Paper or Styrofoam:
A review of the environmental effects of disposable cups

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The University of California San Diego is a leading university in this country. As such, it has a mandate to advocate as well as practice environmental sustainability among other values. This report explores the environmental effects of using paper versus polystyrene (Styrofoam) cups. Other options such as recyclable Polyethylene terephthalate (PETE) plastic and compostable polylactide (PLA) have been eliminated from comparison prior to the writing of this report. The PETE option is more expensive than the university is willing to afford. The PLA cup is also rather expensive, but it is compostable because it is made from corn products. Yet, because the university currently has no options in its waste disposal program to compost PLA cups, it will simply end up in the landfill; the compostability of the product has no benefits to the university.

Styrofoam and paper are the two remaining candidates. In this paper we will use the name Styrofoam, this is a trademarked name for polystyrene, but culturally accepted as a general term. Styrofoam has long had a bad reputation. This began because the production of Styrofoam emitted Chlorofluorocarbons (CFCs). However, the making of Styrofoam has not included CFCs for over two decades. The other large complaint concerning Styrofoam is that it is not biodegradable and essentially will not break down. This will be explored later in this report.

The paper cup has long held a position in the public's mind as renewable and environmentally friendly. This view of paper is too optimistic. This report will show that paper uses petroleum, emits green houses gases, and creates contaminated waste water.

In this study we considered the life cycle of each cup, from "cradle to grave." The factors we considered were the following: raw materials (e.g. paper), inputs necessary for production (e.g. water or electricity), nature and mass of weight produced, travel distance, weight per cup for travel, final disposability of the cup, and of course, the cost.

The first factors to consider are the raw materials. Paper uses 1.5-2.9 grams of petroleum compared with 3.4 grams of petroleum used in the production of Styrofoam. Therefore paper uses less petroleum. However, when considering chemicals used in production, Styrofoam uses only one tenth of those used in paper production (0.07-0.12 vs 1.1-1.7 grams). Also concerning wood, paper uses 25-27 grams, where as Styrofoam uses zero. The conclusion for the raw materials is simple; Styrofoam uses less chemicals, no wood, and only a small amount more petroleum than paper.

The power inputs necessary for production show that Styrofoam is less water and energy intensive. Styrofoam uses less steam, power, and cooling water during production than paper.

The total energy use for hot cups including material resources, transport, and in process energy is generally less for Styrofoam. The thin nature of paper cups leaves little insulation from hot liquids. The result in practice is that a paper sleeve is often used in addition to a paper cup. This yields a measurable increase in the energy use of the total cup. The total energy use for a cold cup is essentially equal for a Styrofoam verses a plastic coated paper cup. However, Styrofoam is much less energy intensive when compared with a wax coated paper cup. It is important to note that wax coated paper cups are usually used for cold liquids. For hot liquids, plastic coatings are used.

The weight of waste resulting from the production of hot and cold cups is much lower for Styrofoam than any other option. The atmospheric emissions from a hot cup, assuming the use of a sleeve, are lower for Styrofoam. If a sleeve is not available with a paper cup, it is likely the consumer will use two cups if consuming a hot liquid. This is not environmentally desirable; either way, Styrofoam has fewer emissions. The emissions from a plastic coated paper cup are less than Styrofoam. However, if a wax coated paper cup were chosen, which is likely, the Styrofoam would be desirable. But, this can only really be applied to strictly cold drinks, because wax coated cups are not made to insulate heat.

As far as transportation and storage is concerned, paper is much heavier per case which increases the cost for transportation, where as Styrofoam is incredibly light. But, paper cups stack together much more compactly that Styrofoam. This means that paper cups can be packaged in much smaller boxes, decreasing the amount of secondary packaging materials. Also, paper cups take up less room in storage than Styrofoam, meaning Styrofoam storage costs are a bit higher. Within transportation and storage, the paper cups actually seem a bit more favorable.

In the end the cups must be disposed of. Both of the cups will be sent to a landfill. Landfills are designed to not allow the contents to decompose. They do their job well; even newspapers can last half over half a century at times. The contents are forced to breakdown anaerobically, without oxygen. When paper cups decompose they release methane, a greenhouse gas much worse than carbon dioxide, yet in San Diego the landfills are capped, capturing the gas which is then collected and used to generate electricity. Styrofoam is essentially environmentally inert, meaning that it does not decompose. This is a negative attribute because it collects in oceans or other parts of the environment. It is also positive because it does not release toxic gases or leach chemicals into the ground water. It is just "there" for thousands of years. This could actually be a benefit in a landfill, especially if there are future plans to build over it. In San Diego, it is not possible to build actual buildings over a landfill, but it is possible to build parks and fields over them. In this case, it is better for the material in a landfill to not biodegrade to leave a solid foundation. This is in favor of Styrofoam.

Recycling is not an option for either product. There is technology to recycle Styrofoam, but it is rather energy intensive and the savings are extremely marginal. It is also focused on waste from electronics packaging, not soiled disposable cups. There is technology to compost certain paper cups, but the wax or plastic lining stands in the way of this. Thus until the City of San Diego or the University of California San Diego develops a composting system that can handle paper cups, composting is not an option for the University.

The University of California at San Diego can currently purchase Styrofoam cups at $23 per 1000 units or paper cups at $42 dollars per 1000 units. Thus paper cups are nearly twice as expensive as Styrofoam, and given the use of approximately 1.3 million cups in the 2005-2006 school year, this would be approximately a cost difference of $24,700. This is a potential cost that the university would prefer not to pass on to the students.

Overall, Styrofoam has a smaller impact on the environment during its creation and use. This is because expanded polystyrene is formed in a simple chemical reaction and it is easily molded to any desired shape. Paper, on the other hand, needs to be made out of trees and converted to a malleable substance that can eventually be made to take the shape of a cup and then finally coated with a wax or plastic to make it water resistant. When discarded, both cups go to the landfill. Styrofoam will essentially not decompose. Paper cups will decompose, but it is an extremely slow process.

It is important to note that, while Styrofoam cups are better than paper from an environmental standpoint, it is a choice between the lesser of two evils. Ideally the authors would like to see a higher emphasis on reducing the number of disposables that are used in the first place. This would be better for the environment independent of the cups the university uses. Also, biodegradable dinnerware would be the most sustainable option for the university in the long run. This dinnerware would probably be made out of corn and would all be compostable. But still, the best option will always be reusable and washable cups. Therefore, the university is recommended to promote new ways to encourage students to bring their own reusable cups to the dining halls. This can be done through a point-offered rewards system or a discount on food and drink. This will reduce the overall consumption and waste of disposable products, which will always be the best option.

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Is Paper Better Than Plastic?

Martin B. Hocking

As consumers become more environmentally conscious they are increasingly concerned about the environmental component of products and services available in their society. Consumer choices are often made instinctively, from necessity, because a detailed analysis of the relative environmental merits of using canned versus fresh versus frozen food, or glass versus paper versus steel versus aluminum packaging would simply be too time-consuming for each purchase.

If, however, the environmental merit question is restricted to a small enough purchase sector it is possible to conduct a complete analysis of relative merit from the initial resource through the manufacturing stages, use attributes, and recycle options through to final use or disposal of the items.

One such analysis was conducted recently, comparing single-use uncoated paper cups and molded polystyrene foam (polyfoam) cups in hot drink applications. This analysis concluded that polyfoam cups have an environmental merit at least similar to that of paper cups.

What Are They Made Of? The major raw material for a paper cup is wood, a renewable resource. However, acquisition of wood for pulpmaking has visibly negative impacts on the landscape from the construction of road access and typical clear-cutting practices. When the clear-cut area occupies an extensive proportion of a watershed, it increases maximum flows and decreases minimum flows of streams draining the watershed, increasing the likelihood of flood and drought in the area served by these streams, although modern management can minimize all of these impacts.

Paper cups are made from bleached pulp, which in turn is obtained in yields of about 50% by weight from wood chips. Bark and some wood waste are also burned to supply a part of the energy requirements of the papermaking process. Thus, an average of some 26 grams (g) of wood plus, for additional energy requirements, an average of about 2 g of residual fuel oil or natural gas, is consumed per paper cup with a finished weight of 10.1 g. More petroleum than this would be needed if the paper cup had a plastic or wax coating, but this option is excluded in this analysis.

A polyfoam cup is made entirely from hydrocarbons (oil and/or gas). Impacts from petroleum exploration and recovery are also significant, from the former particularly in sensitive northern ecosystems and from the latter predominantly from accidental spills during drilling, production, or delivery.

Chemicals Used. Inorganic chemicals are also required for the papermaking process. Relatively small amounts of sodium hydroxide or sodium sulfate are needed for pulping (because much of these chemicals can be recycled), but larger amounts of chlorine, sodium hydroxide, sodium chlorate, sulfuric acid, and other materials are used on a once-through basis in the bleaching process to the extent of 110 to 170 kilograms (kg) per metric ton of pulp. The total non-recycled chemical requirement thus works out to an average of about 1.4 g per paper cup.

The superior properties of polystyrene foam over uncoated paper in a hot drink cup application allow the use of only 15% to 25% as much material to produce a cup. Chemical requirements for polystyrene production are small, totalling about 33 kg per metric ton. This amounts to 0.05 g per cup; or about 4% of the chemical requirement of the paper cup.

Production Needs. The paper cup consumes about 10 times as much steam, 14 to 20 times as much electricity, and twice as much cooling water as a polystyrene foam cup. About 300 times the volume of waste water is produced for the pulp required for the paper cup as compared to the polystyrene required for the polyfoam cup. The contaminants present in the wastewater from pulping and bleaching operations are removed to a varying degree depending on site-specific details, but the residuals present in all categories except mineral salts would still amount to 10 to 40 times those present in the wastewater streams from polystyrene processing.

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Emissions to air total some 14 kg per metric ton of bleached pulp and about 46 kg per metric ton of polystyrene. But because paper cups are four to six times heavier than polyfoam cups, each paper cup results in 1.3 to 1.8 times more mass of air emissions than each polyfoam cup.

Cost. The wholesale price of a paper cup is about 2½ times as much as polyfoam, partly from its greater consumption of raw materials and utilities, and partly from higher labor costs.

Recyclability. The technical side of recycle capability with the polystyrene foam is also straightforward. The restriction that recycled resin may not be used in food applications only partially limits the many possible end uses for recycled polystyrene such as in packaging materials, insulation, patio furniture, etc. Recycle operating problems have largely been solved. An improved infrastructure is all that is required to make this option a more significant reality and convert this perceived negative aspect of polyfoam use to a positive one.

The non water-soluble hot melt or solvent-based adhesive used to bind the parts of a paper cup together makes recycling of this product less straightforward.

Disposal. Polystyrene is relatively inert to decomposition when discarded to landfill. However, there is also increasing evidence that disposal of paper to landfill does not necesarily result in degradation or biodecomposition, particularly in arid regions. If the paper does decompose in a wet landfill, it produces substantial quantities of methane, a potent greenhouse gas, much of which is lost to the air. At the same time, water-soluble substances, which consume oxygen, are contributed to any leachate from the landfill, which also have the potential to cause pollution problems.

Conclusion. It can be seen from this summary of the analysis that even the relatively restricted question of paper versus polyfoam for hot drink cups is complex. But for single-use applications it would appear that polystyrene foam cups should be given a much more even-handed assessment as regards their environmental impact relative to paper cups than they have received during the past few years.

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Paper vs. Plastic Hot Drink Cups

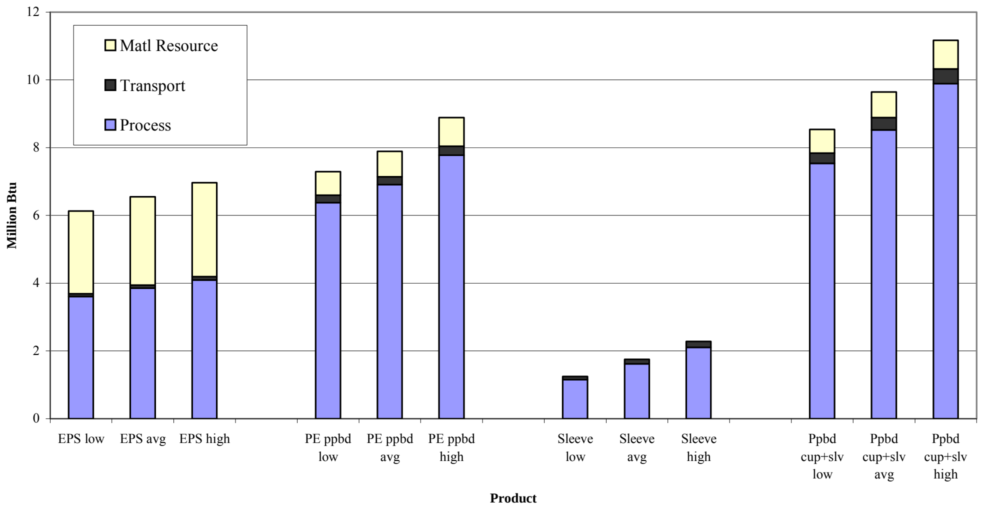
Item	Paper Cup[a]	Polyfoam Cup
Per cup:		
Raw materials		
Wood and bark	25 to 27 g	0 g
Petroleum fractions	1.5 to 2.9 g	3.4 g
Other chemicals	1.1 to 1.7 g	0.07 to 0.12 g
Finished weight	10.1 g	1.5 g
Per metric ton of material:		
Utilities		
Steam	9000 to 12,000 kg	5500 to 7000 kg
Power	980 kWh	260 to 300 kWh
Cooling water	50 m³	130 to 140 m³
Water effluent		
Volume	50 to 190 m³	1 to 4 m³
Suspended solids	4 to 16 kg	0.4 to 0.6 kg
BOD	2 to 20 kg	0.2 kg
Organochlorines	2 to 4 kg	0 kg
Mineral salts	40 to 80 kg	10 to 20 kg
Air emissions		
Chlorine	0.2 kg	0 kg
Chlorine dioxide	0.2 kg	0 kg
Reduced sulfides	1 to 2 kg	0 kg
Particulates	2 to 3 kg	0.3 to 0.5 kg
Chlorofluorocarbons	0	0
Pentane	0 kg	35 to 50 kg
Sulfur dioxide	≈10 kg	3 to 4 kg
Recycle potential:		
To primary user	Possible Washing can destroy.	Easy Negligible water uptake.
After use	Possible. Hot melt adhesive or coating difficulties.	Good. Resin reuse in other applications.
Ultimate disposal:		
Proper incineration	Clean	Clean
Heat recovery	20 MJ/kg	40 MJ/kg
Mass to landfill	10.1 g	1.5 g
Biodegradable	Yes. BOD to leachate methane to air.	No. Essentially inert.

[a] Uncoated fully bleached kraft paper cup.
[b] Molded polystyrene foam bead (seamless) cup.
[c] Many producers of foamable beads have never used CFCs.

"Updated, complete results of Martin B. Hocking's study, as published in the November 1991 issue of Environmental Management, may be obtained by calling 1-800-288-CARE."

Selected charts from 2006 report by Franklin Associates, LTD

Figure ES-1. Energy by Category for 10,000 16-oz Hot Cups (Million Btu)



Results shown in this figure represent the full range of product samples obtained and weighed by Franklin Associates from January 2003 - July 2003. Due to the uncertainties in LCI data, differences in energy results for products in different material categories or for different weight products in the same material category are not considered meaningful unless the percent difference in the results (defined as the difference of two results divided by their average) is greater than 10%. Products in different material categories cannot be considered different if there is any smaller percent difference or overlap in results when the full ranges of product weights available in each material category are compared. See Table 2-32 for a summary of meaningful differences between products.

Figure ES-2. Energy by Category for 10,000 32-oz Cold Cups (Million Btu)

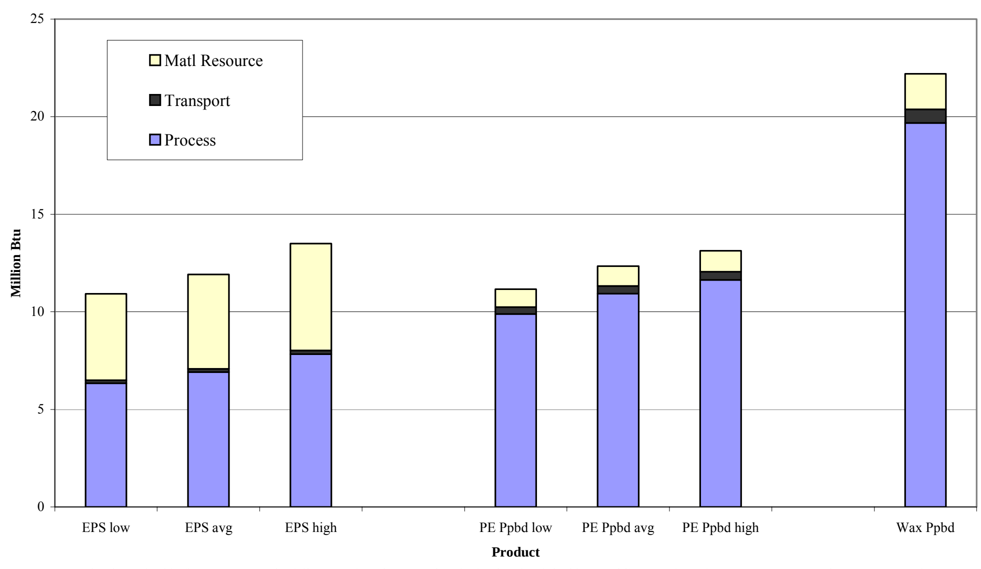


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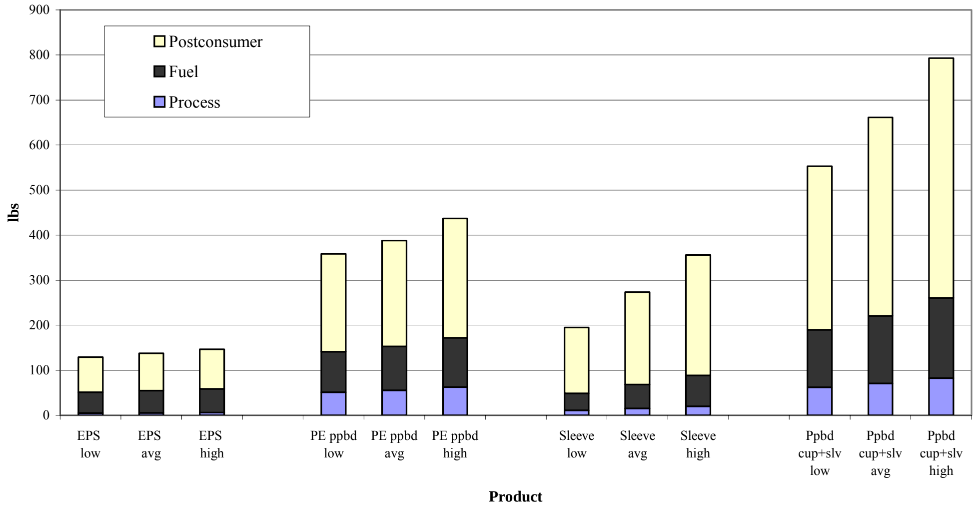
Figure ES-5. Solid Waste by Weight for 10,000 16-oz Hot Cups (Pounds)



Results shown in this figure represent the full range of product samples obtained and weighed by Franklin Associates from January 2003 - July 2003. Due to the uncertainties in LCI data, differences in solid waste results for products in different material categories or for different weight products in the same material category are not considered meaningful unless the percent difference in the results (defined as the difference of two results divided by their average) is greater than 25%. Products in different material categories cannot be considered different if there is any smaller percent difference or overlap in results when the full ranges of product weights available in each material category are compared. See Table 2-32 for a summary of meaningful differences between products.

Figure ES-6. Solid Waste by Weight for 10,000 32-oz Cold Cups (Pounds)

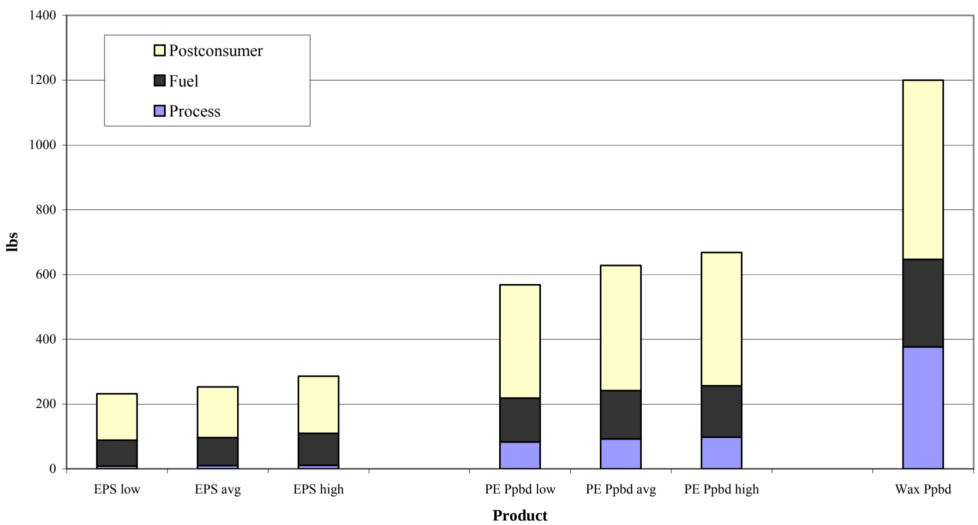


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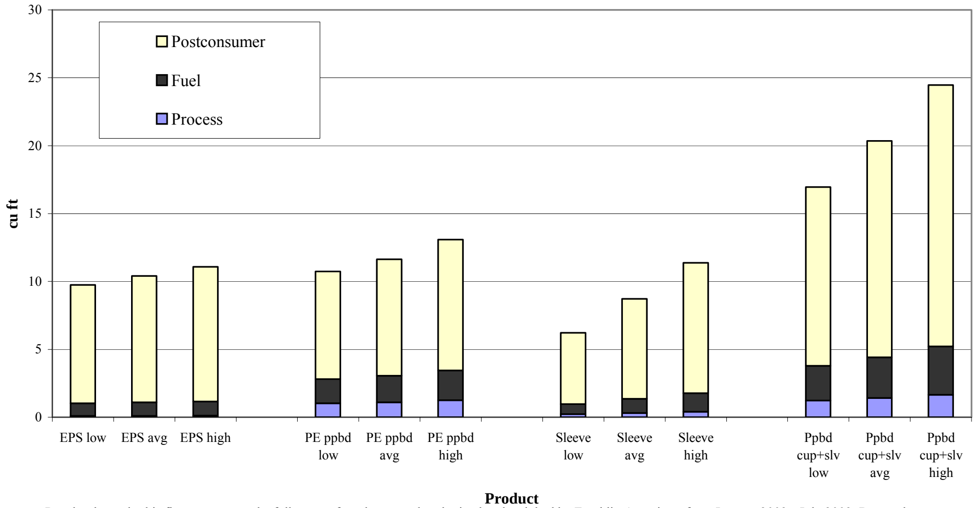
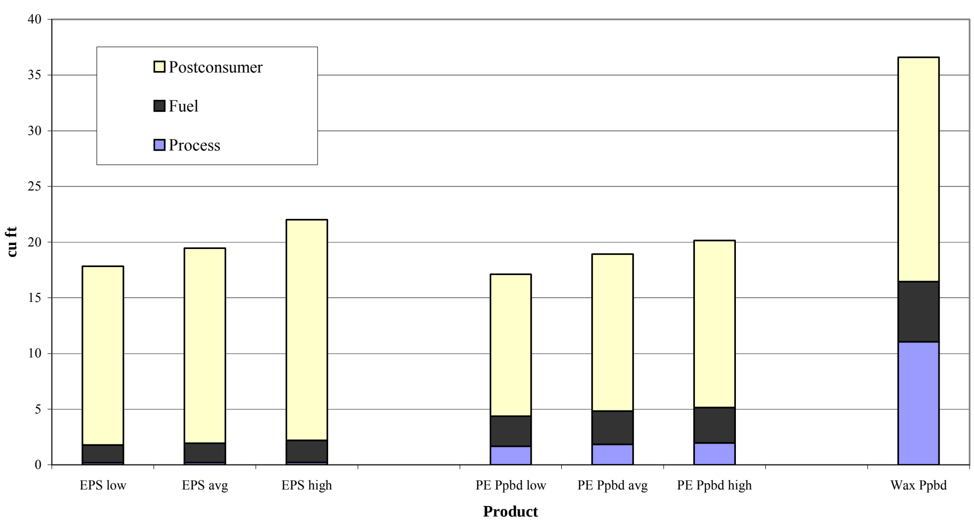
Figure ES-9. Solid Waste by Volume for 10,000 16-oz Hot Cups
(cubic feet)



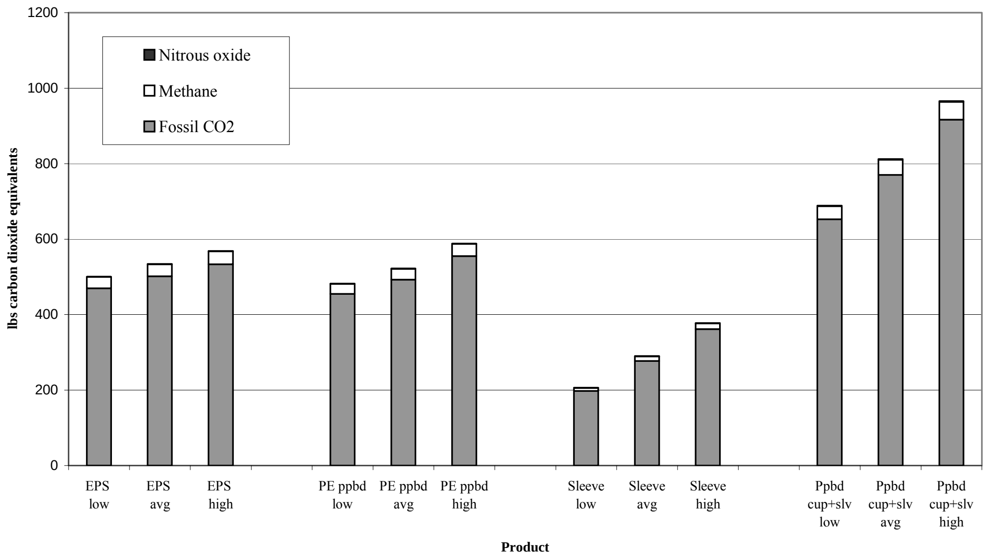
Results shown in this figure represent the full range of product samples obtained and weighed by Franklin Associates from January 2003 - July 2003. Due to the uncertainties in LCI data, differences in solid waste results for products in different material categories or for different weight products in the same material category are not considered meaningful unless the percent difference in the results (defined as the difference of two results divided by their average) is greater than 25%. Products in different material categories cannot be considered different if there is any smaller percent difference or overlap in results when the full ranges of product weights available in each material category are compared. See Table 2-32 for a summary of meaningful differences between products.

Figure ES-10. Solid Waste by Volume for 10,000 32-oz Cold Cups
(cubic feet)



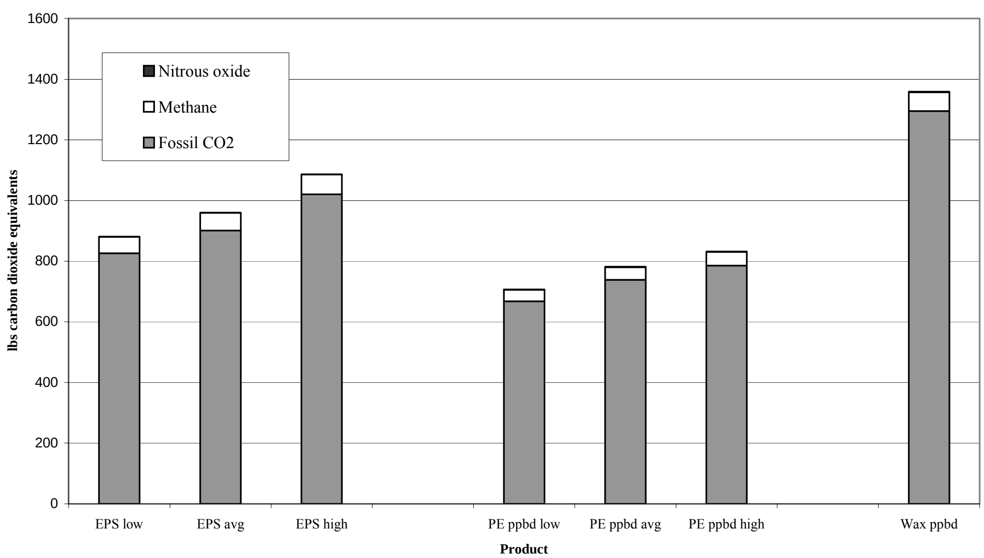
Results shown in this figure represent the full range of product samples obtained and weighed by Franklin Associates from January 2003 - July 2003. Due to the uncertainties in LCI data, differences in solid waste results for products in different material categories or for different weight products in the same material category are not considered meaningful unless the percent difference in the results (defined as the difference of two results divided by their average) is greater than 25%. Products in different material categories cannot be considered different if there is any smaller percent difference or overlap in results when the full ranges of product weights available in each material category are compared. See Table 2-33 for a summary of meaningful differences between products.

Figure ES-13. Atmospheric Emissions for 10,000 16-oz Hot Cups (lbs carbon dioxide equivalents)



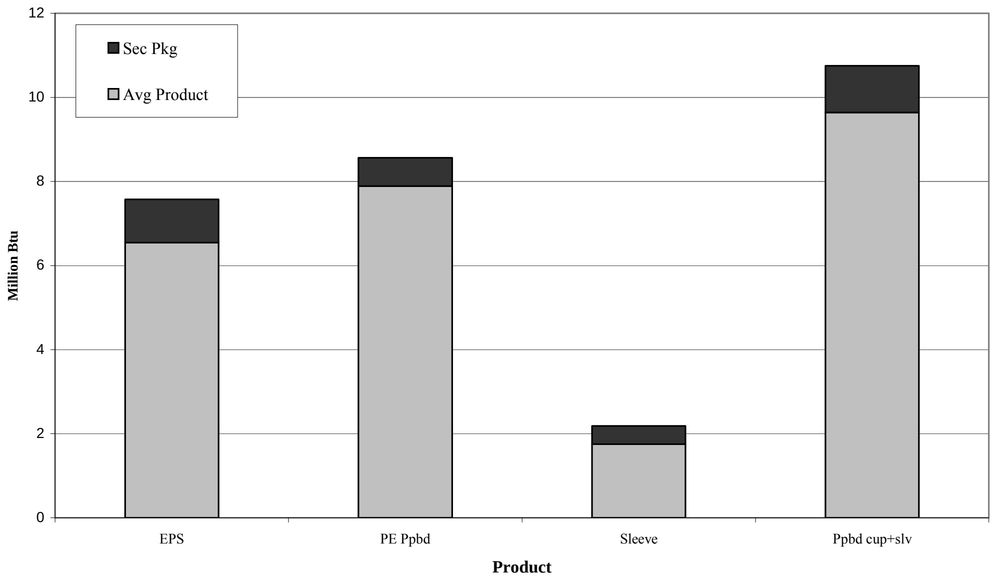
Results shown in this figure represent the full range of product samples obtained and weighed by Franklin Associates from January 2003 - July 2003. Due to the uncertainties in LCI data, differences in GHG results for products in different material categories or for different weight products in the same material category are not considered meaningful unless the percent difference in the results (defined as the difference of two results divided by their average) is greater than 25%. Products in different material categories cannot be considered different if there is any smaller percent difference or overlap in results when the full ranges of product weights available in each material category are compared. See Table 2-32 for a summary of meaningful differences between products.

Figure ES-14. Atmospheric Emissions for 10,000 32-oz Cold Cups (lbs carbon dioxide equivalents)



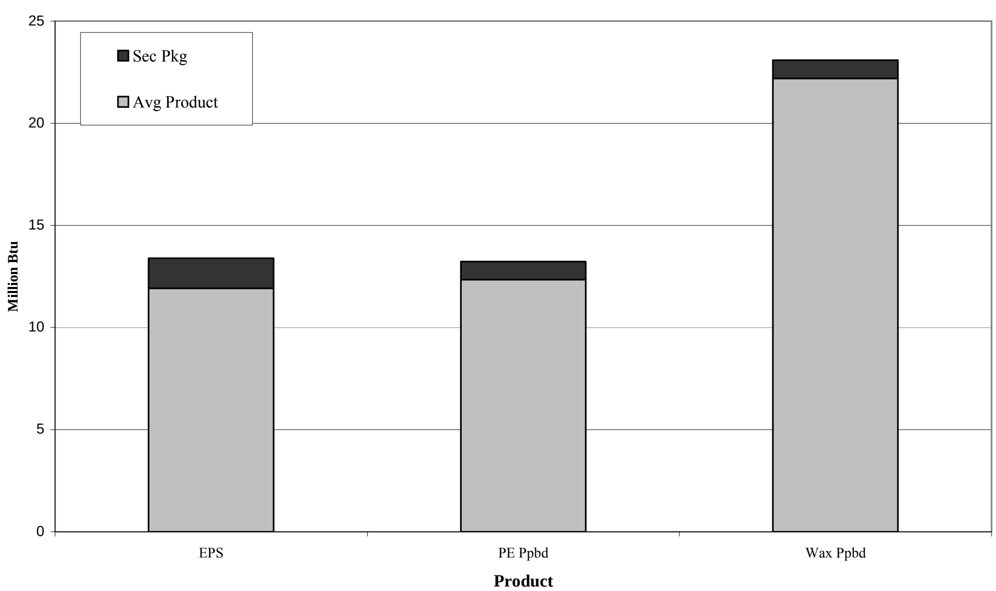
Results shown in this figure represent the full range of product samples obtained and weighed by Franklin Associates from January 2003 - July 2003. Due to the uncertainties in LCI data, differences in GHG results for products in different material categories or for different weight products in the same material category are not considered meaningful unless the percent difference in the results (defined as the difference of two results divided by their average) is greater than 25%. Products in different material categories cannot be considered different if there is any smaller percent difference or overlap in results when the full ranges of product weights available in each material category are compared. See Table 2-33 for a summary of meaningful differences between products.

Figure ES-17. Total Energy for 10,000 16-oz Hot Cups and Secondary Packaging (Million Btu)



Results in this figure represent average weight product plus secondary packaging. The purpose of this figure is to illustrate the contribution of secondary packaging to the environmental burdens for the average weight product in each material category. Conclusions regarding the relative performance of competing products cannot be drawn from this figure because results for the full range of product weights for each material are not shown. For results for the full range of product samples for each material, see Chapter 2.

Figure ES-18. Total Energy for 10,000 32-oz Cold Cups and Secondary Packaging (Million Btu)



Results in this figure represent average weight product plus secondary packaging. The purpose of this figure is to illustrate the contribution of secondary packaging to the environmental burdens for the average weight product in each material category. Conclusions regarding the relative performance of competing products cannot be drawn from this figure because results for the full range of product weights for each material are not shown. For results for the full range of product samples for each material, see Chapter 2.

Figure ES-21. Solid Waste by Weight for 10,000 16-oz Hot Cups and Secondary Packaging (lbs)

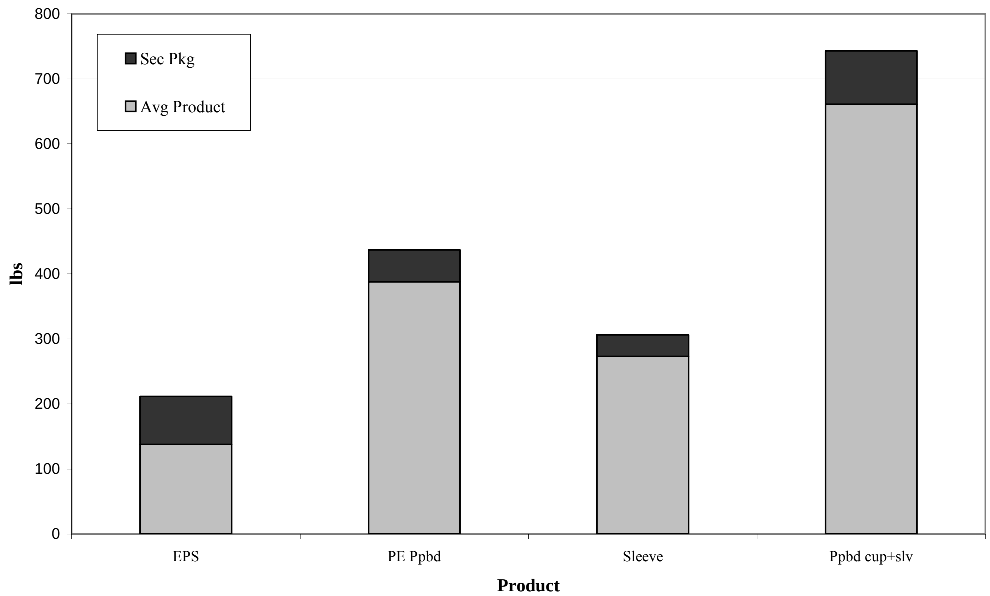


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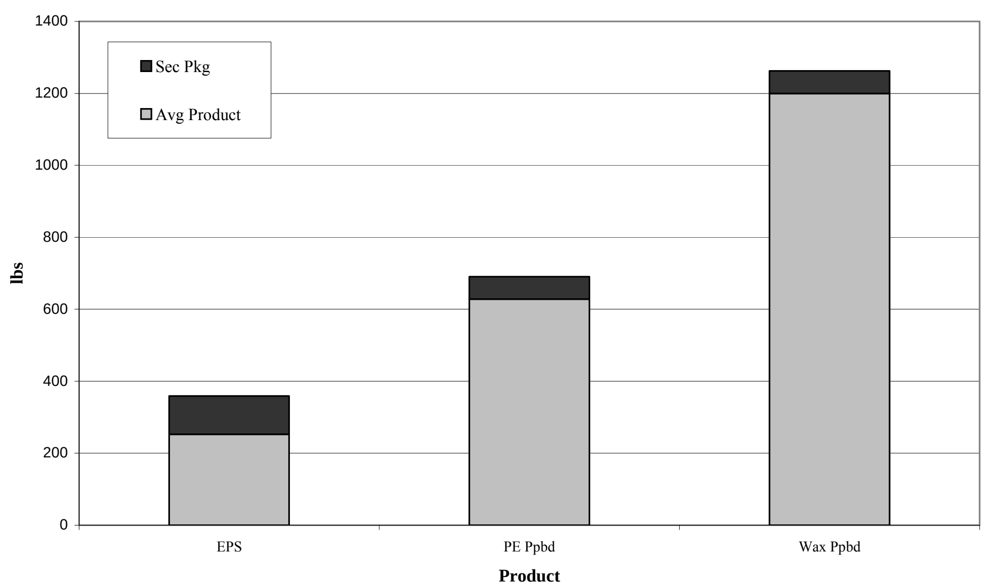
Figure ES-22. Solid Waste by Weight for 10,000 32-oz Cold Cups and Secondary Packaging (lbs)



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