

# Closing the loop

## Design for Recovery Guidelines: **Paper Packaging**

# paper



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## Paper | Table of Contents

<b>Purpose</b> .....	5
<b>Introduction, Scope, and Methodology</b> .....	6
<b>Design for Recovery Guidance</b> .....	7
Treatments Applied during the Papermaking Process.....	8
Treatments Applied during the Conversion Process.....	12
Treatments Commonly Used in the Manufacture and Conversion of Food-Contact Paper Packaging Applications .....	25
Treatments Commonly Used in the Manufacture and Conversion of Non-Food Contact Paper Packaging Applications .....	25
Summary Checklist and Additional Guidance .....	26
<b>Fiber Types used in Packaging</b> .....	28
Wood Fiber .....	28
Non-traditional Sources of Fiber.....	29
<b>Introduction to Papermaking and Paper Packaging</b> .....	32
<b>Survey of End-of-Life Options</b> .....	34
The Recycling Process: Collection, Sorting, Reprocessing.....	36
Composting of Paper Packaging .....	39
Waste-to-Energy Processes .....	42
<b>References</b> .....	46
<b>Interviews and Site Visits</b> .....	51



<b>Appendix A: Existing Protocols and Standards</b> .....	52
<b>Appendix B: Labels</b> .....	54
<b>Appendix C: Summary of Paper Recycler Survey Results</b> .....	55

When considering ways to enhance the sustainability of packaging, a primary goal must be to make wise use of material resources that are recoverable at the end of their useful life and re-used in industrial or biological cycles. To make this happen, it is critical to connect packaging design and manufacture with the available end-of-life recovery systems, creating a “closed loop” material system. Often, however, in the United States, the two ends of the packaging supply chain—the packaging designers and the recyclers—do not communicate effectively with each other, and non-recyclable packaging is created, material resources are sent to landfill, and a closed-loop system is never realized.

Often in the development of new packaging, little attention is paid to its practical recyclability, given the limitations of the current recovery systems. As a result, new packaging is released into the marketplace without an effective infrastructure for its collection and recovery, forcing recyclers to respond as best they can in an ad hoc manner. The *Design for Recovery Guidelines: Paper Packaging* (the Guidelines) will provide information that is necessary to assess the potential recyclability of a new type of package before it is released into the marketplace.

One of the barriers to effective communication along the packaging supply chain is the lack of informational resources explaining how design decisions affect recyclability. This document is an effort to fill this gap. The Association of Postconsumer Plastic Recyclers (APR) has done an excellent job providing its *Design for Recyclability Guidelines* for plastic bottles, explaining which plastic bottles, including their attachments, inks, coatings, and colorants, are compatible or incompatible with today’s various recycling technologies. This document extends this type of technical guidance to paper packaging so that package designers have the information they need to design paper packaging that behaves optimally in the recycling process.

The primary purpose of this document is to explain how different treatments to or components of paper packaging affect a package’s recyclability and compostability. To add context to this guidance, this document also provides an overview of fiber types used in packaging, the papermaking process, packaging collection and sorting, and the end-of-life options available for disposal of paper packaging.



Natural plant fibers, such as papyrus, bark, cotton, straw, and bamboo, have been used to make paper for both writing and packaging purposes for thousands of years. Although the technology to process and use wood fiber has only existed since the mid-1800's, trees are the most economical and abundant source material available today, and therefore wood fiber dominates the global paper industry. Paper is found throughout everyday life: for writing and printing, packaging and wrapping, hygiene and health care, and even structural and construction uses. From a packaging perspective, paper is made from a renewable resource and is both recyclable and compostable. It can provide strength options from delicate tissue to hardy corrugated board, be formed into a variety of shapes, and easily carry printed graphics.

Paper-based packaging is the most commonly used packaging material in the world (Twede & Selke, 2005). As of 2008, paper and paperboard make up 31% (77.42 million tons) of the municipal solid waste stream in the United States. Of that, approximately half (38.29 million tons) is paper used in packaging applications (U.S. Environmental Protection Agency [U.S. EPA], 2009a; U.S. EPA, Office of Resource Conservation and Recovery 2009). While 65.5% of paper packaging is currently recovered (including nearly 77% of corrugated containers), the overall recovery rate for all types of paper and paperboard is 55.5%, meaning the remaining 44.5% is sent to landfill (U.S. EPA, 2009a).

Paper packaging is too valuable a resource to waste. Increasing the recyclability and compostability of paper packaging means that it is more likely to be effectively recovered and utilized in biological and/or industrial closed-loop cycles—one measure of sustainable packaging. Designers play a critical role in the ultimate recovery of their packaging. While there is no question that packaging must be designed to meet strict performance, safety, and cost criteria, designers can elevate recyclability to the same level of importance within their companies. An effective closed-loop system starts with great design.

The Design for Recovery Guidelines for Paper Packaging covers all fiber-based packaging, including both wood fiber and non-wood fiber paper. This document does not cover non-packaging types of paper, such as newsprint or office paper.

This document was written to connect packaging designers with available recovery options in order to encourage the recycling or composting of paper packaging. It does not, however, provide instruction on the closely related issue of incorporating recycled content into paper packaging.

Paper packaging is manufactured to meet performance, health and safety, and market requirements. These Guidelines recognize the importance of those requirements and acknowledge that they are necessary to the safe delivery or marketability of the product and there may be no viable alternatives. However, the sole focus of the Guidelines is on making suggestions that will improve the recyclability and/or compostability of paper packaging.

Finally, barriers to the increased recyclability and compostability of paper packaging may be attributed to design aspects of the package, but also to issues unrelated to design, such as consumer behavior, collection and sorting processes, and infrastructure in communities across the United States. These issues could include consumers choosing not to recycle paper packaging, lack of municipal funding for recycling or composting infrastructure, or cross-material contamination resulting from single-stream collection. This document is limited to a discussion of how the design of paper packaging affects its potential recovery, not the comprehensive issues surrounding successful recovery of paper packaging.

Primary research for this document included telephone interviews; in-person interviews with local, state, and national government agencies and private recycling and waste management organizations; and site visits to material recovery facilities, industrial composting facilities, a waste-to-energy plant, and four paper mills.

In addition, an on-line survey was widely distributed to members of the Technical Association of the Pulp and Paper Industry (TAPPI) who identified themselves as paper recyclers. We received complete or partial responses to the survey questions from 328 individuals. It is important to note that, aside from being TAPPI members, the survey respondents did not identify themselves, their positions, the companies they represent, or provide proof of their expertise in the subject matter. The survey responses were used to determine the major problems and contaminants in the paper repulping and recycling processes and are referenced in the document. A summary of the survey responses is attached in Appendix C.

Collecting paper packaging after use is only the first step in the recovery process. Paper packaging does not simply consist of pure paper fibers. Many other ingredients, or “treatments,” go into making paper packaging, which serves the multiple purposes of protecting a product, advertising it on a shelf, and providing information to the consumer. The treatments can add strength, water repellency, smoothness, color, or texture to the paper. Inks, labels, and wraps can provide information to the consumer as well as graphical appeal to the package and product. Radio frequency identification tags can be used to track a shipment or the shelf location of an item in a retail store.

Packaging designers and paper manufacturers may add different treatments to paper at various stages. Some treatments are applied during the papermaking process itself. Other treatments are applied during the conversion process, in which paper is converted from flat sheets into packaging.

Some of the common treatments applied to paper-based packaging may present challenges to the recycling and/or composting processes. To help mitigate this problem, these Guidelines are intended to inform packaging designers of the impact their design decisions have on beneficial recovery of paper packaging, encouraging them to “close the loop.” To do this, the treatments frequently applied to paper are described below, along with the common packaging applications where they can be found, the potential recovery problems, and any known alternatives.



### Treatments Applied during the Papermaking Process

#### CLAY (KAOLINITE) COATING

##### What is it? Why is it used?

Clay coating is an aqueous coating, clay being the main component. It is used for both function and pigment on fiber substrates (Twede & Selke, 2005). Clay coating is a functional coating that fills the fiber surface and imparts a smoothness, gloss, and level surface to paper to enhance printing (Smook, 2002). Pure clays have a clean white color that imparts whiteness to the paper stock. Coated papers are referred to as “clay-coated” despite the actual formulation of the coating, which may include clay as well as other components such as latexes and binders.

##### Where is it found?

Clay coatings are applied to numerous paper grades before the calendaring process. This gives the paper a glossy surface and prepares the surface for printing. Clay-coated boxboard, used for cereal boxes or tissue boxes, is an example. Although not packaging, magazines and catalogs are printed on a highly clay-coated paper. Clay may actually form a significant proportion (typically 10-15%, going up to 30%) of the thickness of the paper sheet (Smook, 2002). The use of higher amounts of clay fillers may reduce costs, as the filler is often cheaper than the fiber. The amount of clay coating used is limited by bulk and reduction in strength.

##### Clay in Composting

Clay coatings present no challenge to composting operations.

##### Clay in Recycling

Clay coatings must be removed during the repulping process. Clay coatings are typically removed by screening equipment at the discharge end of the hydropulper, although 5% of recyclers surveyed consider them a problem that clogs machinery. For mills using the flotation method for deinking the paper, the clay on coated paper is a necessary component to help bind to and remove the frothy ink particles.

##### Alternatives

Currently there are no suggested alternatives to clay coatings.

#### Did You Know?

Clay coatings may make up between 10-30% of the thickness of a paper sheet for printed applications like catalogs and magazines.



## DYES

### What is it? Why is it used?

Dyes are water-soluble coloring agents that may be added to the papermaking process to produce paper of a specific color.

### Where is it found?

Dyes may be applied to any type of paper packaging, including corrugated containers, boxboard, or molded pulp.

### Dyes in Composting

Dyes typically do not pose a challenge for the composting process.

### Dyes in Recycling

Dyes are also relatively problem-free for the recycling process, although some colors are problematic. In particular, fluorescent and extremely dark colors, especially black, can lead to specks of unwanted color in recycled content paper (Eco-Cycle, n.d.). These should be minimized when possible.

### Alternatives

Dyes could be replaced by the use of printing inks or by the use of white or natural-colored paper.

## Did You Know?

Starch and sizing are added to all types of paper during the papermaking process.

## SIZING

### What is it? Why is it used?

Sizing may be rosin, polymer, or starch (Soroka, 2008). Layers of sizing are applied to a fiber substrate to lend water repellency and prevent absorption of liquids (Smook, 2002). Sizing is added to the pulp slurry to prepare for papermaking and also applied at the dry end of papermaking to fill surface voids and add additional water resistance properties to paper. Sizing is often applied prior to other treatments to help the paper stand up to the application of a water-soluble starch or dye.

### Where is it found?

Sizing is used in the papermaking process and is applied to all types of paper. It can be applied in varying amounts, depending on the degree of water resistance required for the packaging application (Soroka, 2008). For example, paper packaging for frozen food products would require a large amount of sizing due to its intended storage in a cold, wet environment. Sizing is often used in combination with wet strength additives to make paper water-resistant (Twede & Selke, 2005).

### Sizing in Composting and Recycling

Sizing in composting and recycling does not present challenges to either recycling or composting.

### Alternatives

There are no alternatives to sizing.

## STARCH

### What is it?

Starch is a carbohydrate obtained from plants, typically as a byproduct of processing crops such as potatoes, rice, wheat, corn, or tapioca.

### Why is it used? Where is it found?

Starch is added in the papermaking process and is applied to all types of paper. After fiber and clay, it is the third largest ingredient (by weight) in paper (Twede & Selke, 2002). It is used in the papermaking process to add stiffness and (dry) strength to a sheet of paper. Starch is water soluble, but adds some wet strength properties to the paper. It may be added to the pulp slurry in preparation for papermaking, applied as sizing as a dry-end treatment, and it can also be used as an adhesive, such as when attaching corrugating medium to linerboard.

### Starch in Composting and Recycling

Starch in composting and recycling does not present challenges to either composting or recycling.

### Alternatives

There are currently no alternatives to the use of starch.

## WET STRENGTH POLYMERS (OR RESINS)

### What is it? Why is it used?

Wet strength resins are added in the wet-end of the papermaking process to produce a paper that has high resistance to rupture or disintegration when wetted with water. Unlike moisture barriers, which are surface coatings, wet strength is incorporated directly into the paper as part of the fiber's bonding system. A paper that retains more than 15% of its dry strength when completely wetted with water may properly be called wet strength. Depending on how much wet strength additives are used, treated paper can retain between 15% and 50% of its dry strength (Twede & Selke, 2005). Some typical wet strength resins are polyamidoamine-epichlorohydrin, referred to as PAE resin, (for alkaline papermaking) or glyoxylated polyacrylamide for tissue products (Hubbe, n.d.; Smook, 2002).

### Where is it found?

Wet strength additives are used in a variety of different fiber packaging applications, such as beverage carriers, frozen food boxes, corrugated containers that ship produce and meat, and weather-resistant packaging. Non-packaging applications extend to paper towels and products requiring immersion in water, such as photographic paper and filter paper. In general, any paper package holding a product that requires refrigeration, freezer storage, or a moist environment will have some degree of wet strength additive applied. It is important to note that different categories of packaging require different amounts of wet strength additive to achieve the necessary performance requirements. This means that not all wet strength paper is created equal and may not be equally recyclable.

### Wet Strength in Composting

Wet strength additives pose no challenges to composting operations.

### Wet Strength in Recycling

The very property that makes wet strength useful, water repellency, can make it a challenge during the repulping portion of the recycling process. There is significant variability in the pulping technologies used in the paper recycling industry (e.g., batch vs. continuous pulpers, the amount of water used, screen combinations, etc.). There is also a high degree of variability in the mix and quality of fiber that supplies any particular mill. These factors, combined with the variability in the amount of wet strength additives in different packaging applications, make generalizations about the recyclability of board with wet strength additives complicated.

Wet strength additives penetrate the paper to provide water resistance. This can also prevent the water in the pulper from successfully separating the fibers. Clumps of wet-strength-treated paper that cannot be successfully repulped must eventually be removed from the tanks by rappers or in the cleaning screens. The paper mill must pay to dispose of them, along with other contaminants, in a landfill.

Though collected in municipal recycling systems and usually present in small amounts in the recycling stream, the results of the TAPPI member survey conducted for this study indicate that 74.1% of surveyed recyclers would prefer to avoid wet strength paper. The recyclers surveyed considered wet strength paper a contaminant that they either could not handle or did not accept for recycling. However, it should be noted that the survey did not specifically ask for clarification about which types of wet strength products were problematic. The consulting firm R. W. Beck (2009) conducted a survey of community recyclers, sponsored by the American Beverage Association, and found that 71 percent of the U. S. population had access to recycling programs that accept wet strength beverage carriers.

There are numerous conflicting instructions by local communities, MRFs, and paper mills about which wet strength packaging applications are acceptable for collection and recycling. For example, the Recycling Association of Minnesota (n.d.) suggests the following: *“When put into a pulping machine with other recycled paper in a paper mill--which uses water rather than chemicals--the wet strength paperboard will not break down very easily. However, if collected in sufficient quantity, paper mills may make adjustments in the process to accommodate the material. Please check with your local recycling coordinator to see if wet strength paperboard is accepted by your community recycling program.”*

Wet strength paper can be successfully repulped under the right conditions. In general, the two most important variables to success with repulping wet strength paper are longer pulping times and higher water temperatures (Hubbe, n.d.; Meng, 1998; J. Kendrick, personal communication, September 22, 2010). Oxidizers, such as caustic soda or sodium hypochlorite, may be used in combination with higher temperatures and longer pulping time to break down the resin when repulping bleached kraft with wet strength properties. Oxidizers will not be as effective for removing wet strength from unbleached kraft or mechanical pulps, as the lignin remaining in the fiber will consume the oxidizers (Hubbe, n.d.). Adding a deflaker, which breaks up patches of wet strength fiber, as well as additional screens, to the repulping process, may allow a mill to repulp feedstock containing up to 10% wet strength paper (MeadWestvaco, 2010). Another technical process used by mills to repulp wet strength paper combines a two-pH process with the addition of a rewetting surfactant to help water more quickly penetrate the board (Fischer, 1996). If a mill purposely purchases or receives batches of wet strength paper in large quantity, it will optimize repulping techniques (using processes mentioned above) to get a high fiber yield from wet strength paper (C. Klaas, personal communication, September 28, 2010). This strategy is currently being implemented in the U.S. by tissue mills.

### Alternatives

Wet strength additives are used in a wide variety of packaged products and are essential to the safe delivery of many products because they do not disintegrate when wet or subjected to freeze/thaw. There are no treatment alternatives to wet strength additives. For some packaging applications, it may be possible to re-engineer the packaging design to use localized thickening or ribbing, microfluted corrugate, or a honeycomb structure that minimizes the amount of wet strength additive required (Envirowise, 2008). However, since microfluted and honeycomb are open structures, they are not feasible alternatives in applications where the package is subject to submersion or high levels of condensation.

## Treatments Applied during the Conversion Process

### ADHESIVES

#### What is it? Why is it used?

Adhesives are substances that bond two surfaces together. Natural adhesives are made from resins, starches, waxes, or animal products (e.g. gelatins, caseins). Synthetic resins are chemically produced from petroleum or natural gas. Examples include elastomers, thermoplastics, and thermoset adhesives. There are many different materials used to create adhesives, all of which are differentiated by how the bond is formed (Tag and Label Manufacturers Institute, Inc. [TLMII], 1992; Twede & Selke, 2005).

The adhesives most frequently used on paper packaging are:

- Water-based synthetic resin emulsion adhesives (white glues), based on polyvinyl acetate or vinyl acetate copolymers (often ethylene vinyl acetate [EVA]). These emulsions are approximately 20-50% water and 50-80% solids. An initial bond (or green film) forms immediately to hold the surfaces together, and as the water evaporates, the polymer units form a strong adhesive film.
- Hot-melt (thermoplastic) adhesives are 100% solid at room temperature, applied when hot and melted, and harden to bond as they cool. They are thermoplastic adhesives with a polymer backbone such as EVA, in combination with wax and other resins. Hot-melt adhesives melt between 250° and 350° Fahrenheit. They are known for rapid bonding, as they cool to solid state rapidly and do not rely on a solvent or water vehicle to evaporate.
- Pressure sensitive adhesives (PSA) are tacky at room temperature and form an instant bond when pressure is applied. PSA are usually based on acrylics or rubber/resin blends. They are found frequently in applications such as labels and tape, and placed on a silicone-coated release sheet from which they are peeled off for application.
- Cold seal adhesives (also called self seal adhesives) are occasionally, though infrequently, used on paper packaging. Cold seal adhesives contain natural rubber latex and/or copolymers of vinyl acetate and ethylene. These adhesives require minimal pressure to bond, do not require heat, and seal only to themselves (Bentley, 2006). They are commonly found on items such as envelopes, paper laminates, medical bandage wrappers, and wrapping bands for napkins or stacks of money.

#### Where is it found?

Adhesives may be found on almost all types of paper packaging. White glues are used in paper packaging conversion to initially form folding boxboard cartons and corrugated containers (e.g. manufacturers' joints and corrugated glued lap) as well as paper bags, and to apply paper labels to glass containers. Hot-melt glues are used when fast bonding is critical, especially when sealing filled cartons and packages. They are used to seal the tops and bottoms of folding cartons and corrugated cartons. PSA is used for labels and tapes, and sometimes on plastic bottles (I. Valois, personal communication, June 11, 2010).

#### Adhesives in Composting

Adhesives themselves are neither purposely accepted nor forbidden in industrial composting facilities. This is because they arrive at the facility in quite small amounts on larger compostable items, such as paper or biopolymer packages. According to the ASTM International (2003) protocols, if an adhesive (or other substance, such as ink) is present at less than 1% of a package by weight, then it need not be verified for degradability or toxicity, with the exception that all substances added to a package or material must pass heavy metals tests as required by U.S. EPA or (in Europe) EU regulations. Woods End Laboratory in Maine has recently conducted tests specifically to investigate the compostability of adhesives. Their tests demonstrate that when adhesives themselves are treated as the test substance (at 100%) some adhesives met the compostability standards while others inhibited the decay of the packaging material to which they were attached (W. Brinton, personal communication, March 25, 2010).

### Adhesives in Recycling

Although adhesives are attached to the paper packaging and are not explicitly forbidden, adhesives are considered undesirable by paper recyclers. Of survey responses, 83.7% indicated that adhesives are considered a contaminant that must be removed from the pulp. When then asked which of the identified contaminants created the most significant problems in the papermaking process or final product, “adhesives” received the highest response of 45%, more than any other contaminant. Problems listed included creating defects in the paper, holes, and increased dirt count. Adhesives were also considered challenging to equipment maintenance, because adhesive “stickies” build up on the equipment (belts, rollers, clothing), requiring the mills to shut down frequently for cleaning. One comment from the survey encapsulates the general feeling, “[c]learly adhesives are our #1 problem which result in stickies and cause unacceptable holes in our finished product.” This may be more problematic when repulping white, office, envelope, and mixed paper grades than when repulping corrugated board alone. For the former, pressure-sensitive adhesives are used to adhere labels on envelopes (or where pressure-sensitive adhesive tape is used to seal corrugated boxes), while with the latter, liquid adhesives are used in glued lap and hot melt adhesives are typically used to seal the box.

Pressure-sensitive and cold-seal adhesives are the most difficult to deal with for the mills, but they are less common than hot-melt adhesives. Hot-melt adhesive is less difficult to deal with, but it presents challenges of its own. It has a density similar to that of water, which makes it especially difficult to screen out if it fragments (Envirowise, 2008).

An interesting related finding is a laboratory and pilot test conducted by the USDA Forest Service Forest Products Laboratory and the University of Minnesota to assess the behavior of hot-melt pressure-sensitive adhesives on different paper grades during the repulping process. The study found that the presence of wet strength additives and sizing increases the adhesion of pressure-sensitive adhesives to the paper (envelope grade), making it more difficult to repulp (Houtman et al., 2004).

### Alternatives

Alternatives include mechanical fastenings such as staples or interlocking tabs. However, it is clear that adhesives are a necessary component for the construction of most types of paper packaging. The Tag and Label Manufacturers Institute (2010) has produced a laboratory testing protocol and standard for recycling compatible adhesives, as well as a specification for pressure-sensitive adhesive labels. This specification recommends using adhesives that remain cohesive and in large particles during the pulping process so they do not flow through the screens. The specification also recommends adhesives that are hydrophobic so any remaining particles may be removed in the flotation step during deinking (TLMI, 2007). Water-soluble adhesives are more difficult to separate out and can build up on equipment (Envirowise, 2008).

In addition, minimizing the amount of adhesive used is recommended for better recyclability, as well as being a cost-saving measure. Adhesive may be applied in small dots instead of a long strip, making it easier to repulp and screen out those bits of paper (Envirowise, 2008). Alternatively, hydrophobic adhesives are easier to separate from both the pulp and wastewater by flotation (TLMI, n.d.). One survey respondent noted that the pulping process is done in the range of 100-140° Fahrenheit, and suggested that if the adhesive remains solid in that temperature range, it can be easily screened out. Repulpable adhesives are a good solution to consider, especially in the envelope market.

## FOIL AND METALLIZED PAPER

### What is it?

Aluminum is a metal that is added to paper for decorative, folding, or barrier purposes. It may be deposited directly onto paper, or it may be laminated or stamped onto paper as a foil layer. Aluminum is the only metal applied to paper packaging.

### Why is it used?

Aluminum is often applied to packaging for decorative and marketing reasons, such as to catch the consumer's eye or to suggest a high-end, luxury feel (Peterson, Hazen & Parker, 2009). Colored lacquers are used over silver-colored aluminum to give the appearance of gold, copper, or other metallic colors (Soroka, 2002). Cosmetics and personal care packaging are good examples of this.

An aluminum layer has good “dead fold” characteristics, meaning that once it is folded, it holds the new shape without springing back. This helps a paper package maintain a tightly wrapped shape for items such as confectionery or chewing gum (Novelis, 2010).

When aluminum is laminated to paper or metallized on paper or film, its barrier properties also protect the contents of a package from the effects of light, oxygen, oils and fats, or moisture. Examples include aseptic packaging that sandwiches foil between layers of plastic film and paper, paper laminated with aluminum for take-out sandwich wrappers, or other packaging applications that need to protect freshness of food, cosmetics, tobacco, or pharmaceuticals.

### Where is it found?

There are several different methods by which foils and thin layers of aluminum are applied to various packaging formats: stamping, metallizing, and laminating.

### Stamping

Foils may be applied to paper packaging via a hot or cold stamp process. In hot stamping, the foil layer is carried on a release-coated polyester sheet and has a heat-activated adhesive applied to it. With the adhesive side facing the paper substrate, special dies or stamps are heated and used to transfer the foil layer to the substrate using pressure (Soroka, 2002). Cold foil printing is similar to hot stamping, but does not require special dies or heat. In cold foil, the foil layer is applied to an adhesive on paper, which is cured by ultraviolet light.

Foil stamps are almost always coated. The coating may make them scuff-proof or enable printing (protective), tint them a color (decorative), or make the foil heat sealable (sealable). Foil stamping is used for decorative purposes on packaging. It is most suitable when the metallic effects required will cover less than 60% of the package (D. Hutchison, personal communication, April 2, 2010). Foil stamping is used widely in packaging. Examples include wine and beer labels, cosmetics and personal care packaging, and packaging for household consumables. Other non-packaging uses for foil stamping include paperback books and greeting cards.

### Metallizing

Metallizing is a process in which an extremely thin layer of vaporized aluminum is applied to a substrate (paper or polymer) in a vacuum using either the vacuum or the transfer metallizing process. For vacuum metallized paper, the aluminum is deposited onto paper treated with a thin coat of lacquer, and then sealed with a top coat of primer. Transfer metallizing closely resembles the cold-stamping method, with the difference being the amount of foil applied to the paper (D. Hutchison, personal communication, April 2, 2010).

Metallized paper is seen frequently in decorative applications such as beverage and general purpose labels, decorative wrapping paper, bags, posters, and advertisements. However, because the layer of aluminum is not continuous at the microscopic level, the paper metallizing process does not have good barrier properties (Soroka, 2002; Twede & Selke, 2005).

Metallizing may also be done on plastic film (polypropylene or polyester) to create metallized films. Metallized films may commonly be referred to as met-poly film or OPP metallized film. Because the addition of the polymer layer to the aluminum in these metallized films provides both barrier properties and enhanced decorative options, metallized films are frequently combined with paper packaging to form a laminate package.

### Laminating

There are two ways that paper may have aluminum applied using a lamination process. The first is simply applying a thin layer of aluminum foil to paper using an adhesive. This type of lamination is not as common as it once was, but it remains a popular way to package confectionery and chewing gum due to its excellent wrapping properties. It is also found in tobacco and cosmetics packaging.

A second aluminum lamination option is paper laminated with metallized film. Once the film, typically polypropylene or polyester, has been metalized with aluminum, it is applied to the paper with an adhesive (either hot-melt or cold). For decorative uses, the incorporation of the plastic film makes the package shinier than simply using foil-laminated paper on its own (D. Droppo & J. Giusto, personal communication, April 12, 2010).

### Foil in Composting

In the past, foil and metallized paper have been considered a contaminant to the composting process, primarily for aesthetic or cosmetic reasons. As a rule, most industrial composting facilities are hesitant to accept any metals in their feedstock. This cautious attitude results from worries over aesthetics, as well as desire to avoid bits of non-aluminum metals (e.g. paper-wrapped metal wire in “twist-ties”). In fact, aluminum oxidizes and dissolves into the soil at low concentrations (W. Brinton, personal communication, February 26, 2010). The presence of adhesives or lacquers in combination with aluminum may slow the composting process for the paper (W. Brinton, personal communication, March 25, 2010). However, if aluminum is present on metallized film, the traditional petroleum-based polymers will not compost and the pieces of plastic film are seen as a cosmetic contaminant in finished compost product. Sometimes, metallic particles or metallized films do not oxidize and can show up in finished compost product. One composter referred to problems faced after a Christmas holiday when they had received a load containing metallized film-laminated holiday wrapping paper. Because the aesthetics of their finished product are a top concern for industrial composting facilities, composters prefer simply to avoid metals when they can.

### Foil in Recycling

Just as with composting, in the past, foil and metallized paper have been considered a contaminant to the paper recycling process, primarily for aesthetic reasons. Many recycling facilities accept paper packaging with aluminum (stamped or metallized), though sparingly and with caution. Just fewer than 3% of recyclers surveyed for this document said they refused to accept aluminum-bearing paper, while 79% said they must remove aluminum as a

### Did You Know?

Foil particles can cause aesthetic problems in the quality of both recycled-content paper and finished compost product.

contaminant from the pulp. It was reported in 9.3% of the responses that aluminum negatively impacts the quality of their paper. Metallic particles may be visible in recycled-content paper, creating specks and adhesive-related transparent spots (also called “fish-eyes”) in the finished product. The particles can clog screening equipment at paper mills. Finally, aluminum particles in recycled paper packaging, while harmless to health, can set off the metal detectors required for government-mandated inspection on the packing and filling line.

A recent Pira study showed metallic particles successfully separating from the fiber in the pulper and sinking to the bottom to be screened out. This study found that both hot and cold stamped foil on paper samples repulped successfully and did not cause problems with adhesives (stickies). They also suggested the foil particles should be easily screened out with the proper screening equipment (centrifugal or cyclone cleaner screen). However, they noted the foils could pose problems for paper recyclers, based on the type and efficiency of the screening equipment at the mill, the paper grade produced, and the proportion of foil-coated paper in the feedstock. They added the recommendation that foil-stamped paper would be suitable as a minority component of feedstock producing certain recycled grades that had lower aesthetic requirements (Jopson & Collis, 2008).

In contrast, paper laminated with metallized film is not considered easily recyclable (D. Hutchison, personal communication, April 2, 2010). The problem is not the aluminum but the polymer film, which makes repulping the fibers difficult and clogs the screens. Therefore, paper with metallized film is treated as any polymer-coated board is treated. However, packaging made with the other foil or metallizing techniques are repulpable, provided that centrifugal or cyclonic screens are in place (Jopson & Collis, 2008).

### Alternatives

Metallic inks can be considered as alternatives to decorative foil. Polymer coatings or wet strength resins could potentially be used to replace foil's barrier properties. There are no alternatives that can provide foil's unique folding characteristics.

## INKS, OVERPRINT VARNISHES, AND COATINGS

### What are they?

When applied to a variety of packaging substrates, including fiber-based paper and paperboard, inks provide graphic designers and brand owners the ability to convey information or create a representation of a brand image.

Inks can be described generically as consisting of an insoluble pigment and other additives dispersed in a carrier or vehicle. The carrier or vehicle enables a printer to transfer the pigmented ink from the appropriate printing press to the substrate. After the ink has dried or cured, the remaining portion of the vehicle acts as a binder to adhere the pigment to the substrate while also providing varying levels of physical and chemical performance properties.

Overprint varnishes (OPVs) and coatings can be generalized as inks without pigments. They are routinely applied on top of pigmented inks as they offer enhanced physical and chemical properties not achieved with inks alone. Furthermore, gloss levels and textures achievable with OPVs and coatings can be adjusted through formulation and application modifications. Such adjustments can further contribute to the aesthetic value of the package.

Ink is generally characterized as a liquid or a paste based upon its fluidity. The print method, such as offset lithographic, flexo, gravure, or screen, dictates the specific viscosity and rheology requirements of the ink vehicle chosen. Ink vehicles can also vary, based upon the method of drying or curing employed to convert the fluid ink to a solid.

Inks can be formulated to dry using one or a combination of mechanisms. Some components of inks can be absorbed by the fiber packaging, though the rate and extent of absorption will depend upon the ink type as well as whether the fiber based substrate is coated or uncoated. Other inks dry by evaporation of water or solvent with the aid of forced heated air. Several types of inks can also dry by a chemical reaction or polymerization. Such polymerizations commonly include oxidative drying, UV (Ultraviolet) cured and EB (Electron Beam) cured systems.

- Oxidative drying involves a reaction of oxygen with specific components, such as oils with metallic driers, in the ink vehicle. Individual molecules polymerize, converting into an interconnected network of molecules, forming a polymer. Such reactions typically occur over a 24 to 72 hour time frame.
- Ultraviolet (UV) coatings and inks contain compounds classified as photoinitiators. When exposed to an ultraviolet light source, a chemical reaction is initiated, and the inks and coatings cure or solidify to create a hard, protective finish (RadTech Europe, n.d.). UV inks and coatings cure almost instantaneously, offering a production efficiency over traditional inks or coatings that require heat or time to dry (International Paper Knowledge Center, 2010).
- Electron Beam (EB) inks use chemistries similar to UV inks for the vehicle but do not utilize photoinitiators. An alternate power source generates electrons in a controlled manner, which initiates a similar reaction without the use of a photoinitiator.

Both UV and EB systems can produce high gloss to matte textures. These substances are typically described as 100% solids and are usually free of solvents, so they release no volatile organic compounds (VOC) and can be applied in very thin films (“UV Coating,” n.d.). The description “100% solids” implies that the weight of liquid ink or coating applied remains the same throughout the curing process. Other characteristics of UV and EB coatings as detailed by International Paper Knowledge Center (2010) include, “greater opacity, color stability, deeper and more vibrant colors and color tones, sharper graphics, higher gloss, uniform surface to give labels a more vibrant look, scuff resistance, allows for in-line die cutting, chemical resistance, and better outdoor endurance.”



A variety of pigments can be used in inks and coatings. Pigments include black, white, and a wide variety of other colors. Colored pigments typically consist of an organic component derived from a coal tar source, though inorganic pigments are available as well (“Pigment,” 2010). The colors are created by making modifications to the organic structure and potentially incorporating a variety of non-toxic metals and other inorganic minerals and salts. Multiple grades can be obtained for each general color and may vary in strength, shade, opacity, lightfastness, or compatibility with specific ink vehicles.

Azo pigments and dyes are synthetic organic compounds characterized by containing one or more nitrogen-nitrogen double bonds called azo groups in their chemical structure. Azo pigments are most commonly red, orange, yellow, and brown. They may be used to dye items such as textiles and leather, as well as color printing inks (Caribbean Export Development Agency, 2009).

### *Are dyes different?*

Dyes possess some similarities to pigments, though there are several differences. The main difference comes in the form of solubility, cleanliness of color, transparency, available color options, strength, and affinity for certain substrates or solutions. The majority of printing inks for packing use pigments, but some dyes are incorporated as toners. While pigments can be dispersed in an ink vehicle, the pigment remains a distinct particle, especially when printed. In contrast, dyes tend to dissolve in the ink vehicle. Dyes can either have a strong affinity for a substrate to which an ink is applied or can readily re-dissolve when exposed to specific liquids.

### **Why is it used?**

#### **Where is it found?**

The primary purpose of applying inks to fiber packaging is to use color to communicate text, a design, or graphic. Inks can produce textures from high gloss to matte and effects from opaque to transparent in a rainbow of colors. Today, petroleum-based and vegetable-based inks are available. Vegetable-based ink releases fewer volatile organic compounds into the air as compared with petroleum-based inks. Several of the pigments in inks were traditionally supplied by heavy metals, but today these components, such as lead, mercury, cadmium, or hexavalent chromium are subject to U.S. state toxics-in-packaging laws.

Inks are used on almost all types of paper packaging applications. Inks used in flexographic printing are typically used for printing on rough or textured surfaces, such as corrugated containerboard or kraft linerboard. They are also used for newspapers, magazines, and a variety of label applications. Offset lithography is the most common paper printing process, and is used for folding carton stock, as well as labels. Lithographic inks are heavy, oil-based pastes. They require the paper stock to have some water resistance since the printing plates must be dampened with water. They also print best on a paper with a strong, clean surface so that the fiber and clay coatings will remain intact during the printing process. Offset lithographic inks may also be used for newspapers. Gravure printing is used for high-volume printing needs, such as cartons and carton wraps. It offers the ability to print using heavier amounts of ink, which is required for good coverage of metallic inks (Soroka, 2002). The predominant methods of printing can vary by geographic region.

### **Inks in Composting**

In general, inks have not been an issue for the composting process for two reasons. First, inks usually make up less than 1% of the package’s dry weight and thus are not considered significant constituents of the package under the composting standards EN 13432 and ASTM D6868. Typically, compostability standards apply only to the substrate of the package (paper or bioplastic). Second, little published research has been done on the compostability of ink, coating, and adhesive components, though in general they would not be expected to inhibit biodegradation of an otherwise compostable substrate (INX International Ink Company, n.d.).

A major exception to acceptability of inks for composting is the presence of heavy metals. While most inks used in the United States have phased out the use of heavy metals as pigments, it is important to realize that may not be the case in other parts of the world. A recent study found that the category of inks and colorants is one of the top three packaging categories that failed heavy metal assessment testing. The inks and colorants were found on packaging from a variety of product sectors and mostly on packaging produced outside the United States. Lead and cadmium were the most frequently detected contaminants in the inks (Toxics in Packaging Clearinghouse, 2009). The presence of heavy metals contaminates not only compost but also recycled paper products. Packaging designers should specify inks with no heavy metals and confirm that inks used to print their packaging in other countries meet these specifications by regularly testing their packaging.

In the 1990's, EU legislation was introduced to restrict certain azo dyes, especially on products coming into direct skin or oral contact, such as leather, textiles, or toys (Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers [ETAD], 2008). This is because azo dyes are manufactured from aromatic amines, some of which split off carcinogenic amines, such as benzidine, which may be absorbed through skin and the respiratory and intestinal tract. While this specific EU regulation does not apply to packaging materials, it is worth avoiding the use of azo pigments in design-specified printing inks, if possible. It is possible for azo pigments to break down into carcinogenic amines under high temperatures, chemical degradation, or exposure to strong acids, although these conditions are unlikely to occur during the packaging conversion or printing process (Podhajny, 2001). According to the Caribbean Export Development Agency (2009), manufacturers are responsible for ensuring that their products can be certified azo-safe.

### Did You Know?

Water-based inks readily disperse in water and re-settle on the pulp, giving it an undesirable grey color.

### Inks in Recycling

The efficiency of ink removal from a printed substrate can be influenced not only by the ink chemistry selected, but also by the substrate, age of the print, and the type of equipment and methods used by individual paper, paperboard and tissue recycling mills.

According to the European Recovered Paper Council (2009), oil or solvent-based inks, typically used for offset or rotogravure printing, are most easily deinked from paper and the wastewater stream using the flotation deinking process. Inks presenting the most difficulty in the deinking process include UV-cured inks and water-based inks such as inkjet and flexographic inks for newspaper.

UV-cured inks are polymerized and firmly bonded to the surface of the paper, making them extremely difficult to remove from the paper and leading to fiber loss (European Recovered Paper Council, 2009). Nevertheless, in 1992, RadTech, the industry association for UV and electron beam technology, commissioned a study on the repulpability and deinkability of UV and EB inks and coatings. According to the results, paper treated with UV or EB inks and coatings could be repulped and used for low-quality board grades or repulped and deinked and be used for tissue and/or fine writing papers (Korn, 2005). Success in removing UV inks also depends on the volume received as well as the type of equipment installed at individual mills. If a recycling mill receives a large volume of paper printed with UV inks, the mill might tailor their processes to UV ink removal. It might, for example, more finely sort paper grades or modify the deinking process to remove more of the ink, but only if the quantity of UV-printed materials received made the changes economically worthwhile.

Water-based inks have the opposite problem to UV-cured inks. The dye in water-based flexographic and inkjet inks readily dissolves during deinking and disperses into tiny particles that cannot be screened out of the pulp and water slurry (International Association of the Deinking Industry (INGEDE), 2005). These pigment particles remain with the pulp and give the recycled paper an undesirable grayish or speckled color (CEPE, CEPI, FAEP, FEICA, INGEDE, & Intergraf, 2002). However, it should be noted that water-based and UV inks have an environmental benefit in emitting fewer volatile organic compounds to the air during the printing process.

Over 50% of survey responses to the question asking which treatments must be removed in the pulping process mentioned the need for ink removal. In addition, 11% mentioned specific problems that inks cause in the final product, with the majority listing an increase in either the “dirt count” (when ink particles remain concentrated in spots) or effective residual ink concentration (ERIC) (a darkening due to widely dispersed particles of ink) in the paper (Technidyne, n.d.). Metallic and fluorescent inks specks are particularly noticeable, as small particles are more easily visible to the eye. One mill, as well as a few survey respondents, mentioned specific problems with flexographic and/or UV-cured inks. The mill manager said they limit paper with UV-cured inks to 10-15% of feedstock, as those inks do not separate well from the paper. Another respondent cited the challenge in accepting newspapers older than 3-4 months for recycling, as the aging of offset lithographic inks based on oxidative drying materials reduces deinkability significantly.

It is important to note that the equipment in recycled paper mills varies considerably and not all paper mills have deinking equipment. Additionally, certain grades of paper and board may not encounter difficulties during deinking. Technology and equipment exists to deal with ink during the repulping process, but new equipment is expensive and many mills are therefore not equipped for all types of ink removal.

Oil-based inks are easily removed in the deinking process of paper recycling, but they emit volatile organic compounds (VOC) in the use phase. Survey respondents mentioned UV-cured

### Did You Know?

Offset lithographic inks are hard to remove from fiber substrates older than 3 or 4 months.

products as problematic, but there are some indications that not all UV inks pose a problem to recycling based on different types of repulping equipment used. Furthermore, UV and water-based inks produce fewer VOC emissions than oil-based inks do. Water-based inks (flexographic and inkjet) were also noted by respondents as troublesome, but designers can reduce the impact of water-based inks by considering the type of colorant used (dye vs. pigment), as well as by formulation variations. For example, some mills do not use caustic solutions during repulping, which could otherwise solubilize such inks for removal during deinking. While metallic and fluorescent inks were also seen by survey respondents as a problem for recycling, the impact of these colors on recycling is not fully understood because they can be used across a variety of ink systems, from oil-based to UV. Until deinkability is proven, however, their use should be minimized. As noted above, packaging designers should specify inks with no heavy metal content and frequently test any printing done in other countries to verify that it complies with heavy metal regulations. Designers should also avoid azo inks in printed packaging materials.

It is apparent that further investigation of the impact of inks and coatings on recycling and deinkability is needed, though variations in recycling methods and end use requirements must be taken into account.

### MULTI-LAMINATE CARTON

#### What is it?

A multi-laminate carton is a fiber-based package featuring a complex layered structure composed of polymer (low-density polyethylene [LDPE]), aluminum, and fiber. These cartons are made up of 70-75% fiber, with approximately 20% LDPE film and 4% aluminum foil. Lamination is the fusing together of two or more layers of paper with another material. Other layers may include paper, metal foil, or polymers. The plies are usually in roll-fed form (Soroka, 2002). Multi-laminates fall within the larger category of composite packaging, which encompasses any package made of multiple materials.

#### Why is it used?

Lamination is used to provide barrier qualities, strength, cube utilization, shelf-life, or rigidity. The barrier properties of the LDPE and aluminum layers together with an aseptic packaging process allow food items to be aseptically packaged as shelf-stable goods.

#### Where is it found?

Today, these packages hold food items such as soup and broth, juice (including juice boxes for children), milk, soy milk, tofu, tomato-based products, and even wine. Tetra Pak and SIG Combiblock are two well-known manufacturers of aseptic packaging cartons. Plastic screw caps, tabs, and spouts may be added to the laminate carton to make the package reclosable.

#### Multi-laminate Cartons in Composting

To date, these types of packages made with traditional polymers are not compostable.

#### Multi-laminate Cartons in Recycling

Paper laminates offer many packaging advantages in terms of barrier properties, efficiency, cube utilization, reduced weight, and shelf-stability. However, these advantages continue to be offset by the historical lack of widely available, beneficial end-of-life recovery options for these types of packages in the United States, with the exception of waste-to-energy. Because the fiber layers in paper laminates are coated and fused together with plastic and aluminum layers, it can be difficult to separate the fiber layers from layers of other materials.

### Note on Terminology

Multi-laminates with fiber layers may commonly, but confusingly, be referred to as “aseptics,” “brick packs,” “composites,” or even by the trademarked brand name “Tetra Paks.” To add to the confusion, there are a number of other packaging options termed “multi-laminate” that do not contain a fiber layer, such as polymer-foil pouches or wrappers.

Laminates are recyclable, but not in every paper recycling mill. Special equipment is needed, and chemicals may also be used to facilitate the pulping process. There are a limited number of facilities equipped with the appropriate recycling technology optimized to remove the fiber from the other layers; tissue mills are currently best suited for this. Multi-laminate cartons may be pulped in a continuous pulper without the addition of chemicals, but the addition of caustic soda and the use of higher water temperatures speed up the process. In general, aseptic cartons are considered easier to pulp than the gable-top cartons (see Polymers section below), because unlike the poly-coated board used in gable-top cartons, the fiber layers in aseptic cartons do not contain wet strength resin.

The paper layer in laminates is made from strong, high-quality virgin fiber. Because of this, tissue mills are the top customer for recovered laminates, since tissue must be made of strong fiber to meet necessary performance characteristics. The polymer and aluminum layers may be landfilled or used in waste-to-energy facilities.

Though 25 billion multi-laminates were recycled worldwide in 2009, recycling lags in the United States (E. Klein, personal communication, April 2, 2010). R. W. Beck's 2009 survey conducted for the American Beverage Association found that multi-laminates are currently collected in only approximately 30% of the communities in the United States. The Carton Council (2009) is working to expand the U.S. curbside collection of both multi-laminates and gable-top cartons for recycling.

While the primary resource recovered from multi-laminate cartons is fiber, the aluminum and polymer coatings may be recovered and used for waste-to-energy or to make extruded lumber (J. Fielkow, personal communication, April 15, 2010).

### **Alternatives**

Products can be aseptically packaged in other types of materials such as PET or steel. There are no paper alternatives to the “brick” style carton that provide shelf-stability for aseptic packaging.

### **Did You Know?**

At this time, multi-laminate cartons are recycled primarily for their fiber content, and so are sorted with other fiber-based packaging.

### POLYMERS (TRADITIONAL AND BIO-BASED)

#### What is it?

Polymers, such as polyethylene, can be used to coat fiber substrates to impart a range of qualities to the packaging, such as tear resistance, heat sealability, and barrier properties, like grease, water, and chemical resistance. Bio-based polymers are made from renewable feedstocks, such as corn, sugarcane, or cellulose. If they pass the Biodegradable Products Institute (BPI) certification process or the European DIN CERTCO certification process, the various formulations of these polymers, such as polylactic acid (PLA) or polyhydroxyalkanoate acid (PHA), are considered compostable (DIN CERTCO, n.d.; Biodegradable Products Institute [BPI], 2009).

#### Why is it used?

#### Where is it found?

Traditional polymer coatings are used in the creation of a wide range of consumer packaging, including food-contact, pharmaceutical, health care, personal care, and cosmetics packaging. Orange juice and milk cartons are examples of polymer-coated board. Because biopolymer coatings may be certified compostable, they are often used in foodservice packaging applications, such as beverage cartons, hot cups, and food containers.

#### Polymers in Composting

Composters will not take any packaging with a traditional polymer coating or polymer component. However, paper packaging coated with a compostable biopolymer may be acceptable. Most composting facilities will conduct their own field tests to determine whether they will accept compostable biopolymers on a regular basis.

Compostable biopolymers are good alternatives to traditional polymers when composting is the preferred end-of-life option for a paper package. If a smooth printing surface is required, a clay coating may be an acceptable alternative to polymer coating.

#### Polymers In Recycling

Polymer-coated paper, board, and cartons routinely enter the paper recycling process, although some recyclers will not accept them. Like multi-laminate cartons, poly-coated cartons and board may require special pulping equipment or chemicals to fully separate the polymer coating from the fiber. While it may take more time in the pulper to break down, the polymer film will eventually separate from the fiber in the repulping process, where it is removed by a ragger or screened out.

### Did You Know?

Polymer coatings can be removed from paper, but require extra time in the pulper or the installation of special equipment. Without these measures, the polymer coatings can clog equipment.

Recyclers complain that plastics clog screening equipment, and also that they must pay to dispose of the rejected plastic coating sludge in landfill. If the recycling mill collects enough plastic film residue, it may be possible to wash and sell it. Clearly this additional step must take into account the volume of plastic and extra work involved compared to the costs of landfill. Another option is to use the recovered plastic as fuel for a co-generation operation to power the plant, if permits allow.

A larger problem is polymer-coated paper that is treated with wet strength resin for liquid packaging. Gable-top cartons used to package liquids contain a high amount of wet strength resin, which inhibits pulping more than the polymer layer (J. Fielkow, TetraPak, personal communication, April 15, 2010). These cartons are typically pulped in a batch pulper, where the pulping conditions can be controlled and extended as needed, as opposed to a continuous pulper. However, continuous pulpers could also be tailored to repulping cartons, assuming they were collected for recycling in a high enough volume to warrant changing the mill's operating conditions. The main customer for poly-coated gable top cartons is tissue mills, which require high-strength fiber.

#### Alternatives

If the polymer coating is needed for barrier properties, the only alternative option may be a wax coating, which is even less desirable to recyclers than polymer coatings. However, wax coatings have different functions from polymer coatings and are not generally interchangeable.

## RADIO FREQUENCY IDENTIFICATION (RFID) TAGS

### What is it?

Radio frequency identification tags are affixed to packaging and used for automatic identification and data collection purposes. Similar in purpose to a bar code used to track inventory, a RFID tag consists of layers of paper, plastic (PET), and adhesive sandwiching a metal foil antenna or conductive ink (aluminum, copper, or silver), and may include a computer chip or battery (O'Connor, 2008; European Commission, 2007; Maltby et al., 2005).

### Why is it used?

RFID tags store information, such as the contents of a pallet or package, destination in a store, or warehouse location. The information on RFID tags is accessed remotely by readers that display the tag information. The tags have also been suggested as a replacement for UPC bar codes that would not only track inventory information but also inform consumers about how to recycle the package when it is time for disposal (Thomas, 2008). In 2008, the U.S. EPA suggested that RFID tags could play a role in material recovery at a package's or product's end of life by tracking valuable or hazardous materials for collection and recycling (Kowl, 2008).

### Where is it found?

To date, RFID tags remain relatively expensive, and therefore are not in wide use. The tags are used primarily on shipping packaging, such as corrugated containers, high-value merchandise, and pharmaceuticals. Although some retailers have suggested they will soon attach RFID tags to all products sold, the expense of the tags has limited the expansion of this plan (O'Connor, 2008).

### RFID Tags in Composting

While most composters have not yet encountered RFID tags, they would likely not accept packaging with RFID tags attached, due to the tag composition of metals and plastics.

### RFID Tags in Recycling

Because RFID tags are not yet widely used, they remain an unknown for many paper recyclers. Just over half of the survey respondents did not know if RFID tags would be a problem for them, with 16% anticipating problems and 32% stating that RFID tags would not be a problem for recycling. While some recyclers felt that RFID tags could be easily removed in the pulping process, others noted that they are currently relatively rare, but that in larger quantities, they might present unforeseeable issues. Another concern was about the residual effects of special inks or papers that might be used in RFID tags. A 2005 NCASI study determined that RFID tags made of plastic-laminated copper foil antennae remained whole during the pulping process and were screened out with a 98% removal rate. The same study recommended that more research on RFID tags made with conductive silver ink was needed due to concern for elevated silver concentrations in the recycled paper and wastewater treatment system. However, the study's pilot test did not find silver concentrations over the regulatory limits when RFID tags with conductive silver ink were run through a typical pulping process (Maltby et al., 2005).

### Alternatives

RFID tags are not yet widely used, so no alternatives are available, aside from simply not using them. In general, it is recommended RFID tags be saved for use on paper packaging for high value merchandise or for tracking large boxed shipments. If RFID tags are to be used widely, it is recommended to use those that have been demonstrated to not interfere with the paper recycling process, and verify their compatibility with paper recycling mills prior to introducing them into the marketplace.

### WAXES

#### What is it?

Waxes are malleable hydrophobic substances with a higher melting point than fats or oils. Waxes can be natural substances derived from plant or animal origin, produced by purifying petroleum, or completely synthetically made. *Paraffin* is a common synonym, referring to paraffin wax. Waxes are typically applied to fiber packaging to impart water resistance or waterproofing, stain resistance, or for bonding purposes. Wax can be applied by curtain coating or cascade waxing, both of which pass the material through a free-falling curtain(s) of wax (Soroka, 2002). Other application methods include cold-water waxing, which produces a high-gloss wax coating, or dry waxing, which pushes the wax into the fiber, resulting in a matte texture (Twede & Selke, 2005).

#### Why is it used?

#### Where is it found?

Because of its water-resistant characteristics, wax is typically used on packaging that will be refrigerated or frozen or that will be used to ship products on ice. Waxed corrugated containers are often used to ship meat, seafood, fruit, and produce to supermarkets on ice or under refrigeration.

#### Waxes in Composting

Waxes do not present any challenges for composting facilities. This fact suggests that composting waxed corrugated containers, which may often be disposed of along with spoiled food from supermarkets, may be the best way to dispose of waxed paper packaging at end-of-life.

### Did You Know?

Waxed fiber packaging is one of the most undesirable items for recyclers. Wax can cause defects in recycled-content paper and clogs and coats machinery.

#### Waxes in Recycling

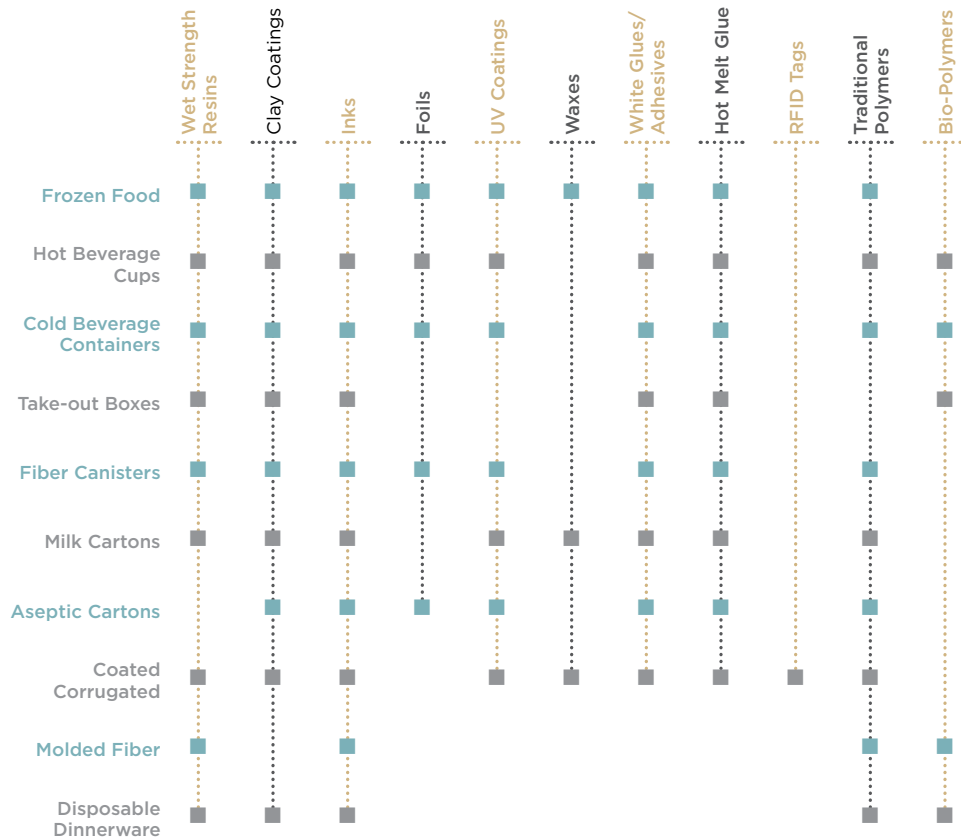
On the contrary, waxed paper packaging is not recyclable. Wax, in the form of “stickies,” causes defects in the finished paper product in the form of dark spots or paper breaks. Wax also clogs and coats machinery and equipment, requiring plant down-time for cleaning. Forty percent of survey respondents mentioned wax, second only to adhesives, as a significant contaminant to the paper recycling process. Some mills have equipment that can deal with wax stickies. Because wax melts with heat, they heat the pulp and then push it through a disperser screen which evenly breaks up the wax particles, rendering the wax much less problematic, since it will not re-agglomerate after dispersal.

#### Alternatives

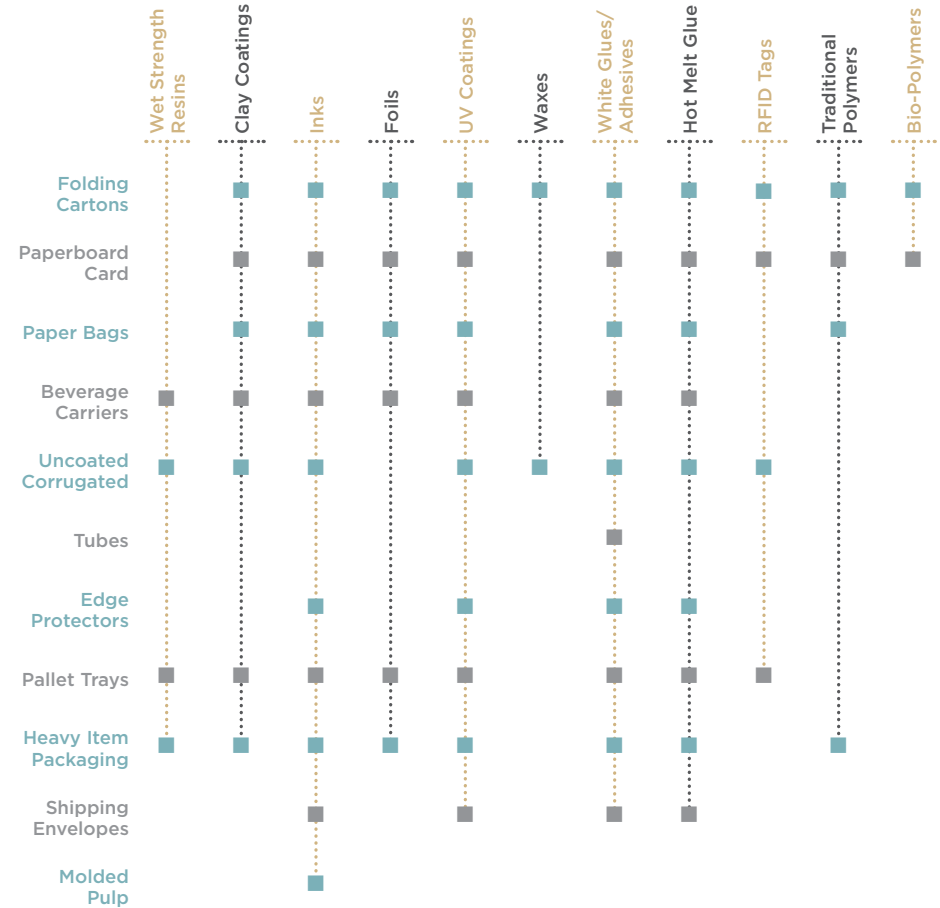
The Fibre Box Association and the Corrugated Packaging Alliance have developed a wax alternative standard that can be used to test the repulpability and recyclability of wax alternatives on corrugated packaging (Corrugated Packaging Alliance, 2009). A number of these alternatives are available and typically use a water-based barrier coating or a water-resistant additive to the paper. Corrugated containers treated with a wax alternative that meets the standard may be labeled as recyclable.



Treatments Commonly Used in the Manufacture and Conversion of Food-Contact Paper Packaging Applications



Treatments Commonly Used in the Manufacture and Conversion of Non-Food Contact Paper Packaging Applications



## Summary Checklist and Additional Guidance

### HERE ARE A FEW QUESTIONS TO CONSIDER WHEN DESIGNING YOUR NEXT PACKAGE:

#### How Does Your Package Fit into Recovery Systems?

- Have you included a step early in the packaging design process to determine the compatibility of your current and future packaging designs with recycling and composting processes?
- Have you considered the availability and type of collection and sorting schemes for recycling or composting over the area where your package will be sold?
- Has the probable fate of the package been considered? Is it beneficial (recycling, composting, waste-to-energy [in Europe]) or is it disposal (landfill or waste to energy [in U.S.]?)
- If the package is to be composted, are all components made of certified compostable biodegradable materials?
- Consider when your packaging will become waste, for instance in retail or event venues, residential settings, or on-the-go. If the package tends to be disposed of with food waste, consider using packaging materials that easily compost to facilitate overall resource conservation.

#### Focus on Physical and Structural Design Elements to Minimize Addition of Treatments or Non-Compatible Materials

- Has an all-paperboard design been considered in place of a paperboard design with plastic inserts?
- Can a blister pack be replaced with an all-paperboard pack with illustrations or photos?
- Could more use be made of interlocking tabs instead of adhesives?
- Can the package be strengthened locally to allow an overall reduction in additives, such as wet strength? For example, use corrugated microflutes (in compression), paper honeycomb, localized ribbing/thickening, etc.
- Can multiple materials be avoided when one or two will meet performance specifications? The fewer types of chemicals, plastics, adhesives, etc. used in packaging production, the more likely they can be removed from the fiber to facilitate recycling and composting.
- If multiple components of different materials are necessary, are they easily disassembled by the consumer in preparation for recycling or composting?

## Guidance on Use of Treatments

- Has the use of potential recycling contaminants (inks, adhesives, additives, coatings, and labels) been minimized?
- Can you avoid the use of fluorescent and extremely dark colors of dye, especially black, to avoid creating specks of unwanted color in recycled content paper?
- Is it possible to minimize the use of wet strength additives and instead use design techniques such as corrugated microfluting, localized thickening or ribbing, or a honeycomb structure to provide strength in wet or moist environments?
- When packaging liquids, can multi-laminate cartons replace poly-coated cartons? Multi-laminate cartons contain no wet strength and are more easily pulped.
- Can labels be reduced or replaced with information that is directly printed on the packaging?
- Can pressure-sensitive and cold seal adhesives be avoided?
- Can hydrophobic adhesives be used in favor of water-based adhesives? Hydrophobic adhesives are easier to separate from both the pulp and the wastewater during the flotation cleaning process, while water-based adhesives can build up on papermaking machinery.
- If using a hot-melt adhesive, is it tough and either high or low density to enable easier removal? Could a hot-melt adhesive with higher-than-typical melting temperatures be used, so that it can remain solid in heated water used for the pulping process?
- On paper packaging, is adhesive applied in discrete “spot weld” blobs, rather than continuous thin strips?
- In packaging aimed at recycling, could foil stamping, paper laminated with aluminum, or transfer metallized paper be used to achieve the same aesthetic effect as paper laminated with metallized film?
- Has paper laminated with metallized film been removed from designs for compostable packaging? If possible, also avoid the use of foil on compostable packaging to minimize rejection by industrial composting facilities.
- Can oil-based inks replace UV-cured or water-based inks (flexographic and inkjet) on packaging to be recycled? Consider avoiding metallic or fluorescent inks until their deinkability is proven.
- Have printing inks intended for either recycling or composting been specified for and checked to ensure no heavy metal content? Do printers for your packaging in other countries comply with heavy metal regulations based on regular testing? Can azo inks be avoided for use on printed packaging materials?
- Can traditional polymer coatings be replaced by certified compostable polymers for compostable packaging?
- Has the amount of polymer coatings been minimized on recyclable packaging to make re-pulping easier?
- Are RFID tags reserved for use only on paper packaging for high value merchandise or for tracking large boxed shipments? Have RFID tags been selected that have been demonstrated to not interfere with the paper recycling process, and has their good behavior in paper recycling mills been verified prior to introducing them into the marketplace?
- Do not use RFID tags on packaging likely to be composted.
- Has a wax-alternative coating been considered for paper to be recycled?
- Has a wax coating been considered instead of polymer coating on packaging that is intended for composting facilities?

### Wood Fiber

The vast majority of paper packaging produced and used in the United States today is made from wood fiber (Smook, 2002). The ingredients for the virgin papermaking process include hardwood or softwood woodchips, sawmill residues, water, and chemicals. Post-consumer or post-industrial recycled paper may also be included, as well as additives such as starch, sizing, pigments, and coatings. If the mill is producing 100% recycled paper, chemicals are not needed for the repulping process but may still be used in the process for deinking or defoaming (GreenBlue Institute, 2009).

To address environmental and social concerns about forestry practices around the world, a growing number of certification programs have been established to encourage sustainable forestry and forest products. Among the most recognized to date are the Forest Stewardship Council (FSC), The Programme for Endorsement of Forest Certification Schemes (PEFC), the Canadian Standard Association's (CSA) National Standard for Sustainable Forest Management, and the Sustainable Forestry Initiative Program (SFI) (Metafore, 2007; International Paper, 2010).

The most common method of creating pulp from wood chips in the United States is by chemical processes, either the kraft (also called sulfate) or sulfite processes. Of the two, the kraft process is more widely used (Smook, 2002). The chemicals, including caustic soda and sodium sulfide, along with de-foaming agents, are added to wood chips and water and placed under high heat and pressure. They dissolve the lignin that holds the cellulose fibers in wood together, producing a fibrous pulp (SPC, 2009). Lignin is a natural adhesive that is non-fibrous in nature, making it unsuitable for inclusion in paper production (Soroka, 2002).

Pulp can also be produced with a mechanical pulping process that uses grinders to extract cellulose from the wood by cutting or abrading it. This process is faster than chemical pulping, but also breaks the fibers, reducing their length and strength. The mechanical (or groundwood) pulp is typically of lesser quality than kraft pulp, and is primarily used in non-packaging applications, such as newsprint and writing paper (Twede & Selke, 2005). It may also be blended with higher-quality chemical pulp to reduce cost (Soroka, 2002).

Finally, semi-chemical pulping combines both methods by combining a partial chemical digestion of hardwood chips with a pass through a mechanical disc refiner to break down the fibers further. This type of pulp is frequently used to make paper for the fluted medium component of corrugated containerboard (Smook, 2002).

Pulp can also be made by mechanically repulping scrap paper (the fibers are physically separated from each other) using water with the possible addition of chemicals. It is then processed into new sheets of paper. Because of the mechanical recycling process, the fibers in paper lose length and strength each time they are broken and chopped. They are not infinitely recyclable, necessitating a constant input of fresh fiber into the marketplace.

Virgin paper pulp for linerboard and medium is usually a shade of tan or brown, depending on the wood type. Recycled pulp can be a range of colors, including brown, gray, or dark cream, depending on the source of the incoming recycled materials. Bleaching not only whitens and strengthens the pulp but also removes additional lignin, which is the source of discoloration in the paper (Soroka, 2002).

### Non-traditional Sources of Fiber

Many plants other than trees can provide fiber that can be turned into paper or packaging (Twede & Selke, 2005). Non-wood fibers represent 7-8% of the total virgin pulp production worldwide (Conservatree, 2004). Most of these non-wood alternatives are annual crops, such as bamboo, hemp, kenaf, straw, and bagasse. In general, these non-wood fiber products represent niche markets, but are becoming more common as consumers look for alternatives to plastic or wood. The use of non-wood fiber is increasing especially in China and India, but also in Africa and Latin America (Twede & Selke, 2005; Smook, 2002). In some cases, these fiber products are made from what was previously considered a waste product.

While non-wood fiber sources make nice paper with good fiber quality and strength, they remain a niche market in the United States due to the difficulties surrounding consistently and quickly procuring the quantities needed to meet the demands of the packaging manufacturing industry. In addition, because non-wood fiber paper and packaging is still a small niche market, there is little information about the manufacturing process and the treatments applied, and even less information about the recyclability of non-wood fiber packaging.

There are several barriers to the wider use of non-wood fibers for paper packaging. First, many of the alternative fiber sources are annual plants, which, by their nature, make proper handling, drying, and storage critical. Unlike wood chips and lumber, they can't be stored outside. If they are not dried properly, for example, they degrade, and there is also a lack of available storage facilities for large volumes of alternative fiber crops.

Second, as annual crops, the plants may be more susceptible to weather conditions, insects, and diseases in any given year. Because of this, there may be tremendous variations in annual productivity and potentially the requirement of additional chemical pesticide treatments or fertilizers.

A third barrier to producing more alternative fiber pulp is that both equipment and pulping techniques are optimized for wood fibers. Twede and Selke (2005) note that alkaline chemical pulping processes (especially soda, a precursor of the kraft process) are most commonly used for non-wood fiber sources. Although bamboo can be pulped in the same process as wood fiber, current pulping equipment and techniques may not be suitable for most alternative fiber

### Did You Know?

Most fiber used to make paper and packaging is wood fiber. Alternative sources typically come from annual crops, such as sugar cane, bamboo, and straw.

sources. In particular, the chemicals used in chemical pulping may be too strong for the lower lignin content of crops such as kenaf, hemp, or straw. According to the Environmental Defense Fund Paper Task Force's White Paper 13 (1996), the higher silica content in grasses (bamboo and straw) can cause other problems. If the pulp contains a higher amount of silica, the paper will be more abrasive, which can damage converting equipment. Silica may also precipitate out of the black liquor as sodium silicate and can cause scaling in the evaporator and recovery boiler equipment at the mill, adversely impacting the typical papermaking process.

Finally, there are economic issues of scale and cost associated with bringing many of these alternative fiber sources to market. Prohibitive costs are often the reason many of these fibers are used only in niche markets, such as fancy writing paper, and not more broadly.

It is presumed that, once pulped, paper made from alternative fiber sources could receive the same coatings and treatments currently applied to wood fiber packaging. According to twenty participants of Conservatree's Paper Listening Study, once it is pulped and made into paper, non-wood fiber paper should be completely recyclable in the existing paper recycling stream along with wood fiber paper. However, a few participants cautioned that there is a lack of information about recycling non-wood fiber paper and that additional studies and pilot projects are needed.

Packaging made from non-wood fibers is compostable, just like wood fiber packaging. The same limitations to composting should apply to fiber packaging across the board, including restrictions on the use of traditional polymer coatings, foils, and other metals.

The following list is not exhaustive, rather a sample of the types of non-wood fiber packaging options available today.

### BAMBOO

Bamboo is a fast-growing perennial grass. There are many species of bamboo that are found on all continents except Europe and Antarctica. It is a significant crop especially in East Asian countries. Bamboo is used in construction, for building products (such as flooring), in textiles, and for food. In packaging applications, it can be made into paper, molded into shapes and trays, and also used in more sturdy “wood-like” applications such as make-up compacts and gift boxes (American Bamboo Society, 2008). For paper applications, it can be used alone to make high-quality artisan papers, but it may be combined with wood fiber for use in items such as linerboard, bag paper, newsprint, and coffee filters (Sustainable is Good, 2009). Bamboo produces a similar quantity of fiber and contains less lignin, but more silica in comparison to temperate pine softwood. It has a physical structure that can be chipped, and it can be pulped in traditional wood pulping equipment with some modifications to deal with its higher silica content (Conservatree, 2004). Because of its popularity in Asia, bamboo packaging is produced and used more frequently in Asian markets.

### HEMP

Hemp is an annual plant that produces long, strong fibers. While it was once extensively grown and used for all types of fiber needs, it fell out of favor in the early 20th century due to its association with its botanical relative, the marijuana plant. It cannot be grown in the U.S. without a difficult-to-obtain permit (Environmental Defense Fund, 1996; Conservatree, 2004). While producing similar amounts of fiber as trees, hemp has less lignin. However, its lignin structure makes it difficult to pulp using a chemical process (Conservatree, 2004). It can be bleached with hydrogen peroxide. Today, there is a niche market for hemp paper, but it is typically more expensive due to the small quantities produced and lack of mills to process hemp fiber.

### KENAF

Kenaf is an annual or biennial crop grown for fiber production. Its fibrous stalk is used in the production of newsprint, as well as for pulp, carpet padding, animal bedding, packing material, etc (Combs, 2000; Geisler, 2009; Environmental Defense Fund, 1996). It may also be added as a source of strong fiber to enhance the quality of recycled paper pulp (ATTRA-National Sustainable Agriculture Information Service, 2008). It contains less lignin than wood, requiring less energy to convert the fibers into pulp (Conservatree, 2004). In addition, the fibers are whiter than wood, and so need less bleaching (Thomas, 2006).

### LEAVES

Packaging can be made from fallen leaves treated with heat, steam, and pressure to clean and form them into shape. The leaves are otherwise a waste product, and typically burned. This material and technique is currently used to produce, market, and sell single-use dinnerware (Verterra, 2010; Smith, 2010).

### PALM FIBER

Palm fiber is the husk biomass remaining after the fruits are stripped out of the fruit bunches of oil palm trees. The fruit is crushed to make palm oil. The fiber from the bunches of husks can be pulped and processed into packaging. It has long fibers which lend strength to the packaging, as well as a naturally waxy finish that repels water and grease (EarthCycle, 2010). It is used to make molded products, such as trays.

The drive to meet growing demand for palm oil by expanding production has led to the conversion of natural forests into plantations and has put significant pressure on ecologically sensitive tropical forests and social pressure on local communities dependent on the forests to make a living. The Roundtable on Sustainable Palm Oil (2009), a non-profit organization made up of industry and NGO representatives, has developed a certification process that ensures palm oil purchased from a certified location is sustainable. While to date certification only applies to palm oil, it is expected that all palm products will be included in future certifications.

### STRAW (RICE AND WHEAT)

Rice and wheat straw, the plant material left over after harvest, can be pulped with water and additives to extract their cellulose for use in making paper and packaging. Straw fiber can be made into corrugated sheets or molded products, such as food service clamshells or protective packaging for fragile products (Rowell & Spelter, 2003). Common additives to the straw pulp might include starch, biopolymers, and clays.

Straw is a free byproduct of the annual crops, which are harvested more quickly and frequently than trees. Other advantages of straw include less lignin and lower moisture content than wood. In addition, because air quality laws in many areas forbid burning crop residue on fields, farmers wishing to clear fields could take advantage of a new market and harvest the straw for sale to paper and packaging manufacturers (Wood, 2002). One of the limitations of crop byproducts is that they are harvested seasonally, so the entire amount of straw would be available for use only within several months after harvest, leading to questions about storage capacity. Also, straw contains a higher percentage of silica than wood and so would require modifications to the traditional wood-fiber pulping process from the bunches of husks (W. Orts, personal communication, October 27, 2008; Environmental Defense Fund, 1996).

### SUGARCANE (BAGASSE)

Bagasse is the plant material left after sugarcane has been harvested and crushed to extract the sugar-rich liquid. This material is often thrown away as a waste product, but may also be burned for energy, or used to produce cellulosic ethanol. Bagasse biomass contains cellulose and can be pulped to make paper and molded products (Fleischer, 2006). As with other annual crops, sugarcane can be harvested more frequently than trees. It has less lignin and requires less bleaching than wood fiber (BioSmart, 2008). Bagasse paper and packaging products, such as polystyrene-like clamshells, are currently more common in countries that grow large quantities of sugarcane, and are slowly gaining use in the United States.

To address the environmental and social effects of growing sugarcane around the world, the Better Sugarcane Initiative is developing a label and certification system to find sugarcane (including sugarcane-based products) that is grown in a way that can be measured by agreed-upon, credible, transparent, and measurable sustainability criteria (Bonsucro Better Sugarcane Initiative, 2011). The BSI is made up of sugar retailers, investors, traders, producers, and NGOs, and was recently spun-off from the World Wildlife Fund.



## Papermaking: Packaging Applications

Papermaking is a term used to describe the process of putting water-saturated pulp slurry, known as furnish, on a papermaking machine to produce any paper type (e.g., office paper, kraft paper, or boxboard). The pulp slurry is a blend of fiber lengths that are optimized for the strength and optical properties of each ply produced (Paper Industry Technical Association [PITA], 2008).

The papermaking process begins at the wet end of the papermaking machine, where a layer of furnish consisting of about 99% water and 1% pulped fiber is dispersed evenly onto a continuously moving wire screen. Some of the excess water is removed by gravity. As the furnish moves through the process, more and more water is removed and the paper is formed as it moves through a series of rollers and dryers. For some types of paperboard, additional layers of furnish may be added (Soroka, 2002). Some coatings and additives, such as starch, sizing, and clay coatings, can be added during the papermaking process (Twede & Selke, 2005).

Virgin pulp and paper mills typically use less than 20% recycled content in their paperboard products. Recycled mills typically use 80% or more recycled content in their paperboard products. Swing mills operate in the middle range—somewhere between 20–80% recycled content (SPC, 2009). According to the American Forest and Paper Association (AF&PA), 74% of all U.S. paper mills use some recovered fiber (L. Rowell, personal communication, May 14, 2010). Both the mill operations and the necessary feedstock are optimized for a particular range of recycled content, from zero to 100%. Altering the type of paper produced and the amount of recycled content it contains may require substantial changes to operations and equipment, as well as expenses costing millions of dollars each time a switch is made to new equipment, for cleaning between runs of different percentages and for mill down time.

## Paper Used in Packaging

Paperboard is a heavy, thick grade of paper which may be separated into two classifications: corrugated containerboard grade and boxboard grade. These two grades are the main types of wood fiber paper used in packaging applications. Molded fiber, made from recycled wood fiber or non-traditional fiber sources, is also used for packaging applications, though in much smaller quantities.

### Did You Know?

Unlike glass and metals that are infinitely recyclable, paper fibers can be recycled between four to six times before they are too short and weak to be used again.

Paper is a highly recyclable material, and if collected after each use, it can be repulped and reused between four to six times before the fibers become too short and weak to be used again (GreenBlue, 2010; WasteOnline, 2010). It can be found as packaging for almost any product for sale today: beverages (milk and juice cartons, composite “brick” packages for shelf-stable milk, juice, and soymilk), food (egg cartons, cereal and pasta boxes), dry goods (boxes for trash bags, fabric softener, facial tissue), clothing (shoe boxes), personal care products (boxes or cards for razors and face creams), take-out food (coffee cups, pizza boxes, paper bags, pastry boxes), electronics, toys, shipping containers, and more.



Virgin corrugated containerboard and boxboard use the same basic production steps—pulping and papermaking. They also use the same basic raw materials. What differentiates various grades of virgin paperboard products is the extent and type of bleaching process used to whiten the pulp, the amount of recycled content in the paperboard, the thickness of the paper, and the finishing or coating steps. Recycled paperboard products differ from virgin types in the raw materials used, the pulping process employed, bleaching, and the cleaning and separation steps (SPC, 2009). Paper packaging made with recycled content must also meet the regulatory requirements set out in the U.S. Food and Drug Administration (2010) guidelines for food-contact packaging applications. There is also a responsibility on the part of the producer to ensure food safety.

Paper mills manufacture rolls of specific grades of paper, defined by basis weight, color, and amount of recycled content. Packaging designers specify the type of paper they would like to use. Converters take the paper and turn it into packaging, such as boxes, adding the treatments requested by the designer. This includes physical conversion, such as cutting, folding, corrugating, shaping, or applying adhesives. Additional treatments are added for barrier properties and appearance, such as polymer coatings, printing inks, foil stamps, labels, or wraps.

Unbleached pulp is commonly used in the fluted medium and liner for corrugated containers, wrappings, sack and bag papers, envelopes, and some types of food packaging boxboard. Bleached pulp is often used for graphic papers, tissue, and solid bleached sulfate (SBS) carton boards, or other applications requiring white paper. Molded pulp is found in trays and shapes used to protect electronics, as well as in fast food drink holders and egg cartons.



The following sections on Recycling, Composting, and Waste-to-Energy detail the existing and emerging processes that result in a beneficial end-of-life scenario for paper packaging.

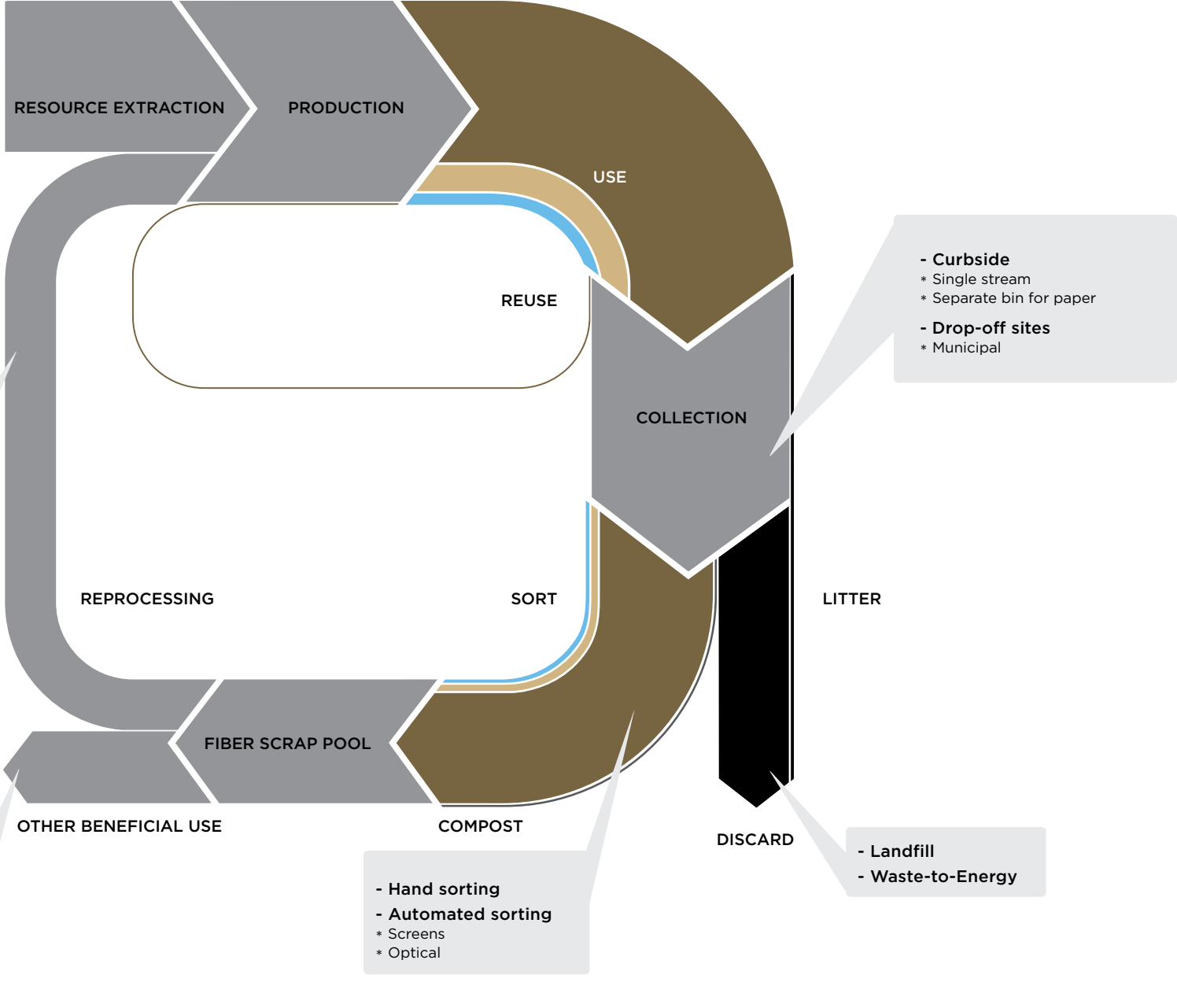
Recycling is considered the highest and best use for paper packaging. However, some paper packaging is not suitable for recycling because it is soiled with food waste or coated with wax. This paper may instead be composted. Finally, in Europe, any paper packaging that does not enter the recycling or composting stream may be incinerated for energy recovery, as it provides a positive calorific gain required for a material to meet the European Union standard for the incineration process. Each of these end-of-life options is described in more detail below.



# Paper | Material Flow

## Key

- Corrugated
- Boxboard & Cartons
- Other Paper Packaging



This graphic is drawn based on data from U.S. EPA's *Municipal Solid Waste in the United States: Facts and Figures 2007* report (U.S. EPA, 2008).

### The Recycling Process: Collection, Sorting, Reprocessing

#### COLLECTION

Paper packaging is frequently collected as a part of municipal and commercial recycling systems. Collection systems for paper include curbside collection, municipal drop-off sites, and commercial collections.

Curbside collections may either use a separate bin for paper (called source-separated or multi-stream collection) or combine the paper with the rest of the collected recyclables in a single bin (known as single-stream). Single-stream collection is growing in popularity in the United States due to its ease of participation for consumers, although the cross-contamination of materials, especially for paper, increases greatly.

Municipal drop-off sites (sometimes called “bring” sites) collect paper in a source-separated manner, typically by requiring the public to sort the paper into categories such as newspaper and magazines, corrugated “cardboard,” mixed (or brown) paper, office paper, etc. There are numerous grades of scrap paper, but common post-consumer scrap grades are OCC (old corrugated containers), ONP (old newspaper), SOP (sorted office paper), and UOP (unsorted office paper). The types of paper collected vary by municipality. For example, waxed corrugated cardboard or telephone books are not desirable to recycled paper mills and are therefore less frequently accepted for collection.

In general, beverages packaged in paper are not included in container deposit programs. However, in one observed instance, the state of South Australia collects paper beverage cartons using a container deposit system. In this case, the specified paper packages (cartons used to hold flavored milks) are returned by the public for the deposit fee at collection depots throughout the state.

Many European countries collect all paper and paper packaging in separate bags, bins, or neighborhood drop-off sites in order to keep the recyclable fiber as valuable and clean as possible and free of food residue, plastic, and broken glass.

#### Did You Know?

Collecting glass separately from paper keeps the paper stream free of contamination. Pieces of glass are problems for paper mills, since the abrasive quality of the particles damages the papermaking equipment.

Commercial collections are tailored by the type of business, such as office building or retail store. Office paper from office buildings, corrugated cardboard from retail shops, and paper packaging or food-contact paper mixed with food waste from restaurants and supermarkets are all examples of commercial collection. In the case of food-contact paper or spoiled food in paper packaging, the appropriate collection would normally be transport to an industrial composting facility instead of a paper recycling mill. However, there are research efforts underway to determine the feasibility of collecting and recycling food-soiled paper packaging (Western Michigan and Global Green’s Coalition for Resource Recovery, 2009).

Efficient transportation of heavy paper bales is important to cost-effective paper recovery, especially as fuel prices rise (Smook, 2002). Paper packaging may be transported via truck, tractor trailer, rail, barge, or container ship. Typically, trucks are the first means of transportation used for collecting paper from the public. Trucks that pick up curbside recycling may travel directly to the material recovery facility (MRF) or take their load to a transfer station, where material is dumped and then loaded on to vehicles (trucks, barges, etc.) with much larger capacity, which then travel to a MRF for sorting. The transfer station process is more cost effective and also reduces the number of trucks on the road. Once paper is sorted, it may be loaded loose (typically into a tractor trailer or barge) or baled for easier transport (truck, container ship, rail).

## SORTING

MRFs are where recyclable materials are sorted from each other. Paper and paper packaging may also be further separated into different categories. The more cleanly sorted, the more valuable the bale of recycled fiber and the more useful it is to a recycled paper mill.

When materials from a single-stream collection system arrive at a sorting plant, paper must be sorted from the other collected materials. Typical non-paper contaminants include plastic bags, bottles, and strapping; metal cans; food waste; and small pieces of glass, plastic, metal, or dirt. In these cases, magnets and eddy currents are used to remove metals. Hand sorting may be used to remove plastic bags and other large contaminants. Hand sorting is also commonly used to remove corrugated containerboard from other types of paper. A vibrating conveyor belt can be used to bounce glass, plastic, and other small contaminants out of the paper stream. Slanted or angle screens may be used to encourage three dimensional objects, such as containers, to roll off and leave flat paper items on the screen. This sorting technique has its limitations, since some non-paper items, such as flattened aluminum cans or steel lids, can be sorted with the paper stream. Any remaining contaminants in the paper are screened out during reprocessing using a variety of screening equipment.

Once paper packaging is separated from non-paper items, it can be sorted into different categories using optical sorting technology. Sorted paper categories are determined by type of fiber, color, and weight or thickness of the paper. The Institute for Scrap Recycling Industries, Inc. (ISRI) (2009), publishes a detailed guide of scrap specifications for various grades of paper. Examples of categories include sorted office paper, corrugated containers, newsprint, hard mixed paper, and mixed paper. Additional sorting can take place within categories, for example, sorting white office paper from colored office paper. Corrugated containerboard is typically removed, most often by hand, before optical sorting. Vibrating conveyor belts are needed to separate or “single sheet” and “fluff” the paper before it can be correctly identified by the optical sensors and sorted by the air jets.

## REPROCESSING

After paper is sorted and baled, all types of paper packaging are mechanically recycled (the fibers are physically separated from each other). All types of paper are repulped in a similar way, combining scrap paper with water in a batch or continuous pulper and running the resulting pulp through a variety of screening equipment. An exception to the usual methods would be made for cartons, in which the fiber may be coated with polyethylene or contain wet strength. This would require the addition of heat and/or caustic soda to the pulping process. Because of the mechanical recycling process, the fibers in paper lose length and strength each time they are broken and chopped. They are not infinitely recyclable, necessitating a constant input of fresh fiber into the marketplace.

Specific feedstock requirements for paper reprocessing machinery are elaborated in the Design Guidance section, which focuses on suitability of all types of paper packaging for recycling and any impediments to the process.

Most recycled paper mills have a preferred type and mix of paper they use depending on the type of paper they wish to produce. They look for consistency across bales with regard to the length and strength of fiber that will meet their product specifications. All types of paper may be re-pulped together to produce recycled-content paper, although each grade of paper is frequently recycled back into that same grade (e.g., corrugated to corrugated) to get the desired qualities of that grade more easily. Because recycled paper fibers become shorter through the recycling process and cannot be recycled indefinitely, virgin fiber must always be added to the system. As paper fibers break down, they can continue to be used in different paper packaging products with lower strength and color requirements, such as molded pulp.

Paper recyclers aim to maximize the yield of fiber from the re-pulping process, but many treatments (e.g. wet strength additives), coatings (e.g. wax, polymers), laminate layers (e.g. foils, polymers), or components (e.g. plastic windows, staples) are all considered contaminants and reduce the amount of fiber that is recovered.

Even after sorting by a MRF, a typical paper recycling plant will re-run the paper through a mini-MRF with magnets, eddy currents, conveyor belts, and hand-sorting to remove large objects, plastic bags, wax-coated paper, and any remaining bottles and cans that may still be present in paper bales. The sorted paper is then combined with water and broken down in the pulper, a piece of equipment resembling a huge blender. The pulping can be done either in a batch pulper, which pulps one discrete batch of paper at a time, or with a continuous pulper, which operates constantly with paper being added and pulp leaving when it reaches the desired consistency.

A ragger, or long rope, is often used to pull out large contaminants that make it past hand-sorters. The ragger dangles into the pulper, where plastic film, rope, string, and unpulpable masses of fiber, such as paper treated with wet strength additives, collect around and adhere to the rope and are pulled out and subsequently landfilled. These unpulpable fibers repel water and often prove to be impossible to separate from each other. They must be disposed of by the recycling mill as waste. Other types of cleaning filters and screens are used to remove smaller contaminants, such as clay coatings, staples, and paper clips. Paper mills may spend millions of dollars each year to dispose of these contaminants at landfills (G. D'Urso, personal communication, May 10, 2010). Some mills may be able to burn the contaminants pulled off by the ragger as fuel in cogenerators that power or heat the facility.

Additional contaminants, such as sand, clay, glass, dirt, foil, ink residue, and bits of expanded polystyrene are screened out and removed by using a variety of techniques, such as screens, centrifuge, and flotation. The pulp may be screened further to disperse and remove wax and adhesive bits, known as "stickies," which can adhere to the equipment and produce defects in the paper.

Tissue mills behave differently than a typical recycled paper mill. In order to recover the valuable strong fibers used to make multi-laminate cartons and poly-coated cartons (such as milk cartons), they have additional equipment and use a combination of heat and caustic soda to break down the packaging during pulping, as the fiber contained in these cartons is extremely difficult to recover using a typical pulping process.

Once sufficiently screened for contaminants, the pulp is run through equipment used during the typical papermaking process, as described above.

### Did You Know?

Though the papermaking process is fairly standard, no two paper recycling mills are alike. They can vary on type of pulping and screening equipment, deinking technology, feedstock, and paper grades manufactured, among other things. What is recyclable in one mill may not be in another.

### REUSE

A small amount of paper packaging is suited for reuse. This is primarily pallets and pallet edge protectors made out of corrugated containerboard that have been designed to withstand multiple loads. Transport boxes made out of corrugated containerboard are also frequently re-used by the commercial sector as goods are shipped between warehouses and stores.

## Composting of Paper Packaging

Compost is defined by the U.S. Composting Council (USCC) (2008a) as the managed process of controlled decomposition of organic material by aerobic microorganisms, producing compost (also called humus), along with carbon dioxide, water vapor, and heat. The aerobic decomposition process sanitizes the compost product through the generation of heat and stabilizes it to support plant growth (U.S. EPA, 2009c). Any organic material is compostable, including most food scraps, plant matter (lawn clippings, leaves), all types of wood (sawdust, chips, tree branches), animal manure from herbivores, compostable biopolymers, and all kinds of paper and paper products. While home composting is practiced by many people in their backyards, this document is focused on industrial composting facilities. These facilities operate at large scale and achieve higher temperatures and more consistent conditions than most home composters can realize. In 2008, the U.S. composted 22.1 million tons of organic waste (U.S. EPA, 2009b). The same report shows that organic material continues to comprise the largest fraction of municipal solid waste, with food scraps and yard trimmings making up 26% and paper making up 31% of the total U.S. municipal solid waste stream (U.S. EPA, 2009b).

Most paper packaging today is recycled to serve the highest and best use of the material. However, composting remains a beneficial end-of-life option for the paper and paper packaging that is not well-suited to recycling (e.g. food- and beverage-soiled paper and waxed corrugated). In particular, the main benefit of diverting paper and other organics from landfills is avoidance of the creation and unmanaged emission of methane, an extremely potent greenhouse gas. Well-run composting facilities emit little methane (U.S. Composting Council [USCC], 2008b; USCC, n.d.). Compost itself has other benefits, such as increasing the soil moisture-holding capacity and reducing the need for fertilizers and herbicides (USCC, 2008a; USCC, 2008b). Paper can be an important source of carbon in the composting process by balancing nitrogen-heavy waste to maintain the correct habitat for the composting bacteria. Adding paper to organic collection from restaurants, institutional kitchens, or supermarkets, where soiled paper may make up a large percentage of the organic waste stream, is especially desirable to composters because it is accompanied by the diverted food waste (USCC, 2010).

Although residential organics collection for composting is growing in the United States, it remains uncommon outside of seasonal yard waste and leaf pickup in the fall. In 2004, *BioCycle Magazine* tallied 3,474 composting facilities in the U.S. that accepted only yard waste (Simmons et al., 2006). In 2009, *BioCycle* conducted a study around food waste composting, and found approximately 90 communities in nine different U.S. states that currently provide residential food waste collection and composting programs, with California and Washington State leading the way with the most participating communities. Program implementation ranges from large cities including San Francisco and Los Angeles, California; Denver, Colorado; and Seattle, Washington, to smaller communities such as Boulder, Colorado and Huron, Ohio (Yepsen, 2009). Residents are typically provided a kitchen pail and separate curbside bin along with instructions on what may be included. Organics collection may also take place at institutions such as hospitals, prisons, corporate campuses, and universities, as well as at restaurants, sports arenas, and concert venues. Finally, some supermarkets dispose of spoiled food along with its compostable packaging at composting facilities. The growing number of food waste collection and composting programs make industrial composting a viable future option for the beneficial recovery of compostable packaging.

It is important to note that industrial composting facilities are strictly permitted at the state level in the U.S., especially if they take food waste or sewage sludge (U.S. EPA, 2009d). Some communities object to the operation of composting facilities for odor reasons, a problem which composting facilities try to avoid and which can be solved by using the correct composting techniques. In an industrial setting, compostable material is mixed and ground up into small pieces. It may be spread in windrows, placed in static aeration piles, or processed in a vessel. Another less common composting option that operates on a smaller scale is vermicomposting, which uses worms to break down organic matter. Anaerobic digestion is considered a waste-to-energy method, but once completed, the resulting material may be used as feedstock for composting in a traditional manner.

Bacteria begin the decomposition process, creating high temperatures that facilitate the breakdown of the components. Aeration is necessary to maintain aerobic conditions: windrows are turned to provide aeration and mixing, air is forced through static piles, and the enclosed vessels rotate or are mixed internally. Moisture is added as needed. According to the ASTM D-6868 testing standard (2003), a polymer-coated paper is considered compostable if it has disintegrated so no more than 10% remains after twelve weeks in a composting process, meets the specified biodegradability test, can support plant life, and is free of contaminants such as heavy metals, pesticides, or harmful pathogens.

To reduce pathogens, composters must comply with the U.S. EPA Processes for Further Removing Pathogens (PFRP) and the corresponding state regulations and certify that the temperature of the material reaches 55°C for three consecutive days for static aeration or in-vessel composting, or fifteen consecutive days for windrow composting (U.S. EPA, 2003). Once the compost has gone through the initial biodegradation, it may be cured for several months in a lower temperature phase to stabilize it (USCC, 2008a).

As with any material reprocessor, the size of the facility and equipment used determines how easily contaminants are removed. A large facility with state-of-the-art equipment will be able to screen contaminants out at the end of the composting process, while a smaller facility may prefer to strictly regulate the incoming raw materials to reduce contaminants from the start.





## COMMONLY COMPOSTED PAPER PACKAGING

All types of paper and paper packaging may be composted as long as there are no undesirable components or layers. However, composting facilities may choose to restrict the packaging accepted to those items which have been certified compostable by the Biodegradable Products Institute (2008) or to packaging items of their own choosing. Industrial composting is a particularly promising future option for the beneficial recovery of food service paper packaging because food scraps, liquid, or grease present no problems for composting. Commonly composted paper packaging includes:

- Old corrugated containers, including paraffin wax-coated containers used for produce and meats, and soiled pizza boxes.
- Food-contact waste paper and packaging, such as paper take-out bags, wax-coated food wrappers, sleeves and clamshells, napkins, paper plates, soiled paper cups (with compostable coatings), and coffee cup sleeves.
- Molded fiber egg cartons and trays, such as take-out drink holders, meat and produce trays, etc.
- While not considered as packaging, old newspapers or newsprint may also be composted if they are no longer acceptable for recycling due to age or condition.

## UNDESIRABLE MATERIALS FOR COMPOSTING

Unlike paper recycling systems, composting operations will accept wax-coated paper, although they typically refuse any paper with plastic or foil coatings. Each composting facility has a different list of items that they consider undesirable or that they refuse to take altogether. However, most consider the following items unacceptable or to be avoided:

- Any plastic resin, either as a coating, a piece of a package, or a stand-alone product, that does not conform to ASTM standards D-6400 (Compostable Plastics) or D-6868 (Biodegradable Plastics Used as Coatings on Paper and Other Compostable Substrates).
- Glass.
- Any metal such as wire and filaments. Metal foil may or may not be accepted by composting facilities.

In the United States, the Biodegradable Products Institute (2011) has developed a standard for certification and third-party testing of biodegradable packaging, as well as a “certified compostable” label for use on packaging. In addition, many industrial composters provide testing services for packaging manufacturers to determine if their package is compostable at that facility. This type of testing is often a requirement mandated by the composting facility before particular types of packaging are allowed to be sent there for disposal.

Some large industrial composting facilities have enough leverage that they can specify exactly which types of packaging may be brought to their facility for composting in order to minimize potential contaminants. Cedar Grove Composting near Seattle, Washington, has developed its own line of compostable food-service ware, which is the only food-service ware that is accepted at their facility (Cedar Grove Packaging, 2008).

## Waste-to-Energy Processes

Waste-to-energy (WTE) describes a process of turning waste products into energy in the form of fuel, electricity, or heat. This may be done by incineration or other techniques, such as gasification (including plasma arc gasification) or anaerobic digestion. WTE is most popular today in countries where landfill area is scarce or where laws are in place mandating the pre-treatment of municipal solid waste prior to landfilling, such as the European Union member countries. For example, after treatment in an incinerator with energy recovery, the remaining ash residue represents 20-30% of the original weight of the municipal solid waste feedstock and only 10% of the original feedstock volume (U.K. Department for Environment, Food and Rural Affairs (DEFRA), 2007).

While the European Union considers incineration with energy recovery to be a beneficial end-of-life option for packaging that provides a calorific gain, this is not the case in the United States. The U.S. Environmental Protection Agency (EPA) (2010b) considers waste-to-energy methods on par with disposal in landfills as the least preferred option for disposing of packaging. However, because waste-to-energy is commonly used as a beneficial end-of-life option for municipal solid waste and packaging in Europe, it is discussed here.

In the United States, WTE facilities are primarily regulated under the federal Clean Air Act and the Resource Conservation and Recovery Act (Waste-to-Energy Research and Technology Council, n.d.). The Clean Air Act requires plants to obtain permits with provisions based on plant size and technology. Federal and state regulators enforce emissions limits for sulfur dioxide, hydrogen chloride, nitrogen oxides, carbon monoxide, particulates, cadmium, lead, mercury, and dioxins. Operating conditions, monitoring, reporting, training, and safety requirements also apply under the Clean Air Act. The Resource Conservation and Recovery Act requires testing of the plants' ash residue to determine that the ash is non-hazardous and properly disposed or reused. States often take authority for enforcement of the regulations and require even stricter environmental limits on the facilities' operation than imposed by the federal rules. State-specific requirements can include more strict emission limits, testing, or reporting than federal rules; additional solid waste management, recycling, noise, site selection, transportation, and related regulations; and water use or waste water management limits.

There are almost no guidance documents that consider whether packaging is suitable for disposal in waste-to-energy facilities, and there is especially limited guidance for the United States. The European Union has a standard, EN13431:2004, stating that in order to be considered recoverable in the form of energy, "packaging shall provide a calorific gain in the energy recovery process" (CEN, 2004). According to this standard, all paper packaging, including all types of paper and board, starch, and cellulose, are considered to fulfill the requirements for energy recovery. Polymers and aluminum foil layers are considered acceptable as well. Aside from specifying the need for packaging to provide calorific gain and not contain any hazardous waste or heavy metals, this document does not contain additional design recommendations for paper packaging that is bound for waste-to-energy facilities.

## INCINERATION

Although common in the past, waste incinerators without the ability to capture energy are becoming less common, as demand for energy grows. Emissions, especially of dioxin, particulate matter, and heavy metals, remain the main concern surrounding incinerators. The ash remaining after incineration must be disposed of, and depending on the incineration and filtration technology used, may contain toxic compounds that must be landfilled.

### INCINERATION WITH ENERGY RECOVERY

New waste-to-energy facilities are built typically to dispose of waste, but include the ability to recover energy from the process. Many countries in Europe have landfill bans for any untreated municipal waste, so anything not recyclable or compostable must pass through an incinerator for energy capture before the resulting ash can be landfilled (DEFRA, 2009). Hazardous waste presents some exceptions to this. The household waste is burned at temperatures of over 1000°C. Ferrous metals are separated out, and any remaining ash or slag residue is landfilled. The waste stream must be characterized and understood in order to keep the calorific value of the waste consistent. DEFRA (2007) notes that in the U.K., raw municipal solid waste has a calorific value of 9-11 megajoules/kilogram, while pre-treated refuse-derived fuel can range up to 17 MJ/kg. According to Dr. Helmut Allgeuer, the manager of the MVA Pfaffenau facility in Vienna, Austria, typical waste-to-energy facilities operate using a feedstock range of 7-15 MJ/kg (personal communication, November 12, 2008). Plastics have a much higher calorific value and must be mixed with organics and other materials to lower the calorific value. Bulky waste must be shredded before entering the incinerator.

The hot flue gas generated by the burning waste heats water in a boiler. The water converts to steam and drives turbines with heat exchangers to create electricity in a generator. Once the water cools and condenses, it returns to the boiler. In addition to generating electricity, some incinerators with energy recovery use co-generation technology to harness the heat generated from the condensing steam to heat and provide hot water to nearby residential and commercial buildings. Plants are required to monitor for emissions based on national or state pollution regulations. The newest facilities extensively monitor emissions, providing multiple filters that remove pollutants including chlorine, fluorine, heavy metals, toxics (such as dioxins), and sulfur and nitrogen oxides, and measuring the size of particles ultimately leaving the incinerator stack.

### Did You Know?

According to the U.S. EPA, in 2009, 11.9% of U.S. municipal solid waste was incinerated with energy recovery.

While generally accepted throughout Europe, incinerators are unpopular in many other countries where the public has experienced air pollution generated by the operation of older plants. In particular, emissions of dioxins and heavy metals have been a major concern. Today, air and water emission regulations for new waste-to-energy incinerators are much more stringent and in practice are less than 10% of typical emissions 20 years ago (DEFRA, 2007; European Parliament and Council, 2000; Waste-to-energy Research and Technology Council, n.d.). In Europe, where many newer waste-to-energy facilities are operating, dioxin emission regulations specify a maximum level of 0.1 ng/m<sup>3</sup> over a six to eight-hour period. For the U.K., DEFRA (2007) puts this in perspective by comparing the amount of dioxins emitted from a waste-to-energy facility to dioxins emitted by accidental fires in a U.K. city of 200,000 over the same period of time.

Capital costs for construction of a new incinerator with energy recovery are considerable, especially for a large facility with an emphasis on strict emissions controls. In the case of MVA Pfaffenau facility in Vienna, built in 2008 with a capacity of 250,000 tons/year of waste, capital costs were approximately 200 million euros, but sale of both electricity and heat amount to approximately 8 million euros/year (Dr. H. Allgeuer, personal communication, March 26, 2010). Coupled with on-going operating and maintenance costs, it is impossible to finance a new facility based solely on the sale of energy. The cost of waste disposal (once large landfills become unnecessary) must also be included. In addition, to maximize the plant's value, infrastructure must be present in the area in order to capitalize on the cogenerated steam heat that can be harnessed for heat and hot water.

## GASIFICATION

Gasification is a process that subjects organic materials to high temperatures, pressure, steam, and controlled amounts of oxygen or air to break down those materials into their basic chemical constituents, carbon monoxide and hydrogen, producing a synthesis gas, or syngas.

Incineration differs from gasification in amount of oxygen used. Incineration burns or oxidizes the organic material, while gasification chemically separates organic material into its molecular components (U.S. Department of Energy, 2008b). Gasification technology, first developed in the 1800s, is currently used to produce electricity by gasifying fossil fuels, like coal, into syngas. However, any carbon-containing material, such as wood waste, biomass, or municipal solid waste can also be used to produce syngas. The syngas can be cleaned of pollutants, such as sulfur or heavy metals, resulting in lower pollutant emissions than traditional incinerators produce. Syngas can be used to drive turbines or engines to produce electricity, or as a replacement for natural gas or diesel fuel (Westinghouse Plasma Corporation, n.d.).

There are various gasification technologies in use today, including fluidized bed gasifiers, fixed-bed gasifiers, and plasma arc gasifiers, or a combination of these. One combination option first gasifies municipal solid waste with a fluid bed gasifier, and then uses a plasma converter, along with steam and oxygen, to clean the syngas and gasify any additional organics that remain after gasification (Advanced Plasma Power, 2010). Plasma arc gasification is a form of gasification which uses high temperatures created by an electrical arc gasifier, pressure, and a controlled oxygen environment to break carbon-containing feedstock into syngas and an inert glass-like slag (Westinghouse Plasma Corporation, 2010).

Gasification plants can use municipal solid waste as a feedstock, eliminating the need to send waste to a landfill. Some communities have suggested they will empty their landfills completely by sending the contents through plasma arc gasification (Skoloff, 2006). This type of gasification is currently in use in several countries, including Taiwan, Japan, Canada, and the U.K (Advanced Plasma Power, 2010). Plans for plasma gasification facilities are proposed for Florida and other US states (Florida Department of Environmental Protection, 2010).

If oxygen is used in the gasification process instead of air, the carbon dioxide produced during gasification is concentrated and can be more easily captured and sequestered than in the incineration process or in landfills (U.S. Department of Energy, 2009). Unlike incineration, no bottom ash or fly ash is produced, and any metals or other inorganic substances collect as inert glass-like slag at the bottom of the tank and can be used as aggregate for activities such as road building. Gasification plants do require an enormous amount of energy to operate, and frequent maintenance is needed to maintain the equipment and ensure safety. Preprocessing the waste, ensuring a supply of pure oxygen, and cleaning the syngas incur additional costs and power needs that counterbalance or outweigh the efficiency of using syngas to make electricity (Wikipedia: "Gasification.").

### ANAEROBIC DIGESTION

Anaerobic digestion is the process by which microorganisms break down organic material in the absence of oxygen and produce biogas. Anaerobic digestion reduces the mass and volume of organic material substantially (U.S. Department of Energy, 2008a). It is well-suited to processing wet wastes, such as sewage sludge, but in practice any carbon-rich substance (yard clippings, paper products, food scraps) can be included, making it a good option for institutions and university campuses that generate food waste. Waste material is shredded and put into sealed containers, “seeded” with material containing anaerobic bacteria, and then held at the constant temperatures preferred by the bacteria. The bacteria consume the feedstock, ultimately producing the biogas, along with water and unconsumed digestate solids. The biogas is mainly comprised of carbon dioxide and methane, which can be burned for electricity and the waste heat used for heating (California Energy Commission, 2008). Water produced by digestion must be treated before release into natural waterways, as it typically has high levels of BOD (biological oxygen demand) and COD (chemical oxygen demand). Digestate solids are typically sent through a traditional aerobic composting process to mature. Afterward, the compost is used to improve soil (U.S. Environmental Protection Agency, 2010a).

Anaerobic digestion directs organic material away from landfills, thereby avoiding landfill methane emissions. Along with the easily captured biogas that produces energy, anaerobic digestion also produces digestate sludge, a beneficial product that enhances soils and fertilizes crops and can be further composted if needed. A benefit of this technology is that it can be quite decentralized, operating on small farms, campuses or institutions, or in small, local areas. However, anaerobic digestion facilities require a high level of technical expertise to operate and high capital costs to build. Though anaerobic digestion and land application of most organic wastes, including compostable packaging, is not objectionable, many communities have a “not in my backyard” (NIMBY) reaction and object to the land application of anaerobically treated sewage sludge for odor or health reasons.



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**Royal Oak Farm, LLC**, Evington, VA

## PAPER MILLS AND RECYCLERS

**MeadWestvaco**, Covington, VA

**Pratt Paper**, Staten Island, NY

**Sonoco Paper Mill**, Richmond, VA

**Visy Paper Mill**, Melbourne, Australia

## WASTE-TO-ENERGY

**MVA Pfaffenau**, Vienna, Austria

## MATERIAL RECOVERY FACILITIES

**Eco-Cycle**, Boulder, CO

**Norcal**, San Francisco, CA

**SP Recycling**, Knoxville, TN

**Sprint Recycling**, New Jersey

**Tönsmeier**, Oppin, Germany

**Veolia**, Brussels, Belgium

**Visy**, Melbourne, Australia

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## Existing protocols and standards that define end-of-life options for paper packaging

ASTM International Standard D6868-3  
Standard Specification for Biodegradable  
Plastics Used as Coatings on Paper and  
Other Compostable Substrates.

DIN CERTCO  
DIN-CERTCO operates a certification  
scheme in Europe for compostable products  
made of biodegradable materials and  
licenses the use of the corresponding Mark  
developed by European Bioplastics. To be  
certified compostable by DIN CERTCO, a  
package must comply with either ASTM  
6400 or EN 13432 standards.

Cedar Grove Composting. Compostability  
Testing. Testing of products that already  
meet ASTM standards 6400, 6868, or  
have received BPI Certification. Retrieved  
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European Committee for Standardization  
(CEN). (2000). EN 13432:2000  
"Requirements for packaging recoverable  
through composting and biodegradation—  
Test scheme and evaluation criteria for the  
final acceptance of packaging."  
[http://www.cen.eu/cen/Products/Where/  
Pages/default.aspx](http://www.cen.eu/cen/Products/Where/Pages/default.aspx)  
Defines the characteristics a material must  
have to be claimed as "compostable" and  
subsequently recycled through composting  
of organic solid waste in the European Union.

European Committee for Standardization  
(CEN). (2004).

- EN13428:2004 "Packaging. Requirements  
specific to manufacturing and  
composition. Prevention by source  
reduction."  
[http://www.cen.eu/cen/Products/Where/  
Pages/default.aspx](http://www.cen.eu/cen/Products/Where/Pages/default.aspx)
- EN13429:2004. "Packaging. Reuse."  
[http://www.cen.eu/cen/Products/Where/  
Pages/default.aspx](http://www.cen.eu/cen/Products/Where/Pages/default.aspx)
- EN13430:2004. "Packaging. Requirements  
for packaging recoverable by material  
recycling."  
[http://www.cen.eu/cen/Products/Where/  
Pages/default.aspx](http://www.cen.eu/cen/Products/Where/Pages/default.aspx)
- EN13431:2004. "Packaging. Requirements  
for packaging recoverable in the form of  
energy recovery, including specification of  
minimum inferior calorific value."  
[http://www.cen.eu/cen/Products/Where/  
Pages/default.aspx](http://www.cen.eu/cen/Products/Where/Pages/default.aspx)

Fibre Box Association  
Voluntary Standard For Repulping and  
Recycling Corrugated Fiberboard Treated to  
Improve Its Performance in the Presence of  
Water and Water Vapor (Wax Alternatives  
Standard).  
[http://www.corrugated.org/  
WaxAlternatives/](http://www.corrugated.org/WaxAlternatives/)

Tag and Label Manufacturers Institute, Inc.'s  
Recycling Compatible Adhesive Standards

- Mill Recycling Trial Protocol
- Laboratory Testing Protocol For Paper  
Labels Coated With Recycling Compatible  
Pressure Sensitive Adhesives
- Determination of Adhesives in Paper  
Handsheets by Image Analysis
- Specification for Paper Labels Coated with  
Recycling Compatible Pressure Sensitive  
Adhesives

Available at  
<http://www.tmi.com/recycling-standards.php>

Toxics in Packaging Clearinghouse, Model  
Legislation  
<http://www.toxicsinpackaging.org/>  
This model legislation was originally drafted  
by the Source Reduction Council of Coalition  
of Northeastern Governors (CONEG) in 1989.  
It was developed in an effort to reduce the  
amount of heavy metals in packaging and  
packaging components that are sold or  
distributed throughout the United States.  
Specifically, the law is designed to phase  
out the use and presence of mercury, lead,  
cadmium, and hexavalent chromium in  
packaging within four years in states that  
enact the legislation. As of 2008, nineteen  
states have adopted this legislation. In  
states using this law, all packaging must  
have a Certificate of Compliance or face  
enforcement actions.

U.S. Composting Council's Seal of Testing  
Assurance  
Tests the physical, chemical, and biological  
properties of compost being produced,  
including Part 503 regulated metals.  
[http://www.compostingcouncil.org/  
programs/sta/](http://www.compostingcouncil.org/programs/sta/)

U.S. Code of Federal Regulations, Title 21,  
Part 176  
Additives re: food packaging: Indirect  
food additives: paper and paperboard and  
components

21 CFR 176.170: Components of paper and  
paperboard in contact with aqueous and  
fatty foods  
"Substances identified in this section may be  
safely used as components of the uncoated  
or coated food-contact surface of paper and  
paperboard intended for use in producing,  
manufacturing, packaging, processing,  
preparing, treating, packing, transporting, or  
holding aqueous and fatty foods, subject to  
the provisions of this section."

21 CFR 176.180: Components of paper and paperboard in contact with dry food  
“The substances listed in this section may be safely used as components of the uncoated or coated food-contact surface of paper and paperboard intended for use in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting, or holding dry food...”

21 CFR 176.260: Pulp from reclaimed fiber  
“Pulp from reclaimed fiber may be safely used as a component of articles used in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting, or holding food, subject to the provisions of paragraph (b) of this section.”

U.S. EPA Code of Federal Regulations Title 40, Part 503, Appendix B, Section B  
Processes to Further Reduce Pathogens (PFRP).

Mandates the time that compost must be at designated temperatures to reduce pathogens. Also specifies testing that must be done to identify heavy metals.

Western Michigan University and Global Green’s Coalition for Resource Recovery. (2009, May 12). Draft Recyclability and Repulpability Protocol for Fiber-Based Hot Cups. Retrieved February 23, 2010, from [http://thecorr.org/recyclingpaperpackagingwithOCC\\_whitepaper.pdf](http://thecorr.org/recyclingpaperpackagingwithOCC_whitepaper.pdf)

This draft proposal for a new recyclability and repulpability protocol suggests that fiber-based hot cups and other food-service packaging may be able to be collected and recycled with old corrugated containers (OCC).



## Labels

### GENERAL

The International Organization for Standardization (ISO) (1999) has a labeling standard ISO 14021 that specifies how environmental claims or labels may appear on product or packaging.

The U.S. Federal Trade Commission also maintains a document, “Guides for the Use of Environmental Marketing Claims,” commonly called the “Green Guides.” The Green Guides specify how environmental claims and labels may be used on products or packages (U.S. Federal Trade Commission, 2009).

### CORRUGATED

The most widely used and known labeling of paper fiber packaging has been developed by the Corrugated Packaging Alliance. The recycling symbol indicates the package can be recycled but does not imply the materials are made from a certain percentage of recycled fibers.

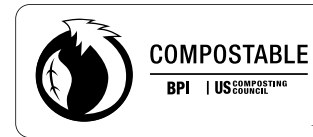


Because wax coatings are considered contaminants to the recycling process, the Corrugated Packaging Alliance encouraged the development of recyclable alternatives that still provide the same moisture and vapor barrier properties as wax. To ensure that alternatives are recyclable, the Fibre Box Association created a voluntary recyclability and repulpability standard for corrugated containers with alternative coatings. If a corrugated container coated with an alternative coating has passed the required tests and meets the voluntary recyclability and repulpability standard developed by the FBA, it may use the modified “Corrugated Recycles” label created by the Corrugated Packaging Alliance.



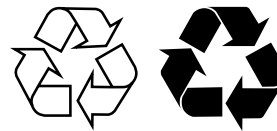
### COMPOST

This label is owned by the Biodegradable Products Institute, which allows member companies that have their finished products certified as meeting ASTM D6400 and/or ASTM D6868 to use the logo to provide assurance of compostability or biodegradability. The label also requires the use of accompanying text, as follows. In the US, the text is, “This product is intended to be composted in a large scale facility. These do not exist in all communities. Please check with your local officials.” In Canada, it reads, “For collection in municipal composting programs, where approved.”



### MÖBIUS LOOP

This commonly used symbol, also known as “the chasing arrows,” is widely recognized as having to do with recycling. However, there is still confusion and uneven interpretation world-wide about whether it means a package is recyclable, whether it is made from recycled content, or both. The U.S. Federal Trade Commission’s Green Guides note that this symbol refers to both recyclability and recycled content when used on a package. When used without a specific number and percent, it implies that the package is made from 100% recycled content.



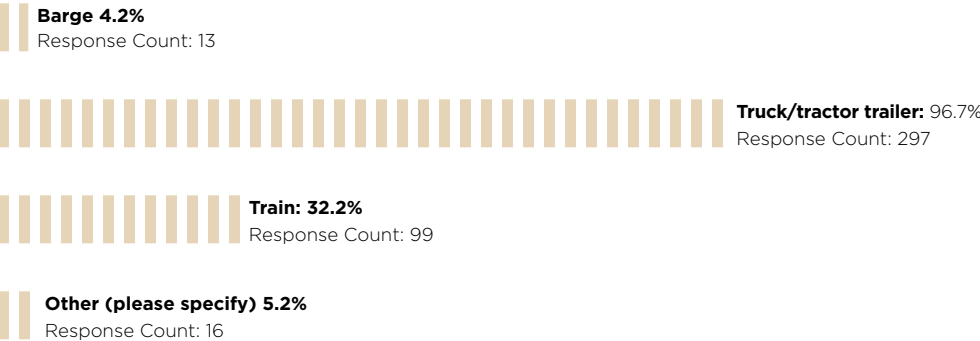
At this time we know of no other labeling schemes or protocols in the United States specifically developed to promote fiber recycling or composting.

An on-line survey was widely distributed to members of the Technical Association of the Pulp and Paper Industry (TAPPI) who identified themselves as paper recyclers. 328 individuals gave complete or partial responses to the survey. It is important to note that, aside from being TAPPI members, the survey respondents did not identify themselves, their positions, or the companies they represent, or provide proof of their expertise in the subject matter. The survey questions, a summary of the survey results, and discussion of the results is included as Appendix C.

**QUESTION 1:**

**How is paper delivered to your plant?**

307 responses, 16 comments



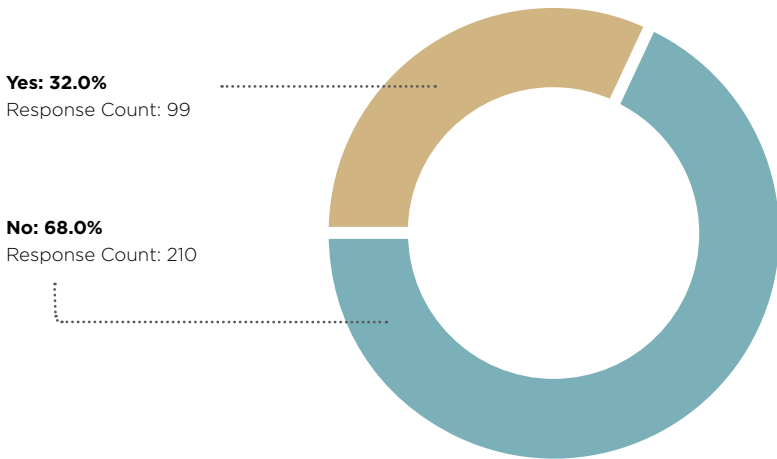
*Discussion of the 16 comments given:*

- 12 comments do not list methods of paper delivery other than the methods listed and therefore do not provide us with any information that is not given by the multiple-choice answers.
- Three responses specify that their paper is delivered by ship.
- One response specifies that their facility receives residential drop-offs.
- It is worth noting that nearly every respondent indicates that a truck/tractor trailer performs some portion of their delivery process.

**QUESTION 2:**

**Does shredded paper pose a problem to your process?**

309 responses, 91 comments



**Discussion of the 91 comments given:**

- 88 responses detail negative aspects of shredded paper in their process, two responses describe positive characteristics of shredded paper in their process, and one response describes both positive and negative aspects of processing shredded paper.
- 33 responses pertain to the issue of contamination within shredded paper. Among these responses various issues regarding contamination are presented:
  - Most responses refer to the difficulties of sortation and contaminant detection that arise from the small sizes of both shredded paper and intermingled shredded contaminants.
  - Few responses center on the persistence of shredded contaminants (such as plastic) long into the pulping process whereupon they may clog machinery.
  - One response claims that in addition to the problem of detection and sortation, brokers will purposefully include contaminants with shredded paper to add weight and inflate price.
  - The aforementioned contaminants include plastic, brown fiber/paper, wax-impregnated boxes, wet strength boxes, adhesive, groundwood, and ash.

- 23 responses involve the problem of loose pieces of shredded paper becoming separated from the bale during transport, handling, and/or feeding, causing housekeeping issues health issues, and fire hazards:
  - Of the four responses that explicitly mention fire hazards, one specifies the cause of the hazard being loose paper blown into the machinery's engine compartment.
  - Five responses mention particulate matter in the air, causing dust and presenting both housekeeping problems and respiratory issues for their workers. This may be one of several issues caused by very finely shredded or pulverized paper (see below), but not necessarily all shredded paper.
  - It is worth mentioning that several of these responses state that these issues would be eliminated if the shredded paper were baled more effectively and completely.

**Attitudes regarding the favorability of shredded paper in the pulping process are mixed:**

- Four responses argue that shredded paper is more difficult to pulp:
  - Two of these responses explicitly mention pulverized paper as causing the problem. Of these responses, one explains that the problem arises when pulverized paper sticks together whereupon it is rejected by the drum screen or clogs the drum screen.
  - One response simply states that "[it is] difficult to feed [the] pulper at [a] steady rate."
  - One response states that shredded paper tends to float on the surface of the pulper and is consequentially wasted when it is rejected by the thrash well.
- Three responses claim that shredded paper is advantageous in pulping:
  - Two of these responses mention that the pulping process is faster with shredded paper and is more energy efficient.
  - One of these responses states that shredded paper exhibits better wettability.
- Two responses concern shredded office paper containing ink from laser printers, which causes problems in the deinking process. One of these responses argues that "[s]hredding was the worst thing that ever happened to deinking."
- Two responses specify the problem of decreased production rate due to the "low density" of shredded paper (interestingly, an unrelated complaint about pulverized paper lists "high density" as the problem, suggesting again that there is a wide gap between problems caused by shredded paper and problems caused by pulverized paper).
- One response states that shredded paper causes "jam ups on the waste paper conveyor."





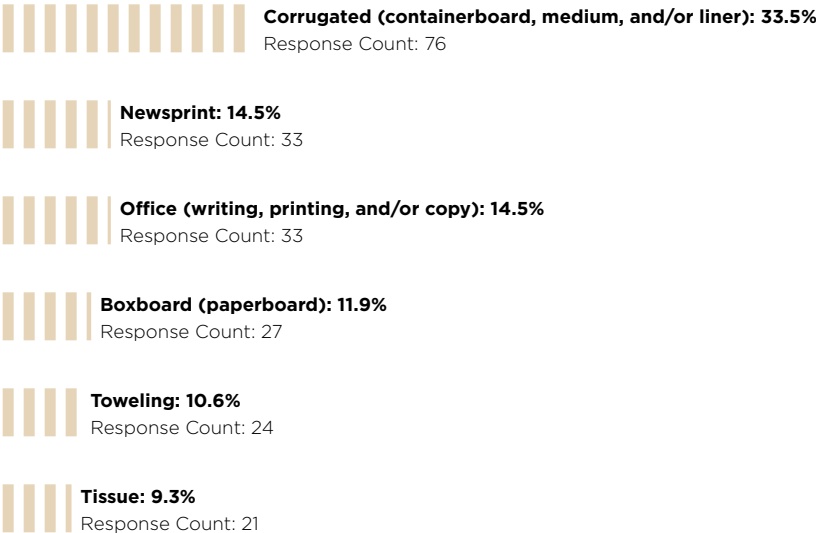
**QUESTION 3:**

**What types of recycled paper grades do you manufacture?**

227 written responses

*Discussion of the 227 comments given:*

- Respondents specified well over 100 distinguishable types of paper.
- The most common responses are summarized in the following table and chart:

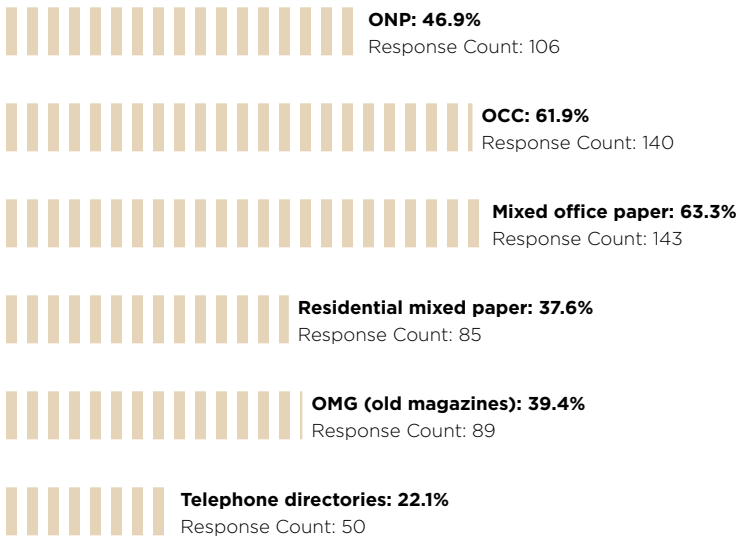


All other specified paper categories each constitute less than 5% of the total responses.

**QUESTION 4:**

**What types of post-consumer recycled feedstocks do you use for the recycled content paper? Please check all that apply.**

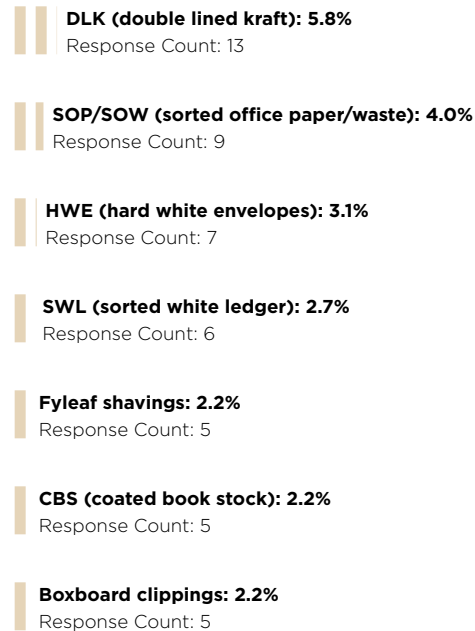
226 responses, 80 comments



**Please list any other feedstocks, and specify if different feedstocks go into the different grades of paper manufactured.** Response Count: 80

*Discussion of the 80 comments given:*

- The overwhelming majority of feedstocks that recyclers indicated they used were included in the multiple-choice section of this question; the feedstock most commonly indicated through written response was only specified by less than 6% of respondents.
- A small number of respondents listed items that are not considered to be “post-consumer,” but still qualify as diverted waste, such as unsold (over-issued) magazines and newspaper, wood that was rejected (hogged) from other mills, and unused clippings from boxboard, envelopes, or printing stock.
- The most common written responses are summarized in the following table and chart:

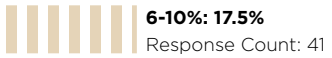


**QUESTION 5:**

**What percentage post-consumer recycled content paper do you manufacture?**

**Check all that apply; if more than one please explain further below.**

234 responses, 42 comments



**Other (please specify)** Response Count: 42 comments

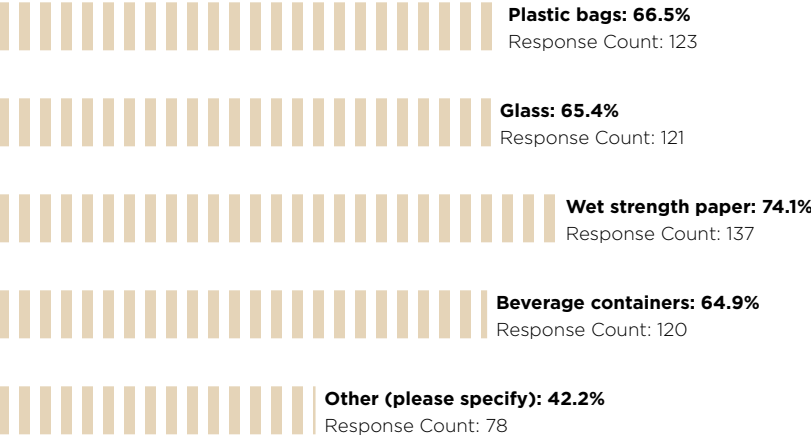
*Discussion of the 42 comments given:*

- The majority of pertinent comments solely list various types or weights of manufactured products along with each product's particular percentage of post-consumer content. These comments do not give enough information to produce a quantitative correlation between percentage of post-consumer and product type.
- A small number of comments give explanations for the production of multiple percentages of post-consumer content. The reasons given are:
  - *Specific client or customer specifications*
  - *Time-varying market demand*
  - *Time-varying availability, quality, and/or cost of recaptured fiber*
  - *Varying capacities of different machines or facilities to use recaptured fiber*
  - *Varying weights of containerboard. One comment specifies that heavier weight containerboard has the ability to contain a higher percentage of post-consumer content while maintaining market performance standards*

**QUESTION 6:**

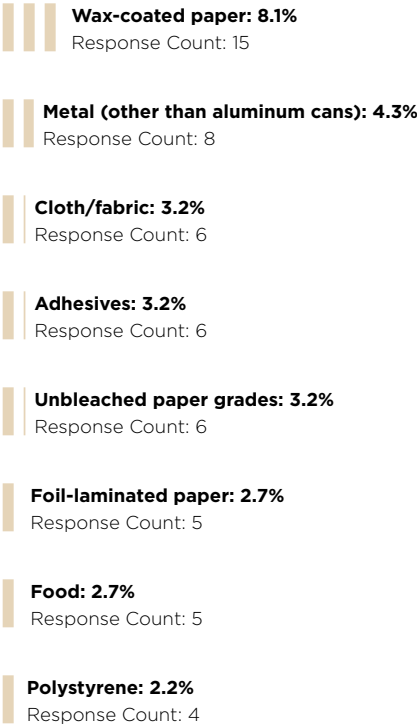
**What are large contaminants you can't handle or refuse to take?  
Check all that apply.**

185 responses, 78 comments



*Discussion of the 78 comments given:*

- The overwhelming majority of major contaminants that were indicated were included in the multiple-choice section of this question. With the exception of wax-coated paper, which 8.1% of respondents listed as a major contaminant, all other specified contaminants were each only indicated by less than 5% of respondents.
- Food and medical waste were appreciably specified as contaminants, probably from the stance that they represent a biohazard and a worker safety issue.
- The most common written responses are summarized in the following table and chart:



**QUESTION 7:**

**Once in the pulper, what are the treatments applied to the paper and other contaminants that must be removed from the pulp? Check all that apply.**

178 responses, 52 comments



*Discussion of the 52 comments given:*

- The overwhelming majority of treatments and other contaminants indicated by respondents were included in the multiple-choice section of this question. Other contaminants listed included: plastics (seven responses, 3.9% of respondents), grit or sand (five responses, 2.8% of respondents), and metal (three responses, 1.7% of respondents).
- Wax is most often mentioned as a problematic contaminant, both in the severity of the defects it may cause and the difficulty of its removal; at least four respondents indicated that their facility does not possess adequate technology for wax removal.

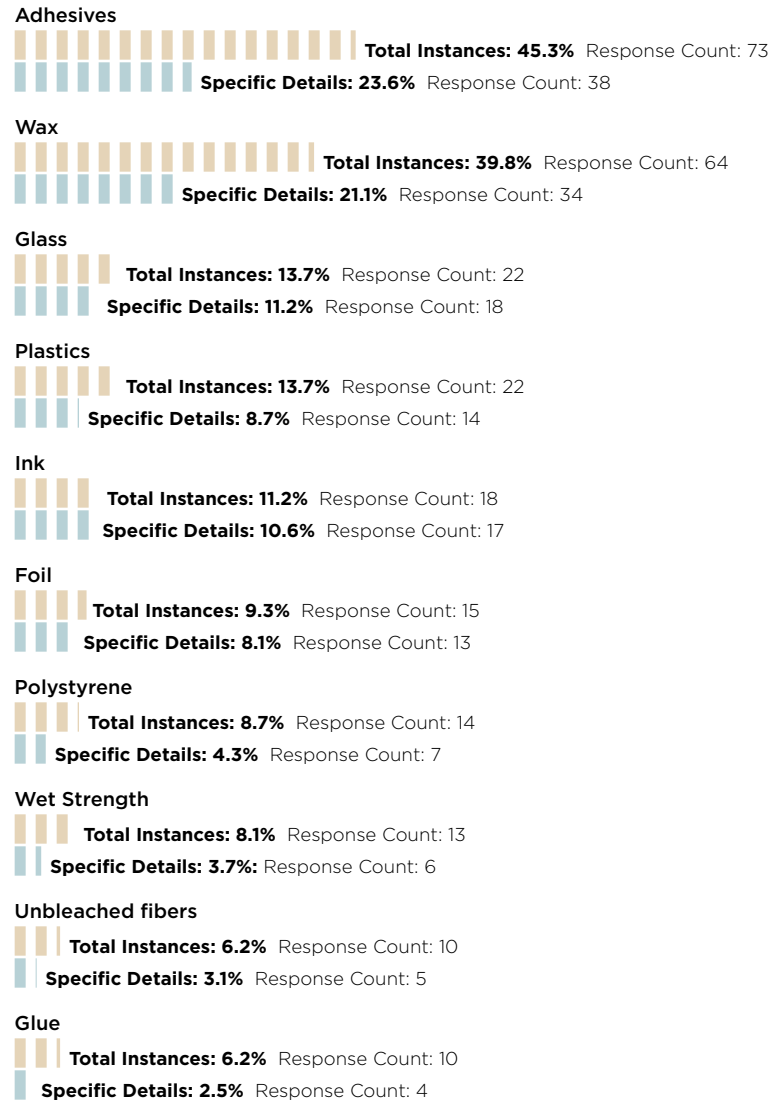
**QUESTION 8:**

**Which (if any) of the contaminants previously listed cause significant problems in your process or final product? Hypothetical examples include: clay coating gums up screen and results in down time for pulper, costing money; adhesives result in stickies or other flaws in finished product; and paraffin wax creates flaws in paper or limits graphics applications.**

161 written responses

*Discussion of the 161 comments given:*

- Approximately half of all comments simply list problematic contraries while the other half of all comments mention the specific problem caused by one or more contraries. Whether or not a comment details the specific problem, any mention of a particular contrary is included in the “total instances” count shown in the table and chart below.
- In addition to the contaminants listed in the table and chart below, there were eight instances of “coatings” being mentioned, but because no explanation of the specific type of coating was given, these comments are not included in this discussion.



## Clay

**Total Instances: 5.0%** Response Count: 8

**Specific Details: 3.7%** Response Count: 6

## Grit/Sand

**Total Instances: 4.3%** Response Count: 7

**Specific Details: 2.5%** Response Count: 4

## Metal

**Total Instances: 4.3%** Response Count: 7

**Specific Details: 3.1%** Response Count: 5

## Staples

**Total Instances: 3.7%** Response Count: 6

**Specific Details: 3.7%** Response Count: 6

## Ash

**Total Instances: 2.5%** Response Count: 4

**Specific Details: 1.2%** Response Count: 2

- In addition to the comments that are summarized above, there are 34 comments that mention stickies as a problematic contaminant but do not specify the particular contaminant type that causes stickies (adhesives, latex, ink, tar, wax, etc.). Of the 34 comments, 15 specify at least one particular problem caused by stickies:

- *About half (seven comments) specify that stickies cause defects in the paper, namely paper breaks and/or holes.*
- *Slightly more than half (nine comments) specify that stickies build up on the equipment (felts, rollers, clothing) and result in downtime for cleaning.*

- As shown above, adhesives are mentioned as a significant problem more than any other contaminant. The 38 comments detailing particular problems caused by adhesives are similar to the comments that generically refer to stickies:
  - *25 comments (65.8%) specify that stickies cause defects in the paper, namely paper breaks, holes (pickouts on the equipment), and/or increased dirt count.*
  - *15 comments (39.5%) specify that stickies build up on the equipment (felts, rollers, clothing), causing downtime for cleaning.*
- 21 of the 38 comments referring to adhesives (55.2%) explicitly state that adhesives cause stickies and their associated problems. In contrast, only four of the 34 wax-related comments (11.8%) mention wax to be their cause of stickies, suggesting that the vast majority of the 34 ambiguously stated comments regarding stickies could be categorized as adhesives-oriented comments. This would reinforce the conclusion that the problems arising from adhesive-caused stickies are the most widespread problems experienced by the surveyed paper manufacturers. One respondent states “[c]learly, our #1 problem are adhesives which result in stickies and cause unacceptable holes in our finished product.”
- Wax is the second most commonly mentioned cause of significant problems. Similar to the comments that refer to adhesives and stickies, the 34 comments detailing wax-caused problems typically refer to flaws created in the final product and/or the buildup of wax on the equipment:
  - *27 comments (79.4%) specify that wax causes flaws and visual defects in the finished product, namely dark spots and/or paper breaks.*
  - *Eight comments (23.5%) specify that wax will coat their equipment (i.e. clothing, felts, dryers, Yankee cylinder, etc.), causing downtime for cleaning.*
- Of the 18 comments that refer to problems caused by glass:
  - *14 comments (77.8%) specify that glass will destroy or cause excessive wear and tear to their equipment (pulper rotors, screen baskets, cleaners, blades, etc.).*
  - *Six comments (33.3%) specify that glass causes holes and/or breaks in their paper.*
  - *Three comments (16.7%) specify that glass will plug their screens, causing downtime.*

- Of the 14 comments that refer to problems caused by plastics:
  - 10 comments (71.4%) specify that plastic pieces clog their detrasher or other screens.
  - Three comments (21.4%) specify that plastics cause defects in their paper (holes, reduced capacity for painting).
  - One comment refers to the high cost of disposing plastic at the landfill.
- Of the 17 comments that refer to ink-caused problems:
  - 14 comments (82.4%) specify that inks degrade their product quality by increasing the ERIC and/or the dirt count.
  - Four comments (23.5%) specify that inks may cause pickouts on their equipment and holes in their finished products.
  - Nine comments (52.9%) specifically mention flexographic and/or UV ink as the problematic ink type.
- Of the 13 comments that refer to problems caused by foil:
  - Five comments (38.5%) specify that foils may degrade their product quality by causing specks and increasing the dirt count.
  - Four comments (30.8%) specify that foils create problems with metal detection in the packaging line.
- Few sets of comments regarding other listed contaminants exhibit enough commonality to merit a quantitative breakdown:
  - Most comments regarding wet strength material refer to its resistance to pulping.
  - Most comments regarding unbleached fibers and glue refer to their negative effects on the visual quality of the finished product.
  - Most comments regarding staples refer to the damage or excessive wear and tear they cause to the machinery.
  - Polystyrene, clay, grit/sand, ash, fluorescent papers, scented papers, metal other than staples, soaps, oil, and carbon paper were also mentioned as problematic contaminants, though not in considerable consistency.

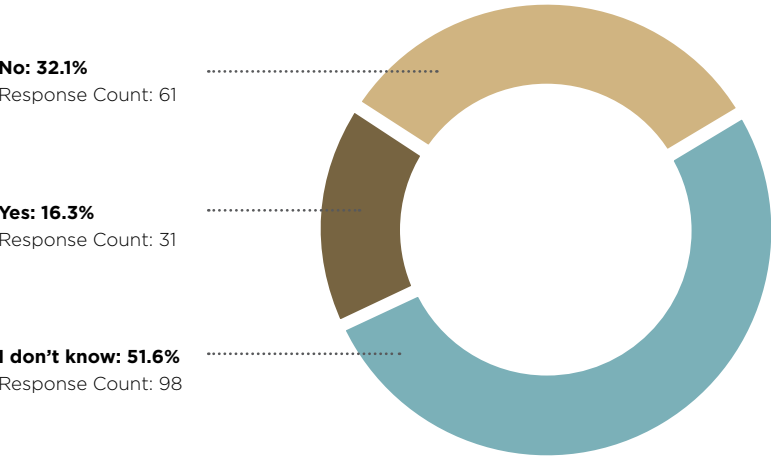




**QUESTION 9:**

**Are you encountering or do you anticipate contamination problems with an increased use of Radio Frequency Identification (RFID) tags on paper packaging?**

190 responses, 42 comments



**Please explain further:**  
42 comments

*Discussion of the 42 comments given:*

- Responses are fairly mixed between those who do and do not expect difficulties in removing RFID tags:
  - Eight comments express confidence that RFID tags are and will continue to be easily removable through screening or in the deinking process.
  - Five comments simply communicate that an increase in the amount of RFID tags that will be present in the future is expected and may present unforeseen difficulties.
  - Two comments present concern about the density contrast between RFID tags and cellulose fiber, which will dictate the ease of removal through centrifugal cleaners.
  - Three comments refer to the problems caused by the adhesives used in affixing the tags.
  - Two comments present concern about the difficulties that will arise if RFID tags are to be constructed from a special ink and/or paper material, both in detection and in the residual effects of such ink.

### QUESTION 10:

**If you could tell a package designer anything about YOUR process, what would it be?**

129 written responses

#### *Discussion of the 129 comments given:*

- The vast majority of the written responses do not refer to any specific aspect of the recycling process:
  - *Many comments are objections to contaminants (e.g., "The less contaminants, the better").*
  - *Many comments are appeals to designers to discontinue their use of materials that are detrimental to the recycling process (e.g., "Eliminate plastic, wax and wet strength").*
  - *Many comments are directed towards those involved in the collection process rather than the design process (e.g., "...try not to send large stones and engine parts, rugs etc.").*
- Numerous comments appeal to designers to use non-paper component types that are easily separable by existing technologies, namely glues that are water soluble and non-paper components that have a significantly different density than the paper components.
- Several comments appeal to designers to use hot melt glues with a higher melting point. One comment specifies that the recycling process is usually performed within the range of 100-140 degrees (F), and if glues were to remain solid in this range, then screens would reject them.
- Several comments are in reference to designers' perceptions of recycled paper products:
  - *Two comments attest to the hygienic quality of their products.*
  - *Two comments refer to inherent and unavoidable variability within their products. One of these comments argues that despite this, recycled products possess comparable functionality to products made of virgin fiber.*
  - *Three comments attest to the identical functionality of products made from recycled content and products made from virgin fiber, namely smoothness and strength.*
  - *One comment expresses frustration towards designers' perception that the blame for lesser quality paper rests on the recycler: "recyclers don't put contaminants [sic] in their process, the contaminants were put in by others."*
- Five comments express confidence in the superiority of their process. One such comment states: "We can handle just about anything."

### QUESTION 11:

**If you could ask a package designer anything about THEIR process, what would it be?**

94 written responses

#### *Discussion of the 94 comments given:*

- Similar to Question 10 most of the 94 given comments do not regard the design process, and many are ambiguous appeals for designers to cease use of materials that inhibit the recycling process (e.g., "Stop using products that do not work well in the recycle stream").
- Numerous comments inquire about the parameters that influence a designer's decision to use non-paper materials (i.e. adhesives and/or coatings) that are non-recyclable instead of materials that possess comparable functionality but pose no challenges to the recycling process.
- Some comments inquire about the factors that influence a designer's decision to use paper made of virgin fiber instead of paper made from recaptured fiber.
- Many comments inquire about the general specifications that designers desire when purchasing paper (e.g., "What sheet property impacts your purchasing decision the most?").
- Numerous comments inquire about the level of consideration that designers give to the overall recyclability of packaging components vs. the overall functionality of the packaging.
- Some isolated comments worth noting are:
  - *"How can you make a feature of the unique characteristics of recycled paper?"*
  - *"Why is so much packaging material required?"*
  - *"How can one safely [convey] a [label regarding recyclability] and stay compliant with FTC regulation[s]?"*
  - *"Why do they consider plastic 'cooler' than recycled paper[?]"*