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

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(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

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(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.

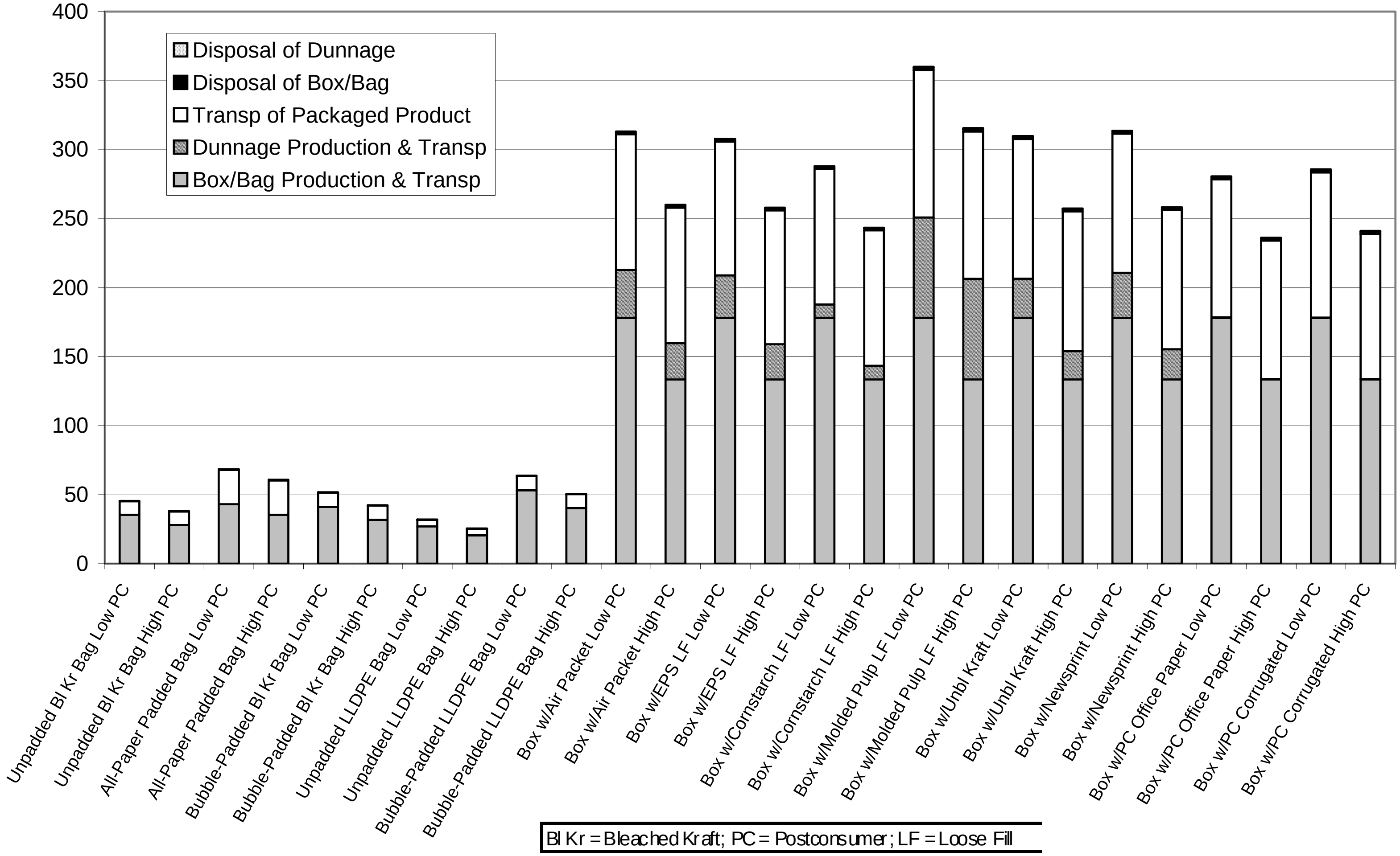
Figure ES-1 shows that total energy requirements for all five shipping bag systems are significantly lower than for the eight corrugated box and dunnage systems defined in Table ES-1. The two main reasons for this are (1) lesser quantities of materials are used in shipping bags, and (2) the more compact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

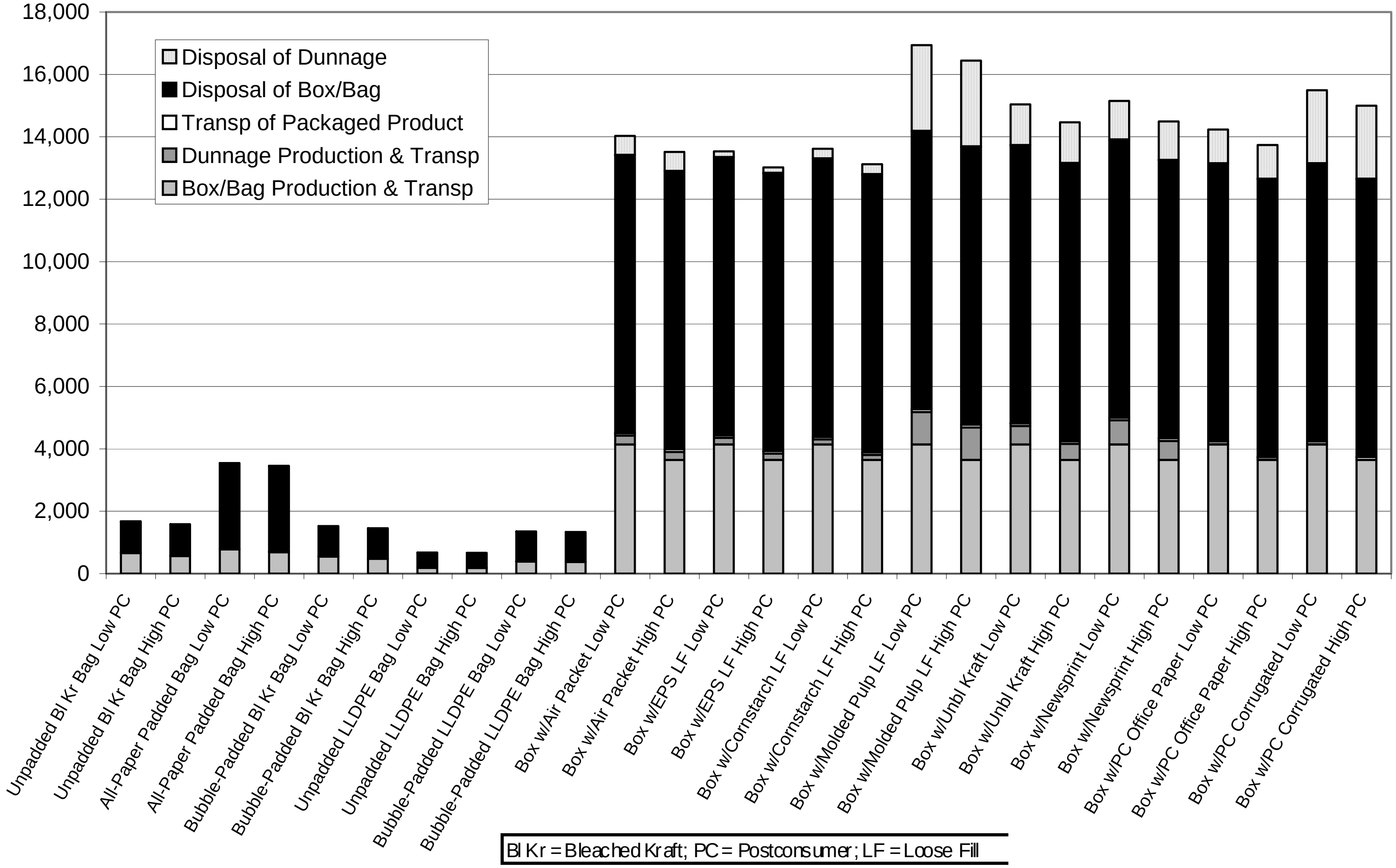
More detailed presentation and discussion of energy results, including energy use by category, energy profiles by fuel source, and energy credit for waste-to-energy combustion of a portion of postconsumer packaging disposed to municipal solid waste can be found in Chapter 3.

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)



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

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)

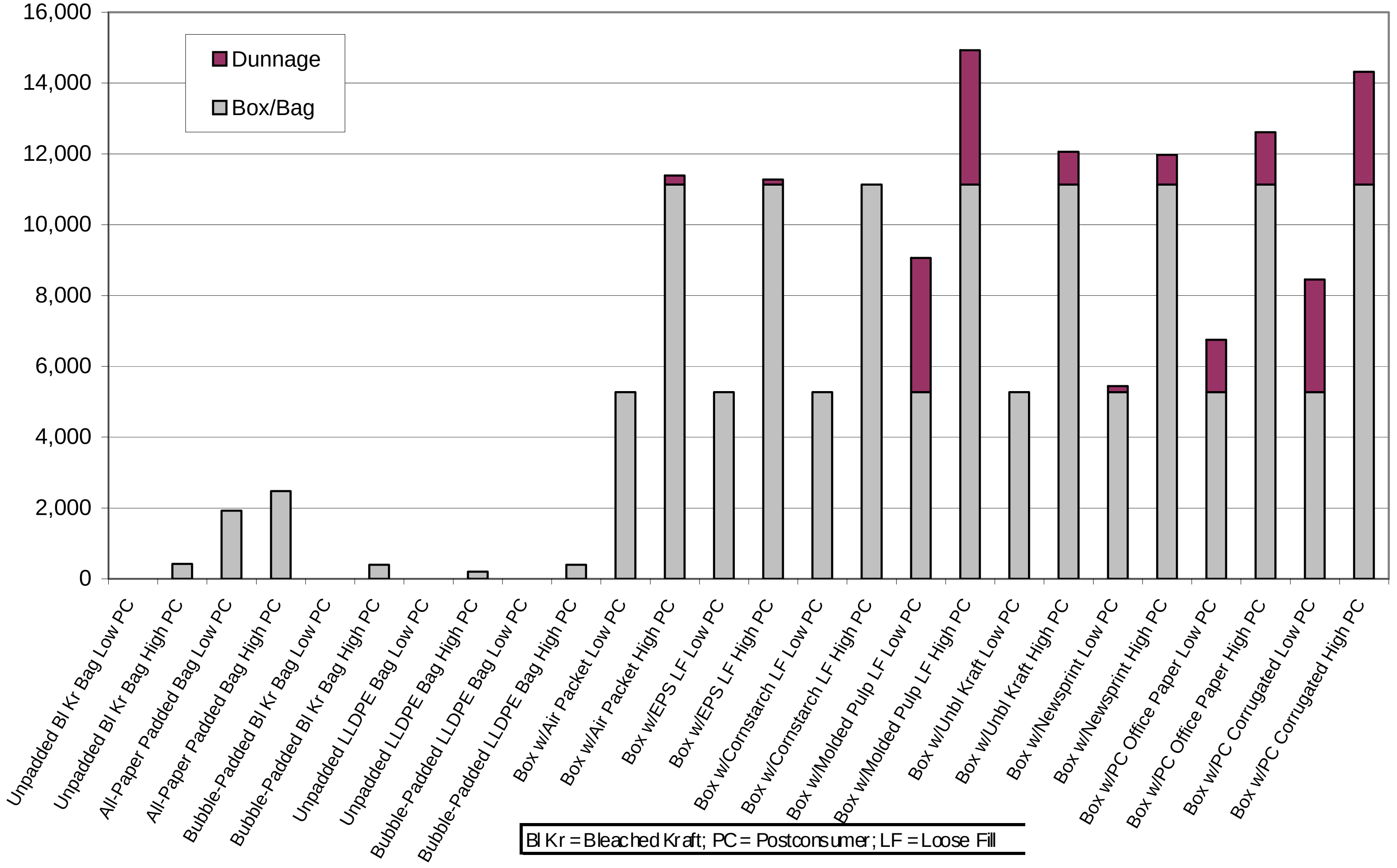
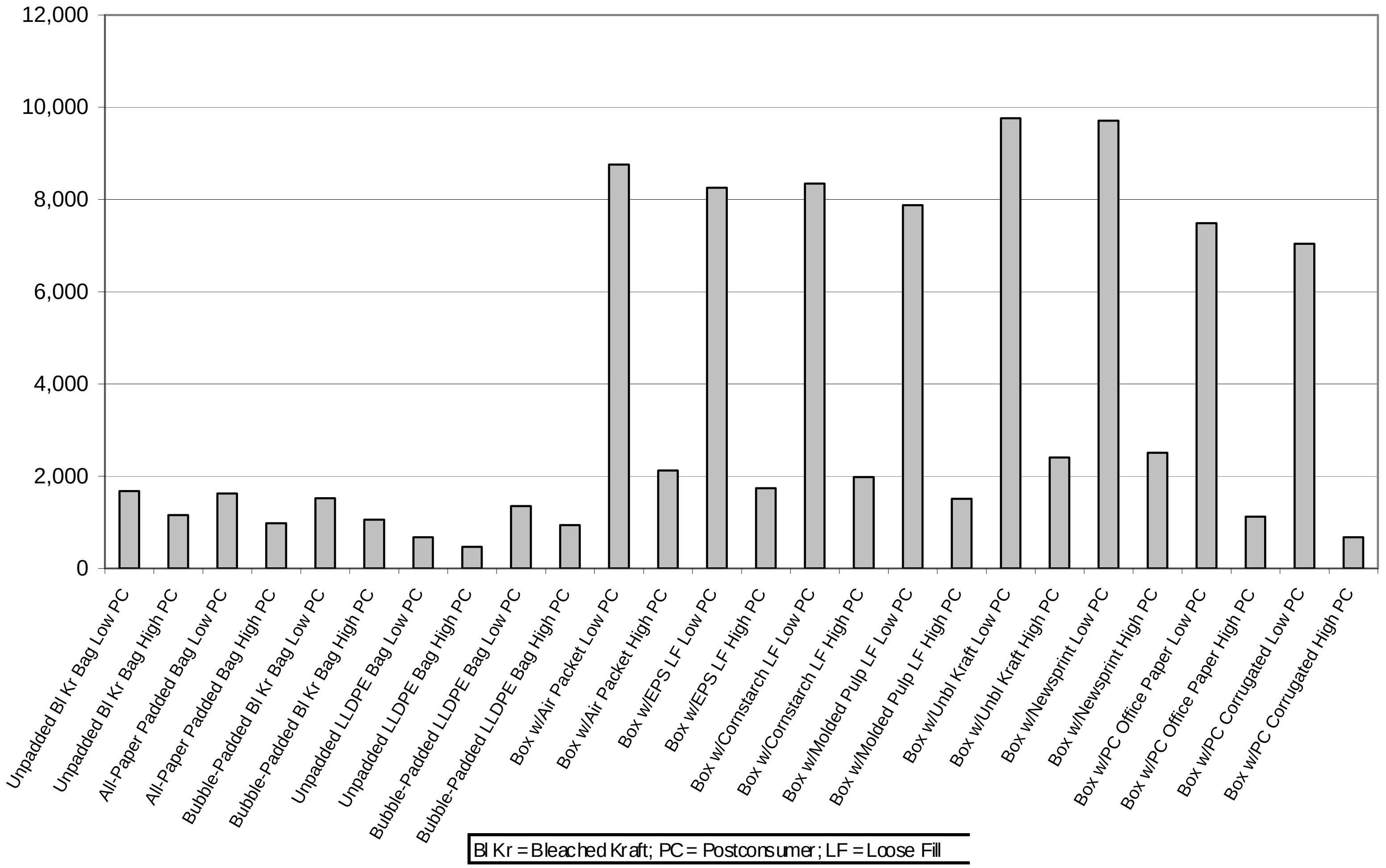


**Figure ES-4. Net Total Solid Waste for 10,000 Packages
(pounds of waste/10,000 packages)**



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.

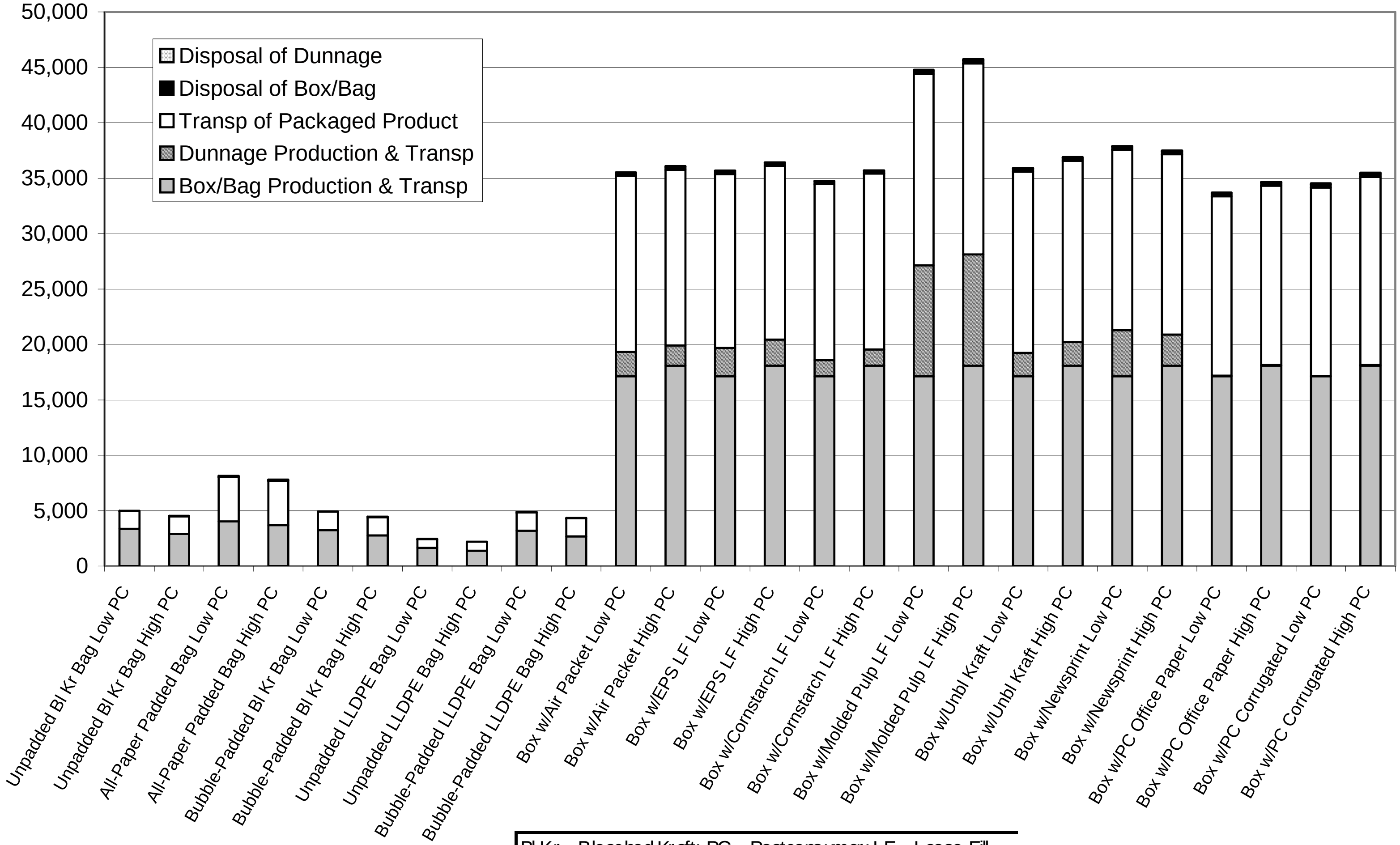
This report evaluates a total of 45 different atmospheric emissions (of which greenhouse gases are only three) and 41 different waterborne emissions. A full discussion of these emissions is not practical; however, a summary comparison is.

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)



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

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.