb	D
Phenol	3.5E-04	lb	E
Oil	0.20	lb	E
Iron	0.0019	lb	E
Ammonia	0.0083	lb	E
Chromium	2.0E-05	lb	E
Lead	9.1E-06	lb	E
Zinc	1.3E-04	lb	E
Process Solid Waste	17.9	lb	C

References: A-6, A-8, A-11, A-20, A-25 through A-28, A-32 through A-36, A-38, A-42 through A-48, and A-53.

Source: Franklin Associates, Ltd.

Table A-4

**DATA FOR THE PRODUCTION OF
1,000 POUNDS OF FUEL GRADE URANIUM**

Energy Usage			**DQI**
Process Energy			
Electricity	4,290,000	kwh	B
Natural Gas	1,900,000	cu ft	B
Residual Oil	561	gal	B
Transportation Energy			
Combination Truck	3,440	ton-miles	D
Diesel	34.13	gal	D
Process Atmospheric Emissions			
Particulates	36,500	lb	B
Nitrogen Oxides	33,300	lb	B
Hydrocarbons (other than methane)	957	lb	B
Sulfur Oxides	120,000	lb	B
Carbon Monoxide	960	lb	B
Carbon Dioxide	11,900	lb	B
Kerosene	221	lb	C
Process Waterborne Emissions			
Chloride	950	lb	E
Sodium	350	lb	E
Calcium	190	lb	E
Iron	4,100	lb	E
Sulfates	110,000	lb	E
Ammonia	330	lb	E
Manganese	201	lb	E
Fluorides	880	lb	E
Nitrates	83	lb	E
Process Solid Waste	5,600,000	lb	C

References: A-11 through A-19, and A-31.

Source: Franklin Associates, Ltd.

Since 1993, all conventional uranium mills in the United States are either inactive, are being decommissioned, or are permanently closed. Only nonconventional uranium plants (in-situ leaching or phosphate byproduct) were producing uranium concentrate in 1995.

Conversion. Subsequent to milling, the uranium oxide is combined with fluorine gas to form uranium hexafluoride gas (UF_6). In this form, the uranium is ready for enrichment to fuel grade uranium.

Enrichment. Gaseous diffusion and gas centrifuge are the two most common methods used to commercially produce enriched uranium. These enrichment processes increase the fissionable portion of the fuel (^{235}U) from its natural abundance of 0.7 percent to a fuel-grade abundance of around 3 percent. Gaseous diffusion is currently used in the United States, while in Europe the gas centrifuge is the commercially used enrichment process.

In the gaseous diffusion process, gaseous UF_6 is passed through a series of porous membrane filters. In the filtering process, UF_6 molecules containing the ^{235}U isotope diffuse through the filters more readily than the molecules containing the larger ^{238}U isotope. A typical gaseous diffusion enrichment process requires more than 1,200 stages to produce uranium enriched to 3 percent. Enrichment is necessary for uranium used as fuel in light-water nuclear reactors, because the amount of fissile ^{235}U in natural uranium is too low to sustain a nuclear chain reaction.

Fuel Fabrication. Enriched UF_6 is next taken to a fuel fabrication plant, where it is converted to uranium dioxide (UO_2) powder. The powder is then compressed into small cylindrical pellets, which are loaded and sealed into hollow rods made of a zirconium-stainless steel alloy. These fuel rods are then shipped to nuclear power plants for use as nuclear reactor fuel.

The energy and emissions for mining and processing uranium to form fuel rods are shown in Table A-4. Almost all of the energy used and environmental emissions released are due to the enrichment step.

Energy for Transportation

Transportation, an important step, occurs often in the production of the primary fuels. The energy requirements associated with the transportation of products are shown in Table A-5. Transportation modes included are: truck, rail, barge, ocean transport, and pipeline. Energy requirements are reported as the quantity of fuel or electricity required per 1,000 ton-miles. Statistical data were used for rail, barge, and pipeline transportation energy (Reference A-4). The energy usage for combination trucks (tractor trailers) weighing greater than 14,000 pounds is calculated based upon the following data:

1. Average miles per gallon for tractor-trailers = 5.9 miles per gallon. These gallons are distributed based on the following fuel usage split: 19.4 percent gasoline tractor-trailers and 80.6 percent diesel tractor-trailers (Reference A-4).

2. A fully loaded tractor-trailer carries a maximum of 45,000 pounds (Reference A-35). It is more common for a load to be volume limited than weight limited.

3. Accounting for empty backhauling and trucks that are not fully loaded increases fuel usage by approximately 25 percent (Reference A-35).

Table A-5

1993 TRANSPORTATION FUEL REQUIREMENTS

		Fuel Consumed per 1,000 Ton-Miles	Energy Consumed (1) (Btu/ton-mile)	DQI
Combination truck (tractor trailer)				
Diesel	gal	9.4	1,465	B
Gasoline	gal	9.4	1,308	B
Single unit truck				
Diesel	gal	26.5	4,129	B
Gasoline	gal	26.5	3,689	B
Rail				
Diesel	gal	2.4	374	B
Barge (2)				
Diesel	gal	2.0	316	C
Residual	gal	0.8	131	C
Total			447	
Ocean freighter (2)				
Diesel	gal	0.1	23	C
Residual	gal	1.8	307	C
Total			330	C
Pipeline - natural gas				
Natural gas	cuft	2,300	2,581	C
Pipeline - petroleum products				
Electricity	kwh	22	241	C
Pipeline - coal slurry				
Electricity	kwh	235	2,578	C

(1) Includes precombustion energy for fuel acquisition.
(2) An average ratio of diesel and residual fuels is used to represent barge and ocean freighter transportation energy.

References: A-4 and A-57.

Source: Franklin Associates, Ltd.

The energy usage for single unit trucks weighing less than 14,000 pounds is calculated based upon the following data:

1. Average miles per gallon for single unit trucks = 6.8 miles per gallon. These gallons are distributed based on the following fuel usage split: 19.4 percent gasoline trucks and 80.6 percent diesel trucks (Reference A-4).

2. A fully loaded single unit truck carries 15,000 pounds maximum of freight (Reference A-35).

3. These types of trucks are used for local deliveries. These trucks will either deliver and pick-up throughout the day and will only be empty at the end of the day or will deliver until empty and then go back to the warehouse for more deliveries. Therefore, calculations are based on single-unit trucks having an average load of 65 percent (References A-16 and A-35).

Fuels used for barge and ocean freighter transportation are diesel and residual fuel oil, with diesel being the dominant fuel for barges and residual oil the dominant fuel for ocean freighters. The Btu per ton-mile values are additive as shown in Table A-5.

Energy Sources for Electricity Generation

To accurately account for the fuels used in the production and processing of the primary fuels, the fuel mix for electricity generation in the U.S., (the composite kilowatt-hour), must be determined.

Utility power plants generate electricity from five basic energy sources: coal, petroleum, natural gas, uranium, and hydropower. A small percentage of electricity is also generated by unconventional sources such as biomass, solar energy, wind energy, and geothermal energy. Wood and wood byproducts are also used to generate electricity, primarily within the forest products industry.

A national fuel grid was developed to relate electricity generation to the average quantities of individual energy sources used to produce electricity in the United States. In general, detailed data do not exist on the energy sources used to generate the electricity consumed by each industry. Electricity production and distribution systems in the United States are interlinked and cannot be separated from one another. Users of electricity, in general, cannot specify the energy sources used to produce their share of the electric power grid. Therefore, the energy sources used to produce the national average electricity grid are used for most industries.

The exception to this is the electricity used by aluminum processes in the aluminum industry. The electricity data for the aluminum industry is developed using region-specific data for that industry. This is because the aluminum industry influenced the building of hydropower facilities in many locations.

Calculation of the U.S. Composite Kilowatt-Hour

Representative fuel and other energy requirements for the average generation of electrical energy are calculated by first determining the requirements to generate one composite kilowatt-hour. A composite kilowatt-hour is defined as a kilowatt-hour of electrical energy produced using the national average fuel mix for electricity production in the United States.

In Table A-6 the total electricity generated from the various types of fuel and other energy sources is presented for both utility and non-utility generators (Reference A-1). The percentage of total electricity generated in the U.S. from each energy source is also calculated in Table A-6.

The data in Table A-6 were used to calculate the quantity of each fossil fuel required to generate one kilowatt-hour of electricity if only that fuel were being used. The results of these calculations are presented in Table A-7. For example, by converting 873,700,000 tons of coal to pounds and dividing by the quantity of kilowatt-hours of electricity generated (1735 x 10^9 kWh), the quantity of coal to produce one kilowatt-hour by utility generators is determined to be 1.01 pound in 1996. Similarly, the quantity of coal to produce one kilowatt-hour by industrial generators is 1.53 pounds. This is one way to evaluate the average efficiency of converting fossil fuels into electricity.

Table A-8 shows the results of the calculations to determine the total fuel requirements for the generation and delivery of one composite kilowatt-hour for 1996 conditions in the United States. For the fossil fuels, the combustion energy of the fuel is multiplied by the quantity of fuel required to generate one kilowatt-hour. This gives the total energy to generate one kilowatt-hour. Multiplying this value by the percent of total electricity generated by the specific fuel results in the quantity of energy contributed by that fuel to the generation of the composite kilowatt-hour.

The contribution of nuclear energy and wood or other renewable fuels to the composite kilowatt-hour is calculated in a similar manner to the calculations used for fossil fuels.

Nuclear power plants generate electricity by harnessing the thermal energy from a controlled nuclear reaction. The reaction is used to produce steam, which in turn drives a turbine-generator to produce electric power.

The thermal efficiency for producing electricity from nuclear reactions is roughly 32 percent. Taking into account this thermal efficiency for electricity generation, the heat factor for nuclear power-derived electricity is 10,740 Btu per kWh of generated electricity (Reference A-1). This translates to 985,000,000 Btu per pound of fuel grade uranium, which is added to precombustion energy and multiplied in Table A-7 by the pounds of uranium needed to produce one kilowatt-hour of electricity and by the percentage of total electricity generated from nuclear power to obtain the energy contribution to the composite kilowatt-hour from nuclear power.

Table A-6

1996 U.S. NATIONAL ELECTRICITY GENERATION BY ENERGY SOURCE

Source	Quantity of Fuel Consumed		Electricity Production (million kwh)	Reference	Percent of Total Generation
Utility Sources					
Coal	873,700,000	tons	1,735,000	1	49.9
Natural gas	2,737,000	million cuft	263,300	1	7.57
Residual oil	110,000,000	barrels	64,500	1, 2 (1)	1.85
Distillate oil	7,800,000	barrels	3,400	1, 2 (1)	0.10
Total Oil	117,800,000	barrels	67,900	1	1.95
Fossil Fuel Subtotal			2,066,200		59.4
Nuclear			674,800	1	19.4
Hydroelectric			328,800	1	9.45
Geothermal			5,200	39	0.15
Biomass			2,000	39	0.057
Photovoltaic			3	39	0.0001
Total (Utility)			**3,077,003**	1	**88.42**
Non-Utility Sources					
Natural gas	2,500,000	million cuft	220,000	2, 3 (1)	6.32
Other gas	1,600,000	million cuft	7,201	39	0.21
Wood	25,900,000	tons (2)	38,800	2, 3 (1)	1.11
Coal	49,100,000	tons	64,000	2, 3 (1)	1.84
Petroleum (3)	42,000,000	barrels	20,400	2, 3 (1)	0.59
Hydroelectric			11,050	2, 3 (1)	0.32
Waste			23,300	39	0.67
Geothermal			11,000	39	0.32
Wind			2,009	39	0.058
Solar			900	39	0.026
Other (4)			4,380	39	0.13
Total (Non-utility)			**403,040**		**11.58**
TOTAL			**3,480,043**		**100.0**

(1) Value calculated using data from two sources.
(2) Assuming 4,500 Btu/lb and 10,400 Btu/kwh (33% thermal efficiency in generation of electricity from wood).
(3) This petroleum product is assumed to be distillate oil.
(4) Other includes hydrogen, sulfur, batteries, chemicals, and spent sulfite liquor.

References: A-1, A-2, A-3, A-39, A-49, and A-50.

Source: Franklin Associates, Ltd.

Table A-7

CALCULATION OF ENERGY CONSUMPTION FOR THE GENERATION AND DELIVERY OF ONE COMPOSITE KILOWATT-HOUR, 1996

	Total Energy (1)				Quantity of Each Fuel to Generate One Kwh (2)	Percent of Composite Kwh (3)	Btu of Fuel Consumed per Composite Kwh
Utility Sources							
Coal	Pre-Combustion	264	Btu/lb				
	Combustion	10,402	Btu/lb				
	Total Energy	10,666	Btu/lb		1.01 lb	49.9	5,243
Natural gas	Pre-Combustion	129	Btu/cuft				
	Combustion	1,022	Btu/cuft				
	Total Energy	1,151	Btu/cuft		10.4 cuft	7.57	805
Residual fuel oil	Pre-Combustion	21,000	Btu/gal				
	Combustion	149,700	Btu/gal				
	Total Energy	170,700	Btu/gal		0.068 gal	1.85	188
Distillate fuel oil	Pre-Combustion	19,300	Btu/gal				
	Combustion	138,700	Btu/gal				
	Total Energy	158,000	Btu/gal		0.091 gal	0.10	13
Subtotal (fossil fuels)						59.4	6,248
Uranium	Pre-Combustion	50,600,000	Btu/lb				
	Combustion	985,321,000	Btu/lb				
	Total Energy	1,035,921,000	Btu/lb		1.09E-05 lb	19.4	2,084
Hydropower	Total energy	3,414	Btu/kwh		--	9.45	323
Other utility (geothermal, biomass, solar, etc.)	Total energy	10,350	Btu/kwh	(4)	--	0.21	21
Total (Utility)						**88.5**	**8,676**
Non-utility Sources							
Natural gas	Pre-Combustion	129	Btu/cuft				
	Combustion	1,031	Btu/cuft				
	Total Energy	1,160	Btu/cuft		12.0 cuft	6.32	779
Wood wastes		10,350	Btu/kwh	(4)		1.11	115
Coal	Pre-Combustion	264	Btu/lb				
	Combustion	11,157	Btu/lb				
	Total Energy	11,421	Btu/lb		1.53 lb	1.84	314
Distillate	Pre-Combustion	19,300	Btu/gal				
	Combustion	138,700	Btu/gal				
	Total Energy	158,000	Btu/gal		0.11	0.59	92
Hydropower	Total energy	3,414	Btu/kwh		--	0.32	11
Other non-utility	Total energy	10,350	Btu/kwh	(4)	--	1.41	146
Total (Non-utility)						**11.6**	**1,458**
TOTAL (U.S. AVERAGE)						**100**	**10,134**
Line loss adjustment: (5)	**Multiply by 1.08**						**10,944**

(1) From Table 9.
(2) From Table 6.
(3) From Table 6.
(4) 3,413 Btu/kwh divided by 0.33 thermal efficiency
(5) Adjusts energy requirements to account for power losses in transmission lines (i.e., the difference between net electricity generation and sales.) References A-1 and A-2.

Source: Franklin Associates, Ltd.

Table A-8

MIX OF FUEL REQUIRED TO GENERATE ONE KILOWATT-HOUR (1996 U.S. average)

			DQI
Coal	0.53	lb	A
Natural gas	1.52	cuft	A
Residual oil	0.0012	gal	A
Distillate oil	0.00071	gal	A
Fuel grade uranium (1)	2.0E-06	lb	A
Hydroelectric	338	Btu	A
Other (2)	234	Btu	A

Includes line loss adjustment.

(1) Calculated.

(2) Other includes wood, waste, geothermal, wind, solar, hydrogen, other gases, batteries, and other small sources of electricity.

Source: Calculated from data presented in Table A-6.

Efficiency calculations for energy sources other than fossil fuels are less meaningful. The quantity of water needed to produce one kilowatt-hour of electricity using hydropower is not an issue in this study. Water for hydropower is a finite, yet renewable, resource. Assigning an efficiency to this source of electricity would be an arbitrary procedure. Therefore, the portion of the composite kilowatt-hour from hydropower is determined using the standard conversion of 3,413 Btu per kilowatt-hour and multiplying by the percentage of total electricity generated from hydropower.

Electricity from wind energy and from photovoltaic cells using solar power falls into the same category as hydroelectric energy. The standard conversion of 3,413 Btu per kilowatt-hour is used to measure energy produced from these sources. Currently, very little electricity is actually being produced using wind energy or photovoltaic cells. Therefore, the contributions of these energy sources to the composite kilowatt-hour do not show up in the national fuel grid.

Renewable energy sources other than hydroelectricity, such as geothermal energy, solar energy for steam generation, and biomass energy, produced less than one percent of the total electricity generated in the U.S. in 1996. These energy sources are presented in Table A-8 under the heading of Other. The contribution from these energy sources is calculated by using the standard conversion factor of 3,413 Btu per kilowatt-hour and assuming an average thermal efficiency of 33 percent for converting the steam produced by these energy sources to electricity. This gives an energy factor of 10,350 Btu per kWh of generated electricity. This energy factor is then multiplied by the percentage of total electricity generated from unconventional energy sources. The energy factor of 10,350 Btu per kWh is consistent with that reported in the November 1993 issue of the U.S. Department of Energy publication, **Monthly Energy Review**.

Adding the energy components of the composite kilowatt-hour shown in Table A-7 gives the total energy required to generate a composite kilowatt-hour of electricity, expressed in total Btu. An adjustment must be made to account for line losses in the transmission of electricity to consumers in order to reflect the true energy requirements for the use of electricity. This line loss adjustment is calculated to be the difference between net electricity generation and sales (Reference A-1). Net electricity generation is the total electricity produced by utilities minus the electricity used in-plant plus the net electricity purchased from non-utility generators and other countries.

In 1996, non-utility generated electricity was about 11 percent of the total U.S. electricity generation (Reference A-2, page 43). Non-utility generated electricity is produced using roughly 55 percent natural gas, 19 percent wood or renewable fuel sources, and 16 percent coal (Reference A-3, page 211).

Precombustion Energy and Emissions for Primary Fuels

Precombustion energy is the summation of all energy inputs into the production of a fuel that is subsequently used as a source of energy. Calculation of precombustion energy requires the tabulation of the fuel requirements for each of the energy sources used in fuel production. Each of these fuel inputs also had energy requirements for production and transportation. This series of inputs creates a complex and technically infinite set of inter-dependent steps. Iterative calculations were employed to evaluate this inter-dependency.

Precombustion energy requirements for primary fuels were calculated using the process and transportation energy requirements presented in Tables A-1 through A-4, the transportation energy requirements in Table A-5, and the electricity production data presented in Tables A-6 through A-8. The results of these iterative calculations are presented in Tables A-10, A-11, A-12a through A-12d, and A-13 for coal, natural gas, petroleum fuels, and nuclear fuels, respectively. The energy requirements shown in Tables A-10 through A-13 include both the process and precombustion energy to produce the fuel.

The environmental emissions that result from producing and combusting fuels used for energy to produce other fuels are also presented in Tables A-10 through A-13. The emissions shown in these tables only include the precombustion emissions, not the process emissions. These fuel-related precombustion emissions are added to the process emissions presented in Tables A-1 through A-4 to obtain total precombustion emissions for each energy source in Tables A-14 through A-31 in the next section of this appendix.

PRIMARY FUEL COMBUSTION

Energy Content of Fuels

The precombustion, combustion, and total energy associated with the consumption of 1,000 units of the various types of fuels used by mobile and stationary sources are reported in Table A-9. Stationary sources include industrial and utility boilers, and other types of stationary industrial equipment such as compressors and pumps. Mobile sources include various modes of transportation such as truck, rail, barge, and ocean freighter.

Table A-9

ENERGY FACTORS FOR VARIOUS FUELS
1996

		Pre-Combustion Energy (Million Btu)	**Combustion Energy** (Million Btu)	**Total Energy** (Million Btu)
Mobile Sources				
Diesel	1,000 gal	19.3	139	158
Gasoline	1,000 gal	16.4	125	142
Residual fuel oil	1,000 gal	21.0	150	171
Industrial Heating				
Coal	1,000 lb	0.26	11.2	11.4
Diesel	1,000 gal	19.3	139	158
Distillate fuel oil	1,000 gal	19.3	139	158
Gasoline	1,000 gal	16.4	125	142
LPG	1,000 gal	12.1	95.5	108
Natural gas	1,000 cuft	0.13	1.03	1.16
Residual fuel oil	1,000 gal	21.0	150	171
Utility Heating				
Coal	1,000 lb	0.26	10.4	10.7
Natural gas	1,000 cuft	0.13	1.02	1.15
Residual fuel oil	1,000 gal	21.0	150	171
Distillate fuel oil	1,000 gal	19.3	139	158
Fuel grade uranium	1,000 lb	50,600	985,320	1,035,920

References: A-1, A-2, and A-4

Source: Franklin Associates, Ltd.

Table A-10

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 POUNDS OF COAL

Total Precombustion Fuel Use and Process Energy			**DQI**
Coal	6.3	lb	B
Natural gas	30.0	cuft	B
Residual oil	0.098	gal	B
Distillate oil	0.86	gal	B
Gasoline	0.027	gal	B
Liquefied petroleum gas	0.0013	gal	B
Uranium (nuclear power)	2.4E-05	lb	B
Hydropower	3,780	Btu	B
Wood and wood wastes	1,310	Btu	B
Other renewable energy	2,030	Btu	B
Precombustion Fuel Related Emissions Only			
Atmospheric Emissions			
Particulates	0.059	lb	B
Nitrogen Oxides	0.23	lb	B
Hydrocarbons (other than methane)	0.085	lb	C
Sulfur Oxides	0.23	lb	B
Carbon Monoxide	0.18	lb	B
Fossil Carbon Dioxide	40.7	lb	A
Non-Fossil Carbon Dioxide	0.30	lb	C
Formaldehyde	9.6E-07	lb	C
Othr Aldehydes	0.0035	lb	C
Other Organics	0.0063	lb	E
Ammonia	8.7E-05	lb	C
Lead	2.7E-06	lb	B
Methane	0.039	lb	B
Kerosene	5.0E-06	lb	D
Chlorine	1.7E-06	lb	D
Hydrochloric Acid	0.0011	lb	C
Hydrogen Fluoride	1.5E-04	lb	C
Metals	1.2E-04	lb	D
Antimony	1.0E-06	lb	E
Arsenic	2.7E-06	lb	E
Beryllium	2.2E-07	lb	E
Cadmium	3.3E-06	lb	E
Chrominum	3.5E-06	lb	E
Cobalt	2.9E-06	lb	E
Manganese	5.4E-06	lb	E
Mercury	8.5E-07	lb	E
Nickel	4.6E-05	lb	E
Selenium	2.5E-06	lb	E
Acreolin	2.1E-07	lb	E
Nitrous Oxide	1.7E-04	lb	E
Benzene	9.3E-07	lb	E
Perchloroethylene	2.3E-07	lb	E
Trichloroethylene	2.0E-07	lb	E
Methylene Chloride	1.0E-06	lb	E
Carbon Tetrachloride	2.3E-06	lb	E
Phenols	5.9E-06	lb	E
Naphthalene	3.4E-07	lb	E
Dioxins	1.1E-12	lb	E
n-nitrodimethylamine	4.4E-08	lb	E
Radionuclides	3.9E-06	Ci	E

(continued)

Table A-10 (cont)

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 POUNDS OF COAL

			DQI
Waterborne Emissions			
Acid	3.2E-09	lb	E
Metal Ion	6.9E-05	lb	E
Dissolved Solids	0.082	lb	D
Suspended Solids	0.012	lb	D
BOD	1.2E-04	lb	D
COD	0.0013	lb	D
Phenol	2.2E-07	lb	E
Oil	0.0015	lb	E
Sulfuric Acid	2.5E-04	lb	E
Iron	8.3E-04	lb	E
Ammonia	1.4E-05	lb	E
Chromium	3.6E-06	lb	E
Lead	5.7E-09	lb	E
Zinc	1.3E-06	lb	E
Chlorides	0.0037	lb	E
Sodium	8.0E-06	lb	E
Calcium	4.3E-06	lb	E
Sulfates	0.0053	lb	E
Manganese	4.8E-04	lb	E
Fluorides	2.0E-05	lb	E
Nitrates	1.9E-06	lb	E
Phosphates	1.2E-04	lb	E
Boron	0.0010	lb	E
Other Organics	4.2E-04	lb	E
Chromates	2.6E-06	lb	E
Cyanide	5.3E-09	lb	E
Mercury	2.8E-10	lb	E
Cadmium	3.6E-06	lb	E
Solid Waste	2.91	lb	C

Calculated from data in Tables A-1 through A-9.

Source: Franklin Associates, Ltd.

Table A-11

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 CUBIC FEET OF NATURAL GAS

			DQI
Total Precombustion Fuel Use and Process Energy			
Coal	0.54	lb	B
Natural gas	104	cuft	B
Residual oil	0.021	gal	B
Distillate oil	0.028	gal	B
Gasoline	0.053	gal	B
Liquefied petroleum gas	1.4E-04	gal	B
Uranium (nuclear power)	2.2E-06	lb	B
Hydropower	347	Btu	B
Wood and wood wastes	187	Btu	B
Other renewable energy	121	Btu	B
Precombustion Fuel Related Emissions Only			
Atmospheric Emissions			
Particulates	0.0038	lb	B
Nitrogen Oxides	0.12	lb	B
Hydrocarbons (other than methane)	0.071	lb	C
Sulfur Oxides	0.13	lb	B
Carbon Monoxide	0.23	lb	B
Fossil Carbon Dioxide	15.7	lb	A
Non-Fossil Carbon Dioxide	0.028	lb	C
Formaldehyde	8.8E-08	lb	C
Othr Aldehydes	3.5E-04	lb	C
Other Organics	8.7E-04	lb	E
Ammonia	9.5E-06	lb	C
Lead	2.8E-07	lb	B
Methane	0.024	lb	B
Kerosene	4.8E-07	lb	D
Chlorine	2.2E-07	lb	D
Hydrochloric Acid	9.8E-05	lb	C
Hydrogen Fluoride	1.3E-05	lb	C
Metals	1.1E-05	lb	E
Antimony	8.9E-08	lb	E
Arsenic	1.9E-07	lb	E
Beryllium	1.4E-08	lb	E
Cadmium	2.7E-07	lb	E
Chrominum	2.3E-07	lb	E
Cobalt	2.5E-07	lb	E
Manganese	3.6E-07	lb	E
Mercury	7.4E-08	lb	E
Nickel	3.8E-06	lb	E
Selenium	2.2E-07	lb	E
Acreolin	1.9E-08	lb	E
Nitrous Oxide	1.2E-05	lb	E
Benzene	6.8E-08	lb	E
Perchloroethylene	2.0E-08	lb	E
Trichloroethylene	1.8E-08	lb	E
Methylene Chloride	8.8E-08	lb	E
Carbon Tetrachloride	1.1E-07	lb	E
Phenols	5.6E-07	lb	E
Naphthalene	3.2E-08	lb	E
Dioxins	1.1E-13	lb	E
n-nitrodimethylamine	4.1E-09	lb	E
Radionuclides	3.6E-07	Ci	E

(continued)

Table A-11 (cont)

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 CUBIC FEET OF NATURAL GAS

		DQI
Waterborne Emissions		
Acid	6.4E-10 lb	E
Metal Ion	1.4E-05 lb	E
Dissolved Solids	0.17 lb	D
Suspended Solids	0.0039 lb	D
BOD	1.8E-04 lb	D
COD	0.0024 lb	D
Phenol	4.4E-08 lb	E
Oil	0.0031 lb	E
Sulfuric Acid	2.1E-05 lb	E
Iron	7.3E-05 lb	E
Ammonia	4.9E-06 lb	E
Chromium	7.9E-06 lb	E
Lead	1.1E-09 lb	E
Zinc	2.7E-06 lb	E
Chlorides	0.0079 lb	E
Sodium	7.6E-07 lb	E
Calcium	4.1E-07 lb	E
Sulfates	0.0063 lb	E
Manganese	4.2E-05 lb	E
Fluorides	1.9E-06 lb	E
Nitrates	1.8E-07 lb	E
Phosphates	1.1E-05 lb	E
Boron	8.4E-05 lb	E
Other Organics	5.1E-04 lb	E
Chromates	2.2E-07 lb	E
Cyanide	1.2E-08 lb	E
Mercury	6.1E-10 lb	E
Cadmium	7.9E-06 lb	E
Solid Waste	0.55 lb	C

Calculated from data in Tables A-1 through A-9.

Source: Franklin Associates, Ltd.

Table A-12a

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 GALLONS OF RESIDUAL FUEL OIL

			DQI
Total Precombustion Fuel Use and Process Energy			**DQI**
Coal	141	lb	B
Natural gas	11,000	cuft	B
Residual oil	43.0	gal	B
Distillate oil	4.90	gal	B
Gasoline	1.40	gal	B
Liquefied petroleum gas	1.40	gal	B
Uranium (nuclear power)	5.7E-04	lb	B
Hydropower	91,500	Btu	B
Wood and wood wastes	49,300	Btu	B
Other renewable energy	31,800	Btu	B
Precombustion Fuel Related Emissions Only			
Atmospheric Emissions			
Particulates	1.34	lb	B
Nitrogen Oxides	9.23	lb	B
Hydrocarbons (other than methane)	6.59	lb	C
Sulfur Oxides	26.6	lb	B
Carbon Monoxide	6.92	lb	B
Fossil Carbon Dioxide	2,860	lb	A
Non-Fossil Carbon Dioxide	6.64	lb	C
Formaldehyde	2.3E-05	lb	C
Othr Aldehydes	0.19	lb	C
Other Organics	0.33	lb	E
Ammonia	0.0024	lb	C
Lead	1.4E-04	lb	B
Methane	4.41	lb	B
Kerosene	1.1E-04	lb	D
Chlorine	5.2E-05	lb	D
Hydrochloric Acid	0.026	lb	C
Hydrogen Fluoride	0.0035	lb	C
Metals	0.0027	lb	D
Antimony	4.1E-05	lb	E
Arsenic	8.6E-05	lb	E
Beryllium	6.0E-06	lb	E
Cadmium	1.3E-04	lb	E
Chrominum	9.8E-05	lb	E
Cobalt	1.2E-04	lb	E
Manganese	1.2E-04	lb	E
Mercury	2.8E-05	lb	E
Nickel	0.0018	lb	E
Selenium	7.9E-05	lb	E
Acreolin	5.1E-06	lb	E
Nitrous Oxide	0.0031	lb	E
Benzene	1.6E-05	lb	E
Perchloroethylene	5.0E-06	lb	E
Trichloroethylene	4.8E-06	lb	E
Methylene Chloride	2.2E-05	lb	E
Carbon Tetrachloride	2.1E-05	lb	E
Phenols	1.3E-04	lb	E
Naphthalene	7.6E-06	lb	E
Dioxins	2.8E-11	lb	E
n-nitrodimethylamine	1.1E-06	lb	E
Radionuclides	9.5E-05	Ci	E

(continued)

Table A-12a (cont)

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 GALLONS OF RESIDUAL FUEL OIL

Waterborne Emissions			**DQI**
Acid	1.5E-07	lb	E
Metal Ion	0.0031	lb	E
Dissolved Solids	30.6	lb	D
Suspended Solids	0.76	lb	D
BOD	0.031	lb	D
COD	0.43	lb	D
Phenol	1.0E-05	lb	E
Oil	0.54	lb	E
Sulfuric Acid	0.0075	lb	E
Iron	0.017	lb	E
Ammonia	9.7E-04	lb	E
Chromium	0.0014	lb	E
Lead	2.6E-07	lb	E
Zinc	4.7E-04	lb	E
Chlorides	1.39	lb	E
Sodium	1.8E-04	lb	E
Calcium	9.7E-05	lb	E
Sulfates	1.13	lb	E
Manganese	0.010	lb	E
Fluorides	4.5E-04	lb	E
Nitrates	4.3E-05	lb	E
Phosphates	0.0038	lb	E
Boron	0.030	lb	E
Other Organics	0.093	lb	E
Chromates	1.1E-04	lb	E
Cyanide	2.0E-06	lb	E
Mercury	1.1E-07	lb	E
Cadmium	0.0014	lb	E
Solid Waste	113	lb	C

Calculated from data in Tables A-1 through A-9.

Source: Franklin Associates, Ltd.

Table A-12b

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 GALLONS OF DISTILLATE FUEL OIL

Total Precombustion Fuel Use and Process Energy			**DQI**
Coal	130	lb	B
Natural gas	10,100	cuft	B
Residual oil	40.0	gal	B
Distillate oil	4.50	gal	B
Gasoline	1.30	gal	B
Liquefied petroleum gas	1.30	gal	B
Uranium (nuclear power)	5.3E-04	lb	B
Hydropower	84,000	Btu	B
Wood and wood wastes	45,300	Btu	B
Other renewable energy	29,200	Btu	B
Precombustion Fuel Related Emissions Only			
Atmospheric Emissions			
Particulates	1.23	lb	B
Nitrogen Oxides	8.47	lb	B
Hydrocarbons (other than methane)	6.05	lb	C
Sulfur Oxides	24.4	lb	B
Carbon Monoxide	6.36	lb	B
Fossil Carbon Dioxide	2,630	lb	A
Non-Fossil Carbon Dioxide	6.10	lb	C
Formaldehyde	2.1E-05	lb	C
Othr Aldehydes	0.18	lb	C
Other Organics	0.30	lb	E
Ammonia	0.0022	lb	C
Lead	1.2E-04	lb	B
Methane	4.05	lb	B
Kerosene	1.0E-04	lb	D
Chlorine	4.7E-05	lb	D
Hydrochloric Acid	0.024	lb	C
Hydrogen Fluoride	0.0033	lb	C
Metals	0.0025	lb	D
Antimony	3.8E-05	lb	E
Arsenic	7.9E-05	lb	E
Beryllium	5.5E-06	lb	E
Cadmium	1.2E-04	lb	E
Chrominum	9.0E-05	lb	E
Cobalt	1.1E-04	lb	E
Manganese	1.1E-04	lb	E
Mercury	2.6E-05	lb	E
Nickel	0.0017	lb	E
Selenium	7.2E-05	lb	E
Acreolin	4.7E-06	lb	E
Nitrous Oxide	0.0028	lb	E
Benzene	1.5E-05	lb	E
Perchloroethylene	4.6E-06	lb	E
Trichloroethylene	4.4E-06	lb	E
Methylene Chloride	2.1E-05	lb	E
Carbon Tetrachloride	1.9E-05	lb	E
Phenols	1.2E-04	lb	E
Naphthalene	7.0E-06	lb	E
Dioxins	2.5E-11	lb	E
n-nitrodimethylamine	9.9E-07	lb	E
Radionuclides	8.7E-05	Ci	E

(continued)

Table A-12b (cont)

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 GALLONS OF DISTILLATE FUEL OIL

			DQI
Waterborne Emissions			
Acid	1.4E-07	lb	E
Metal Ion	0.0029	lb	E
Dissolved Solids	28.1	lb	D
Suspended Solids	0.70	lb	D
BOD	0.029	lb	D
COD	0.40	lb	D
Phenol	9.3E-06	lb	E
Oil	0.50	lb	E
Sulfuric Acid	0.0069	lb	E
Iron	0.016	lb	E
Ammonia	8.9E-04	lb	E
Chromium	0.0013	lb	E
Lead	2.4E-07	lb	E
Zinc	4.4E-04	lb	E
Chlorides	1.28	lb	E
Sodium	1.6E-04	lb	E
Calcium	9.0E-05	lb	E
Sulfates	1.03	lb	E
Manganese	0.0092	lb	E
Fluorides	4.1E-04	lb	E
Nitrates	3.9E-05	lb	E
Phosphates	0.0035	lb	E
Boron	0.028	lb	E
Other Organics	0.085	lb	E
Chromates	9.8E-05	lb	E
Cyanide	1.9E-06	lb	E
Mercury	9.8E-08	lb	E
Cadmium	0.0013	lb	E
Solid Waste	104	lb	C

Calculated from data in Tables A-1 through A-9.

Source: Franklin Associates, Ltd.

Table A-12c

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 GALLONS OF GASOLINE

Total Precombustion Fuel Use and Process Energy			**DQI**
Coal	110	lb	B
Natural gas	8,620	cuft	B
Residual oil	34.0	gal	B
Distillate oil	3.80	gal	B
Gasoline	1.10	gal	B
Liquefied petroleum gas	1.10	gal	B
Uranium (nuclear power)	4.5E-04	lb	B
Hydropower	71,600	Btu	B
Wood and wood wastes	38,600	Btu	B
Other renewable energy	24,900	Btu	B
Precombustion Fuel Related Emissions Only			
Atmospheric Emissions			
Particulates	1.05	lb	B
Nitrogen Oxides	7.22	lb	B
Hydrocarbons (other than methane)	5.16	lb	C
Sulfur Oxides	20.8	lb	B
Carbon Monoxide	5.42	lb	B
Fossil Carbon Dioxide	2,239	lb	A
Non-Fossil Carbon Dioxide	5.20	lb	C
Formaldehyde	1.8E-05	lb	C
Othr Aldehydes	0.15	lb	C
Other Organics	0.26	lb	E
Ammonia	0.0019	lb	C
Lead	1.1E-04	lb	B
Methane	3.45	lb	B
Kerosene	8.9E-05	lb	D
Chlorine	4.0E-05	lb	D
Hydrochloric Acid	0.020	lb	C
Hydrogen Fluoride	0.0028	lb	C
Metals	0.0021	lb	D
Antimony	3.2E-05	lb	E
Arsenic	6.7E-05	lb	E
Beryllium	4.7E-06	lb	E
Cadmium	1.0E-04	lb	E
Chrominum	7.6E-05	lb	E
Cobalt	9.2E-05	lb	E
Manganese	9.1E-05	lb	E
Mercury	2.2E-05	lb	E
Nickel	0.0014	lb	E
Selenium	6.2E-05	lb	E
Acreolin	4.0E-06	lb	E
Nitrous Oxide	0.0024	lb	E
Benzene	1.3E-05	lb	E
Perchloroethylene	3.9E-06	lb	E
Trichloroethylene	3.8E-06	lb	E
Methylene Chloride	1.8E-05	lb	E
Carbon Tetrachloride	1.6E-05	lb	E
Phenols	1.0E-04	lb	E
Naphthalene	6.0E-06	lb	E
Dioxins	2.2E-11	lb	E
n-nitrodimethylamine	8.4E-07	lb	E
Radionuclides	7.4E-05	Ci	E

(continued)

Table A-12c (cont)

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 GALLONS OF GASOLINE

Waterborne Emissions			**DQI**
Acid	1.2E-07	lb	E
Metal Ion	0.0024	lb	E
Dissolved Solids	23.9	lb	D
Suspended Solids	0.60	lb	D
BOD	0.025	lb	D
COD	0.34	lb	D
Phenol	7.9E-06	lb	E
Oil	0.42	lb	E
Sulfuric Acid	0.0059	lb	E
Iron	0.014	lb	E
Ammonia	7.6E-04	lb	E
Chromium	0.0011	lb	E
Lead	2.0E-07	lb	E
Zinc	3.7E-04	lb	E
Chlorides	1.09	lb	E
Sodium	1.4E-04	lb	E
Calcium	7.6E-05	lb	E
Sulfates	0.88	lb	E
Manganese	0.0078	lb	E
Fluorides	3.5E-04	lb	E
Nitrates	3.3E-05	lb	E
Phosphates	0.0030	lb	E
Boron	0.024	lb	E
Other Organics	0.072	lb	E
Chromates	8.3E-05	lb	E
Cyanide	1.6E-06	lb	E
Mercury	8.4E-08	lb	E
Cadmium	0.0011	lb	E
Solid Waste	88.6	lb	C

Calculated from data in Tables A-1 through A-9.

Source: Franklin Associates, Ltd.

Table A-12d

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 GALLONS OF LIQUEFIED PETROLEUM GAS (LPG)

Total Precombustion Fuel Use and Process Energy			DQI
Coal	81.0	lb	B
Natural gas	6,300	cuft	B
Residual oil	25.0	gal	B
Distillate oil	2.80	gal	B
Gasoline	0.80	gal	B
Liquefied petroleum gas	0.80	gal	B
Uranium (nuclear power)	3.3E-04	lb	B
Hydropower	52,500	Btu	B
Wood and wood wastes	28,300	Btu	B
Other renewable energy	18,300	Btu	B
Precombustion Fuel Related Emissions Only			
Atmospheric Emissions			
Particulates	0.77	lb	B
Nitrogen Oxides	5.30	lb	B
Hydrocarbons (other than methane)	3.78	lb	C
Sulfur Oxides	15.2	lb	B
Carbon Monoxide	3.97	lb	B
Fossil Carbon Dioxide	1,642	lb	A
Non-Fossil Carbon Dioxide	3.81	lb	C
Formaldehyde	1.3E-05	lb	C
Othr Aldehydes	0.11	lb	C
Other Organics	0.19	lb	E
Ammonia	0.0014	lb	C
Lead	7.8E-05	lb	B
Methane	2.53	lb	B
Kerosene	6.5E-05	lb	D
Chlorine	3.0E-05	lb	D
Hydrochloric Acid	0.015	lb	C
Hydrogen Fluoride	0.0020	lb	C
Metals	0.0016	lb	D
Antimony	2.4E-05	lb	E
Arsenic	4.9E-05	lb	E
Beryllium	3.4E-06	lb	E
Cadmium	7.4E-05	lb	E
Chrominum	5.6E-05	lb	E
Cobalt	6.7E-05	lb	E
Manganese	6.7E-05	lb	E
Mercury	1.6E-05	lb	E
Nickel	0.0010	lb	E
Selenium	4.5E-05	lb	E
Acreolin	2.9E-06	lb	E
Nitrous Oxide	0.0018	lb	E
Benzene	9.4E-06	lb	E
Perchloroethylene	2.9E-06	lb	E
Trichloroethylene	2.8E-06	lb	E
Methylene Chloride	1.3E-05	lb	E
Carbon Tetrachloride	1.2E-05	lb	E
Phenols	7.7E-05	lb	E
Naphthalene	4.4E-06	lb	E
Dioxins	1.6E-11	lb	E
n-nitrodimethylamine	6.2E-07	lb	E
Radionuclides	5.4E-05	Ci	E

(continued)

Table A-12d (cont)

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 GALLONS OF LIQUEFIED PETROLEUM GAS (LPG)

Waterborne Emissions			**DQI**
Acid	8.5E-08	lb	E
Metal Ion	0.0018	lb	E
Dissolved Solids	17.5	lb	D
Suspended Solids	0.44	lb	D
BOD	0.018	lb	D
COD	0.25	lb	D
Phenol	5.8E-06	lb	E
Oil	0.31	lb	E
Sulfuric Acid	0.0043	lb	E
Iron	0.010	lb	E
Ammonia	5.6E-04	lb	E
Chromium	8.0E-04	lb	E
Lead	1.5E-07	lb	E
Zinc	2.7E-04	lb	E
Chlorides	0.80	lb	E
Sodium	1.0E-04	lb	E
Calcium	5.6E-05	lb	E
Sulfates	0.65	lb	E
Manganese	0.0057	lb	E
Fluorides	2.6E-04	lb	E
Nitrates	2.4E-05	lb	E
Phosphates	0.0022	lb	E
Boron	0.017	lb	E
Other Organics	0.053	lb	E
Chromates	6.1E-05	lb	E
Cyanide	1.2E-06	lb	E
Mercury	6.1E-08	lb	E
Cadmium	8.0E-04	lb	E
Solid Waste	65.0	lb	C

Calculated from data in Tables A-1 through A-9.

Source: Franklin Associates, Ltd.

Table A-13

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 POUNDS OF FUEL-GRADE URANIUM

Total Precombustion Fuel Use and Process Energy			**DQI**
Coal	2,500,000	lb	B
Natural gas	9,800,000	cuft	B
Residual oil	7,300	gal	B
Distillate oil	5,800	gal	B
Gasoline	610	gal	B
Liquefied petroleum gas	23.0	gal	B
Uranium (nuclear power)	10.0	lb	B
Hydropower	1.6E+09	Btu	B
Wood and wood wastes	8.6E+08	Btu	B
Other renewable energy	5.5E+08	Btu	B
Precombustion Fuel Related Emissions Only			
Atmospheric Emissions			
Particulates	7,500	lb	B
Nitrogen Oxides	25,200	lb	B
Hydrocarbons (other than methane)	5,500	lb	C
Sulfur Oxides	54,000	lb	B
Carbon Monoxide	4,800	lb	B
Fossil Carbon Dioxide	6,750,000	lb	A
Non-Fossil Carbon Dioxide	129,000	lb	C
Formaldehyde	0.41	lb	C
Othr Aldehydes	18.9	lb	C
Other Organics	45.8	lb	E
Ammonia	30.7	lb	C
Lead	0.36	lb	B
Methane	14,900	lb	B
Kerosene	2.21	lb	D
Chlorine	0.50	lb	D
Hydrochloric Acid	447	lb	C
Hydrogen Fluoride	61.8	lb	C
Metals	52.7	lb	D
Antimony	0.049	lb	E
Arsenic	0.21	lb	E
Beryllium	0.023	lb	E
Cadmium	0.055	lb	E
Chrominum	0.27	lb	E
Cobalt	0.13	lb	E
Manganese	1.16	lb	E
Mercury	0.17	lb	E
Nickel	1.38	lb	E
Selenium	0.64	lb	E
Acreolin	0.089	lb	E
Nitrous Oxide	50.4	lb	E
Benzene	0.30	lb	E
Perchloroethylene	0.085	lb	E
Trichloroethylene	0.084	lb	E
Methylene Chloride	0.37	lb	E
Carbon Tetrachloride	0.15	lb	E
Phenols	2.57	lb	E
Naphthalene	0.15	lb	E
Dioxins	4.8E-07	lb	E
n-nitrodimethylamine	0.019	lb	E
Radionuclides	1.65	Ci	E

(continued)

Table A-13 (cont)

TOTAL PRECOMBUSTION FUEL USE AND FUEL RELATED EMISSIONS FOR THE PRODUCTION OF 1,000 POUNDS OF FUEL-GRADE URANIUM

Waterborne Emissions			**DQI**
Acid	1.0E-04	lb	E
Metal Ion	2.11	lb	E
Dissolved Solids	27,400	lb	D
Suspended Solids	4,270	lb	D
BOD	27.9	lb	D
COD	385	lb	D
Phenol	0.0068	lb	E
Oil	484	lb	E
Sulfuric Acid	57.5	lb	E
Iron	337	lb	E
Ammonia	3.96	lb	E
Chromium	1.25	lb	E
Lead	1.8E-04	lb	E
Zinc	0.43	lb	E
Chlorides	1,280	lb	E
Sodium	3.49	lb	E
Calcium	1.90	lb	E
Sulfates	2,060	lb	E
Manganese	194	lb	E
Fluorides	8.78	lb	E
Nitrates	0.83	lb	E
Phosphates	28.7	lb	E
Boron	230	lb	E
Other Organics	122	lb	E
Chromates	0.079	lb	E
Cyanide	0.0018	lb	E
Mercury	9.6E-05	lb	E
Cadmium	1.25	lb	E
Solid Waste	1,150,000	lb	C

Calculated from data in Tables A-1 through A-9.

Source: Franklin Associates, Ltd.

Total Environmental Emissions for Process, Utility, and Transportation Fuels

The environmental emissions associated with the consumption of 1,000 units of the various types of fuels by mobile and stationary sources are reported in Tables A-14 through A-32. Precombustion and combustion emissions are shown separately and also totaled. Mobile sources include various modes of transportation such as truck, rail, barge, etc. Stationary sources include industrial and utility boilers, and other types of stationary industrial equipment such as compressors and pumps.

Coal

Utility Boilers. Coal is most commonly burned by utilities as their primary fuel, followed by oil and natural gas. The environmental effects of coal combustion are dependent upon the ash and sulfur content of the coal, the type of boiler, and the firing mechanism used. The sulfur content of coal received by utilities in 1994 ranged from 0.27 weight percent to 4.50 weight percent, and the ash content ranged from 4.10 weight percent to 21.43 weight percent. (Reference A-5, page 66). A national average ash content of 9.87 percent by weight and a sulfur content of 1.18 percent by weight are used in this appendix.

Table A-14 presents the emissions associated with the combustion of 1,000 pounds of coal in utility boilers. Utilities use a mix of coal-fired boilers to produce electricity, and the data in Table A-14 represents a national average of 77 percent pulverized dry-bottom boilers, 11 percent pulverized wet-bottom boilers, 11 percent cyclone boilers, and one percent stoker boilers. Air emissions from coal-fired boilers are mainly particulates, sulfur oxides, and other gaseous products of combustion.

Coal-fired power plants commonly employ particulate control devices, which range in efficiency from about 80 percent for multiple cyclones to more than 99 percent for electrostatic precipitators and bag filters (Reference A-6). It was assumed that an average of 99 percent of the fly ash is collected in particulate control devices. This collected fly ash becomes solid waste along with the bottom ash from the boiler furnaces.

The sulfur oxide emissions from burning coal for utility power generation were calculated using the average sulfur content of coal received by utilities. The sulfur oxide emissions were reduced to appropriately account for the desulfurization units employed by 33 percent of the coal-fired generating units (Reference A-60). Since only 33 percent of utilities have desulfurization units, the sulfur oxide emissions from utility boilers are not significantly lower than the sulfur oxide emissions from industrial boilers. Furthermore, desulfurization units do not remove 100 percent of the sulfur oxides in an effluent stream. On average, utility desulfurization units remove 85 percent of the sulfur oxides emitted from coal combustion.

Some solid waste byproducts from utility coal combustion (fly ash, bottom ash, boiler slag, and flue gas desulfurization material) are now being diverted from the landfill by being incorporated in other useful products, such as cement and concrete products, mineral filler in asphalt, grouting, and wallboard. These diverted materials are not included as solid waste in Table A-14.

Industrial Boilers. In 1994, 11 percent of the coal consumed in the U.S. was used by industry. Industrial combustion of coal is treated separately from combustion of coal for utility boilers because pollutants are often different. Industries often do not burn coal in boilers as large as or of the same type as the utility boilers. They also do not always burn the same kinds of coal. The emissions presented in Table A-15 represent a national average of 44 percent pulverized dry-bottom boilers, 10 percent pulverized wet-bottom boilers, 2 percent cyclone boilers, and 44 percent stoker boilers.

Average ash and sulfur content for coal used by industry was assumed to be the same as for coal being received by utilities. Statistics on the quality of industrial and utility coal show that there is very little difference in the ash and sulfur content (Reference A-39). However, particulate control is generally less efficient for industrial coal boilers, and it is assumed that sulfur oxide control is not employed.

Residual Oil

Utility Boilers. The fuel oil consumed by utilities is mainly residual oil. Emissions from the combustion of residual oil are dependent on the composition of the fuel, the type of boiler, and the firing practices used. Pollutants from oil-fired boilers include ash, sulfur oxides, and other gaseous emissions. For residual oil, both particulate emissions and sulfur oxide emissions are proportional to the sulfur content of the fuel. A national average of 1.2 weight percent was used (Reference A-5, page 212).

About 30 percent of the total ash from combustion of oil is bottom ash. The remaining 70 percent of the ash will travel up the stack. It has been estimated that 42 percent of all oil-fired utility boilers had particulate control devices in 1994. These have an average efficiency of about 60 percent. Therefore, of the ash generated, about 48 percent is collected and will result in solid waste. The remaining 52 percent is released as air emissions (Reference A-8).

Sulfur oxide emissions were calculated based upon the average sulfur content of the fuel oil. Utilities using oil-fired boilers do not currently employ flue gas desulfurization units (Reference A-5, pages 23 and 37). Emissions for the combustion of residual oil in utility boilers are reported in Table A-16. These data are based on use of sulfur oxide controls for 33 percent of utility boilers, and a control efficiency of 85 percent in reducing sulfur oxide emissions where controls are used (Reference 60).

Table A-14

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF COAL IN UTILITY BOILERS
(pounds of pollutants per 1,000 pounds of coal)

	Precombustion (1)	Combustion	Total	DQI
Atmospheric Emissions				
Particulates	2.56	0.31	2.87	B
Nitrogen Oxides	0.23	7.90	8.13	B
Hydrocarbons (other than methane)	0.085	0.035	0.12	C
Sulfur Oxides	0.23	11.7	11.9	B
Carbon Monoxide	0.18	0.30	0.48	B
Fossil Carbon Dioxide	40.7	2,120	2,161	A
Non-Fossil Carbon Dioxide	0.30		0.30	B
Formaldehyde	9.6E-07	4.5E-05	4.6E-05	C
Other Aldehydes	0.0035	1.9E-04	0.0037	C
Other Organics	0.0063		0.0063	D
Ammonia	8.7E-05	2.4E-05	1.1E-04	C
Lead	2.7E-06	9.3E-05	9.6E-05	B
Methane	4.69	0.019	4.71	C
Kerosene	5.0E-06		5.0E-06	D
Chlorine	1.7E-06		1.7E-06	D
Hydrochloric Acid	0.0011	0.18	0.18	C
Hydrogen Fluoride	1.5E-04	0.025	0.025	C
Metals	1.2E-04		1.2E-04	D
Mercaptan				
Antimony	1.0E-06	1.4E-05	1.5E-05	E
Arsenic	2.7E-06	7.0E-05	7.3E-05	E
Beryllium	2.2E-07	8.5E-06	8.7E-06	E
Cadmium	3.3E-06	2.5E-06	5.8E-06	E
Chromium	3.5E-06	9.1E-05	9.4E-05	E
Cobalt	2.9E-06	2.7E-05	3.0E-05	E
Manganese	5.4E-06	2.3E-04	2.4E-04	E
Mercury	8.5E-07	6.6E-05	6.7E-05	E
Nickel	4.6E-05	6.2E-05	1.1E-04	E
Selenium	2.5E-06	2.5E-04	2.5E-04	E
Acreolin	2.1E-07	3.6E-05	3.6E-05	D
Nitrous Oxide	1.7E-04	0.020	0.020	D
Benzene	9.3E-07	2.7E-05	2.8E-05	D
Perchloroethylene	2.3E-07	3.4E-05	3.4E-05	D
Trichloroethylene	2.0E-07	3.4E-05	3.4E-05	D
Methylene Chloride	1.0E-06	1.4E-04	1.4E-04	D
Carbon Tetrachloride	2.3E-06	3.6E-05	3.8E-05	D
Phenols	5.9E-06	6.7E-05	7.3E-05	D
Naphthalene	3.4E-07		3.4E-07	D
Dioxins	1.1E-12	1.9E-10	1.9E-10	D
n-nitrodimethylamine	4.4E-08	7.6E-06	7.6E-06	D
Radionuclides (Ci)	3.9E-06	3.5E-04	3.5E-04	D

(continued)

Table A-14 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF COAL IN UTILITY BOILERS
(pounds of pollutants per 1,000 pounds of coal)

	Precombustion (1)	Combustion	Total	DQI
Waterborne Emissions				
Acid	3.2E-09		3.2E-09	E
Metal Ion	6.9E-05		6.9E-05	E
Dissolved Solids	0.082		0.082	D
Suspended Solids	1.41	0.13	1.54	D
BOD	1.2E-04		1.2E-04	D
COD	0.0013		0.0013	D
Phenol	2.2E-07		2.2E-07	E
Sulfide				E
Oil	0.0015		0.0015	E
Sulfuric Acid	2.5E-04	0.022	0.022	E
Iron	0.12		0.12	E
Hydrocarbons				E
Ammonia	1.4E-05		1.4E-05	E
Chromium	3.6E-06		3.6E-06	E
Lead	5.7E-09		5.7E-09	E
Zinc	1.3E-06		1.3E-06	E
Chlorides	0.0037	0.0070	0.011	E
Sodium	8.0E-06		8.0E-06	E
Calcium	4.3E-06		4.3E-06	E
Sulfates	0.0053		0.0053	E
Manganese	0.078		0.078	E
Fluorides	2.0E-05		2.0E-05	E
Nitrates	1.9E-06		1.9E-06	E
Phosphates	1.2E-04	0.011	0.011	E
Boron	0.0010	0.088	0.089	E
Other Organics	4.2E-04	0.017	0.017	E
Chromates	2.6E-06		2.6E-06	E
Cyanide	5.3E-09		5.3E-09	E
Mercury	2.8E-10		2.8E-10	E
Cadmium	3.6E-06		3.6E-06	E
Solid Waste	345	79	424	B

(1) Sum of precombustion process-related emissions from Table A-1 and precombustion fuel-related emissions from Table A-10.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-15

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF COAL IN INDUSTRIAL BOILERS
(pounds of pollutants per 1,000 pounds of coal)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	2.56	0.61	3.17	B
Nitrogen Oxides	0.23	5.40	5.63	B
Hydrocarbons (other than methane)	0.085	0.066	0.15	C
Sulfur Oxides	0.23	16.2	16.4	B
Carbon Monoxide	0.18	0.76	0.94	B
Fossil Carbon Dioxide	40.7	2,360	2,401	A
Non-Fossil Carbon Dioxide	0.30		0.30	B
Formaldehyde	9.6E-07		9.6E-07	C
Other Aldehydes	0.0035		0.0035	C
Other Organics	0.0063		0.0063	D
Ammonia	8.7E-05	1.6E-04	2.5E-04	C
Lead	2.7E-06	1.0E-04	1.0E-04	B
Methane	4.69	0.079	4.77	C
Kerosene	5.0E-06		5.0E-06	D
Chlorine	1.7E-06		1.7E-06	D
Hydrochloric Acid	0.0011		0.0011	C
Hydrogen Fluoride	1.5E-04		1.5E-04	C
Metals	1.2E-04		1.2E-04	D
Mercaptan				
Antimony	1.0E-06		1.0E-06	E
Arsenic	2.7E-06	8.7E-04	8.7E-04	E
Beryllium	2.2E-07	1.0E-04	1.0E-04	E
Cadmium	3.3E-06	2.8E-04	2.8E-04	E
Chromium	3.5E-06	0.0018	0.0018	E
Cobalt	2.9E-06		2.9E-06	E
Manganese	5.4E-06	0.0029	0.0029	E
Mercury	8.5E-07	2.3E-05	2.3E-05	E
Nickel	4.6E-05	0.0010	0.0011	E
Selenium	2.5E-06	2.0E-12	2.5E-06	E
Acreolin	2.1E-07		2.1E-07	D
Nitrous Oxide	1.7E-04	0.039	0.039	D
Benzene	9.3E-07	3.5E-04	3.5E-04	D
Perchloroethylene	2.3E-07		2.3E-07	D
Trichloroethylene	2.0E-07		2.0E-07	D
Methylene Chloride	1.0E-06		1.0E-06	D
Carbon Tetrachloride	2.3E-06		2.3E-06	D
Phenols	5.9E-06		5.9E-06	D
Naphthalene	3.4E-07		3.4E-07	D
Dioxins	1.1E-12		1.1E-12	D
n-nitrodimethylamine	4.4E-08		4.4E-08	D
Radionuclides (Ci)	3.9E-06		3.9E-06	D

(continued)

Table A-15 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF COAL IN INDUSTRIAL BOILERS
(pounds of pollutants per 1,000 pounds of coal)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	3.2E-09		3.2E-09	E
Metal Ion	6.9E-05		6.9E-05	E
Dissolved Solids	0.082		0.082	D
Suspended Solids	1.41	0.13	1.54	D
BOD	1.2E-04		1.2E-04	D
COD	0.0013		0.0013	D
Phenol	2.2E-07		2.2E-07	E
Sulfide				E
Oil	0.0015		0.0015	E
Sulfuric Acid	2.5E-04	0.022	0.022	E
Iron	0.12		0.12	E
Hydrocarbons				E
Ammonia	1.4E-05		1.4E-05	E
Chromium	3.6E-06		3.6E-06	E
Lead	5.7E-09		5.7E-09	E
Zinc	1.3E-06		1.3E-06	E
Chlorides	0.0037	0.0070	0.011	E
Sodium	8.0E-06		8.0E-06	E
Calcium	4.3E-06		4.3E-06	E
Sulfates	0.0053		0.0053	E
Manganese	0.078		0.078	E
Fluorides	2.0E-05		2.0E-05	E
Nitrates	1.9E-06		1.9E-06	E
Phosphates	1.2E-04	0.011	0.011	E
Boron	0.0010	0.088	0.089	E
Other Organics	4.2E-04	0.017	0.017	E
Chromates	2.6E-06		2.6E-06	E
Cyanide	5.3E-09		5.3E-09	E
Mercury	2.8E-10		2.8E-10	E
Cadmium	3.6E-06		3.6E-06	E
Solid Waste	345	105	450	B

(1) Sum of precombustion process-related emissions from Table A-1 and precombustion fuel-related emissions from Table A-10.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-16

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF RESIDUAL FUEL OIL IN UTILITY BOILERS (pounds of pollutants per 1,000 gallons of residual oil)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.8	1.9	3.7	B
Nitrogen Oxides	9.2	32	41	B
Hydrocarbons (other than methane)	55	0.013	55	C
Sulfur Oxides	28.1	95.9	124	B
Carbon Monoxide	6.9	4.0	10.9	B
Fossil Carbon Dioxide	2,861	25,495	28,356	A
Non-Fossil Carbon Dioxide	6.64		6.64	B
Formaldehyde	2.3E-05	0.0045	0.0045	C
Other Aldehydes	0.51	0.0012	0.51	C
Other Organics	0.33		0.33	D
Ammonia	0.044	1.73	1.77	C
Lead	1.5E-04	0.0056	0.0057	B
Methane	4.41	0.28	4.69	C
Kerosene	1.1E-04		1.1E-04	D
Chlorine	0.0017		0.0017	D
Hydrochloric Acid	0.027	0.68	0.71	C
Hydrogen Fluoride	0.0035	0.034	0.038	C
Metals	0.0027		0.0027	D
Antimony	4.1E-05		4.1E-05	E
Arsenic	8.6E-05	0.0012	0.0013	E
Beryllium	6.0E-06	1.1E-04	1.2E-04	E
Cadmium	1.3E-04	4.0E-04	5.3E-04	E
Chromium	9.8E-05	0.0011	0.0012	E
Cobalt	1.2E-04	0.0048	0.0049	E
Manganese	1.2E-04	0.0023	0.0024	E
Mercury	2.8E-05	6.0E-05	8.8E-05	E
Nickel	0.0018	0.095	0.097	E
Selenium	7.9E-05	4.0E-04	4.8E-04	E
Acreolin	5.1E-06		5.1E-06	D
Nitrous Oxide	0.0031	0.11	0.11	D
Benzene	1.6E-05	2.1E-04	2.3E-04	D
Perchloroethylene	5.0E-06	8.9E-05	9.4E-05	D
Trichloroethylene	4.8E-06		4.8E-06	D
Methylene Chloride	2.2E-05	0.0048	0.0048	D
Carbon Tetrachloride	2.1E-05	0.0063	0.0063	D
Phenols	1.3E-04	0.0036	0.0037	D
Naphthalene	7.6E-06	5.0E-05	5.8E-05	D
Dioxins	2.8E-11	2.6E-09	2.6E-09	D
n-nitrodimethylamine	1.1E-06		1.1E-06	D
Radionuclides (Ci)	9.5E-05	0.066	0.066	D

(continued)

Table A-16 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF RESIDUAL FUEL OIL IN UTILITY BOILERS
(pounds of pollutants per 1,000 gallons of residual oil)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	9.1E-06		9.1E-06	E
Metal Ion	0.19		0.19	E
Dissolved Solids	37.9		37.9	D
Suspended Solids	0.86	1.80	2.7	D
BOD	0.14		0.14	D
COD	0.95		0.95	D
Phenol	6.3E-04		6.3E-04	E
Oil	0.89		0.89	E
Sulfuric Acid	0.0075	0.30	0.31	E
Iron	0.021		0.021	E
Ammonia	0.015		0.015	E
Chromium	0.0014		0.0014	E
Lead	1.6E-05		1.6E-05	E
Zinc	7.1E-04		7.1E-04	E
Chlorides	1.39	0.094	1.5	E
Sodium	1.8E-04		1.8E-04	E
Calcium	9.7E-05		9.7E-05	E
Sulfates	1.13		1.1	E
Manganese	0.010		0.010	E
Fluorides	4.5E-04		4.5E-04	E
Nitrates	4.3E-05		4.3E-05	E
Phosphates	0.0038	0.15	0.15	E
Boron	0.030	1.2	1.2	E
Other Organics	0.093	0.24	0.33	E
Chromates	1.1E-04	0.0072	7.3E-03	E
Cyanide	2.0E-06		2.0E-06	E
Mercury	1.1E-07		1.1E-07	E
Cadmium	0.0014		0.0014	E
Solid Waste	144	33	177	B

(1) Sum of precombustion process-related emissions from Table A-3a and precombustion fuel-related emissions from Table A-12a.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, A-58 and A-59.

Source: Franklin Associates, Ltd.

Industrial Boilers. As with the combustion of residual oil in utility boilers, the emissions from the combustion of residual oil in industrial boilers are dependent on the composition of the fuel, the type of boiler, and the firing practices used. Again, both particulate emissions and sulfur oxide emissions are proportional to the sulfur content of the fuel. The sulfur content of residual fuel for industrial boilers was assumed to be the same as that reported for utility boilers. Emissions from the combustion of residual oil in industrial boilers are reported in Table A-17.

Distillate Oil

Utility Boilers. Distillate oil is a small part of the fuel oil burned for utility boilers. Emissions from the combustion of distillate oil are dependent on the composition of the fuel, the type of boiler, and the firing practices used. Pollutants from distillate oil-fired boilers include ash, sulfur oxides, and other gaseous emissions.

Sulfur oxide emissions were calculated based upon the average sulfur content of the fuel oil–0.3 weight percent (Reference A-6, page 1.3-1). Utilities using oil-fired boilers do not currently employ flue gas desulfurization units (Reference A-5, pages 23 and 37). Emissions for the combustion of distillate oil in utility boilers are reported in Table A-18.

Industrial Boilers. Emissions from the combustion of distillate oil are dependent on the composition of the fuel, the type of boiler, and the firing practices used. Pollutants from distillate oil-fired boilers include ash, sulfur oxides, and other gaseous emissions. Both particulate emissions and sulfur oxide emissions are proportional to the sulfur content of the fuel. An average fuel sulfur content of 0.3 weight percent is used for the emissions presented in Table A-19 (Reference A-6, page 1.3-1).

Natural Gas

Utility Boilers. Although raw natural gas may contain high levels of sulfur, it is removed during processing. The major pollutants from the burning of natural gas are nitrogen oxides. Nitrogen oxide control (if employed) is typically carried out as a boiler operational parameter adjustment. Pollution control devices are not employed for natural gas-fired utility boilers. Table A-20 shows the precombustion and combustion emissions for 1,000 cubic feet of natural gas burned.

Industrial Boilers. The emissions for natural gas-fired industrial boilers are shown in Table A-21. Precombustion emissions, the emissions associated with acquiring and processing natural gas, are the same as those shown in Table A-20 for natural gas used in utility boilers. Combustion emissions differ, however, because industrial boilers are generally smaller than utility boilers and therefore have different operating conditions.

Table A-17

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF RESIDUAL FUEL OIL IN INDUSTRIAL BOILERS (pounds of pollutants per 1,000 gallons of residual oil)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.81	1.9	3.7	B
Nitrogen Oxides	9.23	55.0	64.2	B
Hydrocarbons (other than methane)	54.7	0.28	55.0	C
Sulfur Oxides	28.1	95.9	124	B
Carbon Monoxide	6.92	5.00	11.9	B
Fossil Carbon Dioxide	2,861	25,494	28,355	A
Non-Fossil Carbon Dioxide	6.64		6.64	B
Formaldehyde	2.3E-05		2.3E-05	C
Other Aldehydes	0.51		0.51	C
Other Organics	0.33		0.33	D
Ammonia	0.044		0.044	C
Lead	1.5E-04	0.0087	0.0088	B
Methane	4.41	1.00	5.41	C
Kerosene	1.1E-04		1.1E-04	D
Chlorine	0.0017		0.0017	D
Hydrochloric Acid	0.027		0.027	C
Hydrogen Fluoride	0.0035		0.0035	C
Metals	0.0027		0.0027	D
Antimony	4.1E-05	0.0027	0.0028	E
Arsenic	8.6E-05	0.0052	0.0053	E
Beryllium	6.0E-06	3.3E-04	3.3E-04	E
Cadmium	1.3E-04	0.0089	0.0090	E
Chromium	9.8E-05	0.0058	0.0059	E
Cobalt	1.2E-04	0.0077	0.0078	E
Manganese	1.2E-04	0.0038	0.0039	E
Mercury	2.8E-05	0.0013	0.0013	E
Nickel	0.0018	0.12	0.13	E
Selenium	7.9E-05	0.0030	0.0030	E
Acreolin	5.1E-06		5.1E-06	D
Nitrous Oxide	0.0031		0.0031	D
Benzene	1.6E-05		1.6E-05	D
Perchloroethylene	5.0E-06		5.0E-06	D
Trichloroethylene	4.8E-06		4.8E-06	D
Methylene Chloride	2.2E-05		2.2E-05	D
Carbon Tetrachloride	2.1E-05		2.1E-05	D
Phenols	1.3E-04		1.3E-04	D
Naphthalene	7.6E-06		7.6E-06	D
Dioxins	2.8E-11		2.8E-11	D
n-nitrodimethylamine	1.1E-06		1.1E-06	D
Radionuclides(Ci)	9.5E-05		9.5E-05	D

(continued)

Table A-17 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF RESIDUAL FUEL OIL IN INDUSTRIAL BOILERS
(pounds of pollutants per 1,000 gallons of residual oil)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	9.1E-06		9.1E-06	E
Metal Ion	0.19		0.19	E
Dissolved Solids	37.9		37.9	D
Suspended Solids	0.86	1.80	2.66	D
BOD	0.14		0.14	D
COD	0.95		0.95	D
Phenol	6.3E-04		6.3E-04	E
Oil	0.89		0.89	E
Sulfuric Acid	0.0075	0.30	0.31	E
Iron	0.021		0.021	E
Ammonia	0.015		0.015	E
Chromium	0.0014		0.0014	E
Lead	1.6E-05		1.6E-05	E
Zinc	7.1E-04		7.1E-04	E
Chlorides	1.39	0.094	1.49	E
Sodium	1.8E-04		1.8E-04	E
Calcium	9.7E-05		9.7E-05	E
Sulfates	1.13		1.13	E
Manganese	0.010		0.010	E
Fluorides	4.5E-04		4.5E-04	E
Nitrates	4.3E-05		4.3E-05	E
Phosphates	0.0038	0.15	0.15	E
Boron	0.030	1.20	1.23	E
Other Organics	0.093	0.24	0.33	E
Chromates	1.1E-04	0.0072	0.0073	E
Cyanide	2.0E-06		2.0E-06	E
Mercury	1.1E-07		1.1E-07	E
Cadmium	0.0014		0.0014	E
Solid Waste	144	33	177	B

(1) Sum of precombustion process-related emissions from Table A-3a and precombustion fuel-related emissions from Table A-12a.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, A-58 and A-59.

Source: Franklin Associates, Ltd.

Table A-18

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF DISTILLATE FUEL OIL IN UTILITY BOILERS (pounds of pollutants per 1,000 gallons of distillate oil)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.66	1.00	2.66	B
Nitrogen Oxides	8.47	24.0	32.5	B
Hydrocarbons (other than methane)	50.2	0.76	51.0	C
Sulfur Oxides	25.8	43	69	B
Carbon Monoxide	6.36	4.50	10.9	B
Fossil Carbon Dioxide	2,627	26,500	29,127	A
Non-Fossil Carbon Dioxide	6.10		6.10	B
Formaldehyde	2.1E-05		2.1E-05	C
Other Aldehydes	0.47	0.015	0.48	C
Other Organics	0.30		0.30	D
Ammonia	0.040		0.040	C
Lead	1.4E-04	0.0049	0.0050	B
Methane	4.05	0.05	4.10	C
Kerosene	1.0E-04		1.0E-04	D
Chlorine	0.0015		0.0015	D
Hydrochloric Acid	0.025		0.025	C
Hydrogen Fluoride	0.0033		0.0033	C
Metals	0.0025		0.0025	D
Antimony	3.8E-05	0.0027	0.0027	E
Arsenic	7.9E-05	0.0052	0.0053	E
Beryllium	5.5E-06	3.3E-04	3.3E-04	E
Cadmium	1.2E-04	0.0089	0.0090	E
Chromium	9.0E-05	0.0058	0.0059	E
Cobalt	1.1E-04	0.0077	0.0078	E
Manganese	1.1E-04	0.0038	0.0039	E
Mercury	2.6E-05	0.0013	0.0013	E
Nickel	0.0017	0.12	0.12	E
Selenium	7.2E-05	0.0030	0.0031	E
Acreolin	4.7E-06		4.7E-06	D
Nitrous Oxide	0.0028	0.11	0.11	D
Benzene	1.5E-05	2.3E-04	2.4E-04	D
Perchloroethylene	4.6E-06	8.9E-05	9.4E-05	D
Trichloroethylene	4.4E-06		4.4E-06	D
Methylene Chloride	2.1E-05	5.2E-04	5.4E-04	D
Carbon Tetrachloride	1.9E-05	0.0063	0.0063	D
Phenols	1.2E-04		1.2E-04	D
Naphthalene	7.0E-06		7.0E-06	D
Dioxins	2.5E-11		2.5E-11	D
n-nitrodimethylamine	9.9E-07		9.9E-07	D
Radionuclides (Ci)	8.7E-05		8.7E-05	D

(continued)

Table A-18 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF DISTILLATE FUEL OIL IN UTILITY BOILERS
(pounds of pollutants per 1,000 gallons of distillate oil)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	8.4E-06		8.4E-06	E
Metal Ion	0.18		0.18	E
Dissolved Solids	34.8		34.8	D
Suspended Solids	0.79	1.80	2.59	D
BOD	0.13		0.13	D
COD	0.87		0.87	D
Phenol	5.8E-04		5.8E-04	E
Oil	0.81		0.81	E
Sulfuric Acid	0.0069	0.30	0.31	E
Iron	0.019		0.019	E
Ammonia	0.014		0.014	E
Chromium	0.0013		0.0013	E
Lead	1.5E-05		1.5E-05	E
Zinc	6.5E-04		6.5E-04	E
Chlorides	1.28	0.0094	1.29	E
Sodium	1.6E-04		1.6E-04	E
Calcium	9.0E-05		9.0E-05	E
Sulfates	1.03		1.03	E
Manganese	0.0092		0.0092	E
Fluorides	4.1E-04		4.1E-04	E
Nitrates	3.9E-05		3.9E-05	E
Phosphates	0.0035	0.15	0.15	E
Boron	0.028	1.20	1.23	E
Other Organics	0.085	0.24	0.33	E
Chromates	9.8E-05	0.0072	0.0073	E
Cyanide	1.9E-06		1.9E-06	E
Mercury	9.8E-08		9.8E-08	E
Cadmium	0.0013		0.0013	E
Solid Waste	133	33.0	166	B

(1) Sum of precombustion process-related emissions from Table A-3b and precombustion fuel-related emissions from Table A-12b.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, A-58 and A-59.

Source: Franklin Associates, Ltd.

Table A-19

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF DISTILLATE FUEL OIL IN INDUSTRIAL BOILERS (pounds of pollutants per 1,000 gallons of distillate oil)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.66	1.00	2.66	B
Nitrogen Oxides	8.47	24.0	32.5	B
Hydrocarbons (other than methane)	50.2	0.20	50.4	C
Sulfur Oxides	25.8	42.8	68.6	B
Carbon Monoxide	6.36	5.00	11.4	B
Fossil Carbon Dioxide	2,627	22,757	25,384	A
Non-Fossil Carbon Dioxide	6.10		6.10	B
Formaldehyde	2.1E-05		2.1E-05	C
Other Aldehydes	0.47		0.47	C
Other Organics	0.30		0.30	D
Ammonia	0.040		0.040	C
Lead	1.4E-04	6.4E-04	7.8E-04	B
Methane	4.05	0.051	4.10	C
Kerosene	1.0E-04		1.0E-04	D
Chlorine	0.0015		0.0015	D
Hydrochloric Acid	0.025		0.025	C
Hydrogen Fluoride	0.0033		0.0033	C
Metals	0.0025		0.0025	D
Antimony	3.8E-05		3.8E-05	E
Arsenic	7.9E-05	3.0E-04	3.8E-04	E
Beryllium	5.5E-06	1.8E-04	1.9E-04	E
Cadmium	1.2E-04	8.0E-04	9.2E-04	E
Chromium	9.0E-05	0.0042	0.0043	E
Cobalt	1.1E-04		1.1E-04	E
Manganese	1.1E-04	0.0010	0.0011	E
Mercury	2.6E-05	2.2E-04	2.5E-04	E
Nickel	0.0017	0.0013	0.0030	E
Selenium	7.2E-05		7.2E-05	E
Acreolin	4.7E-06		4.7E-06	D
Nitrous Oxide	0.0028		0.0028	D
Benzene	1.5E-05	0.11	1.1E-01	D
Perchloroethylene	4.6E-06		4.6E-06	D
Trichloroethylene	4.4E-06		4.4E-06	D
Methylene Chloride	2.1E-05		2.1E-05	D
Carbon Tetrachloride	1.9E-05		1.9E-05	D
Phenols	1.2E-04		1.2E-04	D
Naphthalene	7.0E-06		7.0E-06	D
Dioxins	2.5E-11		2.5E-11	D
n-nitrodimethylamine	9.9E-07		9.9E-07	D
Radionuclides (Ci)	8.7E-05		8.7E-05	D

(continued)

Table A-19 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF DISTILLATE FUEL OIL IN INDUSTRIAL BOILERS
(pounds of pollutants per 1,000 gallons of distillate oil)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	8.4E-06		8.4E-06	E
Metal Ion	0.18		0.18	E
Dissolved Solids	34.8		34.8	D
Suspended Solids	0.79		0.79	D
BOD	0.13		0.13	D
COD	0.87		0.87	D
Phenol	5.8E-04		5.8E-04	E
Oil	0.81		0.81	E
Sulfuric Acid	0.0069		0.0069	E
Iron	0.019		0.019	E
Ammonia	0.014		0.014	E
Chromium	0.0013		0.0013	E
Lead	1.5E-05		1.5E-05	E
Zinc	6.5E-04		6.5E-04	E
Chlorides	1.28		1.28	E
Sodium	1.6E-04		1.6E-04	E
Calcium	9.0E-05		9.0E-05	E
Sulfates	1.03		1.03	E
Manganese	0.0092		0.0092	E
Fluorides	4.1E-04		4.1E-04	E
Nitrates	3.9E-05		3.9E-05	E
Phosphates	0.0035		0.0035	E
Boron	0.028		0.028	E
Other Organics	0.085		0.085	E
Chromates	9.8E-05		9.8E-05	E
Cyanide	1.9E-06		1.9E-06	E
Mercury	9.8E-08		9.8E-08	E
Cadmium	0.0013		0.0013	E
Solid Waste	133		133	B

(1) Sum of precombustion process-related emissions from Table A-3b and precombustion fuel-related emissions from Table A-12b.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, A-58 and A-59.

Source: Franklin Associates, Ltd.

Table A-20

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF NATURAL GAS IN UTILITY BOILERS
(pounds of pollutants per 1,000 cubic feet of natural gas)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	0.0038	6.7E-04	0.0045	B
Nitrogen Oxides	0.12	0.39	0.51	B
Hydrocarbons (other than methane)	0.53	0.0014	0.53	C
Sulfur Oxides	1.97	6.7E-04	1.97	B
Carbon Monoxide	0.23	0.035	0.26	B
Fossil Carbon Dioxide	15.7	121	137	A
Non-Fossil Carbon Dioxide	0.028		0.028	B
Formaldehyde	8.8E-08	4.0E-05	4.0E-05	C
Other Aldehydes	3.5E-04		3.5E-04	C
Other Organics	8.7E-04		8.7E-04	D
Ammonia	9.5E-06	0.0030	0.0030	C
Lead	2.8E-07	3.2E-07	6.0E-07	B
Methane	0.38	3.0E-04	0.38	C
Kerosene	4.8E-07		4.8E-07	D
Chlorine	2.2E-07		2.2E-07	D
Hydrochloric Acid	9.8E-05		9.8E-05	C
Hydrogen Fluoride	1.3E-05		1.3E-05	C
Metals	1.1E-05		1.1E-05	D
Antimony	8.9E-08		8.9E-08	E
Arsenic	1.9E-07	1.2E-07	3.1E-07	E
Beryllium	1.4E-08		1.4E-08	E
Cadmium	2.7E-07	3.9E-08	3.0E-07	E
Chromium	2.3E-07	8.6E-07	1.1E-06	E
Cobalt	2.5E-07	1.0E-07	3.5E-07	E
Manganese	3.6E-07	2.7E-07	6.3E-07	E
Mercury	7.4E-08	1.2E-09	7.5E-08	E
Nickel	3.8E-06	1.7E-07	4.0E-06	E
Selenium	2.2E-07	9.3E-07	1.2E-06	E
Acreolin	1.9E-08		1.9E-08	D
Nitrous Oxide	1.2E-05		1.2E-05	D
Benzene	6.8E-08	1.3E-06	1.4E-06	D
Perchloroethylene	2.0E-08		2.0E-08	D
Trichloroethylene	1.8E-08		1.8E-08	D
Methylene Chloride	8.8E-08		8.8E-08	D
Carbon Tetrachloride	1.1E-07		1.1E-07	D
Phenols	5.6E-07		5.6E-07	D
Naphthalene	3.2E-08	4.7E-07	5.0E-07	D
Dioxins	1.1E-13		1.1E-13	D
n-nitrodimethylamine	4.1E-09		4.1E-09	D
Radionuclides (Ci)	3.6E-07	6.1E-05	6.1E-05	D

(continued)

Table A-20 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF NATURAL GAS IN UTILITY BOILERS
(pounds of pollutants per 1,000 cubic feet of natural gas)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	6.4E-10		6.4E-10	E
Metal Ion	1.4E-05		1.4E-05	E
Dissolved Solids	3.04	0.047	3.08	D
Suspended Solids	0.0054	0.050	0.055	D
BOD	0.0027	2.8E-04	0.0030	D
COD	0.019	0.024	0.043	D
Phenol	4.4E-08		4.4E-08	E
Oil	0.054		0.054	E
Sulfuric Acid	2.1E-05		2.1E-05	E
Iron	7.3E-05		7.3E-05	E
Ammonia	4.9E-06	5.4E-05	5.9E-05	E
Chromium	1.4E-04		1.4E-04	E
Lead	1.1E-09		1.1E-09	E
Zinc	4.8E-05		4.8E-05	E
Chlorides	0.14		0.14	E
Sodium	7.6E-07		7.6E-07	E
Calcium	4.1E-07		4.1E-07	E
Sulfates	0.11		0.11	E
Manganese	4.2E-05		4.2E-05	E
Fluorides	1.9E-06		1.9E-06	E
Nitrates	1.8E-07		1.8E-07	E
Phosphates	1.1E-05		1.1E-05	E
Boron	8.4E-05		8.4E-05	E
Other Organics	0.0088		0.0088	E
Chromates	2.2E-07		2.2E-07	E
Cyanide	2.1E-07		2.1E-07	E
Mercury	1.1E-08		1.1E-08	E
Cadmium	1.4E-04		1.4E-04	E
Solid Waste	5.8		5.8	B

(1) Sum of precombustion process-related emissions from Table A-2 and precombustion fuel-related emissions from Table A-11.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-21

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF NATURAL GAS IN INDUSTRIAL BOILERS
(pounds of pollutants per 1,000 cubic feet of natural gas)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	0.0038	0.0094	0.013	B
Nitrogen Oxides	0.12	0.31	0.43	B
Hydrocarbons (other than methane)	0.53	0.0095	0.54	C
Sulfur Oxides	1.97	0.075	2.04	B
Carbon Monoxide	0.23	0.060	0.29	B
Fossil Carbon Dioxide	15.7	118	134	A
Non-Fossil Carbon Dioxide	0.028		0.028	B
Formaldehyde	8.8E-08		8.8E-08	C
Other Aldehydes	3.5E-04		3.5E-04	C
Other Organics	8.7E-04		8.7E-04	D
Ammonia	9.5E-06		9.5E-06	C
Lead	2.8E-07		2.8E-07	B
Methane	0.38	0.0035	0.39	C
Kerosene	4.8E-07		4.8E-07	D
Chlorine	2.2E-07		2.2E-07	D
Hydrochloric Acid	9.8E-05		9.8E-05	C
Hydrogen Fluoride	1.3E-05		1.3E-05	C
Metals	1.1E-05		1.1E-05	D
Antimony	8.9E-08		8.9E-08	E
Arsenic	1.9E-07		1.9E-07	E
Beryllium	1.4E-08		1.4E-08	E
Cadmium	2.7E-07		2.7E-07	E
Chromium	2.3E-07		2.3E-07	E
Cobalt	2.5E-07		2.5E-07	E
Manganese	3.6E-07		3.6E-07	E
Mercury	7.4E-08		7.4E-08	E
Nickel	3.8E-06		3.8E-06	E
Selenium	2.2E-07		2.2E-07	E
Acreolin	1.9E-08		1.9E-08	D
Nitrous Oxide	1.2E-05		1.2E-05	D
Benzene	6.8E-08		6.8E-08	D
Perchloroethylene	2.0E-08		2.0E-08	D
Trichloroethylene	1.8E-08		1.8E-08	D
Methylene Chloride	8.8E-08		8.8E-08	D
Carbon Tetrachloride	1.1E-07		1.1E-07	D
Phenols	5.6E-07		5.6E-07	D
Naphthalene	3.2E-08		3.2E-08	D
Dioxins	1.1E-13		1.1E-13	D
n-nitrodimethylamine	4.1E-09		4.1E-09	D
Radionuclides (Ci)	3.6E-07		3.6E-07	D

(continued)

Table A-21 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF NATURAL GAS IN INDUSTRIAL BOILERS
(pounds of pollutants per 1,000 cubic feet of natural gas)

Waterborne Emissions	**Precombustion (1)**	**Combustion**	**Total**	**DQI**
Acid	6.4E-10		6.4E-10	E
Metal Ion	1.4E-05		1.4E-05	E
Dissolved Solids	3.04	0.047	3.08	D
Suspended Solids	0.0054	0.050	0.055	D
BOD	0.0027	2.8E-04	0.0030	D
COD	0.019	0.024	0.043	D
Phenol	4.4E-08		4.4E-08	E
Oil	0.054		0.054	E
Sulfuric Acid	2.1E-05		2.1E-05	E
Iron	7.3E-05		7.3E-05	E
Ammonia	4.9E-06	5.4E-05	5.9E-05	E
Chromium	1.4E-04		1.4E-04	E
Lead	1.1E-09		1.1E-09	E
Zinc	4.8E-05		4.8E-05	E
Chlorides	0.14		0.14	E
Sodium	7.6E-07		7.6E-07	E
Calcium	4.1E-07		4.1E-07	E
Sulfates	0.11		0.11	E
Manganese	4.2E-05		4.2E-05	E
Fluorides	1.9E-06		1.9E-06	E
Nitrates	1.8E-07		1.8E-07	E
Phosphates	1.1E-05		1.1E-05	E
Boron	8.4E-05		8.4E-05	E
Other Organics	0.0088		0.0088	E
Chromates	2.2E-07		2.2E-07	E
Cyanide	2.1E-07		2.1E-07	E
Mercury	1.1E-08		1.1E-08	E
Cadmium	1.4E-04		1.4E-04	E
Solid Waste	5.8		5.8	B

(1) Sum of precombustion process-related emissions from Table A-2 and precombustion fuel-related emissions from Table A-11.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Industrial Equipment. Natural gas is also used to power industrial equipment. One application is the use of natural gas to power compressors used for the pipeline transportation of natural gas. Again, the major pollutants of concern when using natural gas as a fuel are nitrogen oxides. Lesser amounts of carbon monoxide and hydrocarbons are emitted. However, for each unit of natural gas burned, compressor engines emit significantly more of these pollutants than do external combustion boilers (Reference A-6, page 3.2-1). Emissions for the internal combustion of natural gas are presented in Table A-22.

Diesel

Industrial Equipment. Diesel is used in a wide variety of industrial applications such as mobile refrigeration units, generators, pumps, and portable well-drilling equipment. Table A-23 shows average emissions for the internal combustion of diesel in industrial equipment.

Gasoline

Industrial Equipment. Gasoline is also used in a wide variety of industrial applications such as mobile refrigeration units, generators, pumps, and portable well-drilling equipment. Table A-24 shows average emissions for the internal combustion of gasoline in industrial equipment.

Liquefied Petroleum Gases

Industrial Equipment. Liquefied petroleum gas (LPG) consists of propane, butane, or a mixture of the two. This gas is obtained both from natural gas liquids plants and as a byproduct of petroleum refinery operations.

Gaseous pollutants such as nitrogen oxides, carbon monoxide, and hydrocarbons are produced when LPG is burned as a fuel. Table A-25 shows the precombustion and combustion emissions for the combustion of 1,000 gallons of LPG.

Fuel Grade Uranium

Nuclear power plants generate electricity by harnessing the thermal energy from controlled nuclear fission reactions. These reactions are used to produce steam, which in turn drives a turbine-generator to produce electricity. Environmental emissions for combustion of fuel grade uranium are shown in Table A-26.

Wood Wastes

The combustion of wood waste in boilers is mostly confined to those industries where it is available as a byproduct. It is burned to obtain both heat energy and to alleviate possible solid waste disposal problems. In boilers, wood waste is normally burned in the form of hogged wood, sawdust, shavings, chips, sander dust, or wood trim.

Table A-22

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF NATURAL GAS IN INDUSTRIAL EQUIPMENT
(pounds of pollutants per 1,000 cubic feet of natural gas)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	0.0038	0.0070	0.011	B
Nitrogen Oxides	0.12	1.9	2.0	B
Hydrocarbons (other than methane)	0.53	0.71	1.2	C
Sulfur Oxides	2.0	0.00060	2.0	B
Carbon Monoxide	0.23	0.275	0.50	B
Fossil Carbon Dioxide	16	127	143	A
Non-Fossil Carbon Dioxide	0.028		0.028	B
Formaldehyde	8.8E-08		8.8E-08	C
Other Aldehydes	3.5E-04		3.5E-04	C
Other Organics	8.7E-04		8.7E-04	D
Ammonia	9.5E-06		9.5E-06	C
Lead	2.8E-07		2.8E-07	B
Methane	0.38		0.38	C
Kerosene	4.8E-07		4.8E-07	D
Chlorine	2.2E-07		2.2E-07	D
Hydrochloric Acid	9.8E-05		9.8E-05	C
Hydrogen Fluoride	1.3E-05		1.3E-05	C
Metals	1.1E-05		1.1E-05	D
Antimony	8.9E-08		8.9E-08	E
Arsenic	1.9E-07		1.9E-07	E
Beryllium	1.4E-08		1.4E-08	E
Cadmium	2.7E-07		2.7E-07	E
Chromium	2.3E-07		2.3E-07	E
Cobalt	2.5E-07		2.5E-07	E
Manganese	3.6E-07		3.6E-07	E
Mercury	7.4E-08		7.4E-08	E
Nickel	3.8E-06		3.8E-06	E
Selenium	2.2E-07		2.2E-07	E
Acreolin	1.9E-08		1.9E-08	D
Nitrous Oxide	1.2E-05		1.2E-05	D
Benzene	6.8E-08		6.8E-08	D
Perchloroethylene	2.0E-08		2.0E-08	D
Trichloroethylene	1.8E-08		1.8E-08	D
Methylene Chloride	8.8E-08		8.8E-08	D
Carbon Tetrachloride	1.1E-07		1.1E-07	D
Phenols	5.6E-07		5.6E-07	D
Naphthalene	3.2E-08		3.2E-08	D
Dioxins	1.1E-13		1.1E-13	D
n-nitrodimethylamine	4.1E-09		4.1E-09	D
Radionuclides (Ci)	3.6E-07		3.6E-07	D

(continued)

Table A-22 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF NATURAL GAS IN INDUSTRIAL EQUIPMENT
(pounds of pollutants per 1,000 cubic feet of natural gas)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	6.4E-10		6.4E-10	E
Metal Ion	1.4E-05		1.4E-05	E
Dissolved Solids	3.0		3.0	D
Suspended Solids	0.0054		5.4E-03	D
BOD	0.0027		2.7E-03	D
COD	0.019		1.9E-02	D
Phenol	4.4E-08		4.4E-08	E
Oil	0.054		5.4E-02	E
Sulfuric Acid	2.1E-05		2.1E-05	E
Iron	7.3E-05		7.3E-05	E
Ammonia	4.9E-06		4.9E-06	E
Chromium	1.4E-04		1.4E-04	E
Lead	1.1E-09		1.1E-09	E
Zinc	4.8E-05		4.8E-05	E
Chlorides	0.14		1.4E-01	E
Sodium	7.6E-07		7.6E-07	E
Calcium	4.1E-07		4.1E-07	E
Sulfates	0.11		1.1E-01	E
Manganese	4.2E-05		4.2E-05	E
Fluorides	1.9E-06		1.9E-06	E
Nitrates	1.8E-07		1.8E-07	E
Phosphates	1.1E-05		1.1E-05	E
Boron	8.4E-05		8.4E-05	E
Other Organics	8.8E-03		8.8E-03	E
Chromates	2.2E-07		2.2E-07	E
Cyanide	2.1E-07		2.1E-07	E
Mercury	1.1E-08		1.1E-08	E
Cadmium	1.4E-04		1.4E-04	E
Solid Waste	5.8		5.8	B

(1) Sum of precombustion process-related emissions from Table A-2 and precombustion fuel-related emissions from Table A-11.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-23

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF DIESEL POWERED INDUSTRIAL EQUIPMENT
(pounds of pollutants per 1,000 gallons of diesel fuel)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.66	33.5	35.2	B
Nitrogen Oxides	8.47	469	477.5	B
Hydrocarbons (other than methane)	50.2	37.5	87.7	C
Sulfur Oxides	25.8	31.2	57	B
Carbon Monoxide	6.36	102	108.4	B
Fossil Carbon Dioxide	2,627	23,005	25,632	A
Non-Fossil Carbon Dioxide	6.10		6.10	B
Formaldehyde	2.1E-05	7.00	7.0E+00	C
Other Aldehydes	0.47		0.47	C
Other Organics	0.30		0.30	D
Ammonia	0.040		0.040	C
Lead	1.4E-04		0.0001	B
Methane	4.05		4.05	C
Kerosene	1.0E-04		1.0E-04	D
Chlorine	0.0015		0.0015	D
Hydrochloric Acid	0.025		0.025	C
Hydrogen Fluoride	0.0033		0.0033	C
Metals	0.0025		0.0025	D
Antimony	3.8E-05		0.0000	E
Arsenic	7.9E-05		0.0001	E
Beryllium	5.5E-06		5.5E-06	E
Cadmium	1.2E-04		0.0001	E
Chromium	9.0E-05		0.0001	E
Cobalt	1.1E-04		0.0001	E
Manganese	1.1E-04		0.0001	E
Mercury	2.6E-05		0.0000	E
Nickel	0.0017		0.00	E
Selenium	7.2E-05		0.0001	E
Acreolin	4.7E-06		4.7E-06	D
Nitrous Oxide	0.0028		0.0028	D
Benzene	1.5E-05		1.5E-05	D
Perchloroethylene	4.6E-06		4.6E-06	D
Trichloroethylene	4.4E-06		4.4E-06	D
Methylene Chloride	2.1E-05		2.1E-05	D
Carbon Tetrachloride	1.9E-05		1.9E-05	D
Phenols	1.2E-04		1.2E-04	D
Naphthalene	7.0E-06		7.0E-06	D
Dioxins	2.5E-11		2.5E-11	D
n-nitrodimethylamine	9.9E-07		9.9E-07	D
Radionuclides (Ci)	8.7E-05		8.7E-05	D

(continued)

Table A-23 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF DIESEL POWERED INDUSTRIAL EQUIPMENT
(pounds of pollutants per 1,000 gallons of diesel fuel)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	8.4E-06		8.4E-06	E
Metal Ion	0.18		0.18	E
Dissolved Solids	34.8		34.8	D
Suspended Solids	0.79		0.79	D
BOD	0.13		0.13	D
COD	0.87		0.87	D
Phenol	5.8E-04		5.8E-04	E
Oil	0.81		0.81	E
Sulfuric Acid	0.0069		0.0069	E
Iron	0.019		0.019	E
Ammonia	0.014		0.014	E
Chromium	0.0013		0.0013	E
Lead	1.5E-05		1.5E-05	E
Zinc	6.5E-04		6.5E-04	E
Chlorides	1.28		1.28	E
Sodium	1.6E-04		1.6E-04	E
Calcium	9.0E-05		9.0E-05	E
Sulfates	1.03		1.03	E
Manganese	0.0092		0.0092	E
Fluorides	4.1E-04		4.1E-04	E
Nitrates	3.9E-05		3.9E-05	E
Phosphates	0.0035		0.0035	E
Boron	0.028		0.028	E
Other Organics	0.085		0.085	E
Chromates	9.8E-05		9.8E-05	E
Cyanide	1.9E-06		1.9E-06	E
Mercury	9.8E-08		9.8E-08	E
Cadmium	0.0013		0.0013	E
Solid Waste	133		133	B

(1) Sum of precombustion process-related emissions from Table A-3b and precombustion fuel-related emissions from Table A-12b.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-24

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF GASOLINE POWERED INDUSTRIAL EQUIPMENT
(pounds of pollutants per 1,000 gallons of gasoline)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.42	6.47	7.89	B
Nitrogen Oxides	7.22	102	109	B
Hydrocarbons (other than methane)	42.8	132	175	C
Sulfur Oxides	22.0	5.31	27.3	B
Carbon Monoxide	5.42	3,940	3,945	B
Fossil Carbon Dioxide	2,239	12,844	15,083	A
Non-Fossil Carbon Dioxide	5.20		5.20	B
Formaldehyde	1.8E-05	4.36	4.36	C
Other Aldehydes	0.40		0.40	C
Other Organics	0.26		0.26	D
Ammonia	0.034		0.034	C
Lead	1.2E-04		1.2E-04	B
Methane	3.45		3.45	C
Kerosene	8.9E-05		8.9E-05	D
Chlorine	0.0013		0.0013	D
Hydrochloric Acid	0.021		0.021	C
Hydrogen Fluoride	0.0028		0.0028	C
Metals	0.0021		0.0021	D
Antimony	3.2E-05		3.2E-05	E
Arsenic	6.7E-05		6.7E-05	E
Beryllium	4.7E-06		4.7E-06	E
Cadmium	1.0E-04		1.0E-04	E
Chromium	7.6E-05		7.6E-05	E
Cobalt	9.2E-05		9.2E-05	E
Manganese	9.1E-05		9.1E-05	E
Mercury	2.2E-05		2.2E-05	E
Nickel	0.0014		0.0014	E
Selenium	6.2E-05		6.2E-05	E
Acreolin	4.0E-06		4.0E-06	D
Nitrous Oxide	0.0024		0.0024	D
Benzene	1.3E-05		1.3E-05	D
Perchloroethylene	3.9E-06		3.9E-06	D
Trichloroethylene	3.8E-06		3.8E-06	D
Methylene Chloride	1.8E-05		1.8E-05	D
Carbon Tetrachloride	1.6E-05		1.6E-05	D
Phenols	1.0E-04		1.0E-04	D
Naphthalene	6.0E-06		6.0E-06	D
Dioxins	2.2E-11		2.2E-11	D
n-nitrodimethylamine	8.4E-07		8.4E-07	D
Radionuclides (Ci)	7.4E-05		7.4E-05	D

(continued)

Table A-24 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF GASOLINE POWERED INDUSTRIAL EQUIPMENT
(pounds of pollutants per 1,000 gallons of gasoline)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	7.1E-06		7.1E-06	E
Metal Ion	0.15		0.15	E
Dissolved Solids	29.7		29.7	D
Suspended Solids	0.68		0.68	D
BOD	0.11		0.11	D
COD	0.74		0.74	D
Phenol	4.9E-04		4.9E-04	E
Oil	0.69		0.69	E
Sulfuric Acid	0.0059		0.0059	E
Iron	0.016		0.016	E
Ammonia	0.012		0.012	E
Chromium	0.0011		0.0011	E
Lead	1.3E-05		1.3E-05	E
Zinc	5.5E-04		5.5E-04	E
Chlorides	1.09		1.09	E
Sodium	1.4E-04		1.4E-04	E
Calcium	7.6E-05		7.6E-05	E
Sulfates	0.88		0.88	E
Manganese	0.0078		0.0078	E
Fluorides	3.5E-04		3.5E-04	E
Nitrates	3.3E-05		3.3E-05	E
Phosphates	0.0030		0.0030	E
Boron	0.024		0.024	E
Other Organics	0.072		0.072	E
Chromates	8.3E-05		8.3E-05	E
Cyanide	1.6E-06		1.6E-06	E
Mercury	8.4E-08		8.4E-08	E
Cadmium	0.0011		0.0011	E
Solid Waste	113		113	B

(1) Sum of precombustion process-related emissions from Table A-3c and precombustion fuel-related emissions from Table A-12c.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-25

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF LIQUEFIED PETROLEUM GAS IN INDUSTRIAL BOILERS (pounds of pollutants per 1,000 gallons of LPG)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.0	0.60	1.6	B
Nitrogen Oxides	5.3	20	25	B
Hydrocarbons (other than methane)	31	0.26	32	C
Sulfur Oxides	16.1	0.017	16.2	B
Carbon Monoxide	4.0	3.40	7.37	B
Fossil Carbon Dioxide	1,640	13,600	15,240	A
Non-Fossil Carbon Dioxide	3.8		3.8	B
Formaldehyde	1.3E-05		1.3E-05	C
Other Aldehydes	0.29		0.29	C
Other Organics	0.19		0.19	D
Ammonia	0.025		0.025	C
Lead	8.5E-05	0.28	0.28	B
Methane	2.5		2.5	C
Kerosene	6.5E-05		6.5E-05	D
Chlorine	9.6E-04		9.6E-04	D
Hydrochloric Acid	0.015		0.015	C
Hydrogen Fluoride	0.0020		0.0020	C
Metals	0.0016		0.0016	D
Antimony	2.4E-05		2.4E-05	E
Arsenic	4.9E-05		4.9E-05	E
Beryllium	3.4E-06		3.4E-06	E
Cadmium	7.4E-05		7.4E-05	E
Chromium	5.6E-05		5.6E-05	E
Cobalt	6.7E-05		6.7E-05	E
Manganese	6.7E-05		6.7E-05	E
Mercury	1.6E-05		1.6E-05	E
Nickel	0.0010		0.0010	E
Selenium	4.5E-05		4.5E-05	E
Acreolin	2.9E-06		2.9E-06	D
Nitrous Oxide	0.0018		0.0018	D
Benzene	9.4E-06		9.4E-06	D
Perchloroethylene	2.9E-06		2.9E-06	D
Trichloroethylene	2.8E-06		2.8E-06	D
Methylene Chloride	1.3E-05		1.3E-05	D
Carbon Tetrachloride	1.2E-05		1.2E-05	D
Phenols	7.7E-05		7.7E-05	D
Naphthalene	4.4E-06		4.4E-06	D
Dioxins	1.6E-11		1.6E-11	D
n-nitrodimethylamine	6.2E-07		6.2E-07	D
Radionuclides (Ci)	5.4E-05		5.4E-05	D

(continued)

Table A-25 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF LIQUEFIED PETROLEUM GAS IN INDUSTRIAL BOILERS (pounds of pollutants per 1,000 gallons of LPG)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	5.2E-06		5.2E-06	E
Metal Ion	0.11		0.11	E
Dissolved Solids	21.8		21.8	D
Suspended Solids	0.50		0.50	D
BOD	0.081		0.081	D
COD	0.55		0.55	D
Phenol	3.6E-04		3.6E-04	E
Oil	0.51		0.51	E
Sulfuric Acid	0.0043		0.0043	E
Iron	0.012		0.012	E
Ammonia	0.0088		0.0088	E
Chromium	8.2E-04		8.2E-04	E
Lead	9.3E-06		9.3E-06	E
Zinc	4.1E-04		4.1E-04	E
Chlorides	0.80		0.80	E
Sodium	1.0E-04		1.0E-04	E
Calcium	5.6E-05		5.6E-05	E
Sulfates	0.65		0.65	E
Manganese	0.0057		0.0057	E
Fluorides	2.6E-04		2.6E-04	E
Nitrates	2.4E-05		2.4E-05	E
Phosphates	0.0022		0.0022	E
Boron	0.017		0.017	E
Other Organics	0.053		0.053	E
Chromates	6.1E-05		6.1E-05	E
Cyanide	1.2E-06		1.2E-06	E
Mercury	6.1E-08		6.1E-08	E
Cadmium	8.0E-04		8.0E-04	E
Solid Waste	83		83	B

(1) Sum of precombustion process-related emissions from Table A-3d and precombustion fuel-related emissions from Table A-12d.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-26

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF FUEL-GRADE URANIUM
(pounds of pollutants per 1,000 pounds of uranium)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	44,000		44,000	B
Nitrogen Oxides	58,000		58,000	B
Hydrocarbons (other than methane)	6,500		6,500	C
Sulfur Oxides	174,000		174,000	B
Carbon Monoxide	5,700		5,700	B
Fossil Carbon Dioxide	6,800,000		6,800,000	A
Non-Fossil Carbon Dioxide	129,000		129,000	B
Formaldehyde	0.41		0.41	C
Other Aldehydes	18.9		18.9	C
Other Organics	45.8		45.8	D
Ammonia	30.7		30.7	C
Lead	0.36		0.36	B
Methane	15,000		15,000	C
Kerosene	223		223	D
Chlorine	0.50		0.50	D
Hydrochloric Acid	447		447	C
Hydrogen Fluoride	61.8		61.8	C
Metals	52.7		52.7	D
Antimony	0.049		0.049	E
Arsenic	0.21		0.21	E
Beryllium	0.023		0.023	E
Cadmium	0.055		0.055	E
Chromium	0.27		0.27	E
Cobalt	0.13		0.13	E
Manganese	1.16		1.16	E
Mercury	0.17		0.17	E
Nickel	1.38		1.38	E
Selenium	0.64		0.64	E
Acreolin	0.089		0.089	D
Nitrous Oxide	50.4		50.4	D
Benzene	0.30		0.30	D
Perchloroethylene	0.085		0.085	D
Trichloroethylene	0.084		0.084	D
Methylene Chloride	0.37		0.37	D
Carbon Tetrachloride	0.15		0.15	D
Phenols	2.57		2.57	D
Naphthalene	0.15		0.15	D
Dioxins	4.8E-07		4.8E-07	D
n-nitrodimethylamine	0.019		0.019	D
Radionuclides (Ci)	1.65		1.65	D

(continued)

Table A-26 (cont)

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF FUEL-GRADE URANIUM
(pounds of pollutants per 1,000 pounds of uranium)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	1.0E-04		1.0E-04	E
Metal Ion	2.11		2.11	E
Dissolved Solids	27,000		27,000	D
Suspended Solids	4,270		4,270	D
BOD	27.9		27.9	D
COD	385		385	D
Phenol	0.0068		0.0068	E
Oil	484		484	E
Sulfuric Acid	57.5		57.5	E
Iron	4,440		4,440	E
Ammonia	334		334	E
Chromium	1.25		1.25	E
Lead	1.8E-04		1.8E-04	E
Zinc	0.43		0.43	E
Chlorides	2,230		2,230	E
Sodium	353		353	E
Calcium	192		192	E
Sulfates	112,000		112,000	E
Manganese	395		395	E
Fluorides	889		889	E
Nitrates	83.8		83.8	E
Phosphates	28.7		28.7	E
Boron	230		230	E
Other Organics	122		122	E
Chromates	0.079		0.079	E
Cyanide	0.0018		0.0018	E
Mercury	9.6E-05		9.6E-05	E
Cadmium	1.25		1.25	E
Solid Waste	6,750,000		6,750,000	B

(1) Sum of precombustion process-related emissions from Table A-4 and precombustion fuel-related emissions from Table A-13.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Heating values for this waste range from 4000 to 5000 Btu per pound of fuel on a wet, as-fired basis. The moisture content of as-fired wood is typically near 50 percent, but may vary from 5 to 75 weight percent.

Generally, bark is the major type of waste burned in pulp mills; either a mixture of wood and bark waste or wood waste alone is burned most frequently in the lumber, furniture, and plywood industries. As of 1980, there were approximately 1600 wood-fired boilers operating in the U.S., with a total capacity of over 30 GW (1.0 x 10^{11} Btu per hour).

The emission factors in given in Table A-27 are based on wet, as-fired wood waste with average properties of 50 percent (by weight) moisture and 4500 Btu per pound higher heating value.

Solid wastes from the combustion of wood are proportional to the ash content of the wood. This typically varies between 0.5 and 2.2 percent by weight of dry wood. Some is released as fly ash, and some remains as bottom ash. If there are controls for particulate matter, some of the fly ash is collected before leaving the emissions stack.

The solid residues from the combustion process are boiler ash, clinker and slag, fly ash, and carbon char. The major components of these wastes are silica, alumina, and calcium oxides. Minor constituents include sodium, magnesium, potassium, and trace amounts of heavy metals (Reference A-48). Another source of solid wastes is impurities in wood bark (sand and dirt), which are picked up during transportation as rough logs are dragged to central loading points.

Mobile Sources

Transportation sources such as barges, locomotives, and diesel- and gasoline-powered trucks constitute a major source of air pollution. Some of the emissions, such as carbon monoxide and hydrocarbons, are due to incomplete combustion. Other emissions, such as nitrogen oxides, are normal byproducts of combustion. Lead emissions are directly related to the addition of tetraethyl lead to the fuel as an antiknock compound. Lead emissions in the U.S. have been decreasing significantly due to EPA regulations requiring a phase-out of lead in fuels. The major gaseous pollutants from mobile sources are carbon monoxide, nitrogen oxides, and hydrocarbons.

Trucks. Transportation trucks are classified into two categories. Combination or tractor-trailer trucks are those most commonly used to transport large quantities of material. Single unit trucks are generally used for local delivery. Several assumptions and calculations were made based on these classifications:

1. Single unit delivery trucks have a gross weight of 8,500 to 14,000 pounds. Tractor-trailer trucks include all trucks greater than 14,000 pounds in gross weight.

Table A-27

ENVIRONMENTAL EMISSIONS FOR THE COMBUSTION OF WOOD IN INDUSTRIAL BOILERS
(pounds of pollutant per 1,000 lb of wood—as fired)

Atmospheric Emissions	Combustion (lb/1000 lb)	pounds per MM Btu (1)	DQI
Particulates	0.085	0.019	C
Nitrogen oxides	0.75	0.17	C
Sulfur oxides	0.038	0.0083	C
Carbon monoxide	6.80	1.51	C
Carbon dioxide	1,050	233	C
Lead	6.0E-04	1.3E-04	C
Total organic compounds (unspeciated)	0.11	0.024	D
Speciated organic compounds			
Phenols	0.020	0.0043	E
Formaldehyde	0.0033	7.3E-04	E
Acetaldehyde	0.0015	3.3E-04	E
Benzene	0.0018	4.0E-04	E
Naphthalene	0.0012	2.6E-04	E
Speciated metals			
Potassium	0.39	0.087	E
Zinc	0.0022	4.9E-04	E
Barium	0.0022	4.9E-04	E
Sodium	0.0090	0.0020	E
Iron	0.022	0.0049	E
Chlorine	0.0039	8.7E-04	E
Rubidium	6.0E-04	1.3E-04	E
Manganese	0.0045	0.0010	E
Nickel	2.8E-04	6.2E-05	E
Arsenic	4.4E-05	9.8E-06	E
Chromium	2.3E-05	5.1E-06	E
Solid Wastes	45.0	10.0	C

(1) Wood "as fired" has a higher heating value of about 4500 Btu/lb.
References A-6 and A-48.

Source: Franklin Associates, Ltd.

2. Average miles per gallon for tractor-trailers = 5.9 miles per gallon. These gallons are distributed based on the following fuel usage split: 19.4 percent gasoline tractor-trailers and 80.6 percent diesel tractor-trailers. Average miles per gallon for single unit trucks = 6.8 miles per gallon. These gallons are distributed based on the following fuel usage split: 19.4 percent gasoline trucks and 80.6 percent diesel trucks (Reference A-4).

Emissions from trucks were determined using the following assumptions:

1. Low and high altitude emissions are averaged.

2. 19.4 percent of material transport trucks use gasoline for fuel, 80.4 percent use diesel, and 0.2 percent use LPG (Reference A-4). The use of LPG was considered insignificant.

3. Emissions obtained for each truck model year transporting material in 1990 are weighted based on the miles traveled per model year.

Tables A-28a, A-28b, A-29a and A-29b show the pre-combustion and combustion emissions for tractor-trailer and single unit delivery trucks in 1992.

Locomotives. Table A-30 lists the emissions resulting from transportation of material by locomotives. Freight locomotives use diesel fuel exclusively (Reference A-4).

Barges and Ocean Freighters. Commercial water transport can be categorized by boundary of travel, fuel used, and type of power source. In an effort to narrow these options, the following assumptions were made:

1. Barges are typically vessels traveling in the Great Lakes, rivers, or along a coast. Ocean freighters encompass longer travel not within the range or capability of a barge.

2. Only two options are available for a power source—diesel fuel and steam produced from residual oil.

3. 77.3 percent of barges use diesel fuel in their engines, and 22.7 percent use residual oil to generate steam for steam turbines (Reference A-4).

4. 90.8 percent of ocean freighters utilize residual fuel in steam turbines, and 9.2 percent have diesel engines (Reference A-4).

5. Power usage of the engines is modeled at 50 percent of full capacity. This adjusts for fuel use and emissions occurring at dockside while the engine is idling, as well as fuel use and emissions during transport.

Tables A-31 and A-32 list the emissions for transport of material by barge and ocean freighter, respectively.

Table A-28a

ENVIRONMENTAL EMISSIONS FOR 1992 TRACTOR-TRAILER GASOLINE POWERED TRUCKS (pounds of pollutants per 1,000 gallons of gasoline)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.42	43.3	44.7	B
Nitrogen Oxides	7.22	58.3	65.5	B
Hydrocarbons (other than methane)	42.8	20.5	63.3	C
Sulfur Oxides	22.0	4.34	26.3	B
Carbon Monoxide	5.42	380	385	B
Fossil Carbon Dioxide	2,239	18,400	20,639	A
Non-Fossil Carbon Dioxide	5.20		5.20	B
Formaldehyde	1.8E-05		1.8E-05	C
Other Aldehydes	0.40		0.40	C
Other Organics	0.26	117	117	D
Ammonia	0.034		0.034	C
Lead	1.2E-04	0.031	0.031	B
Methane	3.45		3.45	C
Kerosene	8.9E-05		8.9E-05	D
Chlorine	0.0013		0.0013	D
Hydrochloric Acid	0.021		0.021	C
Hydrogen Fluoride	0.0028		0.0028	C
Metals	0.0021		0.0021	D
Antimony	3.2E-05		3.2E-05	E
Arsenic	6.7E-05		6.7E-05	E
Beryllium	4.7E-06		4.7E-06	E
Cadmium	1.0E-04		1.0E-04	E
Chromium	7.6E-05		7.6E-05	E
Cobalt	9.2E-05		9.2E-05	E
Manganese	9.1E-05		9.1E-05	E
Mercury	2.2E-05		2.2E-05	E
Nickel	0.0014		0.0014	E
Selenium	6.2E-05		6.2E-05	E
Acreolin	4.0E-06		4.0E-06	D
Nitrous Oxide	0.0024		0.0024	D
Benzene	1.3E-05		1.3E-05	D
Perchloroethylene	3.9E-06		3.9E-06	D
Trichloroethylene	3.8E-06		3.8E-06	D
Methylene Chloride	1.8E-05		1.8E-05	D
Carbon Tetrachloride	1.6E-05		1.6E-05	D
Phenols	1.0E-04		1.0E-04	D
Naphthalene	6.0E-06		6.0E-06	D
Dioxins	2.2E-11		2.2E-11	D
n-nitrodimethylamine	8.4E-07		8.4E-07	D
Radionuclides (Ci)	7.4E-05		7.4E-05	D

(continued)

Table A-28a (cont)

ENVIRONMENTAL EMISSIONS FOR 1992 TRACTOR-TRAILER GASOLINE POWERED TRUCKS
(pounds of pollutants per 1,000 gallons of gasoline)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	7.1E-06		7.1E-06	E
Metal Ion	0.15		0.15	E
Dissolved Solids	29.7		29.7	D
Suspended Solids	0.68		0.68	D
BOD	0.11		0.11	D
COD	0.74		0.74	D
Phenol	4.9E-04		4.9E-04	E
Oil	0.69		0.69	E
Sulfuric Acid	0.0059		0.0059	E
Iron	0.016		0.016	E
Ammonia	0.012		0.012	E
Chromium	0.0011		0.0011	E
Lead	1.3E-05		1.3E-05	E
Zinc	5.5E-04		5.5E-04	E
Chlorides	1.09		1.09	E
Sodium	1.4E-04		1.4E-04	E
Calcium	7.6E-05		7.6E-05	E
Sulfates	0.88		0.88	E
Manganese	0.0078		0.0078	E
Fluorides	3.5E-04		3.5E-04	E
Nitrates	3.3E-05		3.3E-05	E
Phosphates	0.0030		0.0030	E
Boron	0.024		0.024	E
Other Organics	0.072		0.072	E
Chromates	8.3E-05		8.3E-05	E
Cyanide	1.6E-06		1.6E-06	E
Mercury	8.4E-08		8.4E-08	E
Cadmium	0.0011		0.0011	E
Solid Waste	113		113	B

(1) Sum of precombustion process-related emissions from Table A-3c and precombustion fuel-related emissions from Table A-12c.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-28b

ENVIRONMENTAL EMISSIONS FOR 1992 TRACTOR-TRAILER DIESEL POWERED TRUCKS (pounds of pollutants per 1,000 gallons of diesel fuel)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.66	29.8	31.5	B
Nitrogen Oxides	8.47	210	218	B
Hydrocarbons (other than methane)	50.2	37.7	87.9	C
Sulfur Oxides	25.8	36.2	62.0	B
Carbon Monoxide	6.36	209	215	B
Fossil Carbon Dioxide	2,627	22,800	25,427	A
Non-Fossil Carbon Dioxide	6.10		6.10	B
Formaldehyde	2.1E-05		2.1E-05	C
Other Aldehydes	0.47	5.50	5.97	C
Other Organics	0.30	116	116	D
Ammonia	0.040		0.040	C
Lead	1.4E-04		1.4E-04	B
Methane	4.05		4.05	C
Kerosene	1.0E-04		1.0E-04	D
Chlorine	0.0015		0.0015	D
Hydrochloric Acid	0.025		0.025	C
Hydrogen Fluoride	0.0033		0.0033	C
Metals	0.0025		0.0025	D
Antimony	3.8E-05		3.8E-05	E
Arsenic	7.9E-05		7.9E-05	E
Beryllium	5.5E-06		5.5E-06	E
Cadmium	1.2E-04		1.2E-04	E
Chromium	9.0E-05		9.0E-05	E
Cobalt	1.1E-04		1.1E-04	E
Manganese	1.1E-04		1.1E-04	E
Mercury	2.6E-05		2.6E-05	E
Nickel	0.0017		0.0017	E
Selenium	7.2E-05		7.2E-05	E
Acreolin	4.7E-06		4.7E-06	D
Nitrous Oxide	0.0028		0.0028	D
Benzene	1.5E-05		1.5E-05	D
Perchloroethylene	4.6E-06		4.6E-06	D
Trichloroethylene	4.4E-06		4.4E-06	D
Methylene Chloride	2.1E-05		2.1E-05	D
Carbon Tetrachloride	1.9E-05		1.9E-05	D
Phenols	1.2E-04		1.2E-04	D
Naphthalene	7.0E-06		7.0E-06	D
Dioxins	2.5E-11		2.5E-11	D
n-nitrodimethylamine	9.9E-07		9.9E-07	D
Radionuclides (Ci)	8.7E-05		8.7E-05	D

(continued)

Table A-28b (cont)

ENVIRONMENTAL EMISSIONS FOR 1992 TRACTOR-TRAILER DIESEL POWERED TRUCKS
(pounds of pollutants per 1,000 gallons of diesel fuel)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	8.4E-06		8.4E-06	E
Metal Ion	0.18		0.18	E
Dissolved Solids	34.8		34.8	D
Suspended Solids	0.79		0.79	D
BOD	0.13		0.13	D
COD	0.87		0.87	D
Phenol	5.8E-04		5.8E-04	E
Oil	0.81		0.81	E
Sulfuric Acid	0.0069		0.0069	E
Iron	0.019		0.019	E
Ammonia	0.014		0.014	E
Chromium	0.0013		0.0013	E
Lead	1.5E-05		1.5E-05	E
Zinc	6.5E-04		6.5E-04	E
Chlorides	1.28		1.28	E
Sodium	1.6E-04		1.6E-04	E
Calcium	9.0E-05		9.0E-05	E
Sulfates	1.03		1.03	E
Manganese	0.0092		0.0092	E
Fluorides	4.1E-04		4.1E-04	E
Nitrates	3.9E-05		3.9E-05	E
Phosphates	0.0035		0.0035	E
Boron	0.028		0.028	E
Other Organics	0.085		0.085	E
Chromates	9.8E-05		9.8E-05	E
Cyanide	1.9E-06		1.9E-06	E
Mercury	9.8E-08		9.8E-08	E
Cadmium	0.0013		0.0013	E
Solid Waste	133		133	B

(1) Sum of precombustion process-related emissions from Table A-3b and precombustion fuel-related emissions from Table A-12b.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-29a

ENVIRONMENTAL EMISSIONS FOR 1992 SINGLE-UNIT GASOLINE POWERED TRUCKS
(pounds of pollutants per 1,000 gallons of gasoline)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.42	63.4	64.8	B
Nitrogen Oxides	7.22	76.5	83.7	B
Hydrocarbons (other than methane)	42.8	26.8	69.6	C
Sulfur Oxides	22.0	4.30	26.3	B
Carbon Monoxide	5.42	528	533	B
Fossil Carbon Dioxide	2,240	18,200	20,440	A
Non-Fossil Carbon Dioxide	5.2		5.2	B
Formaldehyde	1.8E-05		1.8E-05	C
Other Aldehydes	0.40		0.40	C
Other Organics	0.26	171	171	D
Ammonia	0.034		0.034	C
Lead	1.2E-04	0.031	0.031	B
Methane	3.45		3.45	C
Kerosene	8.9E-05		8.9E-05	D
Chlorine	0.0013		0.0013	D
Hydrochloric Acid	0.021		0.021	C
Hydrogen Fluoride	0.0028		0.0028	C
Metals	0.0021		0.0021	D
Antimony	3.2E-05		3.2E-05	E
Arsenic	6.7E-05		6.7E-05	E
Beryllium	4.7E-06		4.7E-06	E
Cadmium	1.0E-04		1.0E-04	E
Chromium	7.6E-05		7.6E-05	E
Cobalt	9.2E-05		9.2E-05	E
Manganese	9.1E-05		9.1E-05	E
Mercury	2.2E-05		2.2E-05	E
Nickel	0.0014		0.0014	E
Selenium	6.2E-05		6.2E-05	E
Acreolin	4.0E-06		4.0E-06	D
Nitrous Oxide	0.0024		0.0024	D
Benzene	1.3E-05		1.3E-05	D
Perchloroethylene	3.9E-06		3.9E-06	D
Trichloroethylene	3.8E-06		3.8E-06	D
Methylene Chloride	1.8E-05		1.8E-05	D
Carbon Tetrachloride	1.6E-05		1.6E-05	D
Phenols	1.0E-04		1.0E-04	D
Naphthalene	6.0E-06		6.0E-06	D
Dioxins	2.2E-11		2.2E-11	D
n-nitrodimethylamine	8.4E-07		8.4E-07	D
Radionuclides (Ci)	7.4E-05		7.4E-05	D

(continued)

Table A-29a (cont)

ENVIRONMENTAL EMISSIONS FOR 1992 SINGLE-UNIT GASOLINE POWERED TRUCKS
(pounds of pollutants per 1,000 gallons of gasoline)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	7.1E-06		7.1E-06	E
Metal Ion	0.15		0.15	E
Dissolved Solids	29.7		29.7	D
Suspended Solids	0.68		0.68	D
BOD	0.11		0.11	D
COD	0.74		0.74	D
Phenol	4.9E-04		4.9E-04	E
Oil	0.69		0.69	E
Sulfuric Acid	0.0059		0.0059	E
Iron	0.016		0.016	E
Ammonia	0.012		0.012	E
Chromium	0.0011		0.0011	E
Lead	1.3E-05		1.3E-05	E
Zinc	5.5E-04		5.5E-04	E
Chlorides	1.09		1.09	E
Sodium	1.4E-04		1.4E-04	E
Calcium	7.6E-05		7.6E-05	E
Sulfates	0.88		0.88	E
Manganese	0.0078		0.0078	E
Fluorides	3.5E-04		3.5E-04	E
Nitrates	3.3E-05		3.3E-05	E
Phosphates	0.0030		0.0030	E
Boron	0.024		0.024	E
Other Organics	0.072		0.072	E
Chromates	8.3E-05		8.3E-05	E
Cyanide	1.6E-06		1.6E-06	E
Mercury	8.4E-08		8.4E-08	E
Cadmium	0.0011		0.0011	E
Solid Waste	113		113	B

(1) Sum of precombustion process-related emissions from Table A-3c and precombustion fuel-related emissions from Table A-12c.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-29b

ENVIRONMENTAL EMISSIONS FOR 1992 SINGLE-UNIT DIESEL POWERED TRUCKS
(pounds of pollutants per 1,000 gallons of diesel fuel)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.66	69.1	70.8	B
Nitrogen Oxides	8.47	312	321	B
Hydrocarbons (other than methane)	50.2	54.2	104	C
Sulfur Oxides	25.8	36.2	62.0	B
Carbon Monoxide	6.36	300	306	B
Fossil Carbon Dioxide	2,630	22,700	25,330	A
Non-Fossil Carbon Dioxide	6.10		6.10	B
Formaldehyde	2.1E-05		2.1E-05	C
Other Aldehydes	0.47	5.50	5.97	C
Other Organics	0.30	186	187	D
Ammonia	0.040		0.040	C
Lead	1.4E-04		1.4E-04	B
Methane	4.05		4.05	C
Kerosene	1.0E-04		1.0E-04	D
Chlorine	0.0015		0.0015	D
Hydrochloric Acid	0.025		0.025	C
Hydrogen Fluoride	0.0033		0.0033	C
Metals	0.0025		0.0025	D
Antimony	3.8E-05		3.8E-05	E
Arsenic	7.9E-05		7.9E-05	E
Beryllium	5.5E-06		5.5E-06	E
Cadmium	1.2E-04		1.2E-04	E
Chromium	9.0E-05		9.0E-05	E
Cobalt	1.1E-04		1.1E-04	E
Manganese	1.1E-04		1.1E-04	E
Mercury	2.6E-05		2.6E-05	E
Nickel	0.0017		0.0017	E
Selenium	7.2E-05		7.2E-05	E
Acreolin	4.7E-06		4.7E-06	D
Nitrous Oxide	0.0028		0.0028	D
Benzene	1.5E-05		1.5E-05	D
Perchloroethylene	4.6E-06		4.6E-06	D
Trichloroethylene	4.4E-06		4.4E-06	D
Methylene Chloride	2.1E-05		2.1E-05	D
Carbon Tetrachloride	1.9E-05		1.9E-05	D
Phenols	1.2E-04		1.2E-04	D
Naphthalene	7.0E-06		7.0E-06	D
Dioxins	2.5E-11		2.5E-11	D
n-nitrodimethylamine	9.9E-07		9.9E-07	D
Radionuclides (Ci)	8.7E-05		8.7E-05	D

(continued)

Table A-29b (cont)

ENVIRONMENTAL EMISSIONS FOR 1992 SINGLE-UNIT DIESEL POWERED TRUCKS
(pounds of pollutants per 1,000 gallons of diesel fuel)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	8.4E-06		8.4E-06	E
Metal Ion	0.18		0.18	E
Dissolved Solids	34.8		34.8	D
Suspended Solids	0.79		0.79	D
BOD	0.13		0.13	D
COD	0.87		0.87	D
Phenol	5.8E-04		5.8E-04	E
Oil	0.81		0.81	E
Sulfuric Acid	0.0069		0.0069	E
Iron	0.019		0.019	E
Ammonia	0.014		0.014	E
Chromium	0.0013		0.0013	E
Lead	1.5E-05		1.5E-05	E
Zinc	6.5E-04		6.5E-04	E
Chlorides	1.28		1.28	E
Sodium	1.6E-04		1.6E-04	E
Calcium	9.0E-05		9.0E-05	E
Sulfates	1.03		1.03	E
Manganese	0.0092		0.0092	E
Fluorides	4.1E-04		4.1E-04	E
Nitrates	3.9E-05		3.9E-05	E
Phosphates	0.0035		0.0035	E
Boron	0.028		0.028	E
Other Organics	0.085		0.085	E
Chromates	9.8E-05		9.8E-05	E
Cyanide	1.9E-06		1.9E-06	E
Mercury	9.8E-08		9.8E-08	E
Cadmium	0.0013		0.0013	E
Solid Waste	133		133	B

(1) Sum of precombustion process-related emissions from Table A-3b and precombustion fuel-related emissions from Table A-12b.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-30

ENVIRONMENTAL EMISSIONS FOR DIESEL POWERED LOCOMOTIVES (pounds of pollutants per 1,000 gallons of diesel fuel)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.66	75.0	76.7	B
Nitrogen Oxides	8.47	266	275	B
Hydrocarbons (other than methane)	50.2	94.0	144	C
Sulfur Oxides	25.8	36.2	62.0	B
Carbon Monoxide	6.36	130	136	B
Fossil Carbon Dioxide	2,630	23,000	25,630	A
Non-Fossil Carbon Dioxide	6.10		6.10	B
Formaldehyde	2.1E-05		2.1E-05	C
Other Aldehydes	0.47	5.50	5.97	C
Other Organics	0.30	7.00	7.30	D
Ammonia	0.040		0.040	C
Lead	1.4E-04		1.4E-04	B
Methane	4.05		4.05	C
Kerosene	1.0E-04		1.0E-04	D
Chlorine	0.0015		0.0015	D
Hydrochloric Acid	0.025		0.025	C
Hydrogen Fluoride	0.0033		0.0033	C
Metals	0.0025		0.0025	D
Antimony	3.8E-05		3.8E-05	E
Arsenic	7.9E-05		7.9E-05	E
Beryllium	5.5E-06		5.5E-06	E
Cadmium	1.2E-04		1.2E-04	E
Chromium	9.0E-05		9.0E-05	E
Cobalt	1.1E-04		1.1E-04	E
Manganese	1.1E-04		1.1E-04	E
Mercury	2.6E-05		2.6E-05	E
Nickel	0.0017		0.0017	E
Selenium	7.2E-05		7.2E-05	E
Acreolin	4.7E-06		4.7E-06	D
Nitrous Oxide	0.0028		0.0028	D
Benzene	1.5E-05		1.5E-05	D
Perchloroethylene	4.6E-06		4.6E-06	D
Trichloroethylene	4.4E-06		4.4E-06	D
Methylene Chloride	2.1E-05		2.1E-05	D
Carbon Tetrachloride	1.9E-05		1.9E-05	D
Phenols	1.2E-04		1.2E-04	D
Naphthalene	7.0E-06		7.0E-06	D
Dioxins	2.5E-11		2.5E-11	D
n-nitrodimethylamine	9.9E-07		9.9E-07	D
Radionuclides (Ci)	8.7E-05		8.7E-05	D

(continued)

Table A-30 (cont)

ENVIRONMENTAL EMISSIONS FOR DIESEL POWERED LOCOMOTIVES (pounds of pollutants per 1,000 gallons of diesel fuel)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	8.4E-06		8.4E-06	E
Metal Ion	0.18		0.18	E
Dissolved Solids	34.8		34.8	D
Suspended Solids	0.79		0.79	D
BOD	0.13		0.13	D
COD	0.87		0.87	D
Phenol	5.8E-04		5.8E-04	E
Oil	0.81		0.81	E
Sulfuric Acid	0.0069		0.0069	E
Iron	0.019		0.019	E
Ammonia	0.014		0.014	E
Chromium	0.0013		0.0013	E
Lead	1.5E-05		1.5E-05	E
Zinc	6.5E-04		6.5E-04	E
Chlorides	1.28		1.28	E
Sodium	1.6E-04		1.6E-04	E
Calcium	9.0E-05		9.0E-05	E
Sulfates	1.03		1.03	E
Manganese	0.0092		0.0092	E
Fluorides	4.1E-04		4.1E-04	E
Nitrates	3.9E-05		3.9E-05	E
Phosphates	0.0035		0.0035	E
Boron	0.028		0.028	E
Other Organics	0.085		0.085	E
Chromates	9.8E-05		9.8E-05	E
Cyanide	1.9E-06		1.9E-06	E
Mercury	9.8E-08		9.8E-08	E
Cadmium	0.0013		0.0013	E
Solid Waste	133		133	B

(1) Sum of precombustion process-related emissions from Table A-3b and precombustion fuel-related emissions from Table A-12b.

References: A-5, A-6, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-31

ENVIRONMENTAL EMISSIONS FOR BARGES
(pounds of pollutants per 1,000 gallons of fuel)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.70	16.1	17.8	B
Nitrogen Oxides	8.64	268	277	B
Hydrocarbons (other than methane)	51.3	62.6	114	C
Sulfur Oxides	26.3	36.2	62.5	B
Carbon Monoxide	6.49	68.2	74.7	B
Fossil Carbon Dioxide	2,680	23,100	25,780	A
Non-Fossil Carbon Dioxide	6.22		6.22	B
Formaldehyde	2.2E-05		2.2E-05	C
Other Aldehydes	0.48	5.50	5.98	C
Other Organics	0.31	7.00	7.31	D
Ammonia	0.041		0.041	C
Lead	1.4E-04		1.4E-04	B
Methane	4.13		4.13	C
Kerosene	1.1E-04		1.1E-04	D
Chlorine	0.0016		0.0016	D
Hydrochloric Acid	0.025		0.025	C
Hydrogen Fluoride	0.0033		0.0033	C
Metals	0.0025		0.0025	D
Antimony	3.9E-05		3.9E-05	E
Arsenic	8.0E-05		8.0E-05	E
Beryllium	5.6E-06		5.6E-06	E
Cadmium	1.2E-04		1.2E-04	E
Chromium	9.2E-05		9.2E-05	E
Cobalt	1.1E-04		1.1E-04	E
Manganese	1.1E-04		1.1E-04	E
Mercury	2.6E-05		2.6E-05	E
Nickel	0.0017		0.0017	E
Selenium	7.4E-05		7.4E-05	E
Acreolin	4.8E-06		4.8E-06	D
Nitrous Oxide	0.0029		0.0029	D
Benzene	1.5E-05		1.5E-05	D
Perchloroethylene	4.7E-06		4.7E-06	D
Trichloroethylene	4.5E-06		4.5E-06	D
Methylene Chloride	2.1E-05		2.1E-05	D
Carbon Tetrachloride	1.9E-05		1.9E-05	D
Phenols	1.2E-04		1.2E-04	D
Naphthalene	7.1E-06		7.1E-06	D
Dioxins	2.6E-11		2.6E-11	D
n-nitrodimethylamine	1.0E-06		1.0E-06	D
Radionuclides (Ci)	8.9E-05		8.9E-05	D

(continued)

Table A-31 (cont)

ENVIRONMENTAL EMISSIONS FOR BARGES
(pounds of pollutants per 1,000 gallons of fuel)

Waterborne Emissions	**Precombustion (1)**	**Combustion**	**Total**	**DQI**
Acid	8.6E-06		8.6E-06	E
Metal Ion	0.18		0.18	E
Dissolved Solids	35.5		35.5	D
Suspended Solids	0.81		0.81	D
BOD	0.13		0.13	D
COD	0.89		0.89	D
Phenol	5.9E-04		5.9E-04	E
Oil	0.83		0.83	E
Sulfuric Acid	0.0071		0.0071	E
Iron	0.019		0.019	E
Ammonia	0.014		0.014	E
Chromium	0.0013		0.0013	E
Lead	1.5E-05		1.5E-05	E
Zinc	6.6E-04		6.6E-04	E
Chlorides	1.31		1.31	E
Sodium	1.7E-04		1.7E-04	E
Calcium	9.1E-05		9.1E-05	E
Sulfates	1.05		1.05	E
Manganese	0.0094		0.0094	E
Fluorides	4.2E-04		4.2E-04	E
Nitrates	4.0E-05		4.0E-05	E
Phosphates	0.0035		0.0035	E
Boron	0.028		0.028	E
Other Organics	0.087		0.087	E
Chromates	1.0E-04		1.0E-04	E
Cyanide	1.9E-06		1.9E-06	E
Mercury	1.0E-07		1.0E-07	E
Cadmium	0.0013		0.0013	E
Solid Waste	135		135	B

(1) Sum of precombustion process-related emissions from Tables A-3b and A-3c, and precombustion fuel-related emissions from Tables A-12b and A-12c.

References: A-4, A-5, A-6, A-10, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

Table A-32

ENVIRONMENTAL EMISSIONS FOR OCEAN FREIGHTERS
(pounds of pollutants per 1,000 gallons of fuel)

Atmospheric Emissions	Precombustion (1)	Combustion	Total	DQI
Particulates	1.68	19.5	21.2	B
Nitrogen Oxides	8.54	82.5	91.0	B
Hydrocarbons (other than methane)	50.7	8.80	59.5	C
Sulfur Oxides	26.0	36.2	62.2	B
Carbon Monoxide	6.41	9.02	15.4	B
Fossil Carbon Dioxide	2,650	25,200	27,850	A
Non-Fossil Carbon Dioxide	6.15		6.15	B
Formaldehyde	2.2E-05		2.2E-05	C
Other Aldehydes	0.47	5.50	5.97	C
Other Organics	0.30	7.00	7.30	D
Ammonia	0.041		0.041	C
Lead	1.4E-04		1.4E-04	B
Methane	4.08		4.08	C
Kerosene	1.0E-04		1.0E-04	D
Chlorine	0.0016		0.0016	D
Hydrochloric Acid	0.025		0.025	C
Hydrogen Fluoride	0.0033		0.0033	C
Metals	0.0025		0.0025	D
Antimony	3.8E-05		3.8E-05	E
Arsenic	7.9E-05		7.9E-05	E
Beryllium	5.5E-06		5.5E-06	E
Cadmium	1.2E-04		1.2E-04	E
Chromium	9.1E-05		9.1E-05	E
Cobalt	1.1E-04		1.1E-04	E
Manganese	1.1E-04		1.1E-04	E
Mercury	2.6E-05		2.6E-05	E
Nickel	0.0017		0.0017	E
Selenium	7.3E-05		7.3E-05	E
Acreolin	4.7E-06		4.7E-06	D
Nitrous Oxide	0.0029		0.0029	D
Benzene	1.5E-05		1.5E-05	D
Perchloroethylene	4.7E-06		4.7E-06	D
Trichloroethylene	4.4E-06		4.4E-06	D
Methylene Chloride	2.1E-05		2.1E-05	D
Carbon Tetrachloride	1.9E-05		1.9E-05	D
Phenols	1.2E-04		1.2E-04	D
Naphthalene	7.0E-06		7.0E-06	D
Dioxins	2.6E-11		2.6E-11	D
n-nitrodimethylamine	9.9E-07		9.9E-07	D
Radionuclides (Ci)	8.8E-05		8.8E-05	D

(continued)

Table A-32 (cont)

ENVIRONMENTAL EMISSIONS FOR OCEAN FREIGHTERS
(pounds of pollutants per 1,000 gallons of fuel)

Waterborne Emissions	Precombustion (1)	Combustion	Total	DQI
Acid	8.5E-06		8.5E-06	E
Metal Ion	0.18		0.18	E
Dissolved Solids	35		35	D
Suspended Solids	0.80		0.80	D
BOD	0.13		0.13	D
COD	0.88		0.88	D
Phenol	5.8E-04		5.8E-04	E
Oil	0.82		0.82	E
Sulfuric Acid	0.0070		0.0070	E
Iron	0.019		0.019	E
Ammonia	0.014		0.014	E
Chromium	0.0013		0.0013	E
Lead	1.5E-05		1.5E-05	E
Zinc	6.6E-04		6.6E-04	E
Chlorides	1.29		1.29	E
Sodium	1.7E-04		1.7E-04	E
Calcium	9.0E-05		9.0E-05	E
Sulfates	1.04		1.04	E
Manganese	0.0092		0.0092	E
Fluorides	4.2E-04		4.2E-04	E
Nitrates	3.9E-05		3.9E-05	E
Phosphates	0.0035		0.0035	E
Boron	0.028		0.028	E
Other Organics	0.086		0.086	E
Chromates	9.8E-05		9.8E-05	E
Cyanide	1.9E-06		1.9E-06	E
Mercury	9.9E-08		9.9E-08	E
Cadmium	0.0013		0.0013	E
Solid Waste	135		135	B

(1) Sum of precombustion process-related emissions from Tables A-3b and A-3c, and precombustion fuel-related emissions from Tables A-12b and A-12c.

References: A-4, A-5, A-6, A-10, A-16, A-41, A-47, A-54, A-55, and A-58.

Source: Franklin Associates, Ltd.

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GLOSSARY

Ash. Impurities in coal, consisting of silica, alumina, and other non-combustible matter. Ash increases the weight of coal, adds to the cost of handling, and can affect its burning characteristics.

Barrel (Petroleum). A unit of volume equal to 42 U.S. gallons.

Biological Oxygen Demand (BOD). An indication of the amount of organic material present in water or wastewater.

Biomass. The total dry organic matter or stored energy content of living organisms that is present at a specific time in a defined unit of the Earth's surface. As an energy source, the Energy Information Administration defines biomass as organic non-fossil material of biological origin constituting a renewable energy source.

Bituminous Coal. A dense black coal, often with well-defined bands of bright and dull material, with a moisture content usually less than 20 percent. Often referred to as soft coal. It is the most common coal and is used primarily for generating electricity, making coke, and space heating.

Boiler. A device for generating steam for power, processing, or heating purposes or for producing hot water for heating purposes or hot water supply.

Btu (British thermal unit). A standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Butane. A normally gaseous straight-chained or branched hydrocarbon (C_4H_{10}). It is extracted from natural gas or refinery gas streams. It includes isobutane and normal butane.

Chemical Oxygen Demand (COD). The amount of oxygen required for the oxidation of compounds in water, as determined by a strong oxidant such as dichromate.

Coal. A black or brownish-black solid, combustible substance formed by the partial decomposition of vegetable matter without access to air. The rank of coal, which includes anthracite, bituminous coal, subbituminous coal, and lignite, is based on fixed carbon, volatile matter, and heating value. Coal rank indicates the progressive alteration, or coalification, from lignite to anthracite.

Combustion Energy. The high heat value directly released when coal, fuel oil, natural gas, or wood are burned for energy consumption.

Combustion Emissions. The environmental emissions directly emitted when coal, fuel oil, natural gas, or wood are burned for energy consumption.

Crude Oil. A mixture of hydrocarbons that exists in liquid phase in underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities.

Curie (Ci). The SI unit of radioactive decay. The quantity of any radioactive nuclide that undergoes $3.7x10^{10}$ disintegrations/sec.

Distillate Fuel Oil. A general classification for one of the petroleum fractions produced in conventional distillation operations. It is used primarily for space heating, on-and off-highway diesel engine fuel (including railroad engine fuel and fuel for agricultural machinery), and electric power generation. Included are products known as No. 1, No. 2, and No. 4 diesel fuels.

Fossil Fuel. Any naturally occurring organic fuel, such as petroleum, natural gas, or coal.

Fossil Fuel Steam-Electric Power Plant. An electricity generation plant in which the prime mover is a turbine rotated by high-pressure steam produced in a boiler by heat from burning fossil fuels.

Flue Gas Desulfurization Unit (Scrubber). Equipment used to remove sulfur oxides from the combustion gases of a boiler plant before discharge to the atmosphere. Chemicals, such as lime, are used as the scrubbing media.

Fugitive Emissions. Unintended leaks of gas from the processing, transmission, and/or transportation of fossil fuels.

Geothermal Energy. Energy from the internal heat of the earth, which may be residual heat, friction heat, or a result of radioactive decay. The heat is found in rocks and fluids at various depths and can be extracted by drilling and/or pumping.

Heat Content of a Quantity of Fuel, Gross. The total amount of heat released when a fuel is burned. Coal, crude oil, and natural gas all include chemical compounds of carbon and hydrogen. When those fuels are burned, the carbon and hydrogen combine with oxygen in the air to produce carbon dioxide and water. Some of the energy released in burning goes into transforming the water into steam and is usually lost. The amount of heat spent in transforming the water into steam is counted as part of gross heat but is not counted as part of net content. Also referred to as the higher heating value. Btu conversion factors typically used by EIA represent gross heat content. Called combustion energy in this appendix.

Heat Content of a Quantity of Fuel, Net. The amount of usable heat energy released when a fuel is burned under conditions similar to those in which it is normally used. Also referred to as the lower heating value. Btu conversion factors typically used by EIA represent gross heat content.

Hydrocarbons: A subcategory of organic compounds that contain only hydrogen and carbon. These compounds may exist in either the gaseous, liquid, or solid phase, and have a molecular structure that varies from the simple to the very heavy and very complex. The category Non-Methane Hydrocarbons (NMHC) is sometimes used when methane is reported separately.

Hydroelectric Power Plant. A plant in which the turbine generators are driven by falling water.

Lease Condensate. A natural gas liquid recovered from gas well gas (associated and non-associated) in lease separators or natural gas field facilities. Lease condensate consists primarily of pentanes and heavier hydrocarbons.

Lignite. A brownish-black coal of low rank with a high content of moisture and volatile matter. Often referred to as brown coal.

Liquefied Petroleum Gases (LPG). Ethane, ethylene, propane, propylene, normal butane, butylene, isobutane, and isobutylene produced at refineries or natural gas processing plants, including plants that fractionate raw natural gas plant liquids.

Methane. A hydrocarbon gas (CH_4) that is the principal constituent of natural gas.

(**Motor) Gasoline.** A complex mixture of relatively volatile hydrocarbons, with or without small quantities of additives, that has been blended to form a fuel suitable for use in spark-ignition engines. "Motor gasoline" includes reformulated gasoline, oxygenated gasoline, and other finished gasoline.

Natural Gas. A mixture of hydrocarbons (principally methane) and small quantities of various nonhydrocarbons existing in the gaseous phase or in solution with crude oil in underground reservoirs.

Natural Gas Liquids (NGL). Those hydrocarbons in natural gas that are separated as liquids from the gas. Natural gas liquids include natural gas plant liquids (primarily ethane, propane, butane, and isobutane), and lease condensate (primarily pentanes produced from natural gas at lease separators and field facilities.)

Nitrogen Oxides (NO_X). Compounds of nitrogen and oxygen produced by the burning of fossil fuels, or any other combustion process taking place in air. The two most important oxides in this category are nitrogen oxide (NO) and nitrogen dioxide (NO_2). Nitrous oxide (N_2O), however, is not included in this category and is considered separately.

Non-Methane Volatile Organic Compounds. Organic compounds, other than methane, that participate in atmospheric photochemical reactions.

Other Organics. Compounds containing carbon combined with hydrogen and other elements such as oxygen, nitrogen, sulfur or others. Compounds containing only carbon and hydrogen are classified as hydrocarbons and are not included in this category.

Particulate Matter (Particulates): Small solid particles or liquid droplets suspended in the atmosphere, ranging in size from 0.005 to 500 microns.

Particulates are usually characterized as primary or secondary. Primary particulates, usually 0.1 to 20 microns in size, are those injected directly into the atmosphere by chemical or physical processes. Secondary particulates are produced as a result of chemical reactions that take place in the atmosphere. In our reports, particulates refer only to primary particulates.

Particulates reported by Franklin Associates are not limited by size range, and are sometimes called total suspended particulates (TSP). The category PM-10 refers to all particulates less than 10 microns in (aerodynamic) diameter. This classification is sometimes used when health effects are being considered, since the human nasal passages will filter and reject any particles larger than 10 microns. PM 2.5 (less than 2.5 microns in diameter) is now considered the size range of most concern for human health effects.

Precombustion Energy. The energy required for the production and processing of energy fuels, such as coal, fuel oil, natural gas, or uranium, starting with their extraction from the ground, up to the point of delivery to the customer.

Precombustion Fuel-related Emissions. The environmental emissions due to the combustion of fuels used in the production and processing of the primary fuels; coal, fuel oil, natural gas, and uranium.

Precombustion Process Emissions. The environmental emissions due to the production and processing of the primary fuels; coal, fuel oil, natural gas, and uranium, that are process rather than fuel-related emissions.

Petroleum. A generic term applied to oil and oil products in all forms, such as crude oil, lease condensate, unfinished oils, petroleum products, natural gas plant liquids, and nonhydrocarbon compounds blended into finished petroleum products.

Plant Condensate. One of the natural gas liquids (NGLs), mostly pentanes and heavier hydrocarbons, recovered and separated as liquids at gas inlet separators or scrubbers in processing plants.

Processing Plant (natural gas). A surface installation designed to separate and recover natural gas liquids from a stream of produced natural gas through the process of condensation, absorption, refrigeration, or other methods, and to control the quality of natural gas marketed or returned to oil or gas reservoirs for pressure maintenance, repressuring, or cycling.

Refinery (petroleum). An installation that manufactures finished petroleum products from crude oil, unfinished oils, natural gas liquids, other hydrocarbons, and alcohol.

Residual Fuel Oil. The heavier oils that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. Included are No. 5, No. 6, and Navy

Special. It is used for commercial and industrial heating, electricity generation, and to power ships.

Subbituminous Coal. A dull, black coal of rank intermediate between lignite and bituminous coal.

Sulfur Oxides (SO_X). Compounds of sulfur and oxygen, such as sulfur dioxide (SO_2) and sulfur trioxide (SO_3).

Total Dissolved Solids (TDS). The TDS in water consists of inorganic salts, minute organic particles, and dissolved materials. In natural waters, salts are chemical compounds composed of anions such as carbonates, chlorides, sulfates, and nitrates, and cations such as potassium, magnesium, calcium, and sodium.

Total Suspended Solids (TSS). TSS gives a measure of the turbidity of the water. Suspended solids cause the water to be milky or muddy looking due to the light scattering from very small particles in the water.

Volatile Organic Compounds (VOCs). Organic compounds that participate in atmospheric chemical reactions.

Uranium. A heavy naturally radioactive metallic element (atomic number 92). Its two principally occurring isotopes are ^{235}U and ^{238}U. ^{235}U is indispensable to the nuclear industry, because it is the only isotope existing in nature to any appreciable extent that is fissionable by thermal neutrons. ^{238}U is also important, because it absorbs neutrons to produce a radioactive isotope that subsequently decays to ^{239}Pu, an isotope that also is fissionable by thermal neutrons.

Uranium Ore. Rock containing uranium mineralization, typically 0.05 to 0.2 percent U_3O_8.

APPENDIX B

DEFINITION OF PACKAGING SYSTEMS

INTRODUCTION

This Appendix provides the following information:

- Definition of the shipped product
- Definition of packaging options
    - Materials and postconsumer recycled content
    - Sizes and weights

Information on the production of packaging materials and fabrication of packaging products can be found in Appendix C. Transportation steps are described in Appendix D. End of life management of packaging materials is discussed in Appendix E.

The LCI analysis of each packaging configuration will be evaluated on the equivalent use basis of delivery of 10,000 packages of mail-order soft goods to consumers. The representative shipped product and the quantities of materials required to package the shipped product using each packaging configuration are characterized in the following sections.

DEFINITION, WEIGHT AND VOLUME OF THE SHIPPED PRODUCT

The amounts of different packaging materials used are important inputs for the life cycle inventory analysis. Burdens from most process steps are expressed as functions of pounds of packaging material used, so determining the weight of different packaging materials used is of key importance. The amount of packaging material used, in turn, is a function of the size, weight and type of product or products being shipped. Knowing the weight of the product(s) shipped is also important because outbound (retailer to customer) transportation burdens are allocated between the burdens of shipping the product and the burdens of shipping the package.

Franklin Associates required from Oregon Department of Environmental Quality (DEQ) a standard weight and volume for a “unit product” and each packaging material used in order to complete the modeling of burdens. An alternative approach, involving modeling a variety of weights and volumes for each packaging material, was not affordable given DEQ’s budget for this study. As such, the project team set about to define the weight and volume of an “average” unit product and the weight and volume of each packaging material that would be used, on average, to ship that product.

In making these determinations, DEQ established as its most important objective avoiding assumptions regarding weights and volumes that could have the undesired consequence of biasing the results of the study in favor of a certain packaging material or combination of materials. Therefore, DEQ developed the following methodology to define average weights and volumes, in a manner designed to avoid biasing the results. Actual averages for real packaging users may vary from the averages used in this study. Study users interested in tailoring the results for their unique circumstances will be able to work with the assumptions, calculations, and results portrayed in the report (and appendices) to derive their own custom findings.

This study focuses on packaging alternatives for shipping non-breakable items from a retailer or retail distribution center/order fulfillment center to a residential customer. Non-breakable items are defined to include most garments of clothing, linens (towels, sheets, etc.) as well as some other durable products including a variety of paper products that are not likely to be broken or damaged if shipped to residential customers in shipping/mailing bags.

The decision to exclude breakable items from the study allows for the use of some important simplifying assumptions. The first assumption is that the packaging options included in this study are all equally adequate in their ability to protect non-breakable items in the normal shipping environment. Put differently, cardboard boxes with different types of void fill and different types of padded and non-padded shipping bags will be equally protective of non-breakable items during transit. (The widespread use of shipping bags for direct-to-customer sales of soft goods, and the very high costs associated with managing returns, suggests that this assumption is reasonable.) Assuming that the damage rates for non-breakable items in different packaging systems are equal (or close to each other) avoids the need to model different product return rates for different packaging systems. This assumption allows us to avoid calculating the environmental burdens of product damage, a complex undertaking that would require selecting a "typical" consumer product or blend of products and modeling the burdens of product manufacturing and waste. If each packaging system results in the same, small percentage of products damaged in transit, then the environmental burdens of product damage are equal across all packaging systems, and these burdens can be conveniently ignored for the purpose of comparing packaging systems.

A corollary assumption is that items shipped in a corrugated cardboard box require void fill only to stabilize the product in transit, and not to cushion the product against shock. Different void fill systems have different protective qualities. Were breakable items being shipped, different box sizes might be needed to allow for adequate levels of internal cushioning and protective packaging (void fill that is less protective would be needed in greater amounts, thus potentially requiring a larger box). Alternatively, if the same size of box was used to ship breakable items regardless of the type of internal packaging used for cushioning, and this resulted in different damage rates in transit (for different cushioning materials), the study team would need to model the environmental burdens of product damage, which is undesirable for the reasons described above.

In order to identify an "average" shipment of non-breakable items, DEQ worked closely with staff from Norm Thompson Outfitters (NTO), one of the companies partnering with DEQ on packaging waste reduction. NTO provided DEQ with data on its four top-selling "soft goods" (a subset of non-breakable items), including the weight and dimensions (as shipped) of each (see Table B-1). All four of these items arrive at Norm Thompson's Distribution Center in a thin polyethylene bag; three of the items also arrive pre-folded. Norm Thompson will not further fold these items when shipping them out, to avoid wrinkling the products. Thus, the dimensions provided by Norm Thompson and shown in Table B-1 represent the actual dimensions of each item as the customer would receive it.

Table B-1.
Norm Thompson Outfitters' Top-Selling "Soft Goods"

	Length (inches)	Width (inches)	Height (inches)	Weight (pounds)
Miracle Cloth (set of 3) (SKU 62355)	8"	8"	2"	0.3
Med. Microfiber (Healthy Back Bag) (SKU 13140)	19"	12"	2"	1.0
Reg. Fleece Duster (SKU 10161)	21"	16"	1"	1.0
Prima Cotton Tee Faux Wrap 3/4 Sleeve (SKU 24739)	22"	12"	0.5"	0.5
SIMPLE AVERAGE	17.5"	12"	1.375"	0.7

The average represents a simple, non-weighted average of all four items. The use of a simple (non-weighted) average is not expected to bias the results of the study.

While an average item may measure 17.5" x 12" x 1.375", some retail customers purchase more than one item. While Norm Thompson sells both "soft goods" and "hard goods" (breakable items outside of the scope of this study), DEQ estimated, using proprietary data provided by NTO, that among shipments to customers that are exclusively made up of soft goods, the average customer orders 1.83 items. (The actual number of items shipped per package might be slightly less than 1.83 on average, as some items may be on back-order and shipped separately.) This was applied to the height and weight of the average parcel (above) as a scaling factor. As a result, the dimensions of the unit product (also called "shipped product") for the purposes of this study are 17.5" x 12" x 2.5" (1.375" x 1.83) and the unit product's weight is 1.28 pounds (0.7 pounds x 1.83).

It is also worth noting that the heights of each product are uncompressed heights of products within their individual polybags. Because all four of these products are textiles, compressing the products by placing additional items on top of them might reduce the actual as-shipped heights slightly.

DEFINITION OF PACKAGING OPTIONS, COMPOSITION, AND LEVELS OF POSTCONSUMER CONTENT

The study team identified a large number of alternative packaging systems that could be used to ship the unit product to residential customers. Budget constraints forced the study team to limit the number of systems evaluated. Each system is described below, including assumptions regarding material composition and levels of postconsumer content. The basic systems can be categorized into three groups:

- Corrugated box with void fill.
- Unpadded shipping bag.
- Padded shipping bag.

Each of these three groups has several alternative packaging systems, as listed below:

Corrugated Box with Void Fill
Void Fill Options Include:

- Inflated polyethylene air packets.
- Expanded polystyrene loose fill.
- Bio-based (starch) loose fill.
- Molded pulp loose fill.
- Unbleached kraft paper (purchased as rolls or sheets and then crumpled up).
- Newsprint (purchased as rolls or sheets and then crumpled up).
- Shredded corrugated.
- Shredded office paper.

Unpadded Shipping Bag
Options included in this study include:

- Kraft paper shipping bag.
- Polyethylene shipping bag.

Padded Shipping Bag
Options included in this study include:

- All-paper shipping bag (kraft liner, macerated newsprint filler).
- Kraft paper shipping bag with polyethylene bubble padding.
- Polyethylene shipping bag with polyethylene bubble padding.

Each of these systems is described below. Quantities of packaging material used are described in later sections of this Appendix.

Due to budget limitations, minor components of packaging systems are not included in the study. These include tape for sealing boxes, adhesives used in the fabrication of shipping bags, self-adhesive tabs and pull tabs for shipping bags, inks, address labels, and postage. The analysis does include adhesive used in the production of corrugated boxes.

In the following discussions, it is helpful to understand the distinction between postconsumer material and postconsumer content. The term "postconsumer" refers to a material or product that has been used for its intended purpose and has come to the end of its life in that use. Postconsumer content refers to the amount of postconsumer material (e.g., postconsumer fiber or resin) incorporated in a product. Different postconsumer contents are modeled for paper, paperboard, and plastic resins in this study. Molded pulp cushion cubes, macerated newspaper (used in envelope padding), and shredded office paper and corrugated (used for dunnage) are all made from 100% postconsumer material, although the postconsumer fiber content in the postconsumer material may be less than 100%. However, because the postconsumer material used has already completed an original useful life (as newspaper, office paper, or a corrugated box), it comes in free of upstream virgin material production burdens just as postconsumer content does.

Corrugated Box

Corrugated boxes are constructed with a fluted layer of medium sandwiched between two layers of linerboard. Paperboard industry statistics (References B-3 through B-6) indicate that an average corrugated box is about 32% by weight medium and 68% by weight linerboard. Paperboard industry statistics report recovered fiber use in containerboard in the following categories: kraft linerboard, semichemical, and recycled containerboard. (Semichemical is used for medium, while recycled containerboard includes both recycled linerboard and medium.) Overall, recovered fiber use in kraft linerboard is 7.7% industrial scrap such as kraft paper trim scrap and box clippings and 9.6% postconsumer old corrugated containers, or OCC. Industry statistics for recovered paper use in semichemical paperboard are 3.2% industrial scrap and 30.1% OCC. These are overall industry statistics; kraft linerboard or semichemical medium produced by individual mills may contain varying amounts of industrial and postconsumer fiber. The recycled content in recycled containerboard (linerboard and medium) is 100% OCC. More detailed description of the processes and input materials for box production are provided in Appendix C.

The study models two options for postconsumer content in corrugated boxes: 38% and 80%. The 38% represents a U.S. average based on paperboard industry statistics for the market shares of virgin linerboard, recycled linerboard, semichemical medium, and recycled medium and the postconsumer recycled content of each. Eighty percent represents a level of postconsumer content that is considered high yet achievable. It was developed based on conversations between staff from Pack Edge Development (under contract to DEQ) and several Pacific Northwest box makers. Specifically, one box maker (Tharco) told Pack Edge staff that Tharco's recycled line of stock cartons contain 80% postconsumer content. Another area box maker, Alliance Packaging, informed Pack Edge that it would be possible to make 100% postconsumer content boxes, although this would require special ordering, and quantities might be limited.

Inflated Polyethylene Air Packets

Inflated polyethylene air packets are sold to order fulfillment centers as flat (deflated) tubes of polyethylene. The tubes are fed into a machine, which uses either electricity or a combination of electricity and compressed air to inflate the tubes and seal them at regular intervals. The resulting “air packets” are used as void fill and cushioning by many retail mail-order companies. Different systems allow for different levels of inflation and packet sizes. DEQ and Pack Edge Development identified four different manufacturers of these types of materials:

- FP International (brand name: “flo-pak Cell-O”)
- Pactiv (brand name: “Pactiv Air 3000 System”)
- Sealed Air Corporation (brand name: “Fill-Air”)
- Storopack (brand name: “AIRplus”)

Samples of all four brands were obtained. The FP International brand was labeled as being HDPE. All three other brands were labeled as LDPE. Pack Edge staff was informed that at one time, one of the LDPE products was co-extruded with nylon as a vapor barrier; however, that company told Pack Edge that nylon was no longer used. DEQ learned from talking with another one of the air packet manufacturers that their product is actually a blend of LDPE and LLDPE. Because the burdens of these materials are fairly similar (see Appendix C), and the manufacturers were unwilling to divulge the exact composition of their products, the study assumes that the inflated polyethylene air packs are 100% LDPE.

None of the manufacturers interviewed by Pack Edge and DEQ indicated that their materials contain recycled content, and their marketing literature was equally silent on this issue. For purposes of the study, we assume that this material contains 0% postconsumer recycled content, although a 30% postconsumer option is also modeled.

Expanded Polystyrene (EPS) Loose Fill

This is one of the most commonly used void fill materials in the U.S. It is often referred to as “packing peanuts” or “foam peanuts”. Technically, it is expanded polystyrene composed of polystyrene resin beads impregnated with blowing agent during polymerization. The blowing agent represents about 5% by weight of the material inputs of EPS foam production. More detail on the production of EPS foam loose fill is provided in Appendix C.

Staff from Pack Edge Development spoke with four manufacturers of EPS loose fill: American Excelsior, Inter-Pac, Space-Pak, and Storopack. Inter-Pac both manufactures loose fill and sells resin to other companies such as Space-Pak. The apparent standard in the EPS loose fill industry is that loose fill made from virgin or preconsumer resin only is colored white, while loose fill that contains some level of postconsumer content is colored green. All manufacturers sell a virgin (0% postconsumer) option; some also sell an option containing some postconsumer material. The levels of postconsumer content used by these four manufacturers in their postconsumer option (as reported to Pack Edge Development) are:

- American Excelsior: 15 – 25% postconsumer content.
- Inter-Pac: guarantees minimum 15% postconsumer content, can get as high as 40% if desired.
- Space-Pak: doesn't sell the green loose fill.
- Storopack: 10% postconsumer content.

This study models two different levels of postconsumer EPS content: 0% and 30%, representing a relatively high but commercially available level of recycled content.

Bio-Based (Starch) Loose Fill

Similar in size, shape, and use to the expanded polystyrene loose fill, this product is made from starch and is typically marketed as "bio-degradable".

Pack Edge Development spoke with representatives of two companies: National Starch and American Excelsior. American Excelsior manufactures starch loose fill. National Starch, in contrast, does not manufacture the loose fill material but licenses independent manufacturers throughout the United States. National Starch also sells base starch to independent manufacturers. Licensees are not required to purchase their starch from National Starch; they can buy it on the open market but still have to pay a royalty to National Starch.

According to National Starch, their product is 85 – 87% corn starch. The remainder is "biodegradable but proprietary in makeup".

The American Excelsior plant manufacturing starch peanuts that is closest to Oregon is located in Yakima, WA. According to staff there, their product is 92 – 94% wheat starch, 1 – 2% talc, and 4 – 7% a "natural, biodegradable plasticizer made by Dow Chemical". The actual percentages are adjusted for manufacturing reasons depending on the weather. Although American Excelsior in Yakima uses wheat starch, they say that the different starches (corn, wheat, potato, rice, etc.) are "more or less interchangeable," and they buy primarily based on price.

Neither National Starch nor American Excelsior was willing to provide additional information about the non-starch components of their product, or the steps (including energy inputs, wastes, emissions etc.) involved in fabricating this product. Franklin Associates was, however, able to estimate energy requirements for fabrication based on the operating specifications for process equipment used in the production of starch loose fill, as described in conversations with starch loose fill producers. Because of the lack of information about the proprietary non-starch components of the loose fill, and because

Franklin Associates only has available data on corn starch, the study makes the simplifying assumption that this packaging material is 100% corn starch by weight.

Molded Pulp Loose Fill

A relatively new product is a flowable loose fill made from molded pulp. Staff from Norm Thompson Outfitters identified UFP Technologies as one company that manufactures a molded pulp loose fill. Marketed under the brand name “Cushion Cubes”, UFP’s product is a paper-based alternative to other loose fills (such as expanded polystyrene and starch-based).

According to a representative from UFP Technologies, Cushion Cubes are made from 100% postconsumer newspaper and water.

Unbleached Kraft Paper

Some companies purchase rolls of unbleached kraft paper for use as void fill. The paper is torn off in sheets, and then crumpled up to fill void spaces in the box. According to discussions between Pack Edge Development and Longview Fiber, the maximum practical postconsumer content for this type of kraft sheet is 50%. This study models a 0% postconsumer and 50% postconsumer unbleached kraft paper.

Newsprint (Unprinted)

Other companies purchase rolls or sheets of unprinted newsprint for use as void fill. Like the kraft paper (above), the paper is crumpled up to fill void spaces in the box. According to staff at an Oregon newsprint mill, this newsprint is typically off-spec product that is not suitable for printing applications (newspapers). It is typically sold in jumbo rolls to converters who then cut it into sheets or re-roll it into smaller rolls.

As users typically purchase from a converter or a converter’s sales representative (wholesaler), and the converter may have purchased paper from multiple mills, it can be difficult for a retailer to specify minimum levels of postconsumer content for this packaging material. Regardless, the study models two different levels of postconsumer content: 10% and 50%. These percentages are considered to be below average and above-average yet still attainable. Franklin Associates’ “industry average” model, based on paperboard industry statistics for use of recycled paper (Reference B-4) for newsprint represents 38% postconsumer newspaper and 62% virgin pulp. More detail on newsprint production is provided in Appendix C.

Norm Thompson Outfitters uses sheets of newsprint as dunnage/void fill at both of its order fulfillment centers in Portland, OR and Kearneysville, WV. According to suppliers, the dunnage used in Oregon averages 30% postconsumer content, while the supplier to the West Virginia site states that postconsumer content isn’t clear due to the large number of supplying mills, but “should be 20% on average”. Similarly, a local (Portland area) supplier of packaging materials (U-Line) interviewed by Pack Edge Development stated that their newsprint dunnage contains 25% postconsumer content.

The State of Oregon surveys Oregon users of newsprint (newspaper publishers) on an annual basis. Combining survey responses from 2000, 2001, and 2002, only 12% of responses (N = 92) were for average postconsumer content higher than 50%. 15% of responses reported average postconsumer content lower than 10%.

Shredded Corrugated

A number of companies sell an on-site shredding machine that produces a void fill material out of "waste" corrugated boxes. This allows order fulfillment centers to reduce their purchase of new materials by utilizing a material that otherwise requires recycling or disposal. Some of these machines produce strips of corrugated that are 1/8" wide and 3 – 12 inches long. The strips can be used to fill void space in outbound boxes. Other machines perforate pieces of corrugated into larger, accordion-like mats that can be rolled around a product similar to bubble wrap. For the purposes of this study, we assume the use of the first type of machine.

The feedstock for these machines are "waste" corrugated received by the distribution center or retailer. Normally, retailers exert little influence over the postconsumer content of packaging used by their product suppliers. As such, the study assumes that the shredded corrugated contains 38% postconsumer content, which is the weighted average postconsumer recycled content for corrugated box components as described in the section on corrugated containers.

Shredded Office Paper

This is office paper that might be generated on-site (for example, in the retailer's administrative or sales office) and then run through a strip-cut (not cross-cut) office paper shredder. Some companies (generally smaller companies) choose to use this material as a void fill, thus reducing their recycling need while also reducing the purchase of new void fill materials.

The composition of shredded paper will vary depending on the unique circumstances of the office and what types of papers are fed into the shredder. For the purposes of this study, we assume that it is 83.6% printing-writing and 16.4% newspaper (Reference B-7).

Non-Padded Kraft Paper Shipping Bag

This packaging material is akin to a manila envelope, but is made of thicker material and is more strongly reinforced than standard manila envelopes. Several major bag manufacturers offer this type of shipping bag with or without reinforcing filaments. The filaments are typically made of fiberglass or some type of plastic. Pack Edge Development destructed a Pactiv "Tuff Kraft" brand mailer with fiberglass filaments and found that the filaments were less than 2% of the mass of the mailer. Due to the availability of bags both with and without filaments, the low relative weight of the filaments, and budget limitations, the study defines this shipping bag to be an all-kraft product without reinforcing filaments.

DEQ and Pack Edge Development staff reviewed literature or spoke with representatives of two of the largest shipping bag manufacturers: Sealed Air Corporation (product: Jiffy Utility Mailers) and Pactiv (product: Tuff-Kraft). According to a Tharco Distributor Price List, the Jiffy Utility Mailers contain 8% postconsumer content. (A sample stock bag obtained from Sealed Air Corporation confirms this as the bag is printed “8% postconsumer”.) Pactiv’s web site claims that the Tuff-Kraft shipping bag contains 50% postconsumer content, although a representative of Pactiv states that Pactiv is moving away from certifying postconsumer content of its products, because their experience is that higher levels of postconsumer content degrades the tear- and puncture-resistance of the kraft, and also because they outsource their kraft from several suppliers and the postconsumer content will vary. For the sake of this study, we model two different levels of postconsumer content: 0% and 30%.

Non-Padded Polyethylene Shipping Bag

This product is a generic polyethylene non-padded shipping bag. There are a variety of different single- and multi-resin (blend) options for this type of bag.

According to the American Plastics Council “Plastic Film Recovery Guide”, “There are a variety of niche film products where (multiple) resins are combined to yield a film product with enhanced properties for a specific application. Most often, this involves the combination of LDPE and HDPE. In such applications, HDPE contributes strength, while LDPE provides a smooth flexible surface with high printability. Common applications include . . . mailing pouches.” The same document also states: “Linear low-density polyethylene (LLDPE) was developed in 1978. Its production process is less costly than high-pressure processes used to produce standard low-density resins, making it attractive to manufacturers. Additionally, its improved stretch and strength characteristics relative to LDPE have led to an increased market share in a variety of film applications, especially for stretch wrap and bags.”

DEQ and Pack Edge Development staff also attempted to find out the resins used in these types of bags sold by two major suppliers, Sealed Air Corporation and Pactiv, as well as the resins used in the stock bags used by Norm Thompson Outfitters. One of the two suppliers would not divulge their resin information, while the other stated that their all-plastic, non-padded shipping bags contain blends of LDPEs and LLDPEs, but no HDPE. The bag currently used by Norm Thompson Outfitters is an all-LLDPE bag.

Because the burdens of LDPE and LLDPE are similar (see Appendix C), and the manufacturers were unwilling to divulge the exact composition of their products, the study assumes that these shipping bags are 100% LLDPE.

Neither of the manufacturers interviewed by Pack Edge and DEQ indicated that their materials contain recycled content, and their marketing literature was equally silent on this issue. For purposes of the study, we assume that this bag contains 0% postconsumer recycled content, although a 30% postconsumer option is also modeled.

Kraft Paper Shipping Bag with Newsprint Padding

This padded shipping bag consists of an outer surface layer and inner liner made from kraft paper, and an inner layer of padding that is made from macerated newsprint/newspapers. Typically, the outer paper is bleached kraft (goldenrod or some other color) while the inner liner is unbleached kraft (dark brown in color).

DEQ and Pack Edge Development staff reviewed literature or spoke with representatives of two of the largest shipping bag manufacturers: Sealed Air Corporation (product: Jiffy Padded Mailers) and Pactiv (product: Pad-Kraft). A representative of Pactiv stated that postconsumer content degrades the tear- and puncture-resistance of the kraft. Pactiv outsources their kraft from several suppliers, and the postconsumer content will vary. Pactiv has discontinued Green Cross certification of this product, and the company would not release the level of recycled content in the kraft paper. However, the Pactiv representative did state that the filler is “100% postconsumer macerated newspaper”.

Pack Edge Development fully deconstructed a Pactiv #7 Pad-Kraft mailer and found it to be 50.0% newspaper/filling, 24.4% brown kraft inner liner, and 25.6% goldenrod outer liner by weight. On the comparable Sealed Air mailer, Pack Edge was not able to separate the inner and outer liner, but otherwise found comparable results: newspaper/filling was 51.7% and liners (combined) were 48.3%.

According to Tharco’s 9/2/2002 Distributor Price List, the Sealed Air Corporation “Jiffy Padded Mailers” contain 62% postconsumer recycled paper fibers. If the macerated newspaper is similar to Pactiv’s and is made from 100% postconsumer newsprint, then the kraft liner(s) averages about 21% postconsumer content (100% of 52% + 21% of 48% = 62%). Although the proportion of inner to outer liner on the Sealed Air Jiffy Padded Mailer is not known, if it is comparable to the Pactiv product (roughly 50/50) then the 21% postconsumer content for the liner could be achieved through having both liners at 21%, one liner as high as 42% and the second liner at 0%, or something in-between.

For the purpose of analysis, this report evaluates two generic bags:

1. Filler: 100% postconsumer newsprint; outer liner: 30% postconsumer content, bleached kraft; inner liner: 30% postconsumer content unbleached kraft.

2. Filler: 100% postconsumer newsprint; outer liner: 0% postconsumer content, bleached kraft; inner liner: 0% postconsumer content unbleached kraft.

Kraft Paper Shipping Bag with Polyethylene Bubble Padding

This padded shipping bag consists of an outer liner made from kraft paper, and an inner layer of padding that is made from a bubble wrap-like material. Typically, the outer liner is bleached kraft (goldenrod or some other color).

As with other shipping bags, DEQ and Pack Edge Development staff reviewed literature or spoke with representatives of two of the largest shipping bag manufacturers: Sealed Air Corporation (product: Jiffylite R Bubble Gold Kraft Mailers) and Pactiv (product: Air-Kraft).

A representative from Pactiv stated that the bubble used in the Air-Kraft mailer is a proprietary blend that contains LDPE, LLDPE, and nylon. Nylon is added to enhance the barrier properties of the other resins, allowing for "significant" source reduction. While Pactiv would not divulge the exact composition of the bubble material, a representative did state that the nylon represents less than 5% of the material, by weight. Preliminary comparisons by Franklin Associates using composition-weighted averages of the burdens of nylon and polyethylene showed that modeling the bubble material as 5% nylon and 95% PE (50% LDPE/50% LLDPE) would not yield significantly different results than modeling the bubble material as a 50%LDPE/50%LLDPE blend without the nylon, but would increase study costs. As the relative burdens of LDPE and LLDPE are similar to each other (see Appendix C), and the exact composition may vary between suppliers, the study makes the simplifying assumption that the bubble material is 50% LDPE and 50% LLDPE, by weight.

As noted in other package descriptions, Pactiv no longer certifies postconsumer recycled content of its mailers. In contrast, the Tharco 9/2/2002 Distributor Price List states that the Sealed Air Corporation "Jiffylite R Bubble Gold Kraft Mailers" contain 15% postconsumer recycled paper fibers and 15% postconsumer recycled plastic.

For the sake of analysis, this study assumes two different options for postconsumer content:

1. 0% postconsumer content bleached kraft, 0% postconsumer content LDPE/LLDPE blend.

2. 30% postconsumer content bleached kraft, 30% postconsumer content LDPE/LLDPE blend.

Polyethylene Shipping Bag with Polyethylene Bubble Padding

This padded shipping bag consists of an outer liner made from polyethylene, and an inner layer of padding that is made from a bubble wrap-like material.

Consistent with this study's approach with the polyethylene unpadded bag and the kraft/bubble padded bag, the study assumes that the outer liner is 100% LLDPE and that the inner bubble material is a 50% LDPE/50% LLDPE blend. For the sake of simplicity, two recycled-content options are modeled:

1. All materials 0% postconsumer content.

2. All materials 30% postconsumer content.

Weight and Volume of Packaging Materials

Drawing on the weight and volume of the shipped product and the different packaging options defined above, this section describes the methodologies used to define the weight and volume of different packaging materials used to transport the shipped product to the final customer. This description has three parts:

- Weight and volume of the shipping bags.
- Weight and volume of the corrugated box.
- Weight and volume of the void-fill materials.

In determining the box and bag sizes that this average product would be shipped in, DEQ's goals were to identify sizes that are reasonable, unbiased, and reflect a likely outcome for companies that are shipping a variety of products. The distinction between companies that ship a limited variety of items vs. a larger variety of items is an important one. Companies that sell and ship a small number of products of a uniform size are better able to optimize the sizes of packaging; if there is no or little variability in the size of products sold, then packaging can be chosen that is "just right" in size. However, many companies which sell mail-order goods to residential customers sell not one but many different sizes of products. Customers may order one or more than one product, and so the number of possible permutations is very large. Order fulfillment (packing) staff are typically provided with a selection of box and/or bag sizes to choose from. Greater variety among box and bag sizes provides greater opportunity to use a shipping package that is optimized: just large enough to provide adequate protection to the product, but not overly large. In fact, a whole industry has sprung up in recent years to help distribution and order fulfillment centers optimize the selection of shipping cartons.

In a perfect world, the average product would be shipped in a bag or box that is optimized in volume (is "just right"). This would minimize the cost of packaging materials, reduce the "cube" of the package and associated expenses, and reduce the environmental burdens associated with several stages of the packaging material's life cycle ("cube" is packaging industry parlance for the effective volume of the package while in shipment). However, most companies that sell a variety of products (typically in combination with each other) are not able to optimize packaging all of the time because doing so would require stocking each packing station with an unrealistically large number of different sizes of bags and/or boxes.

Significant variation exists within companies in this regard. For example, in 2002, the direct-to-customer order fulfillment center for Norm Thompson Outfitters provided each packing station with 15 different sizes of stock boxes. A 2002 study of box utilization at a direct-to-customer order fulfillment center for the larger Williams Sonoma family of companies (which includes Williams Sonoma, Pottery Barn, and Hold Everything) found nine different sizes of stock boxes in use. Also in 2002, seven different sizes of boxes were made available to Pottery Barn retail stores, and six different sizes of boxes were made available to Williams-Sonoma retail stores. Clearly, not all products can be shipped in a box that is sized "just right". The same is true of stock shipping bags.

For example, when Norm Thompson first began using shipping bags, four different sizes of stock bags were purchased. Over the years, this was reduced to just two different sizes, and at times, only one size is actually kept in stock.

One challenge is to determine the sizes of shipping bags and corrugated box that would be used to ship this “average product” for the purposes of modeling life cycle environmental burdens. For starters, it is assumed that the average product is shipped “flat”, that is, without additional folding. (This reflects standard practice among many clothing retailers, as they don’t want to introduce additional wrinkles or creases into the product. It also reflects reality for shipments of other non-breakable items that are not textiles, such as books, that cannot be folded or rolled.)

For the purposes of this study, it is assumed that the average order fulfillment/ packing station will be stocked with a reasonable selection of stock bags and boxes. It is further assumed that packing staff will, on average, optimize the selection of boxes and bags to provide the “best fit” for the outbound product, given the boxes and/or bags provided for their use.

Weight and Volume of Shipping Bags. U.S. industry standards for stock shipping bags are as follows:

Stock #	Size (when flat)
000	4” x 8”
00	5” x 10”
0	6” x 10”
1	7.25” x 12”
2	8.5”x 12”
3	8.5” x 14.5”
4	9.5” x 14.5”
5	10.5” x 16”
6	12.5” x 19”
7	14.25” x 20”

While some order fulfillment centers might choose to carry all of these sizes of stock bags, inventory management limitations, space limitations at individual packing stations, and higher per-bag prices resulting from spreading bag purchases over a larger variety of sizes, make this scenario unlikely. Given the variety in product sizes that might be shipped, it is reasonable to assume that most order fulfillment centers would stock at least the largest stock size available, and then some variety of smaller sizes.

The “shipped product” defined earlier in this appendix measures 17.5” x 12” x 2.5”, which allows it to lie flat within the largest stock size available (bag #7: interior dimensions of 20” x 14.25”, when flat). The average product will not fit into any of the other stock bag sizes. Therefore, the study assumes that the shipped product will be sent to customers inside a #7 stock bag.

It is worth noting that all of the different bag types included in this study can also be purchased in custom sizes (including larger sizes), and that some companies provide different stock sizes than listed above.

Bag weights used in this study are derived primarily through weighing actual #7 stock bags provided by Sealed Air Corporation and Pactiv. Weighing and destructive analysis of multi-material bags was conducted by Scott Kopacek of Pack Edge Development, on behalf of DEQ.

<u>Kraft Paper Shipping Bag.</u> Pack Edge weighed a Sealed Air #7 “Jiffy Utility Mailer” as 0.168 pounds. A Pactiv #7 “TuffKraft” weighed 0.114 pounds after fiberglass filaments were removed. This study uses a simple average of these two results, or 0.141 pounds per bag.

<u>Polyethylene Shipping Bag.</u> Pack Edge weighed a Sealed Air #7 “Shurtuff Durable Mailer” as 0.058 pounds. A Pactiv #7 “Polylite Mailer” weighed 0.076 pounds. This study uses a simple average of these two results, or 0.067 pounds per bag.

<u>Kraft Paper Shipping Bag with Newsprint Padding.</u> Pack Edge destructed and weighed the components of a Sealed Air #7 “Jiffy Padded Mailer” and a Pactiv #7 “Pad-Kraft Mailer”. The Pactiv mailer was separated into three components: outer liner (0.090 pounds), inner liner (0.086 pounds), and newsprint filler (0.176 pounds). The Sealed Air mailer was only separated into two components: liners (0.194 pounds) and newsprint filler (0.208 pounds).

This study assumes filler of 0.192 pounds per bag, or a simple average of the two weighed bags. We assume that the total weight of the inner and outer liner (combined) is the average of the two bags (0.185 pounds, an average of 0.194 [Sealed Air] and 0.176 [Pactiv]), and that the weight of each liner equals the assumed total weight of the liner multiplied by the percentage weight in the Pactiv product. Thus, the assumed outer liner weighs 0.095 pounds and the assumed inner liner weighs 0.090 pounds per bag.

<u>Kraft Paper Shipping Bag with Polyethylene Bubble Padding.</u> Pack Edge destructed and weighed the components of a Sealed Air #7 “Jiffylite Mailer” and a Pactiv #7 “Air-Kraft Mailer”. The bag modeled in this study is based on an average weight of 0.086 pounds kraft per bag (0.090 for Jiffylite and 0.082 for Air-Kraft) and an average weight of 0.047 pounds of bubble per bag (0.050 for Jiffylite and 0.044 for Air-Kraft).

<u>Polyethylene Shipping Bag with Polyethylene Bubble Padding.</u> Pack Edge weighed a Sealed Air #7 “Jiffy Tuffguard Mailer” (0.160 pounds) and a Pactiv #7 “Armor-Lite Mailer” (0.1056 pounds). This study assumes the bag’s weight is 0.1328 pounds, a simple average of the two weighed bags. Pack Edge attempted to destruct and weigh the components of the two bags but was only able to destruct the Sealed Air bag, where the outer layer was found to be 47.5% of the total weight and the bubble was 52.5% of the total weight. These percentages are applied against the assumed bag weight of 0.1328 pounds, resulting in assumed weights of 0.063 pounds of liner and 0.070 pounds of bubble per bag.

Bag volumes of unpadded bags (when filled with a shipped product) are assumed to be 14.25” x 20” x 2.5” (width and length of the stock bag, thickness of the shipped product). Bag volumes of padded bags are assumed to be 14.25” x 20” x 2.9” due to the extra thickness of the padding.

Weight and Volume of the Corrugated Box. A much larger number of stock box sizes are available than sizes of stock shipping bags. By one estimate, at least 200 different sizes of stock boxes are readily and commercially available in the Pacific Northwest. Despite having all these different sizes (plus custom sizes) to choose from, the average order fulfillment center will not stock its packing stations with this many different sizes of boxes. As noted earlier, in 2002, Norm Thompson’s direct-to-customer order fulfillment center supplied its packing stations with a portfolio of 15 different sizes of stock boxes; a Williams-Sonoma direct-to-customer order fulfillment center used nine different sizes, and Williams-Sonoma and Pottery Barn retail stores were provided six and seven different sizes to choose from, respectively.

This being the case, what size corrugated shipping carton is the average order fulfillment center likely to use to ship the average product that is defined earlier in this appendix? For the purposes of estimating environmental burdens of the life cycle of the corrugated box, this is an important question. The size of shipping carton used not only determines the amount of linerboard and medium used, but also the cube of the box and the amount of void space in the box, which in turn impacts the amount of void-fill material (loose-fill “peanuts”, crinkled newsprint, shredded paper, etc.).

The method of box selection used in this study uses a combination of two approaches: first, a review of one retail mail-order company’s actual portfolio of boxes, and second, a review of average void spaces in corrugated boxes among several order fulfillment operations.

The portfolio of box sizes used by Norm Thompson Outfitters forms the basis of the first element of this selection process. Norm Thompson Outfitters is the largest of the Oregon-based companies working with DEQ on packaging waste reduction and also is the company that provided that data used to define the dimensions of the average unit product being shipped. The choice to use an actual portfolio of box sizes from an actual company, rather than defining our own portfolio of “likely box sizes” removes a potential element of bias from the process of box selection.

All 15 of the stock boxes currently used by Norm Thompson at its order fulfillment center were reviewed against the dimensions of the average unit product. Of the 15 boxes in stock, six of the boxes are too small to allow the product to be placed in the box without additional folding. Of the remaining nine box sizes, four are most likely to be selected by packing staff when deciding which box to use to ship this unit product, based on their size and how packing staff might select boxes based on the principle of “best fit” (assumed above). These four box sizes are also the most commonly used of the nine available boxes, collectively representing 82% of the projected number of boxes actually used by Norm Thompson in FY 2003 from among the nine possible boxes.

These four boxes are shown in Table B-2. A packer might select Box #07 because it allows for the product to fit into the box while minimizing void volume. However, there would only be a ½" vertical gap (head space) between the top of the product and the top of the box. Box #26 or Box #08 might be selected if the packer wanted to increase the headspace; the product would barely fit length-wise into Box #26. Finally, Box #18 would get chosen by a packer who wanted to minimize the box's footprint (length times width), although due to its height, this box has the greatest total volume. The other five boxes (not shown) all have significantly larger footprints and/or volumes.

Table B-2.
Possible "Best Fitting" Box Sizes at Norm Thompson Outfitters.

Box #	Interior Length	Interior Width	Interior Height	Total Volume	Product Volume	Void Volume	% Void Volume
#07	21.25"	17.25"	3"	1,100 in^3	530 in^3	570 in^3	52%
#26	17.5"	15"	5.75"	1,510 in^3	530 in^3	980 in^3	65%
#08	22.5"	16.75"	5.25"	1,979 in^3	530 in^3	1,449 in^3	73%
#18	17.75"	13.75"	11.5"	2,807 in^3	530 in^3	2,277 in^3	81%
Unit Product	17.5"	12"	2.5"		530 in^3		

For reference, it is useful to know the average percentage of box cube which is empty space (void) for companies doing order fulfillment in corrugated boxes. We define this as "% Void Space" (also called "% Void Volume" in Table B-2). For example, if a box has interior dimensions of 10" x 10" x 10", its total volume would be 1,000 in^3. If the box is used to ship a product 250 in^3 in volume, then the remaining 750 in^3 of the box would be empty space, or void, resulting in a % void space of 75%.

DEQ has not been able to obtain data for average percentage void space for companies shipping non-breakable soft goods in corrugated boxes. However, DEQ does have limited data sets for two companies shipping a combination of hard and soft goods in corrugated boxes.

The first company, Williams-Sonoma, is also working with DEQ on packaging waste reduction. While most Williams-Sonoma direct-to-customer shipments originate from an order fulfillment center in the Memphis area, retail stores also conduct a limited amount of direct-to-customer shipments in corrugated boxes. DEQ staff conducted an assessment of outbound packaging (including void space) at the Portland Williams-Sonoma store in October 2002. Sixteen actual orders had been packed into shipping cartons by store associates, who were instructed to pack boxes as normal, but not to seal the boxes with tape. After all 16 orders were packed, DEQ staff then measured the interior dimensions of these shipping cartons and measured (or estimated) the volume of the products being shipped.

Of the 16 boxes, all but one had been "scored" in order to reduce the height of the box as shipped. Scoring boxes involves cutting down the four vertical seams of a box, then folding the top (cut) portions of the box sides into the box, as if the box's top flaps had been extended. The advantage of scoring boxes is that it reduces the need for void fill. (In fact, on this day, scoring of boxes reduced the amount of void fill used by 40%.) DEQ measured both the height of boxes scored and the height had the boxes not been scored. Anecdotally, even when opportunities exist to reduce box void by scoring, more boxes used for direct-to-customer shipments appear to be unscored, rather than scored.

The average % void space for the 16 boxes as shipped (scored volumes) was 65%, with a standard deviation of 17%. Had none of the boxes been scored, the average % void space would have been 74%, with a standard deviation of 16%. (These are simple averages that do not take into account differences in box sizes.)

The second company for which DEQ has data on void space is the Portland order fulfillment center for an office products company that sells office products to State agencies as well as many of the local governments that DEQ works with on waste reduction. In a related effort, DEQ and the City of Beaverton, OR, conducted a study in 2002 in which inbound boxes received from this company were evaluated for void space. The DEQ/Beaverton study only looked at boxes that contained "repacked" items that had been packed through an order-fulfillment process. Product boxes with their original product in place (such as a case of paper containing 10 reams of paper) were not evaluated. Over a two-month period starting in May, staff measured the product and box dimensions of 59 boxes (50 received at Beaverton) packed at this company's Portland order fulfillment center. The average % void space for these boxes was 57%, with a standard deviation of 30%.

For reference, it is worth noting that both FedEx and United Parcel Service recommend, when shipping items in a corrugated shipping box, to provide for at least two inches of void space between the product and each side of the shipping box. Greater void spaces are encouraged for fragile items. Were this study's average unit product shipped in a box that met this minimum guidance, the 17.5" x 12" x 2.5" product would be packed into a box with interior dimensions of 21.5" x 16" x 6.5", and the % void space would be 76%.

Only a limited amount of void space data were available for this study. The average void percentages observed for boxed items originating at the office supply company's and Williams-Sonoma's Portland locations were 57% and 65%, respectively. Had Williams-Sonoma not scored its boxes, the void percentage there would have been 74%. Were this study's average unit product packed following minimal UPS and FedEx guidance, the void percentage would be 76%.

Interestingly, this range of real-life data (57% - 74%) is neatly overlapped by the range of possible void percentages contained in Table B-2 (52% - 81%). Of the four boxes shown in Table B-2, which one is most likely to be used? It is reasonable to assume that, on average, breakable items will be shipped with greater cushioning, and thus greater void space, than soft goods. Conversely, non-breakable items (the subject of this study) will be shipped on average with less cushioning, and thus less void space, than hard goods. Box #07, with a void percentage of 52%, is the only box for which: a) the average unit product can be placed in the box without being further folded; and b) the box results in a void percentage lower than that observed for hard goods and mixed soft & hard goods shipments from DEQ's limited data set. In theory, an even smaller box (resulting in less void space) might be used, but this would require using a different list of available stock boxes, and no such list is available to DEQ at this time. Now that the dimensions of the average unit product are known, introducing a different list of stock boxes would potentially introduce bias into the study. Further, since the dimensions of the average unit product were derived using data from Norm Thompson, it seems appropriate to use the same company's portfolio of stock boxes for determining the box size. Therefore, this study assumes that the corrugated box used to ship the average unit product will have the same interior dimensions as Norm Thompson's stock box #07: 21.25" x 17.25" x 3".

According to Pack Edge Development, a box of this size constructed from 200# B-Flute, or an equivalent ECT corrugated paperboard will have exterior dimensions of 21.5" x 17.5" x 3.5" and will weigh 1.39 pounds. (The carton contains 11.37 square feet of corrugated at 122 pounds per 1,000 square feet.)

Weight and Volume of Void Fill Materials. The volume of void fill materials used per unit shipment is roughly equal to (or slightly less than) the void space of the average box with the shipped product inside it. Some retail companies add other items into the box, such as a receipt, catalog, or other materials; rather than modeling or accounting for these types of materials, this study assumes that the box contains only the shipped product and void fill.

Pack Edge Development conducted a void fill study in order to estimate the average amount of void fill material that would be used to ship each package configuration. A "mock product" was created out of a medium density polyurethane foam cut to the unit product dimensions of 17.5" x 12" x 2.5". A "mock carton" with the interior dimensions of 21.25" x 17.25" x 3" was fabricated from 200#, B-flute corrugated fiberboard.

Samples of each void fill material were obtained either directly from the manufacturer or through an authorized local distributor. In either case no reference to this study was made in order to obtain average general inventory samples. It should be noted that there were variations in inflated polyethylene air packets obtained from differing vendors, both in size and inflation level. Several vendors' systems allow for inflation levels to be set by the user. For the purposes of this study we assume that the inflation levels for the samples provided represent what the manufacturer considers to be an average level.

In order to minimize error in the study, data was recorded using five different packers. Each packer completed the study at the same loading center while following the same verbal instructions. Packers were told to load the "mock product" into the "mock carton" and use enough dunnage material to void fill the package so the product would be held in position for shipment. They were told that the added dunnage did not need to cushion the product, but only to hold the product in its relative position. After each packaging configuration was loaded the dunnage was removed, weighed, and recorded.

Results of this study are shown in Table B-3. For all void fill materials except for the inflated polyethylene air packets, the simple average of the five packers is what this study uses as the assumed weight of void fill used per package. For the inflated polyethylene air packets, where two different brands of 8" x 4" packets were provided, the study assumes a simple average of the results for both brands. One brand of 8" x 8" air packets were also evaluated but are not included in the study due to anecdotal observations by study team members that the 8" x 4" packets appear to be more commonly used.

The weights and postconsumer recycled contents of all packaging options analyzed for the defined soft goods shipment are summarized in Table B-4.

Table B-3.
Results of Void Fill Study (Pack Edge Development)

	Loader #1	Loader #2	Loader #3	Loader #4	Loader #5	**Average**	**Standard Deviation**
Cushion Cubes (Molded Pulp)	0.352	0.420	0.382	0.364	0.378	**0.379**	**0.026**
Kraft Paper: 24" x 18", 50#	0.200	0.160	0.158	0.200	0.202	**0.184**	**0.023**
	(5 Sheets)	(4 Sheets)	(4 Sheets)	(5 Sheets)	(5 Sheets)		
Inflated PE Packs: Pactiv (8"x4")	0.090	0.090	0.114	0.086	0.090	**0.094**	**0.011**
	(15 Packs)	(15 Packs)	(19 Packs)	(15 Packs)	(15 Packs)	**(15.8 Packs)**	
Inflated PE Packs: Storopak (8"x4")	0.068	0.070	0.094	0.068	0.072	**0.074**	**0.011**
	(11 Packs)	(11 Packs)	(15 Packs)	(11 Packs)	(11 Packs)	**(11.8 Packs)**	
Average, Pactiv/Storopack (8" x 4")						**0.084**	
Pillow Pack: Storopak (8"x8")	0.040	0.052	0.054	0.052	0.047	**0.049**	**0.006**
	(4 Packs)	(5 Packs)	(5 Packs)	(5 Packs)	(5 Packs)	**(4.8 Packs)**	
EPS Peanuts	0.044	0.042	0.050	0.052	0.050	**0.048**	**0.004**
Cornstarch Peanuts	0.078	0.084	0.094	0.094	0.082	**0.086**	**0.007**
Newsprint (25" x 22.5")	0.118	0.120	0.200	0.204	0.197	**0.168**	**0.045**
	(3 Sheets)	(3 Sheets)	(3 Sheets)	(5 Sheets)	(5 Sheets)		
Loose Fill Shredded OCC	0.284	0.310	0.448	0.234	0.315	**0.318**	**0.079**
Loose Fill Shredded Office Paper	0.132	0.150	0.174	0.140	0.142	**0.148**	**0.016**

All results are pounds of packaging material.
Unit Product: 17.5" x 12" x 2.5"
Unit Product Weight: 1.28 pounds
Shipping Carton: 21.25" x 17.25" x 3"

Table B-4

DEFINITION OF PACKAGING OPTIONS

CORRUGATED BOX		**Postconsumer Recycled Content**	**Pounds/ Package**	**Thou Lb/ 10,000 Packages**
Option 1	industry average linerboard	28%	0.95	9.49
	industry average medium	59%	0.44	4.41
	overall box	38%	1.39	13.90
Option 2	recycled linerboard	71%	0.95	9.49
	recycled medium	100%	0.44	4.41
	overall box	80%	1.39	13.90
DUNNAGE (used with corrugated box)				
Inflated Polyethylene Air Packets				
Option 1	LDPE	0%	0.084	0.84
Option 2	LDPE	30%	0.084	0.84
Polystyrene Foam Loose Fill				
Option 1	EPS	0%	0.048	0.48
Option 2	EPS	30%	0.048	0.48
Starch-based Loose Fill				
	cornstarch	0%	0.086	0.86
Molded Pulp Loose Fill				
	newspaper	100% (1)	0.38	3.79
Kraft Paper (Crumpled)				
Option 1	unbleached kraft	0%	0.18	1.84
Option 2	unbleached kraft	50%	0.18	1.84
Newsprint (Crumpled)				
Option 1	newsprint	10%	0.17	1.68
Option 2	newsprint	50%	0.17	1.68
Shredded Postconsumer Paper(board)				
Option 1	corrugated	100% (1)	0.32	3.18
Option 2	office paper (2)	100% (1)	0.15	1.48

(1) 100% postconsumer material; postconsumer content of postconsumer material may be less than 100%.
(2) 83.6% printing-writing, 16.4% newspaper

Table B-4 (cont.)

DEFINITION OF PACKAGING OPTIONS

SHIPPING BAGS		**Postconsumer Recycled Content**	**Pounds/ Package**	**Thou Lb/ 10,000 Packages**
Unlined Kraft				
Option 1	bleached kraft	0%	0.14	1.41
Option 2	bleached kraft	30%	0.14	1.41
Kraft with Paper Padding				
Option 1	bleached kraft outer	0%	0.10	0.95
	unbleached kraft inner	0%	0.090	0.90
	shredded newspaper pad	100% (1)	0.19	1.92
			0.38	3.77
Option 2	bleached kraft outer	30%	0.10	0.95
	unbleached kraft inner	30%	0.090	0.90
	shredded newspaper pad	100% (1)	0.19	1.92
			0.38	3.77
Kraft with Bubble Wrap				
Option 1	bleached kraft bag	0%	0.086	0.86
	LDPE film (50% of bubble)	0%	0.024	0.24
	LLDPE film (50% of bubble)	0%	0.024	0.24
			0.13	1.33
Option 2	bleached kraft bag	30%	0.086	0.86
	LDPE film (50% of bubble)	30%	0.024	0.24
	LLDPE film (50% of bubble)	30%	0.024	0.24
			0.13	1.33
Unlined Film Bag				
Option 1	LLDPE	0%	0.067	0.67
Option 2	LLDPE	30%	0.067	0.67
Film Bag with Bubble Wrap				
Option 1	LLDPE bag	0%	0.063	0.63
	LDPE film (50% of bubble)	0%	0.035	0.35
	LLDPE film (50% of bubble)	0%	0.035	0.35
			0.13	1.33
Option 2	LLDPE bag	30%	0.063	0.63
	LDPE film (50% of bubble)	30%	0.035	0.35
	LLDPE film (50% of bubble)	30%	0.035	0.35
			0.13	1.33

(1) 100% postconsumer material; postconsumer content of postconsumer material may be less than 100%.

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B-3 "2001 Statistics, Data through 2000; Paper, Paperboard, Wood Pulp" American Forest & Paper Association, October 2001 pp 24, 25, 26, 27, 38, 43, 81.

B-4 "Capacity and Fiber Consumption: Paper, Paperboard, Pulp" 42nd Annual Survey 2000-2004 American Forest & Paper Association, December 2001 Page 24 Recovered Paper Consumed in Paper and Paperboard Manufacture.

B-5 "2001 Annual Statistical Summary Recovered Paper Utilization" Fifteenth Edition Paper Recycling Group, American Forest & Paper Association, April 2001. Page 85.

B-6 Fibre Box Association "Annual Report 2001" Table "Consumption By Corrugator Plants" Table "Containerboard Production and Consumption".

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APPENDIX C

MANUFACTURE OF PACKAGING FOR MAIL-ORDER SOFT GOODS

INTRODUCTION

The energy requirements, raw material requirements, and environmental emissions for the major processes in the manufacture of alternative packaging configurations for mail-order soft goods are presented in this appendix. The analysis begins with raw materials extraction and proceeds through the manufacture of the packaging materials. The tables in this appendix present aggregated data for all steps from raw material extraction through fabrication of packaging material. For shipping bag materials, the tables also include transportation of component materials to the bag manufacturer. Transportation of packaging materials to the order fulfillment center is described in Appendix D.

The steps in the production of the following packaging materials are described in the Material Production section of this appendix:

- Polyethylene Resin
    - Virgin LDPE Resin Production
    - Virgin LLDPE Resin Production
    - Postconsumer Polyethylene Resin Production
- EPS Resin
    - Virgin EPS Resin Production
    - Postconsumer EPS Resin Production
- Cornstarch
- Bleached Kraft Paper (Virgin)
- Unbleached Kraft Paper (Virgin)
- Postconsumer Recycled Paper Production
- Newsprint Production
    - Virgin Newsprint Production
    - Recycled Newsprint Production
- Corrugated Paperboard
    - Kraft Linerboard Production
    - Semichemical Medium Production
    - Recycled Linerboard and Medium Production

Manufacture of the following packaging components are described in the Product Fabrication section of this appendix:

- Polyethylene Film Fabrication
- Polyethylene Inflatable Air Pack Fabrication
- EPS Foam Product Fabrication
- Cornstarch Foam Fabrication

- Molded Pulp Cushion Cubes Fabrication
- Corrugated Box Fabrication
- OCC Shredding
- Paper Shredding

MATERIAL PRODUCTION

This section discusses the processes for manufacturing materials commonly used in mail-order soft packaging. These materials include polyethylene resins, expandable polystyrene (EPS), cornstarch, bleached and unbleached kraft paper, newsprint, and corrugated paperboard. The collection of postconsumer materials is also discussed in this section.

Polyethylene Resin

Polyethylene film is used for manufacturing inflatable air packs, bubble wrap, and shipping bags. Low-density polyethylene (LDPE) is used in the manufacture of bag film linings, bubble wrap, and inflatable air packs. Linear low-density polyethylene (LLDPE) is used in the manufacture of bags, bag film linings, and bubble wrap. The production of polyethylene film includes the following steps:

- Crude Oil Production
- Crude Oil Processing (Desalting, Distillation, and Hydrotreating)
- Natural Gas Production
- Natural Gas Processing
- Ethylene Production
- Virgin LDPE Resin Production
- Virgin LLDPE Resin Production
- Postconsumer Polyethylene Resin Collection and Recycling

Figure C-1 shows the material flows and steps in the production of polyethylene film. These steps are discussed below.

Crude Oil Production. Oil is produced by drilling into porous rock structures located several thousand feet underground. Once an oil deposit is located, numerous holes are drilled and lined with steel casing. Some oil is brought to the surface by natural pressure in the rock structure, but most oil requires some energy to drive pumps that lift oil to the surface. Once oil is on the surface, it is stored in tanks to await transportation to a refinery. In some cases, it is immediately transferred to a pipeline, which transports the oil to a larger terminal.

The American Petroleum Institute identifies three categories of oil extraction wastes: produced water, drilling waste, and associated waste.

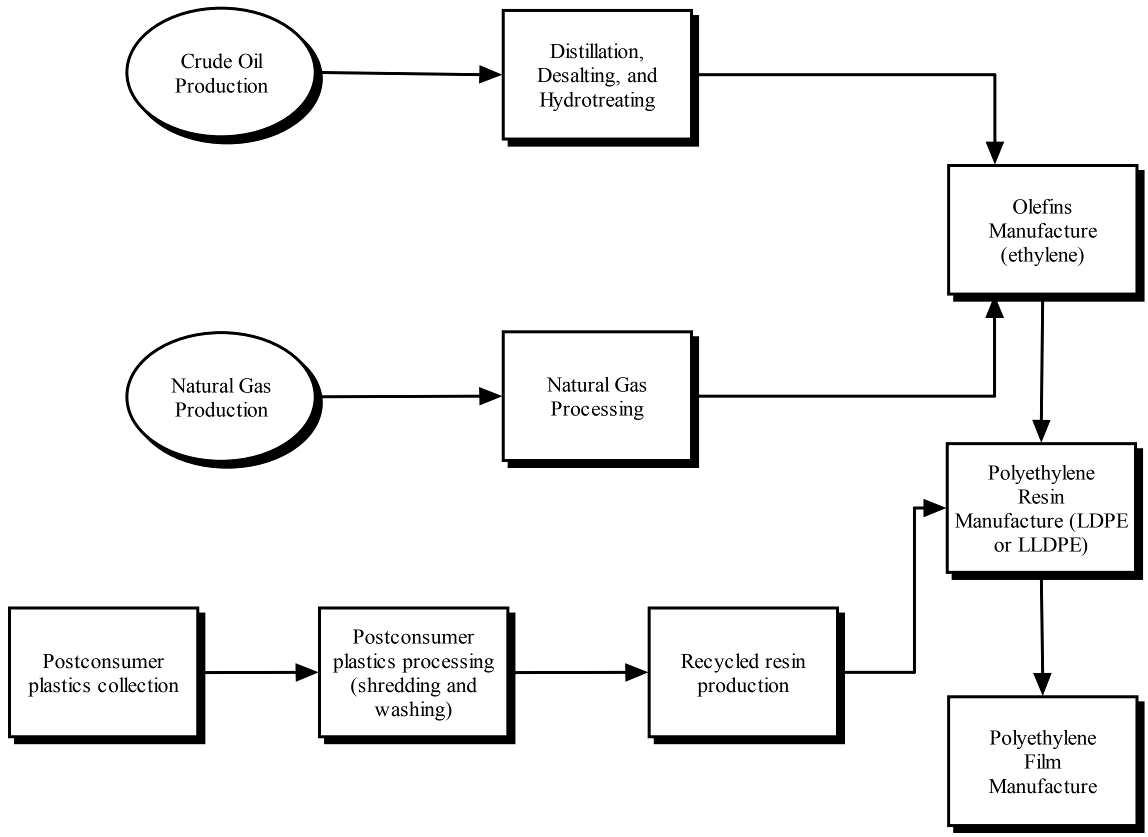

Figure C-1. Flow diagram for the manufacture of polyethylene film.

The water that is extracted with crude oil is called the "oil field brine". The brine goes through a separator at or near the wellhead in order to remove the oil from the water. According to the American Petroleum Institute (API), it is estimated that 17.9 billion barrels of brine water were produced from crude oil production in 1995. This quantity of water equates to a ratio of 3.3 barrels of water for each barrel of oil. The majority of this water (85 percent) is injected into separate wells specifically designed to accept production-related waters. This represents all waters produced by onshore oil production facilities, which are not permitted to discharge "oil field brine" to surface waters (Reference A-29). The remainder of the produced water is from offshore oil production facilities and is assumed to be discharged to the ocean. Therefore, the waterborne wastes represent the brine wastes present in this 15 percent of brine water (Reference A-50). Because crude oil is frequently produced along with natural gas, a portion of the waterborne waste is allocated to natural gas production (Reference A-20).

The second type of oil extraction waste is drilling waste. Drilling waste includes the rock cuttings and fluids produced from drilling a wellbore. Drilling mud, a viscous fluid, is a particular kind of drilling fluid that is commonly used for drilling wellbores.

The third source of waste is associated waste, which is a broad category of small volume wastes. Associated wastes include atmospheric emissions, which are primarily hydrocarbons. These atmospheric emissions originate from the natural gas produced from combination wells and result in line losses and unflared venting.

The transportation data are based on a mix of foreign and domestically produced crude oil. According to the **Petroleum Supply Annual, June 1994,** 49 percent of the crude oil used in the United States is imported.

Crude Oil Processing (Desalting, Distillation, and Hydrotreating). A petroleum refinery is a complex combination of processes that serve to separate and physically and chemically transform the mixture of hydrocarbons found in crude oil into a number of products. Modern refineries are able to vary the different processing steps through which a charge of crude oil passes in order to maximize the output of higher value products. This variation of processing steps can change according to the make-up of the crude oil as well as the economic value of the products. Because of this variation, it is necessary to make certain assumptions about the refinery steps to which crude oil is subjected in order to produce petrochemical feedstocks.

For this analysis, it is assumed that crude oil used to produce feedstocks for olefins production goes through the following refinery operations: desalting, atmospheric and vacuum distillation, and hydrotreating. Due to a lack of facility-specific data, literature sources were used to estimate the energy requirements for these refining steps. A number of literature references were used, most of which showed similar energy inputs (References C-13 through C-17).

Crude desalting is the water-washing of crude oil to remove water-soluble minerals and entrained solids (Reference C-18). For this analysis it is assumed that all of the crude that enters a refinery passes through the desalting step (References C-16 and C-18).

Crude oil distillation separates the desalted crude oil into fractions with differing boiling ranges. Atmospheric distillation is used to separate the fractions with a boiling point less than 650° Fahrenheit (References C-16, C-17, and C-18). At temperatures greater than 650° Fahrenheit thermal cracking of the hydrocarbons starts. Fuel gas or still gas that is liberated from the crude during distillation is further processed into liquefied petroleum gas or natural gas, depending on the carbon chain length. This gas is sold or used in the refinery to generate heat. About 52 percent of the non-electrical energy used in a refinery for direct heating or steam production comes from fuel gas (Reference C-19). Coproduct credit is given on a mass basis for the gas fractions not used for energy in the refinery. Fuel gas or still gas used as an energy source in refining is assumed to have the same composition as natural gas and is shown as process energy, not as raw material.

The residue from the atmospheric distillation unit passes to a vacuum distillation unit where separation of the various fractions can be accomplished at lower temperatures than would be required at atmospheric pressure. The residue or bottoms of the vacuum distillation unit is a valuable coproduct that is further processed to make usable products. Coproduct credit is given on a weight basis for this residue. It is assumed that all of the crude used to produce olefins feedstock passes through atmospheric distillation, while only 46 percent of the initial crude oil charge passes through vacuum distillation (References C-13, C-14, and C-18).

Hydrotreating is a catalytic hydrogenation process that reduces the concentration of sulfur, nitrogen, oxygen, metals, and other contaminants in a hydrocarbon feed. These contaminants can poison or foul catalysts used in catalytic crackers and contribute to air emissions if the hydrocarbon is used as a fuel. It is assumed that all of the feedstock for olefin cracking passes through hydrotreatment. Sulfur and metals removed from crude are separated and sold as coproducts (References C-13 and C-16). Coproduct credit is given for these materials on a mass basis.

Energy requirements for petroleum refineries are usually listed in literature sources as Btu of fuel, pounds of steam, and electricity per 42-gallon barrel of crude processed. For this analysis, a conversion of 3.385 barrels of crude per 1,000 pounds was used. Steam inputs were converted to Btu requirements using a conversion of 1,200 Btu per pound. Btu inputs for steam were added to the Btu inputs listed as fuels, and the total was converted to quantities of fuels using the combustion energy values listed in Appendix A and the following refinery fuel mix: residual oil and residues (coke), 22 percent; purchased natural gas, 24 percent; LPG, 2 percent; and fuel gas or still gas, 52 percent (Reference C-20). Negligible quantities of coal and distillate oil are also used in the “average” refinery.

Desalting, distillation (atmospheric and vacuum), and hydrotreating of crude oil consume the majority of energy required for the refining of petroleum fuels. Still gas, an energy source produced in refineries as a byproduct, is included in the natural gas process energy category in this analysis. Raw material inputs are calculated from the average loss due to atmospheric, waterborne, and solid waste emissions per unit of processed crude oil (Reference C-20). The data in this analysis are representative of petroleum refineries in 1992.

Refined oil products such as ethane, propane, and other linear (paraffinic) and aromatic hydrocarbons used in the production of packaging materials undergo further processing at the refinery (into materials such as ethylene, propylene, butylenes, butadiene, benzene, toluene, and xylenes), so no transportation is necessary between petroleum refining and the production of feedstock petroleum products.

Natural Gas Production. Natural gas is extracted from deep underground wells and is frequently co-produced with crude oil. Because of its gaseous nature, it flows quite freely from wells which produce primarily natural gas, but some energy is required to pump natural gas and crude oil mixtures to the surface. Atmospheric emissions from natural gas production are primarily due to line or transmission losses and unflared venting. The waterborne waste pertains to the portion of natural gas that is produced in combination with oil. These combination wells account for approximately 25 percent of all natural gas production. Natural gas is typically processed at or very near the extraction site, so transportation is not required between natural gas extraction and processing.

Natural Gas Processing. Light straight-chain hydrocarbons are normal products of a natural gas liquids processing plant. The plants typically use compression, refrigeration and oil adsorption to extract these products. Heavy hydrocarbons are removed first. The remaining components are extracted and kept under controlled conditions until transported in high-pressure pipelines, insulated rail cars or barges.

If the natural gas has a hydrogen sulfide content of greater than 0.25 grain per 100 standard cubic feet, it is considered “sour.” Before it can be used, the gas must undergo removal of the hydrogen sulfide by adsorption in an amine solution, a process known as “sweetening.”

The primary pollutants from the natural gas stream are volatile hydrocarbons that leak into the atmosphere. Additional sources of pollutants are natural gas-fired compressor engines. Emissions will also result from the gas sweetening plants if the acid waste gas from the amine process is flared or incinerated. When flaring or incineration is practiced, sulfur dioxide is the major pollutant of concern.

Ethylene Production. The primary process used for manufacturing olefins (ethylene and propylene) is the thermal cracking of saturated hydrocarbons such as ethane, propane, naphtha, and other gas oils. Cracking converts heavier gas oils into more valuable products by breaking down the complex molecule chains which make up the heavier hydrocarbon compounds into simpler, lighter ones. Currently the feedstocks for the production of propylene, ethylene, and other olefins in the United States are approximately 75 percent ethane/propane and 25 percent naphtha.

Typical production of ethylene, propylene, and other coproducts begins when hydrocarbons and steam are fed to the cracking furnace. After being heated to temperatures around 1,000° Celsius, the cracked products are quenched in heat exchangers which produce high-pressure steam. Fuel oil is separated from the main gas stream in a multi-stage centrifugal compressor. The main gas stream then undergoes hydrogen sulfide removal and drying. The final step involves fractional distillation of the various reaction products.

When ethane is the principal feedstock, the final production distribution shows approximately 80 percent ethylene and 20 percent other coproducts. For propane and naphtha feeds, ethylene production represents only 45 percent and 35 percent of the total reaction products, respectively. Therefore, with the present feedstock mix (75 percent ethane/propane, 25 percent heavier fuels), ethylene represents about 60 percent of the total reaction products (assuming the light feed represents 68 percent ethane and 32 percent propane, and assuming the heavier feed to be all naphtha).

Virgin LDPE Resin Production. LDPE is used for the manufacture of inflated air packets and bubble wrap padding. Low-density polyethylene (LDPE) is produced by the polymerization of ethylene in high-pressure reactors (above 3,000 psi). The two reactor types used are autoclaves and tubular reactors. Generally, tubular reactors operate at a higher average ethylene conversion than autoclave reactors. The polymerization mechanism is either free-radical, using peroxide initiators, or ionic polymerization, using Ziegler catalyst.

Reactor effluent consists of unreacted ethylene and polymer. The pressure of the effluent mixture is reduced and the ethylene is purified and recycled back to the reactor. The polyethylene is fed to an extruder and pelletized.

Virgin LLDPE Resin Production. Linear low-density polyethylene (LLDPE) is used for the manufacture of shipping bags and bubble wrap padding. LLDPE is produced through the polymerization of ethylene. Polyethylene is most commonly manufactured by either a slurry process or a gas phase process. Ethylene and small amounts of comonomers are continuously fed with a catalyst into a reactor.

In the slurry process, ethylene and comonomers come into contact with the catalyst, which is suspended in a diluent. Particulates of polyethylene are then formed. After the diluent is removed, the reactor fluff is dried and pelletized (Reference C-28).

In the gas phase process, a transition metal catalyst is introduced into a reactor containing ethylene gas, comonomer, and a molecular control agent. The ethylene and comonomer react to produce a polyethylene powder. The ethylene gas is separated from the powder, which is then pelletized (Reference C-28).

Franklin Associates has a limited number of industry data sets for the production of plastic resins. Because there were not enough LLDPE data sets to combine to protect the confidentiality of the data in an aggregated LLDPE data set, energy and emissions data for producing 1,000 pounds of LLDPE resin were estimated based on proprietary data sets for the production of LLDPE and HDPE (which, like LLDPE, is produced by low pressure gas phase or slurry polymerization), as well as a published data source (Reference C-120).

Postconsumer Polyethylene Resin Production. For this analysis, postconsumer polyethylene products are assumed to be collected by curbside collection techniques using single unit diesel trucks. In the United States, curbside collection of plastics is performed in one of four material mixes: single resins (such as HDPE milk jugs) collected separately; mixed resins (such as HDPE and PET bottles) collected together; an “all containers” mix (such as plastic bottles, glass bottles, and aluminum and steel cans mixed together); and a “single stream” mix (where all recyclables, including containers and fibers, are collected together, although some “single stream” programs continue to collect glass separately). How the plastics are collected, and whether they are compacted on-route, impacts the quantity of fuel used during collection, and it also impacts the amount of energy required to process and sort mixed recyclables after they have been collected. Generally speaking, mixing or commingling of materials on-route reduces collection energy requirements and increases processing energy requirements.

The trend in the United States is a move away from source separation and towards partial commingling and “single stream” collections. Modeling the energy requirements for collection and post-collection processing of each of these approaches is outside of the scope of this study and a simplifying assumption is made that the plastics are kept separate from other curbside recyclables during collection and thus require no intermediate processing to sort them from glass, metal, paper, etc. Although this assumption leads to an underestimation of processing (sorting) energy requirements, this will be offset by an overestimation of collection energy requirements. Relative to the energy required to produce virgin polyethylene resin, the differences in total energy requirements for different post-consumer collection and processing approaches will be small.

Using this approach, curbside collection is assumed to use approximately three gallons of diesel per 1,000 pounds of recyclables that are collected and transported to a processing facility (Reference C-124).

Collected plastics are assumed to be baled without further sorting. Baling is done using a double ram horizontal baler that produces a 30-inch by 44-inch by 46-inch bale (References C-109 and C-115). Bales of postconsumer plastics have an average density of 25 pounds per cubic foot (Reference C-116). The baler uses a 100 horsepower motor and has a throughput of five tons per hour (Reference C-116). An LPG-fueled front-end loader is used to move the material from the collection truck unloading area to the baler.

Once baled, the plastics are transported to a facility where they are granulated, washed, and palletized. The postconsumer plastic is received at the plant, typically in bales of recyclable plastic. The bales are sent through a debaler and then sorted if they contain mixed plastics. Sorting may be done by hand, mechanically, or through a combination of manual and mechanical means. The selected plastics are then sent by conveyor belt to a granulator. The granulated plastic flakes are blown into a washer. They are washed in water of approximately 200 degrees Fahrenheit and then spun dry. The flakes must be completely dry before going into the extruder; therefore, they may be stored to dry for an extended period of time (Reference C-109).

The dried plastic flakes are then sent through an extruder. In the extrusion process, the granules of plastic are fed into a hopper, which feeds into the heated barrel of the extruder. In this barrel, the screw rotates and sends the resin to a melt reservoir. When a sufficient amount of resin is in the reservoir, the screw pushes the plastic through an exit port. The resin is then immersed in a water-filled cooling tank. It is air dried and enters the pelletizer, which cuts the rod of dried resin into small pellets (Reference C-117). The final pellets are packed and sent to plastic product manufacturers.

Energy data for mechanical recycling of plastics is based on a survey of six different recycling plants from across the United States. As very few of the plants could tell how many kilowatt-hours of electricity they use, a survey of motor sizes for each piece of machinery and their throughput was taken. From the motor sizes, an efficiency for each size motor was found (References C-118 and C-119). The motors were assumed to be a 3-phase, 60 Hz, 1750 RPM, wound-rotor type. No energy data are included for mechanical sorting of debaled mixed plastics.

EPS Resin

Expandable polystyrene (EPS) is used in the production of foam packaging products, including loose fill. The production of virgin and recycled EPS are discussed below.

Virgin EPS Resin Production. Foam loose fill, used to fill the void space in packages, is made of expandable polystyrene (EPS). The steps of EPS manufacture are as follows:

- Crude Oil Production
- Crude Oil Processing (Desalting, Distillation, and Hydrotreating)
- Natural Gas Production
- Natural Gas Processing
- Ethylene Production
- Mixed Xylenes Production
- Benzene Production
- Styrene Production
- Blowing Agent Production
- Expandable Polystyrene (EPS) Resin Production

The material flows and steps in EPS production are shown in Figure C-2. Crude oil production, crude oil processing, natural gas production, natural gas processing, and ethylene production are discussed previously in this appendix and are not repeated here. The remaining steps of EPS production (mixed xylenes production, benzene production, styrene production, blowing agent production, and EPS production) are discussed below.

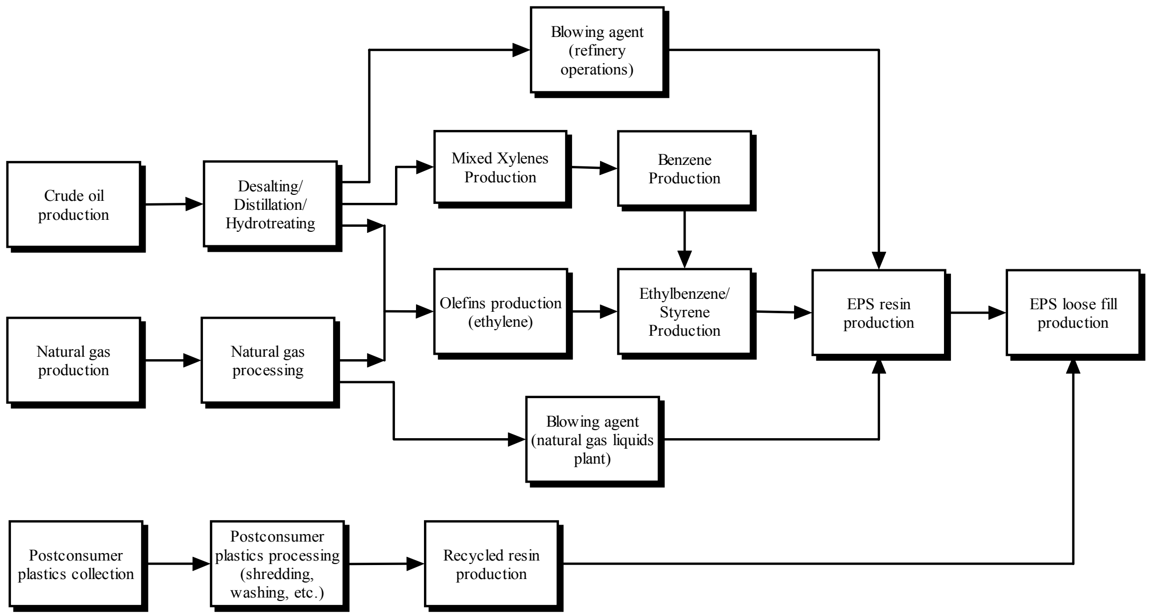

Figure C-2: Flow diagram for the production of EPS loose fill production.

Mixed Xylenes. Reforming processes are used at the refinery to convert paraffinic hydrocarbon streams into aromatic compounds such as benzene, toluene, and xylene. Catalytic reforming has virtually replaced thermal reforming operations. Catalytic reforming has many advantages over thermal reforming including the following:

1. Greater production of aromatics.
2. More olefin isomerization.
3. More selective reforming and fewer end products.
4. Operated at a low pressure, hence comparatively lower cost.

Catalysts such as platinum, alumina, or silica-alumina and chromium on alumina are used (Reference C-17).

Benzene Production. Benzene is naturally produced from crude oil as it is distilled in the refinery process. Also, a large portion of benzene is produced by the catalytic reforming of light petroleum distillate. In the reforming process, refined crude oil is fed through a catalyst bed at elevated temperatures and pressures. The most common type of reforming process is platforming, in which a platinum-containing catalyst is used. Products obtained from the platforming process include aromatic compounds (benzene, toluene, xylene), hydrogen, light gas, and liquefied petroleum gas. The aromatics content of the reformate varies and is normally less than 45 percent (References C-21 and C-22).

The reformate from the platforming process undergoes solvent extraction and fractional distillation to produce pure benzene, toluene, and other coproducts. Additional benzene is often produced by the dealkylation of the toluene.

Styrene Production. The production of styrene monomer is accomplished through a series of processes. The first is the production of ethylbenzene by the alkylation of benzene with ethylene. In this process, benzene initially passes through a drying column. From the drying column, the benzene and ethylene are mixed in a reactor with a suitable catalyst. This reaction is exothermic and occurs at relatively low pressures and temperatures. Unreacted benzene is removed and recycled back to the process. The ethylbenzene is then separated from the solution. The heavy bottoms, tars, and vent gases are burned while the solution is recycled back to the reactor.

Styrene is produced by dehydrogenation of ethylbenzene. The ethylbenzene is mixed with steam, and then allowed to come in contact with a catalyst in a reactor. This reaction is carried out at high temperature under vacuum. The heat is recovered from this reaction, and the hydrocarbon solution is sent to a series of fractionation units. The first separation removes the small amount (4 to 6 percent) of toluene and benzene produced by cracking. This toluene/benzene stream is typically sent back to the benzene plant. The second separation removes unreacted ethylbenzene and recycles it back into the system. Purified styrene monomer is recovered in the third and final phase. Bottoms or tar residue is removed from this third phase (Reference C-23).

Blowing Agent Production. There are a number of blowing agents available for use in foam polystyrene production including n-pentane, isopentane, isobutane, and n-butane. Some manufacturers use carbon dioxide, recovered from other industrial processes, as a blowing agent for polystyrene (Reference C-92). However, n-pentane is the most common blowing agent used for polystyrene foam.

The blowing agent is introduced into the polystyrene polymer during the polymerization step. The vaporization of the blowing agent is responsible for the foam character of the final product.

In this analysis, n-pentane is considered a generic product from either a refinery or a natural gas liquids plant. The n-pentane data in this analysis are based on a 60/40 percent weighted average of the data for natural gas processing and oil refining data discussed previously in this appendix.

Expanded Polystyrene (EPS) Resin Production. Expanded Polystyrene Resin (EPS) resin is typically produced by either a one-step or two-step process. These two processes are discussed below.

One Step EPS Production. Styrene is dispersed in water in a reactor and polymerized in the presence of initiators and suspending agents. Prior to the completion of the polymerization, blowing agent is added to the reactor. The blowing agent is incorporated into the polystyrene beads and the temperature of the reactants is increased to finish off the polymerization. After the reactor and contents are cooled, the beads are dewatered and dried. The waste water is sent to an effluent treatment facility. The dried beads are screened into different sizes and the final EPS products are packed into containers for shipment to molders.

Two Step EPS Production. Styrene is dispersed in water in a reactor and polymerized in the presence of initiators and suspending agents. The reaction is taken essentially to completion by raising the temperature of the reactants to finish off the polymerization. After the reactor and contents are cooled, the beads are dewatered and dried. The waste water is sent to a waste water treatment facility. The dried beads are screened into different fractions and sent to storage.

Each separate polystyrene bead fraction produced in the first step is in turn recharged to a reactor, re-suspended in water and blowing agent is added. The reactor and contents are heated and held at elevated temperatures for a predetermined time while the blowing agent is impregnated into the polystyrene beads. The reactor and contents are cooled and the final EPS product is dewatered and dried a second time. The dried beads are screened into different sizes and the final EPS products are packed into containers for shipment to molders.

The emissions from the one- and two-step processes are similar. The vent streams consist mainly of varying concentrations of blowing agent in air. Typical wastewater effluents include BOD, COD, and suspended solids in varying degrees depending on the treatment processes employed. BOD and COD emissions can be reduced to very low levels by a combination of flocculation, sedimentation, aeration, and biological digestion operations. Solid waste generation includes EPS particulates and dust as well as suspending agent residuals.

Postconsumer EPS Resin Production. EPS loose fill can contain a portion of postconsumer EPS. The recycling of postconsumer EPS includes the following processes:

- Postconsumer Expanded Polystyrene (EPS) Collection
- Recycled Expanded Polystyrene (EPS) Resin Production

Postconsumer Expanded Polystyrene (EPS) Collection. Postconsumer EPS is collected from assemblers of durable goods or from established retail collection programs.

Recycled Expanded Polystyrene (EPS) Resin Production. The recycling process for postconsumer EPS includes shredding the material and passing it through an extruder system. This increases the density of the EPS from 2 pounds per cubic foot to 9-12 pounds per cubic foot. No washing operations are necessary during the recycling process because postconsumer EPS is usually clean (Reference C-114).

Cornstarch Production

Cornstarch is used to make starch-based foam, which can be used as a loose fill alternative to expanded polystyrene (EPS). The production of corn starch requires the growing and harvesting of corn, which includes the production of fertilizers and pesticides. The material flows and steps of cornstarch production are shown in Figure C-3. The steps of cornstarch production are listed below.

- Corn Growing and Harvesting
  - Fertilizer Manufacture
    - Nitrogen Fertilizer
    - Phosphate Fertilizer
    - Potash Fertilizer
  - Pesticide Manufacture
- Corn Starch Production

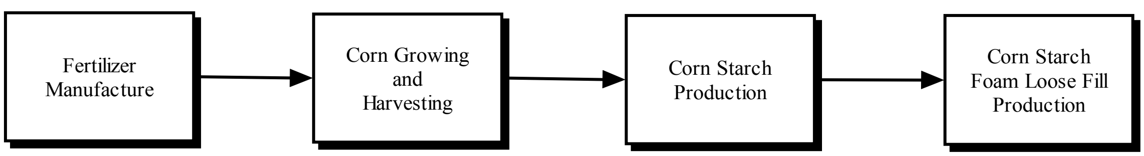

Figure C-3. Flow diagram for the production of corn starch loose fill.

Corn Growing and Harvesting. To produce high corn yields, many factors must be considered. The most important of these factors include temperature, climate, and nutrients. Corn needs nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur from the soil. Soil fertility is easily depleted, especially when the entire plant is harvested for silage. Therefore, these nutrients are added to the soil as fertilizer.

Fertilizer Manufacture. Most corn land receives applications of fertilizer, typically nitrogen, phosphate, and/or potash. Over half of all fertilizers are applied as single nutrient materials. USDA literature reports applications of nitrogen, phosphate, and potash fertilizers in terms of pounds of N, P_2O5, and K_2O (Reference C-29). Figure C-4 shows the steps required to produce each of these fertilizers.

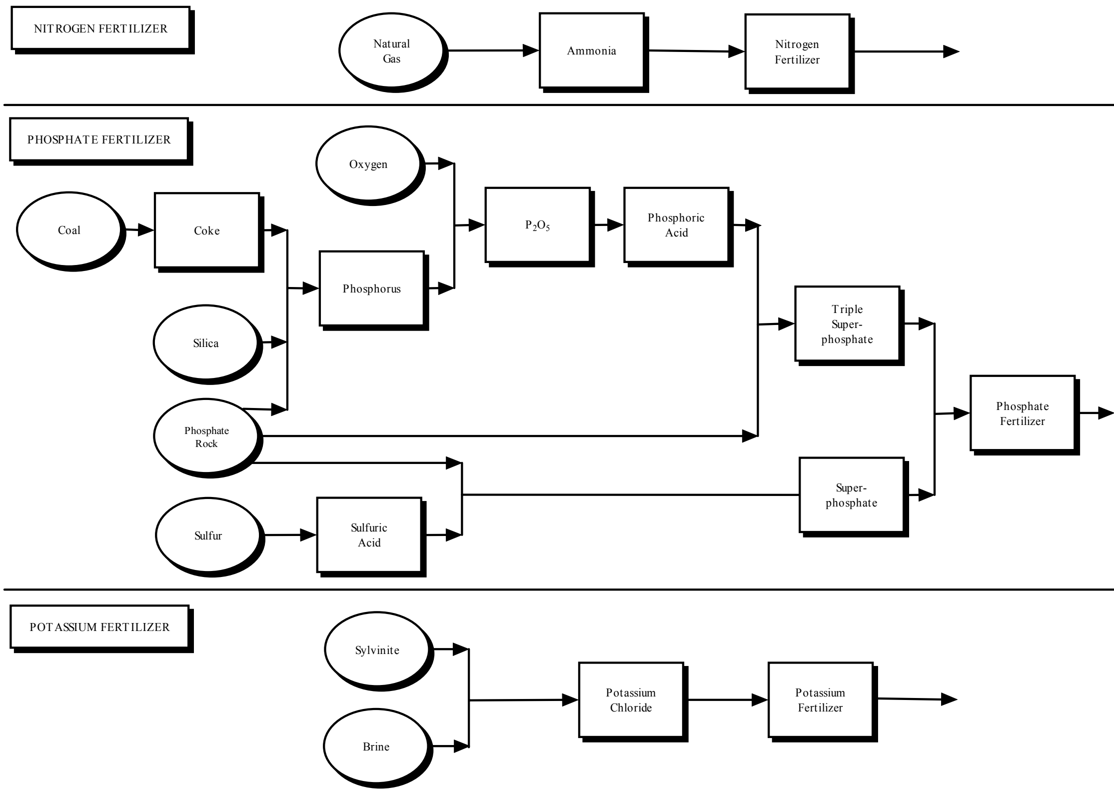

Figure C-4. Flow Diagram for the production of fertilizer.

Nitrogen Fertilizer. Nitrogen as a single nutrient is commonly applied in the form of anhydrous ammonia. The steps in the production of nitrogen fertilizer are listed below.

- Natural gas production
- Ammonia production
- Nitrogen fertilizer production

Natural gas production is discussed previously in this appendix. The remaining steps of nitrogen fertilizer production are discussed below.

Ammonia Production. Ammonia is produced primarily by steam reformation of natural gas. Natural gas and steam are fed into a tubular furnace where the reaction over a nickel reforming catalyst produces hydrogen and carbon oxides. The primary reformer products are then mixed with preheated air and reacted in a secondary reformer to produce the nitrogen needed in ammonia synthesis.

The gas is cooled to a lower temperature and subjected to a water shift reaction in which carbon monoxide and steam are reacted to form carbon dioxide and hydrogen. The carbon dioxide is removed from the shifted gas in an absorbent solution. Hydrogen and nitrogen are reacted in a synthesis converter to form ammonia (References C-30 and C-31).

Nitrogen Fertilizer Production. Nitrogen fertilizer is applied in the form of anhydrous ammonia that is 82 percent by weight N.

Phosphate Fertilizer. Phosphate fertilizer applied as a single nutrient is most commonly in the form of superphosphate, with 16 to 20 percent available P_2O_5, or triple superphosphate, with 44 to 51 percent available P_2O_5. Superphosphates are produced by the action of sulfuric acid on phosphate rock, while triple superphosphates are made by adding phosphoric acid to phosphate rock (References C-32 and C-33). The data are based on half of the phosphate applied as superphosphate and half as triple superphosphate. The following process steps are required for the manufacture of the phosphate fertilizers:

- Superphosphate
  - Phosphate rock mining
  - Crude oil production
  - Crude oil refining
  - Natural gas production
  - Natural gas processing
  - Sulfur production
  - Sulfuric acid production
  - Superphosphate production
- Triple superphosphate
  - Phosphate rock mining
  - Silica mining and processing
  - Coal mining
  - Metallurgical coke production
  - Elemental phosphorus production
  - Oxygen production
  - Phosphorus pentoxide production
  - Phosphoric acid production
  - Triple superphosphate production
- Phosphate fertilizer production

Crude oil production and refining, natural gas production, and natural gas processing are discussed previously in this appendix. Oxygen production is discussed later in this appendix. Coal mining is discussed in Appendix A. The remaining steps in the manufacture of phosphate fertilizers are discussed below:

Phosphate Rock Mining. Phosphate is mined as a natural rock containing mostly calcium phosphate. Large deposits are contained in the United States, North Africa, and the former Soviet Union (Reference C-33).

Sulfur Production. Sulfur exists in nature as elemental sulfur and is also found in ores such as pyrite (FeS_2). Sulfur is also recovered from hydrogen sulfide (H_2S), a component of petroleum and natural gas. Approximately, 10 percent of U.S. sulfur is obtained from limestone during the Frasch process, while the remaining 90 percent is obtained from natural gas and petroleum via the Claus process.

Descriptions of the two sulfur production processes follow.

Frasch Process. Sulfur is obtained from sulfur-bearing porous limestone primarily by the Frasch process. In this process, a set of three concentric pipes are inserted into a well drilled into an underground sulfur dome. Injecting superheated water into the well raises the temperature of the sulfur-bearing rock above the melting point of sulfur.

Compressed air is then injected into the well. This forces the molten sulfur to the surface. As all Frasch mines in the U.S. are near waterways, the sulfur is shipped by insulated barge or boat, or allowed to solidify and shipped as a solid (Reference C-25).

Claus Process. Recovery of sulfur from sour natural gas and crude oil via the Claus process accounts for about 90 percent of the sulfur produced in the United States. Approximately 76 percent of the sulfur produced via Claus recovery is obtained from hydrogen sulfide recovered from petroleum refining, and the remaining 24 percent is recovered from natural gas sweetening (Reference C-25). The following data include the production of sulfur from petroleum refining only.

Hydrogen sulfide is recovered from refinery gases by absorption in a solvent or by regenerative chemical absorption (Reference C-18). Hydrogen sulfide concentrations in the gas from the absorption unit vary. For this analysis, an industry average H_2S gas concentration of 85 percent is used (References C-18 and C-26). This concentrated hydrogen sulfide stream is treated by the Claus process to recover the sulfur. The Claus process is based upon the reaction of hydrogen sulfide with sulfur dioxide according to the exothermic reaction (Reference C-18):

$$2H_2S + SO_2 \rightarrow 3S + 2H_2O \qquad \text{(Reaction 1)}$$

Sulfur dioxide for the reaction is prepared by oxidation of hydrogen sulfide with air or oxygen in a furnace using either the partial combustion process (once-through process) or the split-stream process. The partial combustion method is used when the H_2S concentration is greater than 50 percent and the hydrocarbon concentration is less than 2 percent. The split stream process is used when there is an H_2S concentration of 20 to 50 percent and a hydrocarbon concentration of less than 5 percent.

In the partial combustion method, the hydrogen sulfide-rich gas stream is burned with a fuel gas in an oxygen-limited environment to oxidize one-third of the H_2S to SO_2 according to the reaction (Reference C-16):

$$2H_2S + 2O_2 \rightarrow SO_2 + S + 2H_2O \qquad \text{(Reaction 2)}$$

Sulfur is removed from the burner and the H_2S/SO_2 mixture moves to the catalytic converter chambers.

In the split stream process, one-third of the hydrogen sulfide is split off and completely oxidized to SO_2 according to the reaction:

$$2H_2S + 1.5O_2 \rightarrow SO_2 + H_2O \qquad \text{(Reaction 3)}$$

The remaining two-thirds of the H_2S is mixed with the combustion product and enters the catalytic converter chambers.

The H_2S and SO_2 mixture from either process is passed through one or more catalyst beds and is converted to sulfur, which is removed by condensers between each bed (Reference C-18). For this analysis, an H_2S concentration of 85 percent has been assumed; therefore, it is also assumed that the partial combustion process is used.

Although efficiencies of 96 to 99 percent sulfur recovery have been demonstrated for the Claus process, recovery is usually not over 96 percent and is limited by thermodynamic considerations (References C-16 and C-18). For this analysis, a sulfur recovery efficiency of 95 percent is assumed.

The energy generated from burning hydrogen sulfide to produce SO_2 is usually recovered and used directly to reheat the process stream in secondary and tertiary condensers, or recovered as steam for use in other processes (Reference C-16). Heat released from cooling the exothermic reaction to form sulfur is also recovered. The fuel value of H_2S is not included in the total energy for the system because H_2S is not used as a commercial fuel. The system is also not given an energy credit for any steam exported from the system.

Sulfuric Acid Production. Sulfur is burned with air to produce sulfur dioxide and heat. The heat is used to generate steam that is usually used in adjacent processing plants and to supply energy to the sulfuric acid plant. The energy import (as the calorific value) of sulfur and the energy export of steam cancel in the energy balance for this process. The sulfur dioxide gas is converted to sulfur trioxide and combined with dilute sulfuric acid to form the concentrated product.

Superphosphate Production. Superphosphate is produced by the addition of sulfuric acid to phosphate rock. Superphosphate is a mixture of gypsum and calcium phosphate.

Silica Mining and Processing. Silica is obtained from glass sand, a high purity quartz sand with high silica content and typically less than one percent of iron oxide, chromium compounds, and alumina, calcium, or magnesium oxides. In general, the U.S. consumption of glass sand is met by U.S. production, but some high purity glass sand is imported. Glass sand deposits exist in New Jersey in the form of unconsolidated sand banks, and as sandstone found in the Alleghenies and the Mississippi Valley. The east-west belt of states running from Pennsylvania to Illinois has rich resources for glass sand.

Mining operations vary depending on the nature of the deposit at each location. Open pit excavation and dredging are the two basic mining methods, each requiring a combination of many types of equipment including crushers, screens, washers, classifiers, and grinding mills.

Metallurgical Coke. The two proven processes for manufacturing metallurgical coke are known as the beehive process and the byproduct process. The primary method for manufacturing coke is the byproduct method, which accounts for more than 98 percent of U.S. coke production. In the byproduct method, air is excluded from the coking chambers, and the necessary heat for distillation is supplied from external combustion of some of the gas recovered from the coking process.

Elemental Phosphorus Production. Elemental phosphorus is produced from phosphate rock by a reaction with coke and silica in an electric furnace. Elemental phosphorus is one of several materials resulting from this process.

Phosphorus Pentoxide Production. Oxidation of elemental phosphorus produces phosphorus pentoxide.

Phosphoric Acid Manufacture. Hydration of phosphorus pentoxide produces phosphoric acid.

Triple Superphosphate Production. Triple superphosphate is produced by the addition of phosphoric acid to phosphate rock. It has three times the amount of available phosphate as in superphosphate and contains no gypsum.

Phosphate Fertilizer Production. Phosphate fertilizer is applied in the form P_2O_5. This study assumes that the superphosphate is applied with 20 percent available P_2O_5 and the triple superphosphate with 50 percent available P_2O_5.

Potash. Potash fertilizer is generally applied in the form of potassium chloride (KCl), which is sold in various agricultural grades, containing 60 to 62 percent K_2O, 48 to 52 percent K_2O, or 22 percent K_2O. The following steps are required for the production of potash fertilizer:

- Sylvinite Mining and Processing
- KCl Production
- Potash fertilizer production

Sylvinite Mining and Processing. Most of the U.S. supply of KCl produced from sylvinite ore is mined from deep deposits in the Carlsbad, New Mexico region. Sylvinite mining and processing is assumed to be similar to soda ash mining and processing.

KCl Production. KCl is obtained from sylvinite ore and purified by fractional crystallization or flotation. It is also extracted from salt lake brines and purified by recrystallization (References C-32 and C-33).

KCl is prepared from sylvinite ore by passing hot liquor through a series of steam-heated turbomixer dissolvers countercurrent to a flow of crushed ore. KCl and a small amount of NaCl go into solution. When the solution is cooled from its boiling point, KCl separates out. Waste tailings from the process, largely NaCl, are carried out of the plant to waste storage. A large part of the process liquor is decanted to be used again (Reference C-32). The solid portion of the tailings, including the NaCl, is included in the reporting of process solid waste.

KCl is also produced by extraction from the brines of Searles Lake, California. This brine, containing various salts, is carbonated with flue gas from the boiler plant. Sodium bicarbonate separated by this reaction is calcined and converted to dense soda ash. Crude borax is crystallized from the carbonated end liquor by cooling under vacuum. The filtrate is returned to the lake. Soda ash, KCl, borax/boric acid, and salt cake are produced by brine extraction (Reference C-32).

Potash Fertilizer. The potash fertilizer analyzed in this study is based on application as KCl containing 50 percent K_2O. Seventy-five percent of the KCl is assumed to be produced from sylvinite and 25 percent from brine extraction.

Pesticide Manufacture. Pesticides applied to corn include a variety of herbicides, insecticides, defoliants, and desiccants. Fungicides, miticides, and growth regulators may be applied as well. A wide variety of pesticides have been formulated to address the varying needs and conditions of each region; thus, the types and quantities of pesticide applied to corn acreage vary widely. As a result, the effects of individual pesticides on the environment also vary. Due to the complexity and variability of pesticide manufacture and use, and the budget limitations for this study, data on pesticide manufacture is not included in this analysis.

Corn Growing and Harvesting. Whole grain corn is composed of 71.7 percent starch (Reference C-34). Corn is a warm weather plant requiring a growing season of about 140 days with an average daytime temperature of 75°F with nighttime temperatures exceeding 58°F. High yields also require 16 to 26 inches of rainfall. Irrigation is used on most corn-growing farms to supplement inadequate rainfall. Fertilizer and limes are added to bring necessary nutrients to the soil. Pesticides are added to destroy insects, fungus, and any other pests that would hurt the plant.

Pesticide use in corn production can lead to significant environmental burdens. For example, atrizine used in corn production is a major contaminant of groundwater and surface water. However, pesticide emissions are difficult to quantify since there are many pesticides used, each varying in application rate and degradability. Emission rates also vary widely depending on the soil type and topography, pesticide application process, weather factors such as wind and rain, etc. Because pesticide manufacture is not included in this study and because of the wide variability in pesticide emissions in agricultural runoff, pesticide emissions are not included in this study.

Today, corn harvesting is mostly done by multi-row combines. The corn is removed from the cobs in the field, then stored for drying. The cobs and husks are left in the field to decompose. Agricultural wastes that are returned to the land for natural decomposition without waste treatment are not reported as solid waste.

After drying, the corn is transported to customers. Corn used in the production of corn starch must be transported to a wet milling plant.

Cornstarch Production. Cornstarch is produced from corn by wet milling. The corn is soaked in steeping tanks containing a solution of 0.3 percent sulfur dioxide in water to soften the kernel and dissolve inorganic components. This steep liquor is later concentrated for sale as a coproduct. The softened corn is lightly milled to free the germ from the kernel. The germ is then processed for oil removal. The remaining corn fraction, mostly starch, protein, and hulls, is then heavily milled. The starch is washed from the hulls, and the resulting starch slurry is separated, refined, washed, and dried.

Bleached Kraft Paper

Bleached kraft paper is used for the fabrication of shipping bags. Figure C-5 shows the flow diagram for the production of 1,000 pounds of bleached kraft fiber incorporating both virgin and postconsumer fiber. The production of virgin bleached kraft paper includes the following steps:

- Roundwood Harvesting
- Wood Residues (Chips)
- Salt (Sodium Chloride) Mining
- Sodium Chlorate Production
- Production of Caustic Soda (Sodium Hydroxide) and Chlorine

- Hydrogen Production
- Hydrogen Peroxide Production
- Oxygen Production
- Limestone Mining
- Lime Production
- Cornstarch Production
- Kraft Bleached Paper Manufacture

Cornstarch production is discussed previously in this appendix and is not repeated in this section. The remaining steps of bleached kraft paper production are discussed below.

Roundwood Harvesting. The technique of harvesting trees has become a highly mechanized process. Typically, trees are harvested by using a feller buncher to fell the wood. The wood is pulled to the roadside, where branches are removed and the wood is cut to manageable lengths for loading on trucks and delivery to the mill. After the wood is cleared from the forest, a variety of site preparations are used. On some sites debris is manually removed from the forest before replanting, while other sites are left to grow back naturally. Finally, some harvested sites are burned to remove any remaining debris before replanting. Emissions do result from clearing the site by burning, but this practice occurs infrequently compared to the mass of trees harvested. It is assumed that these emissions are negligible for this study.

Trees harvested specifically for wood pulp production account for approximately 53 percent of the wood delivered to the average U.S. paper mill. The remainder comes from wood residues (sawdust and chips) generated by lumber production or other wood processing operations (Reference C-51).

An unknown amount of water pollution in the form of suspended solids results from runoff from road building into the harvested forests as well as erosion from cut-over lands. The extent to which these solids actually reach streams depends on many factors, including the grade, amount of surface disturbance, soil type, and rainfall. In some areas, significant quantities of these solids could end up in streams. Although perhaps as much as seven pounds of suspended solids are generated, their final deposition is divided between streams and other locations within the forest. Therefore, suspended solids emissions from roundwood harvesting were not included in this analysis since the amount of stream pollution from this source is highly variable and a reasonable average could not be determined from published or unpublished source within the budget constraints for this project.

Wood Residues Production. Wood residues used in the production of paper are mill residues generated either by lumber mills or by other wood processing operations. It is estimated that mill residues make up about 90 percent of the wood residues used by paper mills, and forest residues make up the remaining 10 percent.

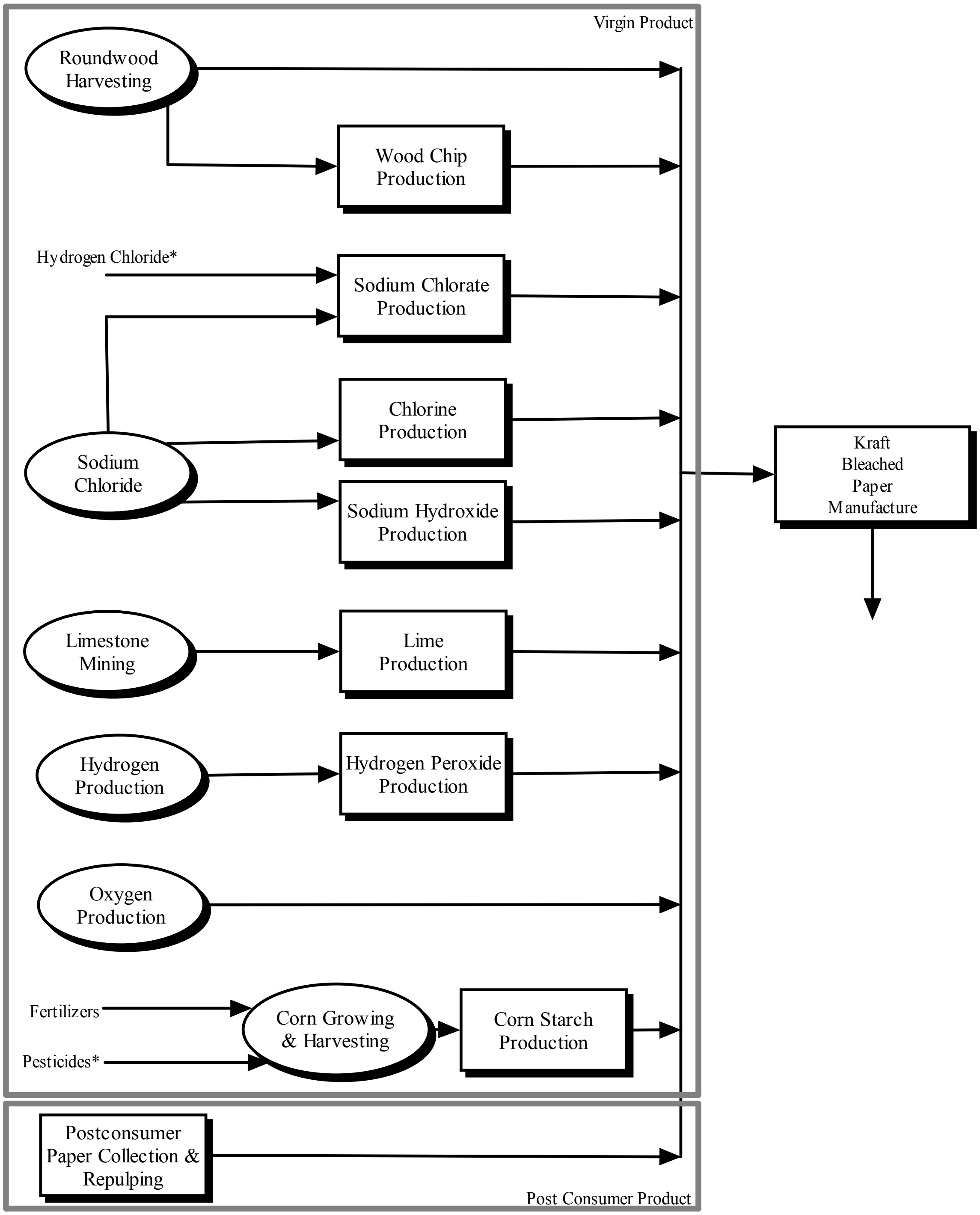

Figure C-5. Flow diagram for the production of 1,000 pounds of kraft bleached paper with virgin and post consumer product.

* These materials are considered negligible in the model.

Typically the wood that a sawmill receives will already be delimbed and cut to manageable lengths. The roundwood is sorted by diameter and then sent to a debarker. After debarking, the logs are conveyed through a series of cutting and planing operations. Roughly 75 to 80 weight percent of the tree as received is converted to lumber, with the remaining 20 to 25 percent becoming wood chips and fines. The chips are sold to pulp mills, and the fines are either burned as an energy source or burned for waste disposal.

Forest residues are small diameter trees, limbs, and cuttings that are turned into chips in the forest. In general, wood residues are generated on site or quite close to the mills. This study assumes that 90 percent of wood residues result from mill operations and 10 percent result from forest operations.

Salt (Sodium Chloride) Mining. For the most part, salt-based chlorine and caustic (sodium hydroxide) facilities use captive salt from another process or salt recovered from underground deposits. According to the U.S. Geological Survey, 48% of domestically-produced salt comes from the brine process and 35% comes from halite mining. Evaporation of seawater is a smaller source of salt.

In the brine process, an injection well is drilled and pressurized fresh water is introduced to the bedded salt (Reference C-27). The brine is then pumped to the surface for treatment. Salt mines are widely distributed throughout the United States. Rock salt is recovered from the mining of halite, a mineral rich in sodium chloride.

Sodium Chlorate Production. Sodium chlorate is used to produce chlorine dioxide at the pulp mill site. The chlorine dioxide is used for bleaching. Sodium chlorate is produced from electrolysis of salt brine similar to the production of caustic and chlorine, except that the chlorine and caustic are not separated, but are instead allowed to mix (Reference C-35). Hypochlorite forms first, followed by the formation of sodium chlorate.

Production of Caustic Soda (Sodium Hydroxide) and Chlorine. Caustic soda (sodium hydroxide) and chlorine are produced from salt by an electrolytic process. The aqueous sodium chloride solution is electrolyzed to produce caustic soda, chlorine, and hydrogen gas. For this analysis, resource requirement and environmental emission coproduct credit is allocated on a weight basis to each of the materials produced in the cell. Thus, the burdens per 1,000 pounds are the same for all coproducts. The reason for giving coproduct credit on a weight basis is that it is not possible, using the electrolytic cell, to get chlorine from salt without also producing sodium hydroxide and hydrogen, both of which have commercial value as useful coproducts. Likewise, sodium hydroxide cannot be obtained without producing the valuable coproducts of chlorine and hydrogen.

Furthermore, it is not possible to control the cell to increase or decrease the amount of chlorine or caustic soda resulting from a given input of salt. This is determined by the stoichiometry of the reaction. The electrolytic cell is perceived as a “black box” with an input of salt and electricity, and an output of chlorine, sodium hydroxide, and hydrogen.

The electrolysis of sodium chloride is performed by one of two processes: the mercury cathode cell process, or the diaphragm cell process. About 83 percent of electrolyzed chlorine and caustic soda production comes from the diaphragm process, with the remainder coming from the mercury cell process (Reference C-36).

The diaphragm cell uses graphite anodes and steel cathodes. Brine solution is passed through the anode compartment of the cell, where the salt is decomposed into chlorine gas and sodium ions. The gas is removed through a pipe at the top of the cell. The sodium ions pass through a cation-selective diaphragm. The depleted brine is either resaturated with salt or concentrated by evaporation and recycled to the cell. The sodium ions transferred across the diaphragm react at the cathode to produce hydrogen and sodium hydroxide. Diffusion of the cathode products back into the brine solution is prevented by the diaphragm.

The mercury cathode cell process is described by:

$$NaCl + x\ Hg \rightarrow 1/2\ Cl_2 + Na(Hg)_x \text{ and}$$
$$Na(Hg)_x + H_2O \rightarrow NaOH + 1/2\ H_2 + x\ Hg$$

Chlorine gas collects at graphite anodes. The chlorine gas from the anode compartment is cooled and dried in a sulfuric acid scrubber. The gas is then cooled further to a liquid for shipment, generally by rail and barge. Metallic sodium reacts with the mercury cathode to produce an amalgam, which is sent to another compartment of the cell and reacted with water to produce hydrogen and high purity sodium hydroxide. Mercury loss is a disadvantage of the mercury cathode cell process. Some of the routes by which mercury can escape are in the hydrogen gas stream, in cell room ventilation air and washing water, through purging of the brine loop and disposal of brine sludges, and through end box fumes.

Hydrogen Production. Hydrogen and carbon dioxide are coproducts in the production of synthesis gas. Synthesis gas is primarily produced from natural gas by steam-methane reforming. Natural gases, or other light hydrocarbons, and steam are fed into a primary reformer over a nickel catalyst to produce hydrogen and carbon oxides, generally referred to as synthesis gas. About 70 percent of the hydrocarbon feed is converted to synthesis gas in the primary reformer (Reference C-18).

The effluent from the reformers is fed into carbon monoxide shift converters where the carbon monoxide reacts with water to form carbon dioxide and hydrogen. The effluent from the shift converters is cooled, and condensed water is removed. The carbon dioxide and some excess hydrogen are also removed from the synthesis gas as coproducts.

The ratio of carbon monoxide to hydrogen in the synthesis gas differs depending on the specifications for the synthesis gas, and therefore the amounts of hydrogen and carbon dioxide coproducts differ also. Synthesis gas is a raw material for many different processes, each with specific requirements. Because of this difference in requirements, it is difficult to show an accurate average material balance for this process. The data for hydrogen production are estimates of the synthesis gas production. Raw material inputs for hydrogen are based on the conversion of methane to carbon monoxide and hydrogen.

Hydrogen Peroxide Production. Hydrogen peroxide can be produced by several electrochemical or organic routes. This study characterizes hydrogen peroxide from the oxidation/reduction of an anthraquinone--the predominant commercial route to hydrogen peroxide.

An anthraquinone in an organic solvent is first catalytically hydrogenated. This material is then oxidized with oxygen taken from air back to anthraquinone, with hydrogen peroxide being produced as a byproduct. The hydrogen peroxide is water-extracted from the reaction medium and the solvent and anthraquinone are recycled.

No energy consumption or environmental emissions data are available for the production of hydrogen peroxide. A very conservative estimate of the energy consumption is made based on other industrial processes.

Oxygen Production. Oxygen is manufactured by cryogenic separation of air, a technique by which air is liquefied, and the oxygen is collected by fractionation. The oxygen is produced in the form of a liquid that boils at 300°F below zero at normal atmospheric pressure. Therefore, it must be kept under stringent conditions of temperature and pressure for handling. Most oxygen plants are located near their point of consumption to minimize transportation difficulties, although there is a small amount of long-distance hauling in insulated rail cars.

Limestone Mining. Limestone is quarried primarily from open pits, but underground mining is becoming more common in the central and eastern United States. The percentage of limestone mining that is open pit and the percentage of limestone mining that is underground are unknown. The energy data (and fuel-related pollutants) used in this analysis represent a combination of open pit and underground mining. The process emission data is based solely on open pit techniques. The most economical method of recovering the limestone has been through blasting, followed by mechanical crushing and screening (References C-27 and C-37). Airborne particulates are generated in the form of limestone dust during many of the operations.

Lime Production. Lime is never found in a natural state, but is manufactured by calcining (burning) high purity calcitic or dolomitic limestone at high temperatures. The calcination process drives off carbon dioxide, forming calcium oxide (quicklime). The subsequent addition of water creates calcium hydroxide (hydrated or slaked lime). The term lime is a general term that includes the various chemical and physical forms of quicklime and hydrated lime. Most of the lime produced in the United States in 1994 was quicklime (85%), with hydrated lime (13%) and dead-burned dolomite (2%) accounting for the rest.

The data in this section are for the production of quicklime (References C-38 and C-39).

Solid wastes generated during the manufacture of lime include impurities removed from limestone, tailings collected in the lime production process, and lime kiln dust collected from particulate control devices on the lime kilns. Based on lengthy discussions with a representative of the National Lime Association and a confidential lime industry expert, it was assumed that all collected lime dust and tailings from lime production are either sold for various useful purposes, injected back into mines, replaced in quarries, or land applied on-site (Reference C-40 and C-41). This may not be true of a few smaller companies, which are not close to their source of limestone. The solid waste in the data table is an estimate from a representative of the lime industry and includes packaging and other industrial wastes that may be disposed of in a municipal landfill (Reference C-41).

Kraft Bleached Fiber Production. Kraft pulp is the most widely used type of wood pulp in the United States today, accounting for 80 percent of the total wood pulp produced. It is used in either an unbleached or bleached form. The data in this section are for bleached paperboard.

The kraft pulping process is based on chemical digestion of wood, which has been previously debarked and chipped. The digester is a closed container that holds the wood chips and digestion liquors. The liquor is mainly an aqueous solution of chemicals including sodium sulfide and sodium hydroxide.

In order for digestion to take place, heat and pressure are applied to the mixture of wood and liquor. The digestion process delignifies the wood and removes other chemical components from the wood, leaving mostly wood fiber with some lignin and complex sugars.

At this point the pulp is bleached using one or a combination of the following: chlorine, caustic, oxygen, ozone, chlorine dioxide, hydrogen peroxide, and others (Reference C-42). Chlorine dioxide, generated on-site from sodium chlorate, is most commonly used. A mixture of the bleaching agents based on an average of the mill data collected has been used.

One of the features of the kraft process is that the used digestion liquor, called black liquor, is burned for energy. Combustion of black liquor and the bark removed from logs entering the mill often provides a significant portion of the energy to operate a pulp mill. Because the black liquor contains a high percentage of flammable wood components, it burns readily. The digestion liquor remaining after the black liquor is burned is known as green liquor. Lime is added to the green liquor to produce white liquor, which is then returned to the digester.

The airborne emissions of organic halogens for kraft paper were reported by a private industry source and so are confidential. Cradle-to-gate data for the production of bleached virgin kraft paper are shown in Table C-1.

Unbleached Kraft Paper

Unbleached kraft paper is used as dunnage material that fills void spaces in a package, as well as for the inner layer of padded, all-paper shipping bags. The material flows for the production of unbleached kraft paper with both virgin and postconsumer fiber content are shown in Figure C-6. The production of virgin unbleached kraft paper includes the following steps:

- Roundwood Harvesting
- Wood Residues (Chips)
- Salt Mining
- Sodium Hydroxide Production
- Sodium Sulfate Mining
- Limestone Mining
- Lime Production
- Cornstarch Production
- Unbleached Kraft Paper Production

Material inputs that account for less than 1% of the weight of the output product are not included. Roundwood harvesting, wood residues production, salt mining, sodium hydroxide production, limestone mining, lime production, and cornstarch production are discussed previously in this appendix and are not repeated here. The remaining steps of unbleached kraft paper production are discussed below.

Sodium Sulfate Mining. Sodium sulfate is consumed in the Kraft pulping process. The upper levels of Searles Lake, California, the Great Salt Lake in Utah, and the brines of west Texas all contain sodium sulfate. Typically, sodium sulfate crystals are removed from cooled brine. The crystals are then dissolved again and precipitated to achieve the desired purity. No industry data sets were available for sodium sulfate production; the sodium sulfate data in this analysis are based on Census of Mineral Industries data for SIC Code 1474, which covers potash, soda, and borate minerals.

Unbleached Kraft Paper Production. Kraft pulp is the most widely used type of wood pulp in the United States today, accounting for approximately 80 percent of the total wood pulp produced. The kraft pulping process is based on chemical digestion of wood that has been previously debarked and chipped. The digester is a closed container, which holds the wood chips and digestion liquors. The liquor is mainly an aqueous solution of chemicals including sodium sulfide and sodium hydroxide.

Table C-1

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF BLEACHED VIRGIN KRAFT PAPER FOR SHIPPING BAGS (includes all steps from raw material extraction through production of virgin kraft paper and shipment to bag manufacturer)

Raw Materials			
Roundwood Harvesting	4,070	lb	
Salt Mining	3.79	lb	
Hydrogen Production	0.53	lb	
Oxygen Production	1.70	lb	
Limestone Mining	27.7	lb	
Nitrogen Fertilizer	0.48	lb	
Phosphate Fertilizer	0.19	lb	
Potash Fertilizer	0.21	lb	
Corn Growing & Harvesting	32.8	lb	
Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			7.03
Total Resource			7.03
Process Energy			
Electricity	433	kwh	4,847
Natural gas	1,976	cu ft	2,292
LPG	6.4E-05	gal	0.0068
Coal	252	lb	2,890
Distillate oil	0.47	gal	72.8
Residual oil	18.0	gal	3,046
Gasoline	3.0E-04	gal	0.042
Diesel	1.31	gal	205
Wood	10,533	thou Btu	10,533
Total Process			23,885
Transportation Energy			
Combination truck	295	ton-miles	
Diesel	2.77	gal	433
Rail	7.74	ton-miles	
Diesel	0.019	gal	2.90
Barge	0.40	ton-miles	
Diesel	8.0E-04	gal	0.12
Residual oil	3.2E-04	gal	0.054
Ocean freighter	0.18	ton-miles	
Diesel	1.8E-05	gal	0.0027
Residual	3.2E-04	gal	0.053
Pipeline-natural gas	0.024	ton-miles	
Natural gas	0.055	cu ft	0.064
Pipeline-petroleum products	0.010	ton-miles	
Electricity	2.3E-04	kwh	0.0026
Total Transportation			436

Table C-1 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF BLEACHED VIRGIN KRAFT PAPER FOR SHIPPING BAGS

Environmental Emissions*

Atmospheric Emissions		
Particulates	1.67	lb
Nitrogen Oxides	5.83	lb
Hydrocarbons	0.011	lb
Sulfur Oxides	5.38	lb
Carbon Monoxide	0.98	lb
Aldehydes	3.7E-06	lb
Other Organics	0.094	lb
Odorous Sulfur	0.020	lb
Ammonia	0.040	lb
Mercury	1.9E-05	lb
Chlorine	0.015	lb
Carbon Dioxide (fossil)	11.6	lb
Carbon Dioxide (non-fossil)	0.010	lb
Total Reduced Sulfur	0.40	lb
Solid Wastes	118	lb
Waterborne Emissions		
Acid	0.0030	lb
Dissolved Solids	0.28	lb
SuspendedSolids	6.17	lb
BOD	2.83	lb
COD	4.36	lb
Phenol	5.6E-08	lb
Sulfides	5.2E-06	lb
Oil	5.2E-05	lb
Iron	2.0E-05	lb
Cyanide	1.1E-07	lb
Chromium	1.4E-08	lb
Nickel	3.8E-08	lb
Mercury	5.4E-08	lb
Lead	3.8E-08	lb
Phosphates	0.059	lb
Phosphorus	0.10	lb
Nitrogen	0.039	lb
Zinc	3.8E-08	lb
Ammonia	0.28	lb
Sodium Dichromate	3.4E-06	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

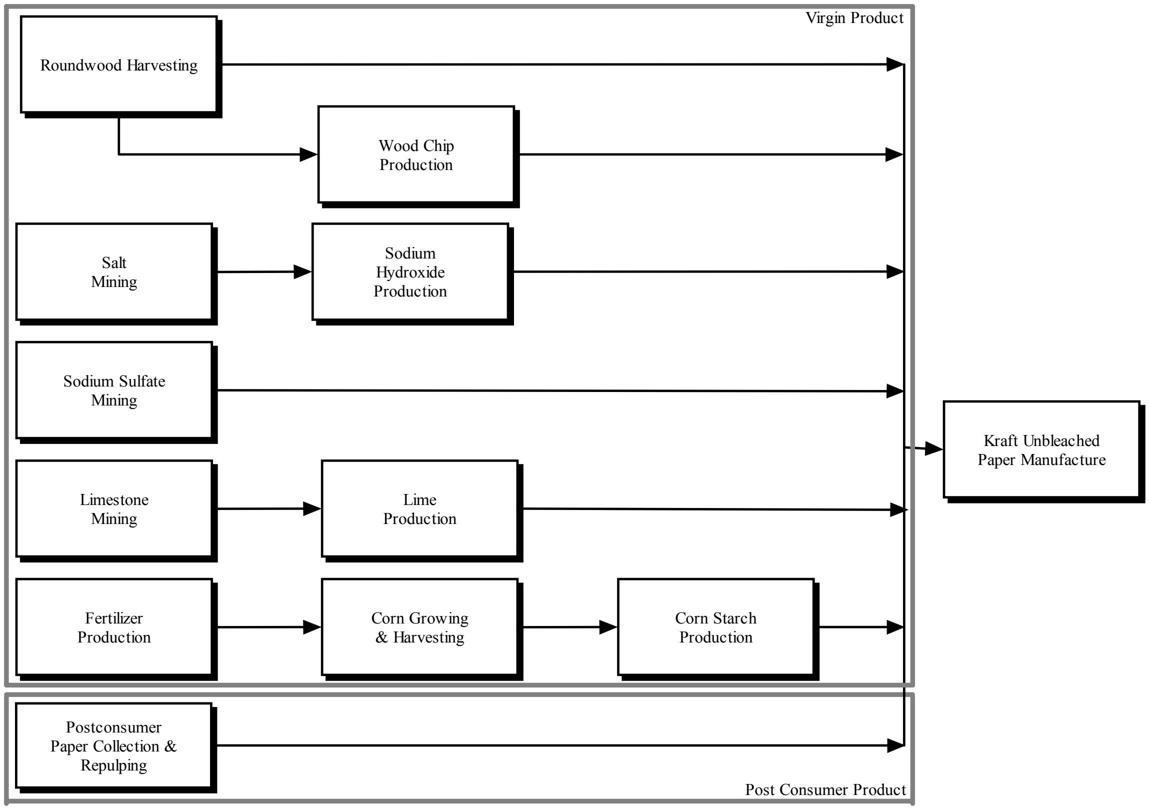

Figure C-6. Flow diagram for the production of kraft unbleached paper with virgin and post consumer product.

In order for digestion to take place, heat and pressure are applied to the mixture of wood and liquor. The digestion process delignifies the wood and removes other chemical components from the wood, leaving mostly wood fiber with some lignin and complex sugars.

One of the features of the kraft process is that the used digestion liquor, called black liquor, is burned for energy. Combustion of black liquor and the bark removed from logs entering the mill often provides a significant portion of the energy to operate a pulp mill. Because the black liquor contains a high percentage of flammable wood components, it burns readily. The digestion liquor remaining after the black liquor is burned is known as green liquor. Lime is added to the green liquor to produce white liquor, which is then returned to the digester.

After the wood pulp is “blown” from the digester by the steam used in the process, the pulp is washed free of the chemicals, screened and refined for entry into the paper-forming section of the mill.

The fiber is pumped to the paper machine as a very dilute suspension in water. To form the paper, the fiber suspension drains onto a finely woven plastic or wire mesh belt that moves over a series of vacuum boxes where the sheet is mechanically dewatered. Next, the sheet is transferred from the wire mesh to a synthetic fabric. This felt conveys the sheet to a pressure roll with an internal vacuum box designed to remove additional water. This same pressure roll also transfers the web to the dryer. This operation is the final drying operation for the sheet. The paperboard (containing about five percent moisture) is then wound onto rolls.

Cradle-to-gate data for the production of unbleached virgin kraft paper for shipping bags are shown in Table C-2. Cradle-to-gate data for the production of unbleached virgin kraft paper for dunnage are shown in Table C-3.

Postconsumer Recycled Paper(board)

Because a bright white appearance is not necessary for the recycled paper packaging products in this analysis, it is assumed that the recycled fiber is not deinked or bleached. The collection, repulping, and papermaking processes are thus the same for bleached and unbleached recycled paper, except for the sources of postconsumer fiber. The steps in postconsumer paper recycling are discussed below.

- Postconsumer Paper Collection
- Recycled Paper Production

Postconsumer Paper Collection. The majority of postconsumer fiber used in recycled unbleached kraft paper is recovered from old corrugated containers (OCC). Recovered office paper and magazines contribute a small amount to the postconsumer content in recycled kraft paper. The infrastructure for recycling postconsumer corrugated shipping containers in the United States is well established, particularly for warehouses and supermarkets. Typically, the used boxes are loaded onto a conveyer that takes them to a baler. The bales of boxes are then fork-lifted into a diesel truck that ships them to the recycled paperboard mill, where they are repulped. For recycled bleached kraft paper, the main source of recycled content is postconsumer office paper.

Data for the collection of postconsumer paper(board) include the transportation requirements for collecting the material and shipping it to a recycled paper(board) mill. The majority of both postconsumer OCC and postconsumer office paper are generated by commercial or industrial sites. This analysis thus uses commercial and industrial recycling data to represent collection of all grades of postconsumer paper(board).

Table C-2

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF UNBLEACHED VIRGIN KRAFT PAPER FOR SHIPPING BAGS (includes all steps from raw material extraction through production of unbleached virgin kraft paper and shipment to bag manufacturer)

Raw Materials

Roundwood Harvesting	5,469	lb
Limestone Mining	19.3	lb
Sulfur Production	1.09	lb
Salt Mining	2.02	lb
Nitrogen Fertilizer	0.29	lb
Phosphate Fertilizer	0.11	lb
Potash Fertilizer	0.14	lb
Corn Growing	19.7	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			4.22
Total Resource			4.22
Process Energy			
Electricity	98.4	kwh	1,102
Natural gas	1,205	cu ft	1,398
LPG	0.0014	gal	0.15
Coal	275	lb	3,155
Distillate oil	0.015	gal	2.31
Residual oil	0.57	gal	95.9
Gasoline	0.0011	gal	0.16
Diesel	1.79	gal	279
Wood	9,388	thou Btu	9,388
Total Process			15,421
Transportation Energy			
Combination truck	305	ton-miles	
Diesel	2.87	gal	448
Rail	15.9	ton-miles	
Diesel	0.038	gal	5.95
Barge	0.39	ton-miles	
Diesel	7.9E-04	gal	0.12
Residual oil	3.1E-04	gal	0.053
Ocean freighter	1.20	ton-miles	
Diesel	1.2E-04	gal	0.019
Residual	0.0022	gal	0.36
Pipeline-natural gas	0.049	ton-miles	
Natural gas	0.11	cu ft	0.13
Pipeline-petroleum products	0.083	ton-miles	
Electricity	0.0018	kwh	0.020
Total Transportation (for shipping bags)			455

Table C-2 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF UNBLEACHED VIRGIN KRAFT PAPER FOR SHIPPING BAGS

Environmental Emissions*

Atmospheric Emissions		
Particulates	1.81	lb
Nitrogen Oxides	7.05	lb
Hydrocarbons	0.024	lb
Sulfur Oxides	12.0	lb
Carbon Monoxide	8.22	lb
Aldehydes	0.012	lb
Ammonia	0.091	lb
Lead	7.7E-10	lb
Mercury	1.0E-04	lb
Chlorine	4.3E-07	lb
Hydrogen Chloride	8.3E-08	lb
Carbon Dioxide (fossil)	8.25	lb
Carbon Dioxide (non-fossil)	0.0059	lb
Total Reduced Sulfur	0.058	lb
Solid Wastes	75.6	lb
Waterborne Emissions		
Acid	0.025	lb
Metal Ion	1.3E-05	lb
Dissolved Solids	0.066	lb
SuspendedSolids	1.96	lb
BOD	1.31	lb
COD	13.0	lb
Phenol	7.5E-08	lb
Sulfides	1.6E-07	lb
Oil	6.4E-05	lb
Iron	1.2E-05	lb
Cyanide	6.8E-08	lb
Chromium	1.1E-08	lb
Aluminum	0.11	lb
Nickel	1.2E-09	lb
Mercury	1.6E-09	lb
Lead	2.2E-09	lb
Phosphates	0.095	lb
Phosphorus	0.065	lb
Nitrogen	0.023	lb
Zinc	1.7E-08	lb
Ammonia	0.043	lb
Nitrates	0.0024	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-3

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF UNBLEACHED VIRGIN KRAFT PAPER FOR DUNNAGE (includes all steps from raw material extraction through fabrication of packaging material)

Raw Materials

Roundwood Harvesting	5,469	lb
Limestone Mining	19.3	lb
Sulfur Production	1.09	lb
Salt Mining	2.02	lb
Nitrogen Fertilizer	0.29	lb
Phosphate Fertilizer	0.11	lb
Potash Fertilizer	0.14	lb
Corn Growing	19.7	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			4.22
Total Resource			4.22
Process Energy			
Electricity	98.4	kwh	1,102
Natural gas	1,205	cu ft	1,398
LPG	0.0014	gal	0.15
Coal	275	lb	3,155
Distillate oil	0.015	gal	2.31
Residual oil	0.57	gal	95.9
Gasoline	0.0011	gal	0.16
Diesel	1.79	gal	279
Wood	9,388	thou Btu	9,388
Total Process			15,421
Transportation Energy			
Combination truck	295	ton-miles	
Diesel	2.77	gal	433
Rail	7.74	ton-miles	
Diesel	0.019	gal	2.90
Barge	0.40	ton-miles	
Diesel	8.0E-04	gal	0.12
Residual oil	3.2E-04	gal	0.054
Ocean freighter	0.18	ton-miles	
Diesel	1.8E-05	gal	0.0027
Residual	3.2E-04	gal	0.053
Pipeline-natural gas	0.024	ton-miles	
Natural gas	0.055	cu ft	0.064
Pipeline-petroleum products	0.010	ton-miles	
Electricity	2.3E-04	kwh	0.0026
Total Transportation (for dunnage)			436

Table C-3 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF UNBLEACHED VIRGIN KRAFT PAPER FOR DUNNAGE

Environmental Emissions*

Atmospheric Emissions		
Particulates	1.81	lb
Nitrogen Oxides	7.05	lb
Hydrocarbons	0.024	lb
Sulfur Oxides	12.0	lb
Carbon Monoxide	8.22	lb
Aldehydes	0.012	lb
Ammonia	0.091	lb
Lead	7.7E-10	lb
Mercury	1.0E-04	lb
Chlorine	4.3E-07	lb
Hydrogen Chloride	8.3E-08	lb
Carbon Dioxide (fossil)	8.25	lb
Carbon Dioxide (non-fossil)	0.0059	lb
Total Reduced Sulfur	0.058	lb
Solid Wastes	75.6	lb
Waterborne Emissions		
Acid	0.025	lb
Metal Ion	1.3E-05	lb
Dissolved Solids	0.066	lb
SuspendedSolids	1.96	lb
BOD	1.31	lb
COD	13.0	lb
Phenol	7.5E-08	lb
Sulfides	1.6E-07	lb
Oil	6.4E-05	lb
Iron	1.2E-05	lb
Cyanide	6.8E-08	lb
Chromium	1.1E-08	lb
Aluminum	0.11	lb
Nickel	1.2E-09	lb
Mercury	1.6E-09	lb
Lead	2.2E-09	lb
Phosphates	0.095	lb
Phosphorus	0.065	lb
Nitrogen	0.023	lb
Zinc	1.7E-08	lb
Ammonia	0.043	lb
Nitrates	0.0024	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Recycled Paper Production. Postconsumer paper is recycled by repulping shredded material. In the repulping process, the collected paper is mixed with water in a huge blender-like vat, called a repulper. Blades at the bottom of the vat churn the water and beat the paper fiber away from any coatings. As the repulper is drained, filters allow the paper fibers to pass through. Any coatings are screened off and disposed. Much of the short fibers are also screened off of the pulp. The sludge can be collected from the repulper for beneficial uses, such as animal bedding or ground cover at landfills, or can be thrown away as solid waste. Additional chemicals are used if recycled pulp must be deinked for use in applications such as office paper, but recycled pulp used in packaging applications such as dunnage paper and shipping bags would not be deinked. In this analysis, data for the recycling of postconsumer paper include the repulping and papermaking steps.

Cradle-to-gate data for the production of unbleached recycled kraft paper for shipping bags are shown in Table C-4. Cradle-to-gate data for the production of bleached recycled kraft paper for shipping bags are shown in Table C-5.

Newsprint

The steps in the production of newsprint containing virgin and postconsumer content are shown in Figure C-7. The details for the production of virgin newsprint and 100 percent postconsumer newsprint are discussed below.

Virgin Newsprint. The production of virgin newsprint includes the following processes:

- Roundwood Harvesting
- Wood Residues Generation
- Salt Mining
- Sodium Chlorate Production
- Production of Caustic Soda (Sodium Hydroxide) and Chlorine
- Mechanical Pulp Manufacture
- Thermomechanical Pulp Manufacture
- Bleached Kraft Pulp Manufacture
- Newsprint Production

Roundwood harvesting, wood residues, salt mining, sodium chlorate production, caustic soda production, and bleached kraft manufacture are discussed previously in this appendix and are not repeated here. Mechanical pulp manufacture, thermomechanical pulp manufacture, and newsprint production are discussed below.

Table C-4

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF UNBLEACHED RECYCLED KRAFT PAPER FOR SHIPPING BAGS (100% POSTCONSUMER CONTENT)
(includes all steps from postconsumer material collection through production of unbleached recycled kraft paper and shipment to bag manufacturer)

Raw Materials			
OCC/Wastepaper Collection	1,056	lb	
Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	292	kwh	3,271
Natural gas	531	cu ft	616
LPG	0.029	gal	3.08
Coal	220	lb	2,528
Distillate oil	0.014	gal	2.19
Residual oil	0.24	gal	40.5
Diesel	0.28	gal	43.4
Total Process			6,504
Transportation Energy			
Combination truck	184	ton-miles	
Diesel	1.73	gal	271
Single unit truck	10.6	ton-miles	
Diesel	0.28	gal	43.7
Total Transportation			315
Environmental Emissions*			
Solid Wastes	62.2	lb	
Waterborne Emissions			
Dissolved Solids	0.30	lb	
SuspendedSolids	3.01	lb	
BOD	3.03	lb	
COD	4.76	lb	
Phenol	0.0024	lb	
Sulfides	0.20	lb	
Oil	0.20	lb	
Iron	0.20	lb	
Aluminum	0.10	lb	
Phosphates	0.065	lb	
Zinc	0.0028	lb	
Ammonia	0.0050	lb	

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-5

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF BLEACHED RECYCLED KRAFT PAPER FOR SHIPPING BAGS (100% POSTCONSUMER CONTENT)
(includes all steps from postconsumer material collection through production of bleached recycled kraft paper and shipment to bag manufacturer)

Raw Materials			
OCC/Wastepaper Collection	1,056	lb	
Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	292	kwh	3,271
Natural gas	531	cu ft	616
LPG	0.029	gal	3.08
Coal	220	lb	2,528
Distillate oil	0.014	gal	2.19
Residual oil	0.24	gal	40.5
Diesel	0.28	gal	43.4
Total Process			6,504
Transportation Energy			
Combination truck	184	ton-miles	
Diesel	1.73	gal	271
Single unit truck	10.6	ton-miles	
Diesel	0.28	gal	43.7
Total Transportation			315
Environmental Emissions*			
Solid Wastes	62.2	lb	
Waterborne Emissions			
Dissolved Solids	0.30	lb	
SuspendedSolids	3.01	lb	
BOD	3.03	lb	
COD	4.76	lb	
Phenol	0.0024	lb	
Sulfides	0.20	lb	
Oil	0.20	lb	
Iron	0.20	lb	
Aluminum	0.10	lb	
Phosphates	0.065	lb	
Zinc	0.0028	lb	
Ammonia	0.0050	lb	

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

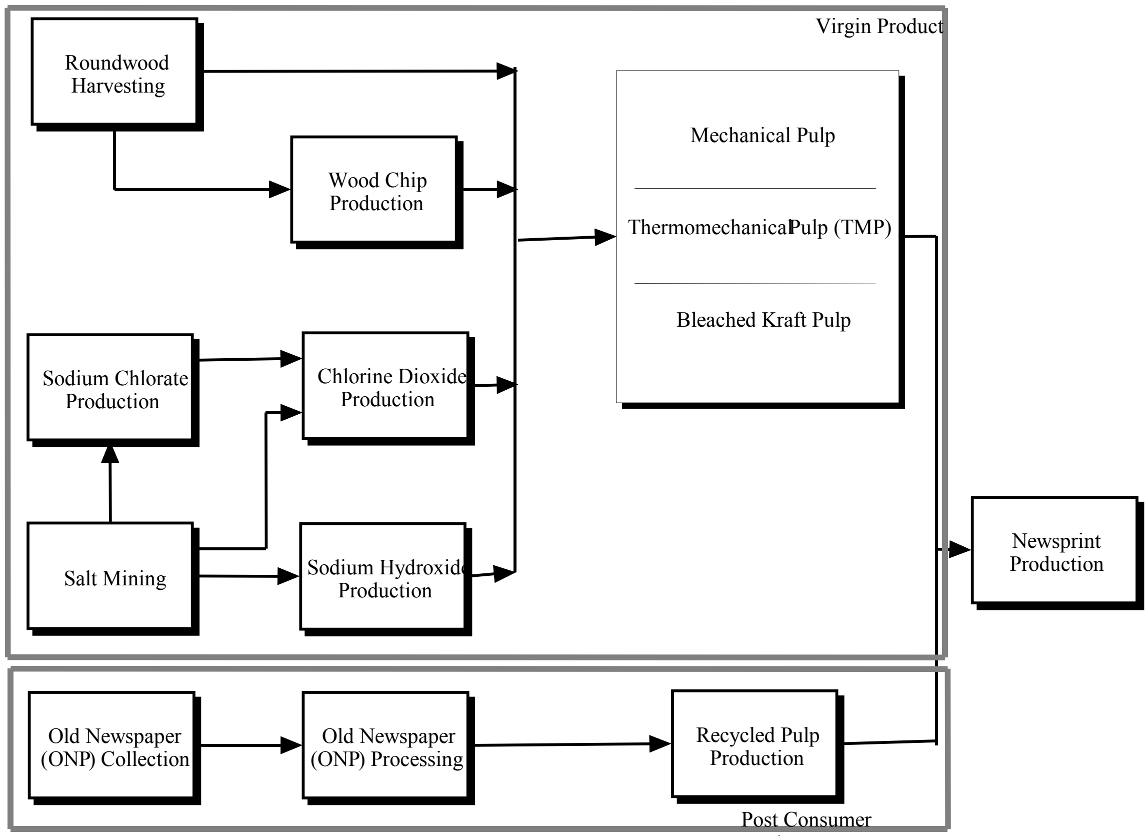

Figure C-7 Flow diagram for the production of newsprint with virgin and postconsumer content.

Mechanical Pulp Manufacture. Mechanical pulp, which is commonly either stone groundwood pulp (SGP) or refiner mechanical pulp (RMP), is one of the types of pulp used for manufacturing newsprint (Reference C-35). Data on refiner mechanical pulp production, which employs a disc refiner to break down wood chips, are now available. The data for mechanical pulp in this analysis represent only the stone groundwood process. The SGP process produces pulp by pressing blocks of wood against an abrasive rotating stone surface. Very little, if any, chemicals are used in this process (Reference C-35). No chemicals are assumed to be used in the production of groundwood pulp. (Usually bleached kraft pulp is blended with groundwood to make newsprint.)

Thermomechanical Pulp Production. Thermomechanical pulp (TMP) uses wood chips as its source of fiber. The wood chips are steamed for a short period of time prior to and during refining. Steam softens the chips and, therefore, results in a greater percentage of long fibers and less imperfections in the pulp produced compared to mechanical pulp. Longer fibers produce a stronger pulp than the stone groundwood or refiner mechanical pulp.

Newsprint Production. Virgin newsprint is made primarily from mechanical pulps. The fiber products are brought into the stock storage chest where they are mixed with water and combined with other pulps to form a suspension (furnish), which is ready to be made into paper.

From stock prep, the furnish is fed into the headbox. With the use of pressure, the headbox deposits the furnish in a regulated fashion onto a wire mesh. From the headbox, the wire mesh moves over a series of vacuum boxes where the sheet is mechanically dewatered.

Next, the furnish sheet is transferred from the wire mesh to a synthetic fabric. This felt conveys the sheet to a pressure roll with an internal vacuum box designed to remove additional water. This same pressure roll also transfers the web to the dryer. This operation is the final drying operation for the sheet.

Once the fiber has passed through the dryer, it has entered the "dry end" of the papermaking operation. From the dryer, the paper is passed through calendar rolls to soften and smooth the paper, and wound onto a large, bulk size reel (now referred to as a parent roll). As the fiber passes through the papermaking process, scrap or broke that is created is fed directly into the holding chest underneath the machine to be repulped and sent back to the headbox. This internally recycled scrap is referred to as machine broke.

Cradle-to-gate data for the production of virgin newsprint dunnage are shown in Table C-6.

Recycled Newsprint (100% Postconsumer). The postconsumer inputs to recycled newsprint production are predominantly old newspapers. Production of newsprint containing 100 percent postconsumer fiber includes the following steps:

- Old Newspaper (ONP) Collection
- Recycled Newsprint Production

Old Newspaper (ONP) Collection. The energy and emissions associated with the collection of old newspaper are based on data for similar processes.

Recycled Newsprint Production. The first step in recycled newsprint production is repulping, as described earlier in this appendix in the section **Recycled Paper Production**. Recycled pulp used to produce newsprint used for dunnage paper would not be deinked.

Table C-6

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN NEWSPRINT DUNNAGE PAPER (includes all steps from raw material extraction through fabrication of packaging material)

Raw Materials

Roundwood Harvest	2,703	lb
Salt mining	35.9	lb

Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	1,047	kwh	11,726
Natural gas	5,509	cu ft	6,390
LPG	1.9E-05	gal	0.0021
Coal	19.3	lb	222
Residual oil	0.61	gal	103
Gasoline	5.9E-04	gal	0.083
Diesel	0.97	gal	151
Wood	1,757	thou Btu	1,757
Total Process			20,350
Transportation Energy			
Combination truck	146	ton-miles	
Diesel	1.37	gal	214
Rail	80.7	ton-miles	
Diesel	0.19	gal	30.2
Barge	0.31	ton-miles	
Diesel	6.2E-04	gal	0.097
Residual oil	2.5E-04	gal	0.042
Total Transportation			245

Table C-6 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN NEWSPRINT DUNNAGE PAPER

Environmental Emissions*

Atmospheric Emissions		
Particulates	1.55	lb
Nitrogen Oxides	0.34	lb
Hydrocarbons	0.094	lb
Sulfur Oxides	0.66	lb
Aldehydes	0.0097	lb
Other Organics	1.00	lb
Odorous Sulfur	0.11	lb
Mercury	9.8E-06	lb
Chlorine	5.5E-06	lb
ChlorineDioxide	0.0041	lb
Solid Wastes	138	lb
Waterborne Emissions		
Dissolved Solids	0.091	lb
SuspendedSolids	5.57	lb
BOD	5.64	lb
COD	4.04	lb
Phenol	3.1E-07	lb
Sulfides	2.7E-06	lb
Nickel	2.0E-08	lb
Mercury	2.8E-08	lb
Lead	1.4E-06	lb
Zinc	1.7E-04	lb
Methanol	0.014	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

The recycled pulp is then sent to the newsprint (papermaking) section of the mill, where it substitutes for the mechanical pulp, TMP, and bleached kraft pulp used to produce virgin newsprint. The recycled pulp goes through the same papermaking process as described for virgin newsprint.

Cradle-to-gate data for the production of recycled newsprint dunnage are shown in Table C-7.

Table C-7

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF RECYCLED NEWSPRINT DUNNAGE PAPER MADE FROM 100% POSTCONSUMER MATERIAL (includes all steps from postconsumer material collection through fabrication of packaging material)

Raw Materials			
ONP Collection For Recycled Newsprint	1,265	lb	
Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	117	kwh	1,313
Natural gas	2,855	cu ft	3,312
Diesel	0.18	gal	27.7
Total Process			4,652
Transportation Energy			
Combination truck	101	ton-miles	
Diesel	0.95	gal	149
Single unit truck	12.7	ton-miles	
Diesel	0.34	gal	52.4
Total Transportation			201
Environmental Emissions*			
Atmospheric Emissions			
Particulates	1.00	lb	
Other Organics	1.00	lb	
Solid Wastes	190	lb	
Waterborne Emissions			
SuspendedSolids	5.03	lb	
BOD	3.02	lb	

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Corrugated Paperboard

The material flows and steps in the production of corrugated containers are shown in Figure C-8. The production of corrugated products includes:

- Unbleached Kraft Linerboard Production
- Semichemical Medium Production
- Old Corrugated Container (OCC) Collection
- Recycled Paperboard (Linerboard and Medium) Production

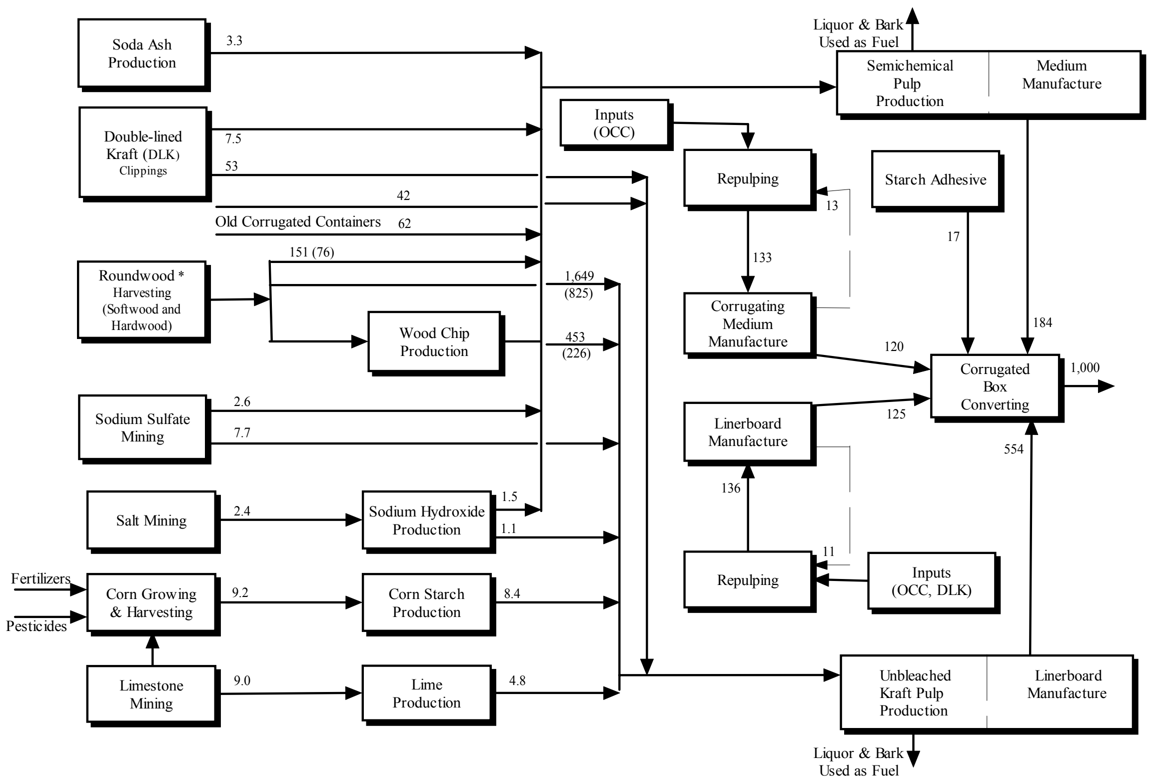

Figure C-8. Process Flow Diagram for the Production of 1,000 Pounds of Corrugated Containers.
All weights shown in pounds. Numbers in parentheses represent bone-dry weight of wood.
*Managed and/or unmanaged forest.

The production of unbleached kraft paper and old corrugated container collection are already discussed in this appendix and are not repeated here. The production of semichemical medium and recycled paperboard is discussed below. The only input material to any of these paper grades that has not already been discussed in this appendix is soda ash, used in the production of semichemical pulp.

Soda Ash Production. Soda ash (sodium carbonate) produced in the U.S. comes from natural soda ash obtained from trona or from alkaline brines. Almost all domestic soda ash comes from either the Green River Basin in Wyoming or Searles Lake in California, although a small amount is produced in Colorado. Underground trona mining is similar to coal mining. The most common methods are the room and pillar method and the long wall method.

In both of these processes the material is undercut, drilled, blasted, crushed, and then transported to the surface. Solution mining is presently being developed as a more efficient technique. In the refining process, the predominant energy use is in the calcining of bicarbonate to produce carbonate (Reference C-27). This analysis uses current percentages of production by each method to apportion energy and emissions data for soda ash production.

Semichemical Medium Production. Most of the increase in semichemical pulp production in the past 40 years has been made using non-sulfur semichemical processes, not only because of tightened environmental regulations, but also because of realization of higher yields and simpler recovery systems. There are three major pulping processes used to manufacture semichemical pulps in integrated as well as stand-alone semichemical pulp mills:

- Neutral Sulfite (NSSC) process, which uses sodium carbonate and sulfur or, in some cases, sodium sulfite purchased as a byproduct from a nearby chemical operation as the cooking chemical.
- Green Liquor process, which uses green liquor for the kraft recovery process as the cooking chemical.
- Non-sulfur process, which uses a combination of sodium carbonate, sodium hydroxide, and traces of other proprietary chemicals to enhance the properties of the pulp.

Many semichemical operations integrated with kraft mills use green liquor from the kraft recovery process as the cooking chemical. This allows integration of the semichemical cooking chemical preparation and recovery into the kraft recovery cycle. The quality of semichemical pulp is superior when produced by the neutral sulfite process, but it produces less pulp per pound of wood. The pulp yields from wood in the semichemical pulping processes range from 75 to 88 percent.

The data presented is based on two different process – the non-sulfur process and the NSSC process. A market share average of 60 percent non-sulfur and 40 percent NSSC was used in combining the data sets (Reference C-96).

Semichemical paperboard typically contains some recycled fiber. The proportion of recycled fiber will vary for specific mills. For this study, the fibrous raw materials used by the mills surveyed are similar to the national averages for semichemical paperboard.

Recycled Paperboard (Linerboard and Medium) Production. The collected wastepaper includes primarily old corrugated containers (OCC) and double-lined kraft (DLK). Also, small amounts of postconsumer office wastepaper and old newspapers can be used. Typically, these products are recycled by repulping shredded material.

In the repulping process, the collected paper is mixed with water in a huge blender-like vat, called a repulper. Blades at the bottom of the vat churn the water and beat the paper fiber away from any coatings. As the repulper is drained, filters allow the paper fibers to pass through. The coating is screened off and disposed. Much of the short fibers are also screened off of the pulp. The sludge can be collected from the repulper for beneficial uses, such as animal bedding or ground cover at landfills, or can be thrown away as solid waste.

The proportion of postconsumer fiber and industrial scrap consumed varies for specific recycled paperboard mills. The fibrous raw materials used in this data set reflect the national averages.

PRODUCT FABRICATION

This section discusses the fabrication of mail-order packaging for soft goods. This includes polyethylene film and inflated air packets, expanded polystyrene foam, cornstarch foam, molded pulp cushion cubes, corrugated boxes, and shredded materials used as dunnage. This report does not include assembly of these materials into composite packages such as paper shipping bags with bubble wrap lining. No data were available on the fabrication of bubble wrap from polyethylene resin.

Polyethylene Film Fabrication

Extrusion is a process that forms a film by using mechanical and thermal energy to melt a thermoplastic resin and force it through a die (Reference C-99). An extrusion system includes a hopper, a screw barrel, a screen pack, a breaker plate, an adapter valve, and a die. The hopper ensures a constant, sufficient feed of pelletized resin to the extruder. The screw barrel consists of a long, rotating screw that melts the resin through mechanical energy provided by the screw and thermal energy provided by heaters that surround the barrel. The screen pack consists of a series of mesh screens that filter impurities from the resin. The breaker plate creates a smooth, laminar flow of the resin. The adapter valve adjusts the back pressure on the screw barrel, ensuring that the extruder is always filled with resin as well as aiding in the mechanical shearing of the resin. The die forces the resin into its final form (Reference C-98).

Extrusion relies on electrical energy to drive the screw in the extruder barrel and to power the ceramic heaters that heat the extruder barrel. Energy data are available for turning the extruder screw, but no data are available for the ceramic heaters. The extrusion screw is constantly shearing and mixing the resin mixture. The ceramic heaters, on the other hand, are necessary during the startup of the extruder, but are used intermittently during continuous operation (Reference C-98). It is thus assumed that the electrical energy to drive the extrusion screw accounts for the majority of the energy for the extrusion process. In fact, one reference (Reference C-99) asserts that the friction produced by the extruder screw producers enough heat to melt the resin mixture without the assistance of ceramic heaters.

A small amount of smoke is produced at the extruder die. This smoke is captured by a fume collection system that prevents it from being released to the atmosphere (Reference C-98). It is assumed in this study that negligible amounts of airborne emissions are released from extrusion.

In this analysis, the energy and emissions data for polyethylene film fabrication are based on published power requirements for extrusion equipment and the assumptions discussed above.

Table C-8 shows the cradle-to-gate data for the production of virgin LDPE film, while data for the production of recycled LDPE film are shown in Table C-9. Cradle-to-gate data for the production of virgin LLDPE film are shown in Table C-10 and for recycled LLDPE film in Table C-11.

Fabrication of Polyethylene Inflated Air Packets

Inflated polyethylene air packets are typically sold to order fulfillment centers as flat (deflated) tubes of polyethylene film. (Companies can purchase the air packets pre-inflated although this is not cost effective unless very small quantities are needed.) The tube stock is fed into a machine that uses either electricity or a combination of electricity and compressed air (for higher volume machines) to inflate the tubes and seal them at regular intervals.

In this analysis, the energy data for the fabrication of inflated air packets are based on the use of a mid-range machine marketed by Storopack that produces 48 feet of inflated air packets per minute and draws an estimated 220 – 230 Watts of electric power. Data were converted to pounds of inflated air packets based on the packing study described in Appendix B.

Cradle-to-gate data for the production of virgin LDPE sealed air packets are shown in Table C-12. Cradle-to-gate data for the production of recycled LDPE sealed air packets are shown in Table C-13.

EPS Foam Product Fabrication

There are several steps for expanding polystyrene into foam. Polystyrene, in the form of small beads, is first expanded with heat and dry steam. This vaporizes the blowing agent and expands the softened beads. The polystyrene is then conveyed through a cool air stream to a storage container. The storage phase allows the blowing agent content to drop below three percent (Reference C-49). The final product is then produced by molding or extrusion.

Table C-8

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN LDPE FILM
(includes all steps from raw material extraction through production of virgin LDPE film and shipment to bag manufacturer)

Raw Materials

Crude Oil Production	255	lb
Natural Gas Production	781	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			18,200
Petroleum			5,103
Total Resource			23,304
Process Energy			
Electricity	659	kwh	7,377
Natural gas	7,144	cu ft	8,287
LPG	0.043	gal	4.58
Distillate oil	0.24	gal	37.6
Residual oil	0.64	gal	109
Gasoline	0.81	gal	112
Total Process			15,927
Transportation Energy			
Combination truck	518	ton-miles	
Diesel	4.87	gal	761
Rail	563	ton-miles	
Diesel	1.35	gal	211
Barge	10.7	ton-miles	
Diesel	0.021	gal	3.34
Residual oil	0.0086	gal	1.44
Ocean freighter	517	ton-miles	
Diesel	0.052	gal	8.07
Residual	0.93	gal	157
Pipeline-natural gas	53.5	ton-miles	
Natural gas	123	cu ft	143
Pipeline-petroleum products	114	ton-miles	
Electricity	2.50	kwh	28.0
Total Transportation			1,312

Table C-8 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN LDPE FILM

Environmental Emissions*

Atmospheric Emissions		
Particulates	0.19	lb
Nitrogen Oxides	1.11	lb
Hydrocarbons	12.5	lb
Sulfur Oxides	30.6	lb
Carbon Monoxide	0.23	lb
Aldehydes	0.010	lb
Methane	5.98	lb
Ammonia	0.0013	lb
Lead	3.5E-07	lb
Chlorine	5.3E-05	lb
Hydrogen Chloride	4.1E-05	lb
Solid Wastes	100	lb
Waterborne Emissions		
Acid	0.13	lb
Metal Ion	0.0061	lb
Dissolved Solids	47.8	lb
SuspendedSolids	0.35	lb
BOD	0.29	lb
COD	1.11	lb
Phenol	2.0E-05	lb
Sulfides	0.060	lb
Oil	0.87	lb
Iron	1.1E-04	lb
Cyanide	3.2E-06	lb
Chromium	0.0022	lb
Mercury	1.7E-07	lb
Lead	5.1E-07	lb
Phosphates	0.0067	lb
Zinc	0.0019	lb
Ammonia	4.6E-04	lb
Chlorides	2.21	lb
Cadmium	0.0022	lb
Organic Carbon	0.14	lb
Sulfates	1.70	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-9

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF RECYCLED LDPE FILM (100% POSTCONSUMER CONTENT)
(includes all steps from postconsumer material collection through production of recycled LDPE film and shipment to bag manufacturer)

Raw Materials			
Postconsumer LDPE resin (collection and recycling)	1,010	lb	
Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	486	kwh	5,443
Natural gas	36.4	cu ft	42.2
LPG	0.11	gal	11.8
Total Process			5,497
Transportation Energy			
Combination truck	194	ton-miles	
Diesel	1.82	gal	285
Single unit truck	125	ton-miles	
Diesel	3.32	gal	518
Total Transportation			803
Environmental Emissions*			
Solid Wastes	121	lb	

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-10

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN LLDPE FILM
(includes all steps from raw material extraction through production of virgin LLDPE film and shipment to bag manufacturer)

Raw Materials

Crude Oil Production	256	lb
Natural Gas Production	785	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			18,291
Petroleum			5,129
Total Resource			23,420
Process Energy			
Electricity	499	kwh	5,595
Natural gas	6,885	cu ft	7,986
LPG	0.043	gal	4.60
Distillate oil	0.24	gal	37.8
Residual oil	0.65	gal	109
Gasoline	0.81	gal	113
Total Process			13,846
Transportation Energy			
Combination truck	518	ton-miles	
Diesel	4.87	gal	761
Rail	554	ton-miles	
Diesel	1.33	gal	208
Barge	10.7	ton-miles	
Diesel	0.021	gal	3.36
Residual oil	0.0086	gal	1.45
Ocean freighter	519	ton-miles	
Diesel	0.052	gal	8.11
Residual	0.93	gal	158
Pipeline-natural gas	53.7	ton-miles	
Natural gas	124	cu ft	143
Pipeline-petroleum products	87.9	ton-miles	
Electricity	1.93	kwh	21.7
Total Transportation			1,305

Table C-10 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN LLDPE FILM

Environmental Emissions*

Atmospheric Emissions		
Particulates	0.25	lb
Nitrogen Oxides	1.11	lb
Hydrocarbons	10.4	lb
Sulfur Oxides	30.7	lb
Carbon Monoxide	0.23	lb
Aldehydes	0.010	lb
Methane	6.01	lb
Ammonia	0.0014	lb
Lead	3.6E-07	lb
Chlorine	5.4E-05	lb
Hydrogen Chloride	4.1E-05	lb
Solid Wastes	102	lb
Waterborne Emissions		
Acid	0.13	lb
Metal Ion	0.0061	lb
Dissolved Solids	48.0	lb
SuspendedSolids	0.12	lb
BOD	0.095	lb
COD	0.58	lb
Phenol	2.0E-05	lb
Sulfides	0.060	lb
Oil	0.88	lb
Iron	1.1E-04	lb
Cyanide	3.2E-06	lb
Chromium	0.0022	lb
Mercury	1.7E-07	lb
Lead	5.1E-07	lb
Phosphates	0.0067	lb
Zinc	0.0019	lb
Ammonia	4.6E-04	lb
Chlorides	2.22	lb
Cadmium	0.0022	lb
Organic Carbon	0.14	lb
Sulfates	1.70	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-11

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF RECYCLED LLDPE FILM (100% POSTCONSUMER CONTENT) (includes all steps from postconsumer material collection through production of recycled LLDPE film and shipment to bag manufacturer)

Raw Materials			
Postconsumer LLDPE resin (collection and recycling)	1,010	lb	
Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	486	kwh	5,443
Natural gas	36.4	cu ft	42.2
LPG	0.11	gal	11.8
Total Process			5,497
Transportation Energy			
Combination truck	194	ton-miles	
Diesel	1.82	gal	285
Single unit truck	125	ton-miles	
Diesel	3.32	gal	518
Total Transportation			803
Environmental Emissions*			
Solid Wastes	121	lb	

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-12

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN LDPE SEALED AIR PACKETS (includes all steps from raw material extraction through production of LDPE tube stock, plus inflating and sealing at the order fulfillment center)

Raw Materials

Crude Oil Production	255	lb
Natural Gas Production	781	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			18,200
Petroleum			5,103
Total Resource			23,304
Process Energy			
Electricity	663	kwh	7,425
Natural gas	7,144	cu ft	8,287
LPG	0.043	gal	4.58
Distillate oil	0.24	gal	37.6
Residual oil	0.64	gal	109
Gasoline	0.81	gal	112
Total Process			15,975
Transportation Energy			
Combination truck	498	ton-miles	
Diesel	4.68	gal	731
Rail	542	ton-miles	
Diesel	1.30	gal	203
Barge	10.7	ton-miles	
Diesel	0.021	gal	3.34
Residual oil	0.0086	gal	1.44
Ocean freighter	517	ton-miles	
Diesel	0.052	gal	8.07
Residual	0.93	gal	157
Pipeline-natural gas	53.5	ton-miles	
Natural gas	123	cu ft	143
Pipeline-petroleum products	114	ton-miles	
Electricity	2.50	kwh	28.0
Total Transportation			1,274

Table C-12 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN LDPE SEALED AIR PACKETS

Environmental Emissions*

Atmospheric Emissions		
Particulates	0.19	lb
Nitrogen Oxides	1.11	lb
Hydrocarbons	12.5	lb
Sulfur Oxides	30.6	lb
Carbon Monoxide	0.23	lb
Aldehydes	0.010	lb
Methane	5.98	lb
Ammonia	0.0013	lb
Lead	3.5E-07	lb
Chlorine	5.3E-05	lb
Hydrogen Chloride	4.1E-05	lb
Solid Wastes	110	lb
Waterborne Emissions		
Acid	0.13	lb
Metal Ion	0.0061	lb
Dissolved Solids	47.8	lb
SuspendedSolids	0.35	lb
BOD	0.29	lb
COD	1.11	lb
Phenol	2.0E-05	lb
Sulfides	0.060	lb
Oil	0.87	lb
Iron	1.1E-04	lb
Cyanide	3.2E-06	lb
Chromium	0.0022	lb
Mercury	1.7E-07	lb
Lead	5.1E-07	lb
Phosphates	0.0067	lb
Zinc	0.0019	lb
Ammonia	4.6E-04	lb
Chlorides	2.21	lb
Cadmium	0.0022	lb
Organic Carbon	0.14	lb
Sulfates	1.70	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-13

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF RECYCLED LDPE SEALED AIR PACKETS (100% POSTCONSUMER MATERIAL)
(includes all steps from postconsumer material collection through production of recycled LDPE tube stock, plus inflating and sealing at the order fulfillment center)

Raw Materials			
Postconsumer LDPE resin (collection and recycling)	1,010	lb	
Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Process Energy			
Electricity	490	kwh	5,491
Natural gas	36.4	cu ft	42.2
LPG	0.11	gal	11.8
Total Process			5,545
Transportation Energy			
Combination truck	194	ton-miles	
Diesel	1.82	gal	285
Single unit truck	125	ton-miles	
Diesel	3.32	gal	518
Total Transportation			803
Environmental Emissions*			
Solid Wastes	131	lb	

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Cradle-to-gate data for the production of virgin EPS loose fill are shown in Table C-14. Cradle-to-gate data for the production of recycled EPS loose fill are shown in Table C-15.

Table C-14

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN EPS LOOSE FILL
(includes all steps from raw material extraction through fabrication of packaging material)

Raw Materials

Crude Oil Production	978	lb
Natural Gas Production	254	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			5,907
Petroleum			19,586
Total Resource			25,492
Process Energy			
Electricity	1,051	kwh	11,777
Natural gas	17,599	cu ft	20,415
LPG	0.17	gal	17.6
Distillate oil	0.75	gal	117
Residual oil	6.16	gal	1,039
Gasoline	0.35	gal	48.3
Total Process			33,414
Transportation Energy			
Combination truck	619	ton-miles	
Diesel	5.82	gal	909
Rail	717	ton-miles	
Diesel	1.72	gal	269
Barge	128	ton-miles	
Diesel	0.26	gal	40.0
Residual oil	0.10	gal	17.3
Ocean freighter	1,983	ton-miles	
Diesel	0.20	gal	31.0
Residual	3.57	gal	603
Pipeline-natural gas	17.3	ton-miles	
Natural gas	39.9	cu ft	46.3
Pipeline-petroleum products	342	ton-miles	
Electricity	7.53	kwh	84.3
Total Transportation			1,999

Table C-14 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF VIRGIN EPS LOOSE FILL

Environmental Emissions*

Atmospheric Emissions		
Particulates	0.12	lb
Nitrogen Oxides	0.36	lb
Hydrocarbons	9.51	lb
Sulfur Oxides	10.4	lb
Carbon Monoxide	0.070	lb
Aldehydes	0.039	lb
Methane	1.94	lb
Ammonia	0.0052	lb
Lead	1.4E-06	lb
Chlorine	2.0E-04	lb
Hydrogen Chloride	1.6E-04	lb
Carbon Dioxide (fossil)	36.3	lb
Solid Wastes	50.3	lb
Waterborne Emissions		
Acid	0.037	lb
Metal Ion	0.023	lb
Dissolved Solids	16.4	lb
SuspendedSolids	0.34	lb
BOD	0.60	lb
COD	1.08	lb
Phenol	7.6E-05	lb
Sulfides	0.020	lb
Oil	0.34	lb
Iron	4.1E-04	lb
Cyanide	1.0E-06	lb
Chromium	7.1E-04	lb
Mercury	5.6E-08	lb
Lead	1.9E-06	lb
Phosphates	0.0019	lb
Zinc	5.9E-04	lb
Ammonia	0.0018	lb
Chlorides	0.72	lb
Cadmium	7.1E-04	lb
Organic Carbon	0.046	lb
Sulfates	0.55	lb
Hydrocarbons	0.10	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-15

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF RECYCLED EPS LOOSE FILL (100% POSTCONSUMER CONTENT) (includes all steps from postconsumer material collection through fabrication of packaging material)

Raw Materials			
Postconsumer EPS collection	1,100	lb	
Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	834	kwh	9,336
Natural gas	7,563	cu ft	8,773
Total Process			18,109
Transportation Energy			
Combination truck	604	ton-miles	
Diesel	5.68	gal	887
Single unit truck	300	ton-miles	
Diesel	7.96	gal	1,243
Rail	604	ton-miles	
Diesel	1.45	gal	226
Total Transportation			2,356
Environmental Emissions*			
Atmospheric Emissions			
Nitrogen Oxides	0.12	lb	
Hydrocarbons	0.84	lb	
Carbon Monoxide	0.020	lb	
Solid Wastes	100	lb	

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Cornstarch Foam Fabrication

Cornstarch foam is produced by an extrusion process. Starch and water are mixed in an extruder; a composition of 21 percent water by weight is desired (Reference C-108). The extruding equipment is equipped with heaters, but the majority of heat in the cornstarch and water mixture arises from the shear force of the rotating screws in the extruder (Reference C-106). When the mixture exits the small holes of the extruder, the water instantly flashes into steam, forming the foam. The foam is cut to length as it exits the extruder. Cradle-to-gate data for the production of cornstarch loose fill are shown in Table C-16.

Molded Pulp Cushion Cubes Fabrication

Molded pulp cubes are used as dunnage in shipping containers. The steps in the production of molded pulp cubes are shown in Figure C-9 and include the following processes:

- Old newspaper (ONP) Collection
- Repulping
- Molded Pulp Loosefill Production

Old newspaper collection and repulping are discussed previously in this appendix and are not repeated here. The manufacture of molded pulp loosefill is discussed below.

Molded Pulp Loosefill Production. The molding of pulp starts in a slurry tank that is constantly replenished with pulp. The slurry tank feeds into forming equipment that use metal plates to press the pulp into the desired shape. The molded pulp is then transferred to a gas-fired heater that dries the product. Cradle-to-gate data for the production of molded pulp loose fill from 100% postconsumer newspaper are shown in Table C-17.

Table C-16

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF CORNSTARCH LOOSE FILL (includes all steps from raw material extraction through fabrication of packaging material)

Raw Materials

Nitrogen Fertilizer	15.9	lb
Phosphate Fertilizer	6.19	lb
Potash Fertilizer	7.59	lb
Corn Growing & Harvesting	1,092	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			234
Total Resource			234
Process Energy			
Electricity	465	kwh	5,207
Natural gas	708	cu ft	821
Coal	17.0	lb	195
Distillate oil	0.0060	gal	0.93
Residual oil	0.73	gal	123
Gasoline	0.0017	gal	0.24
Diesel	0.69	gal	107
Total Process			6,455
Transportation Energy			
Combination truck	443	ton-miles	
Diesel	4.16	gal	650
Rail	449	ton-miles	
Diesel	1.08	gal	168
Barge	1.24	ton-miles	
Diesel	0.0025	gal	0.39
Residual oil	0.0010	gal	0.17
Ocean freighter	5.84	ton-miles	
Diesel	5.8E-04	gal	0.091
Residual	0.011	gal	1.77
Pipeline-natural gas	0.80	ton-miles	
Natural gas	1.83	cu ft	2.12
Pipeline-petroleum products	0.35	ton-miles	
Electricity	0.0077	kwh	0.086
Total Transportation			823

Table C-16 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF CORNSTARCH LOOSE FILL

Environmental Emissions*

Atmospheric Emissions		
Particulates	0.82	lb
Nitrogen Oxides	5.2E-04	lb
Hydrocarbons	0.36	lb
Sulfur Oxides	0.89	lb
Carbon Monoxide	0.0035	lb
Aldehydes	1.2E-04	lb
Ammonia	0.020	lb
Carbon Dioxide (non-fossil)	0.33	lb
Solid Wastes	46.0	lb
Waterborne Emissions		
Acid	0.10	lb
Dissolved Solids	3.36	lb
SuspendedSolids	11.1	lb
BOD	1.22	lb
COD	1.95	lb
Phenol	1.9E-06	lb
Oil	0.0017	lb
Iron	6.8E-04	lb
Cyanide	3.8E-06	lb
Chromium	4.7E-07	lb
Phosphates	0.29	lb
Nitrogen	1.29	lb
Ammonia	0.0012	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Figure C-9. Flow diagram for the production of molded pulp loosefill.

Table C-17

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF MOLDED PULP LOOSE FILL MADE FROM 100% POSTCONSUMER NEWSPAPER (includes all steps from postconsumer material collection through fabrication of packaging material)

Raw Materials			
Postconsumer paper collection	1,050	lb	
Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	663	kwh	7,426
Natural gas	7,256	cu ft	8,417
Diesel	0.15	gal	23.0
Total Process			15,866
Transportation Energy			
Single unit truck	78.8	ton-miles	
Diesel	2.09	gal	326
Total Transportation			326
Environmental Emissions*			
Solid Wastes	50.0	lb	

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Corrugated Box Fabrication

The fabrication of corrugated boxes includes cutting, folding, and gluing operations. Data for the fabrication of corrugated boxes are based on confidential data provided by industry sources (Reference C-87). Cradle-to-gate data for the production of average postconsumer recycled content corrugated boxes are shown in Table C-18, and data for 80% postconsumer recycled content boxes are shown in Table C-19.

OCC Shredding

Shredding machinery is used to reduce corrugated material into dunnage. Local shredding operations reduce the need for transporting the shredded material. In this analysis, the energy requirements for OCC shredding are based on the equipment specifications and throughput available from leading equipment manufacturers. Cradle-to-gate data for the production of shredded corrugated loose fill are shown in Table C-20.

Paper Shredding

When paper is used as dunnage, it must be shredded. Industrial shredding equipment uses rotating blades to shred high volumes of paper. Actual energy used for shredding will vary with the type of shredding equipment used. Cradle-to-gate data for the production of shredded paper loose fill are shown in Table C-21. Cradle-to-gate data for the production of shredded paper padding for shipping bags are shown in Table C-22.

Table C-18

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF CORRUGATED BOXES WITH AVERAGE POSTCONSUMER RECYCLED CONTENT (38%)
(includes all steps from raw material extraction and postconsumer material collection through box production and shipment to order fulfillment center)

Raw Materials

Roundwood	4,119	lb
Wood residues	427	lb
Postconsumer corrugated	502	lb
Kraft clippings	51.2	lb
Salt mining	3.33	lb
Soda ash	3.31	lb
Sodium sulfate	17.2	lb
Limestone mining	17.5	lb
Sulfur production	1.08	lb
N2 fertilizer	0.55	lb
Phosphate fertilizer	0.21	lb
Potash fertilizer	0.26	lb
Corn growing	37.6	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			6.22
Total Resource			6.22
Process Energy			
Electricity	254	kwh	2,845
Natural gas	1,256	cu ft	1,457
LPG	0.012	gal	1.22
Coal	218	lb	2,508
Distillate oil	0.020	gal	3.19
Residual oil	0.41	gal	68.4
Gasoline	7.4E-04	gal	0.10
Diesel	0.89	gal	139
Wood	5,405	thou Btu	5,405
Total Process			12,427
Transportation Energy			
Combination truck	176	ton-miles	
Diesel	1.65	gal	258
Single unit truck	4.10	ton-miles	
Diesel	0.11	gal	17.0
Rail	70.8	ton-miles	
Diesel	0.17	gal	26.5
Barge	1.33	ton-miles	
Diesel	0.0027	gal	0.42
Residual oil	0.0011	gal	0.18
Ocean freighter	0.81	ton-miles	
Diesel	8.1E-05	gal	0.013
Residual	0.0015	gal	0.25
Pipeline-natural gas	0.042	ton-miles	
Natural gas	0.096	cu ft	0.11
Pipeline-petroleum products	0.055	ton-miles	
Electricity	0.0012	kwh	0.014
Total Transportation			303

Table C-18 (continued)

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF CORRUGATED BOXES WITH AVERAGE POSTCONSUMER RECYCLED CONTENT (38%)

Environmental Emissions*

Atmospheric Emissions		
Particulates	1.95	lb
Nitrogen Oxides	3.47	lb
Hydrocarbons	0.020	lb
Sulfur Oxides	5.89	lb
Carbon Monoxide	4.04	lb
Aldehydes	0.0060	lb
Other Organics	9.3E-06	lb
Odorous Sulfur	0.029	lb
Ammonia	0.045	lb
Lead	1.2E-09	lb
Mercury	5.0E-05	lb
Chlorine	4.7E-07	lb
Hydrogen Chloride	5.0E-08	lb
Carbon Dioxide (fossil)	4.06	lb
Carbon Dioxide (non-fossil)	0.0029	lb
Solid Wastes	69.5	lb
Waterborne Emissions		
Acid	0.014	lb
Metal Ion	7.8E-06	lb
Dissolved Solids	0.15	lb
SuspendedSolids	3.04	lb
BOD	2.45	lb
COD	9.19	lb
Phenol	8.6E-04	lb
Sulfides	0.072	lb
Oil	0.072	lb
Iron	0.072	lb
Cyanide	1.0E-07	lb
Chromium	1.4E-08	lb
Aluminum	0.090	lb
Nickel	1.5E-09	lb
Mercury	2.0E-09	lb
Lead	2.1E-09	lb
Phosphates	0.075	lb
Phosphorus	0.032	lb
Nitrogen	0.034	lb
Zinc	0.0010	lb
Ammonia	0.023	lb
Pesticides	8.7E-04	lb
Nitrates	0.0012	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-19

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF CORRUGATED BOXES WITH HIGH POSTCONSUMER RECYCLED CONTENT (80%)
(includes all steps from raw material extraction and postconsumer material collection through box production and shipment to order fulfillment center)

Raw Materials

Roundwood	1,610	lb
Wood residues	173	lb
Postconsumer corrugated	901	lb
Kraft clippings	18.2	lb
Salt mining	0.91	lb
Sodium sulfate	5.90	lb
Limestone mining	7.29	lb
Sulfur production	0.51	lb
N2 fertilizer	0.39	lb
Phosphate fertilizer	0.15	lb
Potash fertilizer	0.19	lb
Corn growing	26.7	lb

Energy Usage			**Total Energy Thousand Btu**
Energy of Material Resource			
Natural Gas			4.98
Total Resource			4.98
Process Energy			
Electricity	294	kwh	3,296
Natural gas	1,093	cu ft	1,268
LPG	0.024	gal	2.55
Coal	234	lb	2,691
Distillate oil	0.021	gal	3.21
Residual oil	0.32	gal	53.5
Gasoline	2.7E-04	gal	0.038
Diesel	0.53	gal	82.6
Wood	1,850	thou Btu	1,850
Total Process			9,247
Transportation Energy			
Combination truck	182	ton-miles	
Diesel	1.71	gal	267
Single unit truck	8.64	ton-miles	
Diesel	0.23	gal	35.8
Rail	3.38	ton-miles	
Diesel	0.0081	gal	1.27
Barge	0.11	ton-miles	
Diesel	2.3E-04	gal	0.036
Residual oil	9.1E-05	gal	0.015
Ocean freighter	0.46	ton-miles	
Diesel	4.6E-05	gal	0.0071
Residual	8.2E-04	gal	0.14
Pipeline-natural gas	0.027	ton-miles	
Natural gas	0.063	cu ft	0.073
Pipeline-petroleum products	0.031	ton-miles	
Electricity	6.8E-04	kwh	0.0076
Total Transportation			305

Table C-19

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF CORRUGATED BOXES WITH HIGH POSTCONSUMER RECYCLED CONTENT (80%)

Environmental Emissions*

Atmospheric Emissions		
Particulates	1.41	lb
Nitrogen Oxides	1.39	lb
Hydrocarbons	0.013	lb
Sulfur Oxides	2.36	lb
Carbon Monoxide	1.62	lb
Aldehydes	0.0024	lb
Odorous Sulfur	0.011	lb
Ammonia	0.018	lb
Lead	9.8E-10	lb
Mercury	2.0E-05	lb
Chlorine	1.3E-07	lb
Hydrogen Chloride	2.5E-08	lb
Carbon Dioxide (fossil)	1.63	lb
Carbon Dioxide (non-fossil)	0.0012	lb
Solid Wastes	52.2	lb
Waterborne Emissions		
Acid	0.0067	lb
Metal Ion	4.0E-06	lb
Dissolved Solids	0.26	lb
SuspendedSolids	3.11	lb
BOD	2.81	lb
COD	6.55	lb
Phenol	0.0019	lb
Sulfides	0.16	lb
Oil	0.16	lb
Iron	0.16	lb
Cyanide	8.0E-08	lb
Chromium	1.1E-08	lb
Aluminum	0.10	lb
Nickel	3.4E-10	lb
Mercury	4.8E-10	lb
Lead	6.8E-10	lb
Phosphates	0.076	lb
Phosphorus	0.013	lb
Nitrogen	0.027	lb
Zinc	0.0023	lb
Ammonia	0.013	lb
Pesticides	8.7E-04	lb
Nitrates	4.7E-04	lb

* Total process emissions. Fuel-related emissions (associated with the extraction, processing, delivery, and combustion of the process and transportation fuels shown in this table) are calculated by the model based on data shown in Appendix A tables and are not shown here.

Source: Franklin Associates.

Table C-20

**DATA FOR THE PRODUCTION OF 1,000 POUNDS OF
LOOSE FILL (100% SHREDDED POSTCONSUMER CORRUGATED)
(includes shredding of postconsumer material collected at order fulfillment center)**

			Total Energy Thousand Btu
Raw Materials			
OCC Collection	1,000	lb	
Energy Usage			
Process Energy			
Electricity	7.00	kwh	78.4
Total Process			78.4

Source: Franklin Associates.

Table C-21

**DATA FOR THE PRODUCTION OF 1,000 POUNDS OF
LOOSE FILL (100% SHREDDED POSTCONSUMER OFFICE PAPER)
(includes shredding of postconsumer material collected at order fulfillment center)**

			Total Energy Thousand Btu
Raw Materials			
Paper Collection	1,000	lb	
Energy Usage			
Process Energy			
Electricity	22.0	kwh	246
Total Process			246

Source: Franklin Associates.

Table C-22

DATA FOR THE PRODUCTION OF 1,000 POUNDS OF PADDING FOR SHIPPING BAGS (100% SHREDDED POSTCONSUMER NEWSPAPER)
(includes all steps from postconsumer material collection through shipment to bag manufacturer and shredding)

Raw Materials			
Paper Collection	1,000	lb	
Energy Usage			**Total Energy Thousand Btu**
Process Energy			
Electricity	23.0	kwh	257
Diesel	0.14	gal	21.9
Total Process			279
Transportation Energy			
Single unit truck	75.0	ton-miles	
Diesel	1.99	gal	310
Total Transportation			310

Source: Franklin Associates.

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APPENDIX D

TRANSPORTATION

OVERVIEW OF TRANSPORTATION SEGMENTS

A Life Cycle Inventory includes the resource and energy use, solid wastes, and emissions not only for all the processes in the life cycle of a product system from cradle-to-grave, but also for the transportation steps required to move materials between these processes. For this study, transportation steps are grouped into three basic segments: (1) transportation of raw materials and intermediate materials from point of extraction to the location where they are manufactured into packaging materials, (2) transportation of packaging materials from the manufacturer to the mail order distribution center (order fulfillment center), and (3) transportation of packaged goods from the order fulfillment center to the mail-order goods customer.

For the purposes of this study, it is assumed that the order fulfillment center (packaging user) is located in Oregon, and that the final customer (household) is located in the United States. To simplify the analysis, the study assumes a single order fulfillment center and a single "average" customer, intended to represent reasonable averages for the purpose of estimating transportation requirements and associated environmental burdens.

To arrive at reasonable locations for the order fulfillment center and customer, the study begins with the year 2000 population centers of the United States and the State of Oregon, as determined by the U.S. Department of Commerce, Census Bureau. The population center is determined as the place where an imaginary, flat, weightless and rigid map of the United States (or Oregon) would balance perfectly if all residents were of identical weight. The population center of the United States for the 2000 Census is three miles to the east of Edgar Springs, Missouri. The population center of the State of Oregon is located near Lyons, Oregon.

Both Edgar Springs (population 190) and Lyons (population 1,008) are located in areas that are rural in nature. This is not surprising, given that the majority of the land in the U.S. is rural. In contrast, the majority of the U.S. population lives in suburban or urban areas, and direct-to-customer order fulfillment centers may be more likely to be sited in more urbanized areas, closer to population centers and a larger number of road, rail, and air freight options. To make the shipping scenario more representative of assumed industry averages, the study assumes that the order fulfillment center is located not in Lyons but in Salem, OR. Salem (2000 population 136,924) is approximately 26 miles to the west of Lyons and is located on Interstate 5. It is also the capital city of Oregon.

The authors recognize that this configuration of locations is unique and not representative of all possible configurations. The results of this study can be adapted to represent different transportation scenarios.

SHIPPING MODES/DISTANCES FOR RAW MATERIALS TO PACKAGING MANUFACTURERS

It is not practical to attempt to trace back the entire specific supply chain for each packaging material for several reasons. First, as can be seen in the flow diagrams in Appendix C, the "process tree" from raw material extraction to packaging manufacture consists of multiple processes that would be extremely time-consuming to research for a specific chain of suppliers. Also, many of the inputs to processes preceding packaging manufacture are commodity materials that can be obtained from any number of suppliers at various locations.

The shipping modes and distances used to model the transportation of raw materials and intermediate materials through all transportation steps up to the packaging manufacturer are based on Franklin Associates' LCI database for US processes. The transportation distances reflect the average distance that the output of each process is transported to a subsequent user of the material. These transportation distances and modes have been determined in previous in-depth analyses of these processes, taking into account locations of manufacturing plants and subsequent users, and are believed to be sufficiently representative for use in this study. Where DEQ was able to provide specific information on transportation of inputs to packaging material production, these data were used in place of industry average data. Transportation data specific to this study are summarized in Table D-1.

SHIPMENT OF PACKAGING MATERIALS TO ORDER FULFILLMENT CENTER

This section describes the assumed transportation distances and modes for packaging materials shipped to the order fulfillment center. The study assumes that the order fulfillment center (packaging user) is located in Salem, Oregon.

Corrugated Box: Average Post-Consumer Content

Corrugated cartons are manufactured from roll stock of kraft linerboard and corrugated medium. Box plants in Oregon purchase most of their linerboard and corrugated medium from mills located in the states of Oregon and Washington, although purchases from mills in California, British Columbia, and Montana are not unheard of. According to the *2002 Lockwood-Post's Directory of the Pulp, Paper, and Allied Trades*, there are 8 mills manufacturing kraft linerboard (or linerboard) and 4 mills manufacturing corrugated medium in Oregon and Washington. The Lockwood-Post's Directory also lists 20 box plants in Oregon and Washington. Some of these box plants are vertically integrated with mills (such as Weyerhaeuser and Boise Cascade) while others are independent (such as Tharco). Sourcing of materials by box plants is very complex. Even the vertically integrated box plants may purchase linerboard and medium from mills owned by other companies, and mills may sell linerboard and medium to box plants owned by other companies. Box plants may use linerboard from one company and corrugated medium from another.

Table D-1

TRANSPORTATION MODES AND DISTANCES FOR PACKAGING MATERIALS
(all distances in miles)

	Diesel Tractor-Trailer Truck	Single-Unit Diesel Truck	Rail	Ocean Freighter
Corrugated Box (1)				
linerboard -avg box	82			
linerboard - 80% postconsumer recycled content box	145			
medium - avg box	115			
medium - 80% postconsumer recycled content box	156			
Inflated Polyethylene Air Packets				
LDPE resin (TN) to tube stock mfr (CA)	959		959	
LDPE tube stock to dist ctr	1180			
EPS Loose Fill				
EPS resin (virgin) to loose fill mfr	1211		1211	
EPS resin (postconsumer) to loose fill mfr	1208		1208	
EPS loose fill (virgin) to dist ctr	105			
EPS loose fill (recycled) to dist ctr	214			
Starch-based Loose Fill				
cornstarch (KS) to loose fill mfr (WA)	883.5		883.5	
cornstarch loose fill to dist ctr	231			
Molded Pulp Loose Fill				
postconsumer newspaper to molded pulp loose fill mfr		150		
molded pulp loose fill to dist ctr	752			
Kraft Paper (Crumpled) (2)				
unbleached kraft from mill to converter to dist ctr	122			
Newsprint (Crumpled) (3)				
newsprint from mill to converter to dist ctr	101			
On-Site PC Shredded Office Paper/Corrugated	0			

(1) Includes transportation from mill to box manufacturer to distribution center.
(2) Same transportation data used for virgin and recycled content material.
(3) Same transportation data used for both levels of recycled content material.

Table D-1 (cont.)

TRANSPORTATION MODES AND DISTANCES FOR PACKAGING MATERIALS
(all distances in miles)

	Diesel Tractor-Trailer Truck	Single-Unit Diesel Truck	Rail	Ocean Freighter
Unpadded Kraft Bag (2)				
bleached kraft to shipping bag mfr	200			
shipping bag to dist ctr	1180			
Kraft Bag with Paper Padding				
kraft paper to bag mfr (2)	200			
postconsumer newspaper to bag mfr		150		
bag to dist ctr	1180			
Kraft with Bubble Wrap (4)				
kraft paper to bag mfr	200			
LDPE resin to bag mfr	1000		1000	
LLDPE resin to bag mfr	1000		1000	
recycled LDPE resin to bag mfr	100			
recycled LLDPE resin to bag mfr	100			
bag mfr to dist ctr	1180			
Unlined LLDPE Film Bag (5)				
LLDPE resin to bag mfr	1000		1000	
recycled LLDPE resin to bag mfr	100			
LLDPE shipping bags to dist ctr	1274			4517.5
LLDPE Film Bag with Bubble Wrap (4)				
LLDPE resin to bag mfr	1000		1000	
LDPE resin to bag mfr	1000		1000	
recycled LLDPE resin to bag mfr	100			
recycled LDPE resin to bag mfr	100			
bag mfr to dist ctr	1180			

(1) Includes transportation from mill to box manufacturer to distribution center.
(2) Same transportation data used for virgin and recycled content material.
(3) Same transportation data used for both levels of recycled content material.
(4) Bubble wrap extruded from resin at bag mfr; resin 50% LDPE, 50% LLDPE.
(5) Assumes 50% bags manufactured in US, 50% overseas.
Transportation of resin to bag manufacturer assumed to be the same in U.S. or Asia.
Data for transportation of bag to dist ctr is weighted average for foreign and domestic bags.

The market share of each of these mills and box plants in the corrugated box market in Salem is not known, would be difficult to research, and is also subject to change as market prices, long-term contracts, and mill conditions (fiber supply, energy prices, maintenance shutdowns, etc.) fluctuate. Instead, this study makes the simplifying assumption that market share in Salem is equally determined by two variables: mill capacity, and distance from Salem.

Mill capacity is known from the Lockwood-Post's Directory. All other things being equal, mills manufacturing more linerboard (or medium) are expected to have greater market share. Similarly, all other things being equal, mills that are closer to Salem are expected to have greater market share there.

If there are N mills (numbered 1, 2, . . . , N) , each with daily capacity of C_n and a distance from Salem of D_n (where n ranges from 1 to N), then assumed market share (MS) in Salem of mill n is estimated as follows:

$MS_n = (C_n \times (R - D_n))/\Sigma(C \times (R - D))$ [summed from 1 to N]

where $R = 0.5 \times (370 \text{ miles} + D_{max})$

D_{max} is the distance from Salem that the farthest mill that manufactures linerboard or corrugated medium is located while still being in Oregon or Washington. D_{max} for linerboard is 256 miles (the Port Townsend Paper mill in Port Townsend, WA) and D_{max} for medium is 263 miles (the Boise Cascade mill in Wallula, WA). According to the Lockwood-Post Directory, the closest mill manufacturing linerboard and corrugating medium outside of Oregon and Washington is the Norampac mill in Burnaby, British Columbia, approximately 370 miles from Salem. Thus, R equals the mid-point between D_{max} (the farthest mill still in Washington or Oregon) and Burnaby. The value of R can be thought of as the radius of a circle, centered on Salem, for which box plants will draw within when purchasing material for fabricating boxes to be sold in Salem. This simple estimation technique assumes that boxes used in Salem will be constructed from linerboard and medium manufactured at mills located within this circle.

Under this approach, the estimated market shares of major linerboard and corrugated mills are as follows:

Major Linerboard Mills

Company	Location	Miles from Salem	Capacity (TPD)	Market Share (Estimated)
Weyerhaeuser	Springfield OR	64	2,000	27%
Longview Fiber	Longview WA	95	2,200	26%
Weyerhaeuser	Albany OR	24	1,550	24%
Georgia Pacific	Toledo OR	83	1,175	15%
Simpson	Tacoma WA	190	870	6%

(Pt. Townsend Paper, Sonoco (Sumner, WA) and Smurfit-Stone (Tacoma, WA) each have an estimated market share of <2%.)

Corrugated Medium Mills

Company	Location	Miles from Salem	Capacity (TPD)	Market Share (Estimated)
Georgia Pacific	Toledo OR	83	1,100	57%
Weyerhaeuser	North Bend OR	174	620	20%
Longview Fiber	Longview WA	95	400	20%
Boise Cascade	Wallula WA	263	325	4%

After each mill's market share is estimated, it is expressed as a decimal and multiplied by its mileage to Salem. These mileages are then summed, in order to estimate market-share weighted distances from the mills to the order fulfillment center.

Five miles are added to each sum to account for travel to a box plant that might not be located on-route from the mill directly to the end user. With six box plants in the Portland area and two in the Salem area, it is assumed that linerboard and medium will not be sent from a mill through Salem to a box plant beyond Salem. Put differently, this assumption means that linerboard from mills in Albany, Springfield and Toledo, and corrugated medium from Toledo and North Bend (all of which are south of Salem) that is used in boxes in Salem will be converted at a box plant in Salem, rather than being shipped through Salem to Portland (or beyond) and then back south to Salem.

This results in an estimated travel distance for 82 miles for linerboard and 115 miles for corrugated medium. This study assumes that these materials are exclusively transported by truck, per a conversation with a representative of Weyerhaeuser's Springfield mill.

Corrugated Box: 80% Post-Consumer Content

The post-consumer content of products manufactured in different mills is not known to the authors. The requirement of 80% post-consumer content may cause the box plant(s) to cast farther afield for linerboard. For example, Tharco (a major box converter in the Pacific Northwest), told Pack Edge Development that when making their "high-recycled content" box (80% post-consumer content), they source material from the I-5 Corridor, as far away as the San Francisco Bay area.

According to the Lockwood-Post's Directory, there is one linerboard and two corrugating medium mills in the San Francisco Bay area. Thus, using the weighting formula described for "average" post-consumer corrugated boxes (above), D_{max} for linerboard is 600 miles (the Gaylord linerboard mill in Antioch, CA) and D_{max} for medium is 655 miles (the Inland Paper mill in Newark, CA). These higher values of D_{max} also bring several additional mills (in Montana and British Columbia) into the weighting formula. The next closest mills to Antioch and Newark are located in Southern California (the Smurfit-Stone linerboard mill in Vernon and Weyerhaeuser medium mill in Oxnard) and R is defined as the midpoint between D_{max} and these more-distant mills.

Using the same estimation methodology and assumptions as was done for the "average" corrugated box (above) results in an estimated transportation distance of 145 miles for high-recycled-content linerboard and 156 miles for high-recycled-content medium. Again, this study assumes that these materials are exclusively transported by truck.

Inflated Polyethylene Air Packets

The authors are aware of three major manufacturers of LDPE (or LDPE/LLDPE) inflatable polyethylene air packets in the U.S.: Storopack, Pactiv, and Sealed Air Corporation.

According to conversations between Pack Edge Development and representatives of Storopack, Storopack's "tube stock" for pillow packs is made in Los Angeles using resin shipped from Tennessee. From Los Angeles, tube stock is trucked to a warehouse in Kent, WA for sale to customers throughout the Pacific Northwest, including Oregon. Transportation modes from Tennessee to Los Angeles are not known, however, Pack Edge Development was told that polystyrene beads used at Storopack's Kent, WA facility are shipped there from Memphis using a combination of rail and truck. Having no further information, the study assumes that polyethylene resin shipped from Tennessee to Los Angeles is shipped 50% by rail, and 50% by truck.

Neither Sealed Air Corporation nor Pactiv informed the authors where their tube stock is fabricated, although when asked, one representative of Pactiv was willing to state that all of their packaging material is made in the United States, and that the largest Pactiv facility serving the Western U.S. is in Visalia, CA. This study assumes that Pactiv manufactures pillow pack tube stock at this facility, although this is not known as a fact. The source of the resin is also not known, so for the sake of consistency, it is assumed to be shipped from Memphis, consistent with Storopack (above). Pack Edge staff's experience purchasing items from Pactiv (in Oregon) is that materials are typically shipped to Oregon from a stocking warehouse in Kent, WA, so this study assumes that tube stock is trucked from Visalia, CA to Kent, and then from Kent to Salem for use.

The authors have no information from Sealed Air Corporation except that they have a facility in Hayward, CA. As with Pactiv, it is assumed that tube stock is manufactured at this facility, using resin shipped from Tennessee. Consistent with Storopack and Pactiv, the study assumes that this tube stock is shipped to a stocking warehouse in Kent, WA for sale to customers in Oregon.

Finally, it is assumed that each of the three companies have equal market shares in Salem (33.3%).

Distances are as follows (per MapQuest):

- Memphis, TN to Los Angeles (Storopack resin): 1,798 miles (50% rail/50% truck). Los Angeles to Kent, WA: 1,130 miles (100% truck).
- Memphis, TN to Visalia, CA (Pactiv resin, assumed): 1,884 miles (50% rail/50% truck). Visalia, CA to Kent, WA: 966 miles (100% truck).
- Memphis, TN to Hayward, CA (Sealed Air resin, assumed): 2,073 miles (50% rail/50% truck). Hayward, CA to Kent, WA: 802 miles (100% truck).
- Kent, WA to Salem, OR: 214 miles (100% truck).

- Average distance: resin to fabricator: 1,918 miles.
- Average distance: fabricator to stocking warehouse: 966 miles.
- Average distance: stocking warehouse to user (Salem): 214 miles.

Therefore, the study assumes that 50% of the resin travels an average of 1,918 miles by rail, and that 50% of the resin travels an average of 1,918 miles by truck. The finished product is assumed to be transported an average of 966 miles from California to Washington via truck, and then another 214 miles from Washington to Salem via truck for a total of 1,180 miles. These assumed distances apply to both the 0% recycled content and the 30% recycled content options.

Expanded Polystyrene (EPS) Loose Fill

Pack Edge Development identified the following fabricators as being closest to Salem: Space-Pak in Clackamas, OR (non-recycled only); Storopack in Kent, WA and Salt Lake City, UT; and FP International (Redwood City, CA). Given the very low density of these materials, this study assumes that the user in Salem will be purchasing from fabricators in the Pacific Northwest, and that fabricators outside of the Pacific Northwest will not be selling significant quantities of this product in Salem due to higher transportation distances and costs.

Not knowing the absolute or relative production quantities of Space-Pak (Clackamas) and Storopack (Kent), it is assumed that their relative market share in Salem is solely a function of transportation distance. While Space-Pak is 46 miles from Salem, Storopack is 214 miles. How will this effect Space-Pak’s market share in Salem relative to Storopack's? All other things being equal, it seems reasonable that Space-Pak will have greater market share in Salem than Storopack.

Consistent with the methodology used to estimate market share for corrugated boxes (described above), the midpoint between the greater of the two distances (Storopack; 214 miles) and the next closest fabricator (FP International, Redwood City, CA; 615 miles) is used to define a circle, centered on Salem, with radius of 414 miles. It is assumed that fabricators located inside this circle will be selling products in Salem, and that their market share is proportional to 414 miles less their distance from Salem. This results in the assumption that Space-Pak supplies 65% of the Salem market, and Storopack supplies 35%.

Space-Pak only sells expanded polystyrene loose fill made from 100% virgin resin. The study assumes that all of the polystyrene loose fill containing recycled content used in Salem is fabricated at Storopack's facility in Kent, WA, for a transportation distance of 214 miles.

What about the primary feedstock, polystyrene beads? Pack Edge learned in interviewing Space-Pak (see Appendix B) that Space-Pak buys their resin from Inter-Pac in Tupelo, MS (distance from Clackamas: 2,426 miles). Inter-Pac's web site makes no reference to facilities other than their headquarters in Tupelo and a recycling plant in Georgia. In contrast, Storopack's web site cites 22 locations in North America, including Kent, WA and San Jose, Downey, and Anaheim, CA. But according to a sales representative for Storopack, polystyrene beads used in the fabrication of EPS loose-fill in Kent are shipped to Kent from Memphis, TN "via truck or container shipped via rail".

Lacking information on Inter-Pac's shipment method, as well as what percentage of Storopack resin shipments to Kent are rail vs. truck, the study assumes that 50% of shipments from Memphis to Kent (Storopack) and from Tupelo to Clackamas (Inter-Pac/Space-Pak) are via rail, and the other 50% of shipments are done via truck. Lacking information on rail lines, the study makes the simplifying assumption that the mileage by rail between two points is the same as the mileage on highways.

Therefore, for the post-consumer EPS loose fill (Storopack only), it is assumed that both types of beads (virgin and post-consumer) are shipped from Memphis, TN to Kent, WA (2,416 miles; 50% rail, 50% truck) and then the fabricated product travels from Kent, WA to Salem, OR (214 miles, 100% truck).

For the virgin EPS loose fill, it is assumed that the market share is 65% Space-Pak (Clackamas, OR) and 35% is Storopack. Storopack's beads and products are shipped as described in the previous paragraph. Space-Pak's beads are shipped from Tupelo, MS to Clackamas, OR (2,426 miles; 50% rail, 50% truck) and then the fabricated product travels from Clackamas, OR to Salem (46 miles, 100% truck). Thus, the weighted average for beads are: 1,211 miles by rail and 1,211 miles by truck. The weighted average for finished product is 105 miles by truck.

Bio-Based (Starch) Loose Fill

The closest fabricator to Salem of vegetable starch peanuts identified by Pack Edge Development is American Excelsior, in Yakima, Washington. No other fabricators were identified in the Pacific Northwest. Due to the low density of this material, and lack of other nearby fabricators, it is assumed that starch loose fill used in Salem, OR will be fabricated at this facility in Yakima.

According to a representative of American Excelsior's Yakima facility, their starch comes from "somewhere in the Midwest" and is transported to Yakima via truck. National Starch, who licenses the technology, manufactures corn starch in North Kansas City, MO and Indianapolis, IN. However, licensees (such as American Excelsior) are not required to buy starch from National Starch. In fact, American Excelsior's Yakima plant is currently using wheat starch, not corn starch. Not knowing exactly where American Excelsior is purchasing their wheat starch from, the study assumes North Kansas City, which is the same as the closer of National Starch's two locations.

Therefore, it is assumed that the raw starch is shipped 1,767 miles (North Kansas City to Yakima, per MapQuest) and the finished product (expanded starch peanuts) is shipped 231 miles (Yakima to Salem, per MapQuest) via truck. For consistency and ease of comparison of burdens with expanded polystyrene loose fill, it is assumed that the transportation of starch from North Kansas City to Yakima is 50% truck and 50% rail.

Molded Pulp Loose Fill

The only manufacturer of this material known to DEQ in the Western U.S. is UFP Technologies in Visalia, CA. Per MapQuest, the driving distance from Visalia CA to Salem OR is 752 miles. A representative of UFP in Visalia informed DEQ that "Cushion Cubes can only be shipped economically in truckload quantities using a 53' dry van. A high cube van will transport 390 - 10 cu ft bags - 5850 pounds of product. Materials are stored and shipped in 10 cu ft plastic bags." The average transportation distance and mode for collection of postconsumer newspaper is assumed to be 150 miles by single-unit diesel truck.

Unbleached Kraft Paper

As was done with linerboard (see section on corrugated boxes, above), the study assumes that market share of unbleached kraft paper used in Salem is an equal function of two variables: mill capacity and distance from Salem. All assumptions and methodologies to estimate market share are the same as described above for linerboard, except for the following changes:

- Oregon and Washington mills identified by the Lockwood-Post's Directory as making kraft papers other than linerboard were added to the list.

- Oregon and Washington mills identified by the Lockwood-Post's Directory as making kraft linerboard only were removed from this list. (Mills that were identified as producing "linerboard and other kraft paper" were retained in the list.)
- It is likely that rolls of kraft paper will not be shipped directly from the mills to an end user but rather would first go to a converter that will cut rolls into smaller rolls usable by a retail warehouse. The Lockwood-Post's Directory clearly identified only one site in the Pacific Northwest that might fit this category (Pac-Paper, Inc. in Vancouver, WA), although other companies may but are not clearly identified as such. As Vancouver is on the route between all but one of the kraft mills in this category and Salem, 5 miles was added to their distance from Salem to allow for a side trip to the converter. The one Oregon mill that might be manufacturing this type of paper, per the Lockwood-Post's Directory, is the Weyerhaeuser kraft mill in Albany, OR; the distance that its kraft paper travels to Salem is calculated as a trip from Albany to Vancouver (through Salem) and then back to Salem.

The resulting transportation distance using estimated market share is 122 miles. Because of the relatively small distances involved, it is assumed that all shipping is done by truck.

Because the study models 0% and 50% post-consumer content options, and 50% is attainable by several regional mills, the study assumes equal transportation distances for both options.

Newsprint (Unprinted)

The study uses the same method as described for kraft paper (above), with data from the Lockwood-Post Directory for the following 5 mills: Georgia-Pacific (Clatskanie, OR), SP Newsprint (Newberg, OR), Blue Heron Paper (Oregon City, OR), North Pacific Paper Corp. (Longview, WA), and Abitibi-Consolidated (Steilacoom, WA). R is the mid-point between the farthest of these five mills (Abitibi-Consolidated) and the closest newsprint mill outside of the Interstate-5 corridor of Oregon and Washington (Inland Empire Paper in Spokane).

All mileages are for two stages: first from the mill to Vancouver (Pac-Paper, Inc., the assumed location of the roll/sheet converter) and then from Vancouver to Salem, with an additional five miles added for travel within Vancouver to the converter. The resulting market-share-weighted transportation distance (estimated) is 101 miles. This distance is applied to both the 10% and the 50% post-consumer content options. As with other regionally-produced paper products, it is assumed that all shipping of this product is done via truck.

Shredded Corrugated

For the purposes of this study, it is assumed that the order fulfillment center can fully meet its void fill needs by shredding “waste” corrugated boxes that are available on-site. The burdens associated with shipping this corrugated, and recycling or disposing of it (rather than shredding it for reuse), are allocated to the inbound products that are shipped in the corrugated, not to outbound packaging options, and so are excluded from this study for all packaging options.

Shredded Office Paper

For the purposes of this study, it is assumed that the order fulfillment center can fully meet its void fill needs by shredding “waste” office paper that is available on-site. The burdens associated with shipping this office paper, and recycling or disposing of it (rather than shredding it for reuse), are allocated to non-related processes, such as office operations, and so are excluded from this study for all packaging options.

Non-Padded Kraft Paper Shipping Bag

Pack Edge Development and DEQ attempted to obtain information about the fabrication of these types of bags from two major suppliers: Pactiv and Sealed Air Corporation. Limited information was gathered from Pactiv only; no information was obtained from Sealed Air Corporation.

According to a Pactiv representative, all Pactiv products are manufactured in the United States. Pactiv has several manufacturing facilities; the largest facility serving the Western U.S. is located in Visalia, California. It is assumed that non-padded kraft paper shipping bags are fabricated here, although this is not known for a fact.

The Visalia plant is not a paper mill, so the rolls of kraft are manufactured off-site. There are several kraft mills in both the San Francisco area as well as Southern California. Visalia is roughly equidistant from these two metropolitan areas. It is assumed that the kraft paper is manufactured in one of these areas and shipped in rolls approximately 200 miles to Visalia.

Pack Edge Development’s experience is that stock shipping bags sold in Oregon are typically first warehoused in the Seattle area (around Kent, WA), then transported to Portland (or Salem) by truck.

Per MapQuest, the distance from Visalia, CA to Kent, WA is 966 miles, and the distance from Kent, WA to Salem OR is 214 miles. Total kraft shipping distance is estimated at 1,380 miles (first 200 miles in rolls, then 966 + 214 miles as mailers). It is assumed that all materials (rolls of kraft and fabricated product) are transported via diesel tractor trailer.

Non-Padded Polyethylene Shipping Bag

Major vendors of poly bags known to Pack Edge Development are Elkay Plastics, Pactiv, and Sealed Air Corporation. Limited information was obtained from Elkay Plastics and Pactiv; no information was obtained from Sealed Air Corporation. For the purpose of estimating transportation distances, it is assumed that 50% of these types of shipping bags used in Salem are supplied by Elkay, and the other 50% are supplied by Pactiv.

According to a representative of Elkay Plastics, almost all of their polyethylene stock bags are made overseas and enter the U.S. primarily in Los Angeles and Chicago. This study assumes that the Elkay stock bags used in the Pacific Northwest are manufactured in Asia and enter the U.S. through Los Angeles.

The location of Elkay's suppliers in Asia is not known. This study assumes a simple average of three possible locations: Kaoshiung, Taiwan; Guangzhou, China; and Singapore. Nautical miles from these three locations to Los Angeles measure:

- Kaoshiung, Taiwan: 7318;
- Guangzhou, China: 7737; and
- Singapore: 8500;

for a simple average of 7,852 nautical miles (9,035 miles).

According to a Pactiv representative, all Pactiv products are manufactured in the United States. Pactiv has several manufacturing facilities; the largest facility serving the Western U.S. is located in Visalia, California. It is assumed that non-padded polyethylene shipping bags are fabricated here, although this is not known for a fact.

Pack Edge Development's experience is that stock shipping bags sold in Oregon are typically first warehoused in the Seattle area (around Kent, WA), then transported to Portland (or Salem) by truck.

According to MapQuest, other relevant distances are:

- Long Beach (Port of Los Angeles) to Kent, WA: 1154 miles.
- Visalia, CA to Kent, WA: 966 miles.
- Kent, WA to Salem OR: 214 miles.

Consistent with previously described materials, the study assumes that all West Coast shipments of materials are conducted using diesel tractor trailers.

Therefore, the study assumes that 50% of the bags are transported 9,035 miles by ocean freighter from Asia to Long Beach/Los Angeles; 1,154 miles by diesel tractor trailer to Kent, WA; and a final 214 miles by diesel tractor trailer to Salem. The other 50% are assumed to be transported 966 miles by diesel tractor trailer from Visalia, CA to Kent, WA; and then 214 miles by diesel tractor trailer to Salem.

Kraft Paper Shipping Bag with Newsprint Padding

Pack Edge Development and DEQ attempted to obtain information about the fabrication of these types of bags from two major suppliers: Pactiv and Sealed Air Corporation. Limited information was gathered from Pactiv only; no information was obtained from Sealed Air Corporation.

According to a Pactiv representative, all Pactiv products are manufactured in the United States. Pactiv has several manufacturing facilities; the largest facility serving the Western U.S. is located in Visalia, California. It is assumed that this product is fabricated here, although this is not known for a fact.

The Visalia plant is not a paper mill, so the kraft paper is manufactured off-site. There are several kraft mills in both the San Francisco area as well as Southern California. Visalia is roughly equidistant from these two metropolitan areas. The study assumes that the kraft paper is manufactured in one of these areas and shipped in rolls approximately 200 miles to Visalia. The study also assumes an average distance of 150 miles for collection and delivery of post-consumer newspaper used in the envelope padding.

Pack Edge Development's experience is that stock shipping bags sold in Oregon are typically warehoused in the Seattle area (around Kent, WA), then transported to Portland (or Salem) by truck.

Per MapQuest, the distance from Visalia, CA to Kent, WA is 966 miles, and the distance from Kent, WA to Salem OR is 214 miles.

Therefore, assumed transport distances for primary components of these mailers are 200 miles by diesel tractor trailer truck for kraft paper and 150 miles by single-unit diesel truck for the postconsumer newspaper used for the macerated padding. The mailers themselves are then shipped an assumed distance of 1,180 miles by tractor trailer from Visalia, CA to Salem, OR via Kent, WA.

Kraft Paper Shipping Bag with Polyethylene Bubble Padding

Pack Edge Development and DEQ attempted to obtain information about the fabrication of these types of bags from two major suppliers: Pactiv and Sealed Air Corporation. Limited information was gathered from Pactiv only; no information was obtained from Sealed Air Corporation.

According to a representative of Pactiv, all Pactiv bubble mailers sold in Oregon are manufactured in Visalia, California. Pactiv buys resin and extrudes plastic (both bubble and non-bubble film) themselves. The study assumes that the Visalia facility extrudes bubble on site, and then converts sheets of bubble and kraft into shipping bags. Franklin Associates estimated resin transportation distances based on the assumption that the virgin resin suppliers used by the packaging producers are located in the same general area and use the same transportation modes as suppliers providing EPS resin to packaging manufacturers on the west coast.

For postconsumer resin, a database of recycled plastics products and markets published on the website PlasticsResource.com for the American Plastics Council shows at least 30 sellers of recycled polyethylene in California. Assuming that most of recycled polyethylene is from within California, transportation of postconsumer resin is estimated to be 100 miles by tractor-trailer truck.

The Visalia plant is not a paper mill, so the kraft paper is manufactured off-site. There are several kraft mills in both the San Francisco area as well as Southern California. Visalia is roughly equidistant from these two metropolitan areas. The study assumes that the kraft paper is manufactured in one of these areas and shipped in rolls approximately 200 miles.

Pack Edge Development's experience is that stock shipping bags sold in Oregon are typically first warehoused in the Seattle area (around Kent, WA), then transported to Portland (or Salem) by truck.

Per MapQuest, the distance from Visalia, CA to Kent, WA is 966 miles, and the distance from Kent, WA to Salem OR is 214 miles.

Therefore, assumed transport distances for primary components of these mailers are 200 miles (kraft), 1,000 miles each by tractor trailer and by rail for virgin resins, and 100 miles by tractor trailer for recycled resins. The mailers themselves are then shipped an assumed distance of 1,180 miles by tractor trailer from Visalia, CA to Kent, WA and on to Salem, OR.

Polyethylene Shipping Bag with Polyethylene Bubble Padding

Pack Edge Development and DEQ attempted to obtain information about the fabrication of these types of bags from two major suppliers: Pactiv and Sealed Air Corporation. Limited information was gathered from Pactiv only; no information was obtained from Sealed Air Corporation.

According to a representative of Pactiv, all Pactiv bubble mailers sold in Oregon are manufactured in Visalia, California. Pactiv buys resin and extrudes plastic (both bubble and non-bubble film) themselves. The study assumes that the Visalia facility extrudes both the external barrier material and the internal bubble on site, and then converts rolls of both materials into shipping bags. Assumptions regarding the source of virgin and recycled resins and transportation modes are the same as for resins used in the bubble-padded kraft mailers.

Pack Edge Development's experience is that stock shipping bags used in Oregon are typically first warehoused in the Seattle area (around Kent, WA), then transported to Portland (or Salem) by truck.

Per MapQuest, the distance from Visalia, CA to Kent, WA is 966 miles, and the distance from Kent, WA to Salem OR: 214 miles.

Therefore, assumed transport distances for primary components of these mailers are 1,000 miles each by tractor trailer and by rail for virgin resins, and 100 miles by tractor trailer for recycled resins. The mailers themselves are then shipped an assumed distance of 1,180 miles by tractor trailer from Visalia, CA to Kent, WA and then to Salem, OR.

SHIPMENT OF PACKAGED PRODUCT TO CUSTOMER

There are a number of different methods that the distribution center (order fulfillment center) could use to ship the packaged parcel to the residential customer. The U.S. Postal Service, Federal Express (FedEx) and United Parcel Service (UPS) are three of many organizations that provide this type of door-to-door delivery service. These and other shipping companies offer a variety of shipping options, including overnight delivery (typically air) as well as options that are slower (typically ground or ground/air combinations). Depending on the speed with which the parcel needs to be delivered, the locations of the sender and customer, and the hubs through which the parcel might travel, the parcel could be transported by airplane (cargo jet and/or smaller plane), rail car, a variety of different tractor trailer combinations, and/or delivery truck/van. In fact, there are a very large number of different routes and combinations of modes that the parcel might travel en route from the assumed start point (Salem, OR) to the assumed end point (Edgar Springs, MO). Representatives of both FedEx and UPS were unable to provide information on the more common routes that this parcel might travel.

Because of budget limitations, and also to simplify the analysis, the study assumes that the parcel will be shipped ground delivery, thus avoiding the need to model and estimate the impacts of air freight. Readers can adapt the results of this study to evaluate different ground shipping scenarios.

At the suggestion of UPS, Pack Edge Development shipped a box (empty) from Oregon to Rolla, MO. Rolla is approximately 20 miles from Edgar Springs and according to FedEx is the location of the local FedEx station that serves Edgar Springs. Pack Edge Development shipped a similar parcel using FedEx. Both items were shipped from Wilsonville, OR. (Items shipped from Salem via both UPS ground and FedEx ground would pass through Wilsonville on their way to Portland.) Pack Edge Development obtained tracking histories for these parcels, and then representatives from UPS and FedEx provided information on the types of delivery vehicles used to transport the parcels for each segment of their travel. Package starting segments (Salem to Portland) and ending segments (Rolla to Edgar Springs) are assumed.

Estimated UPS mileages are as follows, per MapQuest (unless noted otherwise):

- Point of collection to Salem, OR UPS station: 5 miles (assumed) in a P70 (delivery truck).
- Salem, OR to Portland, OR: 48 miles in a T28 (28’ trailer).
- Portland, OR to Commerce City, CO: 1,256 miles in a T28.
- Commerce City, CO to Salina, KS: 428 miles in a T28.
- Salina, KS to Lenexa, KS: 176 miles in a T28.
- Lenexa, KS to Rolla, MO: 235 miles in a T28.
- Rolla, MO to Edgar Springs, MO: 20 miles in a P70 (assumed).

- P70 total: 25 miles.
- T28 total: 2,143 miles (98.8% of total mileage).
- Grand total: 2,168 miles.

Estimated FedEx mileages are as follows, per MapQuest (unless noted otherwise):

- Point of collection to Salem, OR FedEx station: 5 miles (assumed) in a delivery truck.
- Salem, OR to Portland, OR: 48 miles in a 28’ pup trailer.
- Portland, OR to Kansas City, KS: 1,836 miles in a 28’ pup trailer.
- Kansas City, KS to Rolla, MO: 223 miles in a 28’ pup trailer.
- Rolla, MO to Edgar Springs, MO: 20 miles in a delivery truck (assumed).

- Delivery truck total: 25 miles.
- 28’ pup trailer total: 2,107 miles (98.8% of total).
- Grand total: 2,133 miles.

For modeling purposes, this report takes a simple average of these two deliveries as a reasonable estimate of how the average parcel shipped via ground freight might travel from Salem, OR to Edgar Springs, MO. The simple averages are:

- Delivery truck total: 25 miles.
- Trailer total: 2,125 miles (98.8% of total).
- Grand total: 2,150 miles.

SHIPMENT OF RETURNED PRODUCT AND PACKAGING MATERIALS TO ORDER FULFILLMENT CENTER

It is assumed that when customers return product to the order fulfillment center, the returned packages will also be shipped ground freight and the average mileage in delivery truck and diesel tractor trailer will be the same as for delivery of the product from the order fulfillment center to the customer.

ENVIRONMENTAL BURDENS FOR TRANSPORTATION

The transportation data shown in Table D-1 (and in the Appendix C tables) are used in conjunction with the data in Appendix A for the relevant transportation mode(s) to determine the fuel consumption and environmental burdens for each transportation step.

Weight and Volume-Limited Shipments

Franklin Associates' LCI model calculates fuel use based on a fully weight loaded vehicle. For some low-density materials, however, a shipped load fills by volume before it reaches its weight limit. In this study, transportation of all types of loose fill (EPS, starch-based, and molded pulp) is calculated based on a volume-limited load.

In addition, DEQ performed calculations using the weight and volume of soft mail-order goods packaged in various box/dunnage combinations and shipping bag configurations, and the maximum weight and volume loads of the delivery vans and trailers most commonly used to deliver packaged mail-order goods to customers, to evaluate whether shipments of packaged goods would be weight-limited or volume-limited. As shown in Table D-2, the results indicate that delivery trucks and trailers fill by volume instead of weight. Thus, fuel use and emissions for transportation of packaged product are modeled based on the fuel economy for a volume-loaded vehicle rather than a fully weight-loaded vehicle.

Allocation of Transportation Burdens

Although delivery trucks and trailers fill by volume rather than weight, the fuel consumption of the vehicle is tied to the vehicle weight. Thus, the environmental burdens for transportation of packaged goods are allocated to the packaging based on its contribution to the vehicle load weight. Because the purpose of the vehicle trip is to deliver packaged product, all transportation burdens are allocated between the product and packaging (none are allocated to the weight of the vehicle itself). The fuel economy of the vehicle is calculated based on the weight of a full volume load of packaged product. Table D-3 shows the percentage of the package delivery fuel use and emissions allocated to the packaging for each packaging configuration in this study, based on the packaging's weight percentage of the packaged product.

Table D-2

WEIGHT AND VOLUME LOADING OF DELIVERY VEHICLES

		Lightest Bag (1)	Heaviest Bag (2)	Lightest Box (3)	Heaviest Box (4)
Weight of Packaging (lbs)		0.067	0.38	1.44	1.77
Product Weight (lbs)		1.28	1.28	1.28	1.28
Total Weight per Pkg (lbs)		1.35	1.66	2.72	3.05
Length (in)		20	20	21.5	21.5
Width (in)		14.25	14.25	17.5	17.5
Height (in)		2.5	2.75	3.5	3.5
Volume per Pkg (cu in)		713	784	1317	1317
	Maximum Vehicle Load	**Maximum Number of Packages**			
T28 trailer (5)					
By Weight (lb)	30,440	22,598	18,371	11,199	9,984
By Volume (cu in)	3,478,464	4,882	4,438	2,641	2,641
P70 delivery van (6)					
By Weight (lb)	5,600	4,157	3,380	2,060	1,837
By Volume (cu in)	1,209,600	1,698	1,543	919	919

(1) unpadded polyethylene
(2) kraft bag w/macerated newsprint padding
(3) corrugated box + EPS loose fill
(4) corrugated box + molded pulp loose fill
(5) T28 trailer: gross vehicle weight 40,000 lb, unladen wt 9,560 lb, 2013 cu ft.
(6) P70 delivery van: gross vehicle weight 15,000 lb, unladen wt 9,400 lb, 700 cu ft.

Table D-3

ALLOCATION OF PACKAGED GOODS TRANSPORTATION BURDENS TO PACKAGING
(all weight in pounds)

Packaging Configuration	Component Wt/Pkg	Total Wt of Packaging	Wt of Packaged Product (1)	Wt % Packaging
Corrugated Box with	1.39			
Sealed Air Packets	0.084	1.47	2.75	54%
EPS Loose Fill	0.048	1.44	2.72	53%
Starch-Based Loose Fill	0.086	1.48	2.76	54%
Molded Pulp Loose Fill	0.379	1.77	3.05	58%
Crumpled Kraft Paper	0.184	1.57	2.85	55%
Crumpled Newsprint	0.168	1.56	2.84	55%
Shredded Corrugated	0.318	1.71	2.99	57%
Shredded Office Paper	0.148	1.54	2.82	55%
Shipping Bag				
Unlined Bleached Kraft		0.14	1.42	10%
Kraft with Paper Padding		0.38	1.66	23%
Kraft with Bubble Wrap		0.13	1.41	9%
Unlined LLDPE Film Bag		0.07	1.35	5%
LLDPE Film Bag with Bubble Wrap		0.13	1.41	9%

(1) Product weight = 1.28 lb

REFERENCES

D-1 Research conducted for Oregon Department of Environmental Quality by David Allaway, DEQ.

D-2 Franklin Associates estimates.

D-3 PlasticsResource.com website.

APPENDIX E

WASTE MANAGEMENT

OVERVIEW

This appendix discusses the fate of packaging materials that have served their intended purpose of delivering packaged soft goods to a consumer. Options include the following:

- Reuse by the customer for returns of unwanted mail-order goods
- Reuse by the customer for shipping other outgoing goods
- Recycling by the customer
- Disposal by the customer
  - On-site burning (small percentage)
  - Littering (small percentage)
  - Managed municipal solid waste stream
    - Landfill
    - Combustion with energy recovery

Packaging used for returning unwanted goods may be reused, recycled, or disposed when received at the order fulfillment center.

Currently, it is estimated that about 80 percent of discarded municipal solid waste (MSW) in the U.S. that is not diverted for reuse, recycling, or composting is landfilled, and the remaining 20 percent is burned in waste-to-energy facilities (Reference E-1). Therefore, combustion of 20 percent of the postconsumer materials that are discarded and not reused, recycled, or composted is included in this study. In the LCI energy results, an energy credit for waste-to-energy combustion of 20 percent of disposed packaging components is assigned to each system.

Customer Management of Packaging Materials

The study assumes that 10% of the packaging materials sent to customers will be reused to return the packaged products to the distribution center/order fulfillment center. Customers may choose to return products because they are not wanted (gifts) or due to size, color, defects, or other reasons. Ten percent is an assumption based on very limited data from Norm Thompson Outfitters and the anecdotal experience of study contributors (Reference E-2). According to Norm Thompson, returns are typically shipped to its order fulfillment center in their original packaging materials.

Thus, decisions regarding ultimate end-of-life management of the packaging materials are made at two different locations: the residential customer (90%) and the order fulfillment center (10%).

Reuse/Recycling/Disposal of Packaging by Residential Customers. Although many of the packaging materials used in this study are technically recyclable and/or reusable, actual reuse and recycling by residential customers depends on many factors, including the following:

- Customer access
  - to recycling programs (curbside or drop-off)
  - to packaging stores that accept loose fill for reuse
- Types of materials accepted by recycling programs
- Customer awareness that materials are reusable/recyclable
- Availability of residential space to store materials until they can be recycled/reused
- Convenience of participation in recycling programs
- Customer level of environmental commitment

The following assumptions were made in assessing residential reuse/recycling of packaging:

- Because of the low value and relative bulk of packaging materials, they are likely to be recycled only by customers with access to curbside recycling.
- The only materials likely to be accepted by curbside recycling programs are unpadded, unlined kraft paper shipping bags and possibly other all-paper(board) packaging components such as crumpled kraft paper or newsprint, corrugated boxes, molded paper loose fill, and all-paper padded shipping bags. Few if any curbside programs would accept shredded loose fill, pillow packs, polyethylene film shipping bags, or composite shipping bags.
- Except for the 10% of packaging used for returns, the only materials expected to be reused by customers are EPS and cornstarch loose fill. Although molded pulp loose fill is equally reusable, it is a new product that customers are unlikely to be familiar with and thus less likely to save and reuse. The larger size of the cushion cubes compared to foam loose fill “peanuts” may also make the molded pulp less appealing to customers for storage and later reuse. Molded pulp loose fill is also unlikely to be accepted by packaging stores for reuse because its appearance is very different from EPS and starch-based foam loose fill shapes, and stores would not be expected to store and reuse molded pulp loose fill separately from foam loose fill. Because the lower reuse of molded pulp shapes is based on expected customer behavior rather than functionality of the product, the LCI report will provide guidance on how to adapt molded pulp results to reflect reuse equivalent to foam loose fill.

Residential recovery/recycling of various paper grades was analyzed in the study **Recovered Paper: Future Challenges and Opportunities**, prepared for the American Forest & Paper Association by Franklin Associates, Ltd., July 9, 2002. Table 5-4 in that report, "Residential Postconsumer Generation and Recovery, 2000", showed 12% recovery of residential corrugated, but residential recovery of shipping bags and other packaging paper was insignificant.

Reuse of EPS loose fill was addressed in the study **Waste Management and Reduction Trends in the Polystyrene Industry, 1974 – 1994**, prepared by Franklin Associates, Ltd. for the Polystyrene Packaging Council in August 1996. A survey of 39 mailing services and catalogue businesses indicated that 50% of the loose fill that they used was loose fill returned to their stores by consumers (standard deviation 40-65%). It is assumed that a similar percentage of customers that do not have access to packaging stores (e.g., rural mail-order customers) would save and reuse loose fill at home.

Reuse/Recycling/Disposal of Packaging by Order Fulfillment Centers. Table E-1 shows assumed rates of recycling and reuse for packaging materials used for return shipments of goods. (This is not the same as consumer returns of packaging materials to mailing service stores for use, discussed in the preceding section.) Reuse of packaging materials to return unwanted items to order fulfillment centers represents a second useful life of the packaging material, replacing the need for the customer to purchase new boxes, shipping bags, or envelopes.

The study assumes that all loose fill materials are reused at a rate of 80%, as long as they are received and can be stored and returned to packing stations in the same format (same volume) as new (purchased) loose fill. This applies to inflated polyethylene air packets, polystyrene loose fill, corn starch loose fill, molded paper loose fill, shredded OCC, and shredded office paper. Because the materials have much more financial value reused than recycled, the study assumes that if they aren't reused, these materials will be disposed, so the recycling rate for these materials is 0%.

Because corrugated boxes will have had labels affixed to them twice already (once to the customer and again for the return) the study assumes that the order fulfillment center will not reuse the boxes a third time. Most order fulfillment centers are likely to have corrugated cardboard recycling service, so the study assumes that the returned corrugated cardboard boxes are recycled at a rate of 90%, with the remaining 10% disposed.

Kraft paper void fill and newsprint void fill is reusable, but reuse of these materials requires greater effort and/or additional storage space (compared to unused product in flat sheets or rolls) because they have been crinkled/wadded up. The study assumes that these materials are less likely to be reused than the flowable and other loose fills, for which bulk dispenser systems and storage may already be in place. Kraft paper may be recycled with corrugated and newsprint/newspaper is a fairly common recyclable in warehouse/shipping environments as well. For these materials, the study assumes a 20% reuse rate and a 40% recycling rate, for a total diversion rate of 60%, with the remaining 40% disposed.

Table E-1.
Assumed Rates of Reuse and Recycling for Packaging
Returned to Order fulfillment centers

Packaging Material	% Recycling	% Reuse
Corrugated	90%	0%
Inflated polyethylene air packets	0%	80%
Polystyrene foam peanuts	0%	80%
Cornstarch loosefill peanuts	0%	80%
Flowable loosefill made from recycled newsprint	0%	80%
Purchased Kraft paper (unbleached)	40%	20%
Purchased newsprint-style paper	40%	20%
Loosefill OCC shredded on-site	0%	80%
Loosefill high grade paper shredded on-site	0%	80%
PE bag(s) without liner	0%	0%
Kraft bag(s) without liner	40%	0%
Kraft paper bag with PE air-padded liner	0%	0%
Kraft bag with 100% news padding	0%	0%
PE bag with PE air-padded liner	0%	0%

It is very unlikely that shipping bags will be reused as they are designed for single-use but may be reusable if re-taped. Recycling for the kraft-only bag is assumed to be 40% (same as kraft void fill paper). Recycling for all other shipping bags is assumed to be 0% due to their low value (macerated newsprint), multi-material construction, and/or lack of recycling opportunities.

Management of Discarded Packaging

Packaging that is not reused or recycled by consumers typically becomes part of the managed municipal solid waste stream. It is recognized that some small fraction of postconsumer packaging may be burned by consumers, particularly in rural areas, or littered; however, no data exist to quantify these amounts or their impacts with any degree of confidence. Thus, disposal of postconsumer packaging by on-site burning or littering is not included in this analysis. This analysis considers only landfilling and WTE combustion as management options for postconsumer packaging.

Landfilling of Discarded Packaging. Approximately 80 percent of all discarded municipal solid waste in the U.S. that is not diverted for reuse, recycling, or composting is currently being landfilled. This analysis examines landfilling as a waste management option. The energy requirements for landfilling operations include the energy required to collect and transport solid waste to the landfill and to run the compacting equipment at the landfill.

The energy to transport materials to the landfill is derived by converting the weight of each material to the volume it occupies in the packer truck and multiplying the volume by the average fuel use per truckload. The packer truck densities used in this study are reported in Table E-2. A typical packer truck has a 25-cubic-yard volume and generally achieves a volume utilization of 80 percent. Packer trucks are assumed to use approximately 10.4 gallons of diesel per load (Reference E-6) on average, although actual fuel use will depend on the mode of transportation and distance to landfill, which can vary widely between communities. The amount of diesel fuel allocated to haul the postconsumer solid waste is calculated by the following equation:

$$\frac{Wt.of\ Discards}{Packer\ Truck\ Density\ of\ Discards}\ X\ \frac{10.4\ gal\ diesel}{25\ cu\ yd\ X\ 0.8} \qquad (Equation\ 1)$$

The diesel fuel requirements for the operation of landfill equipment are calculated using Equation 2.

$$\frac{Wt.\ of\ Discards}{Landfill\ Density\ of\ Discards}\ X\ \frac{500\ gal\ diesel}{2{,}667\ cu\ yd} \qquad (Equation\ 2)$$

The materials buried in the landfill are reported in the analysis as postconsumer solid waste. The solid waste is reported both by weight and by volume. The landfill density factors shown in Table E-2 are used to convert the weight of the discarded materials to the volume they occupy in the landfill. These factors are based on landfill samples and compaction tests.

Combustion with Energy Recovery. Approximately 20 percent of the nation's disposed municipal solid waste is burned rather than buried in a landfill (Reference E-1). The majority of MSW incinerators recover the energy released from burning the wastes, primarily to generate electricity. This analysis reports the energy content of the materials burned in MSW incinerators. The energy content of the materials evaluated in this study is based on the higher heating values (HHVs) reported for the postconsumer materials. These values are listed in Table E-3. The weight of the material burned is multiplied by its HHV to determine the amount of energy released. Most MSW incineration facilities produce electricity but not steam. Usable energy production is actually HHV x (thermal efficiency) x (transmission efficiency). Thermal efficiency for the generation of electricity from WTE combustion of MSW is around 33 percent or lower. Transmission losses are about 8 percent. As a result, the usable energy delivered from combustion of MSW is HHV x 0.33 x (1/1.08), or about 28 percent of the HHV of the material. The energy credit is shown separately in the LCI energy results in the report.

Table E-2

PACKER TRUCK AND LANDFILL DENSITY FOR PACKAGING

	Packer truck density (lb./cu. yd.)	Landfill density (lb./cu. yd.)
Polyethylene Film Packaging	544	670
Polystyrene Packaging	200	240
Paper Packaging	602	740
Corn Starch Packaging	1700	2000
Molded Pulp Packaging	664	819
Newsprint/Newspaper Packaging	602	740
Corrugated boxes	609	750

References: E-1, E-7, and E-8

Source: Franklin Associates

Table E-3

HIGHER HEATING VALUES AND ASH CONTENT OF MATERIALS

	Ash Content (percent)	Higher Heating Value (HHV) (Btu/lb)
Kraft Paper	1.01%	7,261
Newsprint/Newspaper	1.43%	7,979
Low-density polyethylene (LDPE)	0%	19,965
Linear Low-density Polyethylene (LLDPE)	0%	19,985
Polystyrene, foam	0%	17,840
Corrugated	5.06%	7,945
Corn Starch	1.06% *	7,560
Molded Pulp	1.43% **	7,979

* The ash content for food waste is assumed for corn starch.
** The ash content for newsprint is assumed for molded pulp.
References: E-8, E-9, and E-10.

Source: Franklin Associates

The quantity of solid waste for each system is reduced when postconsumer materials are burned. The ash content of the materials is used to determine the quantity of solid waste contributed by the portion of materials that is burned instead of landfilled. Air and waterborne emissions data from the combustion of specific postconsumer materials are not available. These emissions are also not available for landfilling of specific materials. Therefore, the air and water emissions associated with combustion and landfilling are not addressed in this report.

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E-1 U.S. EPA. **Municipal Solid Waste in the United States: 1999 Facts and Figures.** Franklin Associates, Ltd. June, 2001.

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E-3 "Curbside collection participation: Influences and motivations." Rebecca Davio, Ph.D. **Resource Recycling**, August 2001, Vol. XX, No. 8.

E-4 **Recovered Paper: Future Challenges and Opportunities.** Prepared for American Forest and Paper Association by Franklin Associates, Ltd. July 9, 2002. Table 5-4 Residential Postconsumer Generation and Recovery, 2000.

E-5 **Waste Management and Reduction Trends in the Polystyrene Industry, 1974 – 1994.** Prepared .for the Polystyrene Packaging Council by Franklin Associates, Ltd. August 1996. Page 18.

E-6 Personal communication between Franklin Associates, Ltd. and Bob Yost of Douglas County, Kansas. February, 2003.

E-7 **Estimates of the Volume of MSW and Selected Components in Trash Cans and Landfills.** Prepared for The Council for Solid Waste Solutions by Franklin Associates, Ltd. and The Garbage Project. February 1990.

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E-10 Fire, Frank L. **Combustibility of Plastics.** Van Nostrand Reinhold. 1991.