

Comparative Life Cycle Assessment of Traytite® and Tray- and Film Frozen Food Packaging

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ABSTRACT

This paper describes the process and results of a life cycle analysis (LCA) comparing two types of frozen food packages. The analysis looks at the raw materials consumption, manufacturing process, and disposal and recycling of the two types of packaging for frozen entrees: tray-and-film packages and Traytite® packages. The report quantifies, for each package type, the consumption of raw materials, as well as energy consumption and the creation of harmful emissions. The final part of the analysis examines recycling and disposal. We conclude with recommendations for decreasing the environmental impact of frozen food packages. The results of the LCA suggest that the Traytite®-style package has a smaller environmental impact than the tray-and-film package.

INTRODUCTION

In the frozen food industry there are two basic types of packaging for heat-and-eat entrees. One package option is the traditional, tray-and-film package (Figure A). This type of package is the most common and is characterized by a plastic tray with a film covering, placed inside a paperboard box. The tray in this type of package is made of a type of plastic known as PET (polyethylene terephthalate). PET is synthesized in amorphous form, then dried, heated, formed, and cut in custom configurations to make the plastic trays in which food is packaged and heated by the consumer. This study pertains only to single-compartment trays. The tray is covered with a thin film, which is also made of PET. The tray, covered by the film, is packaged in a box made of solid bleached sulfate (SBS) paperboard.

The other type of package, called Traytite® (Figure B), likewise is composed of SBS paperboard. For the Traytite® package the paperboard is coated with a PET film that allows it to be microwavable. The lid of the Traytite® package also is composed of SBS, coated with PET. The Traytite® package is sealed by applying heat and pressure.

The purpose of this study is to evaluate the environmental impacts of each frozen food package type from the cradle to the gate, with the ultimate goal of comparing the two and find which one has the least environmental impact. This study looks at the environmental footprint of both packages by analyzing their raw materials consumption, energy consumption, and the harmful emissions released during their production and use.



Figure A: Typical tray-and-film package



Figure B: Typical Traytite® package

METHODS AND DATA SOURCES

LCA Process

This LCA was conducted according to the guidance document published by the U.S. Environmental Protection Agency entitled "Life Cycle Assessment: Principles and Practice."¹ The document defines four basic steps in conducting an LCA: goal and scope definition, inventory analysis, impact assessment, and improvement analysis. The major stages in the study are raw material acquisition, materials manufacture, production, use/reuse/maintenance, and waste management. These distinctions and stages were used as the method for building this LCA comparing two types of frozen food packing.

The basic building block for conducting an LCA is the individual process. Paper pulping, for example, is one individual process. Each process has two elements: inputs and outputs. An input is any raw material, secondary material resulting from a previous process (called intermediate material) or energy that is used in the process. An output is any result of the process, including an intermediate product (or, in the case of the final

¹ Scientific Applications International Corporation (SAIC), "Life Cycle Assessment: Principles and Practice," U.S. Environmental Protection Agency Life-Cycle Assessment Research, LCA 101, May 2006, <http://www.epa.gov/nrmrl/lcaccess/lca101.html> (accessed Nov 2008).

process, the final product), waste emissions to air and water, or any other types of waste. A basic diagram of this unit process is provided below in Figure 1.

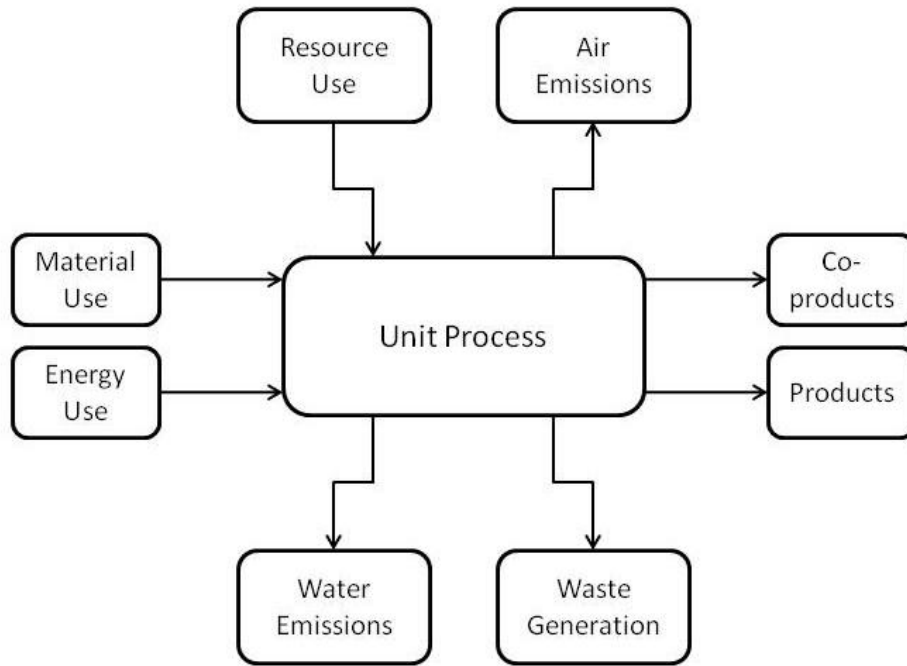


Fig. 1: Unit Process

All the individual processes involved in making a product compose the product's system. In an LCA, the boundaries of this system, also known as the scope of the system, must be defined because it is not always possible, or desirable, to assess a product from the formation of every raw material that goes into it to its eventual disposal. The first step in an LCA is to define the scope and goal of the assessment. The scope of this study is defined as an assessment of tray-and-film and Traytite® packaging from the harvest of the raw material for the packaging to the freezing of the food-filled packages at the factory. We chose these boundaries because the goal of the assessment is to ascertain the difference in energy and waste associated with, and therefore the environmental impact of, both types of packaging. These differences begin with the harvesting of the raw materials and end when the packages are frozen at the filling plant before being shipped to various destinations. A diagram of the system is provided below in Figure 2.

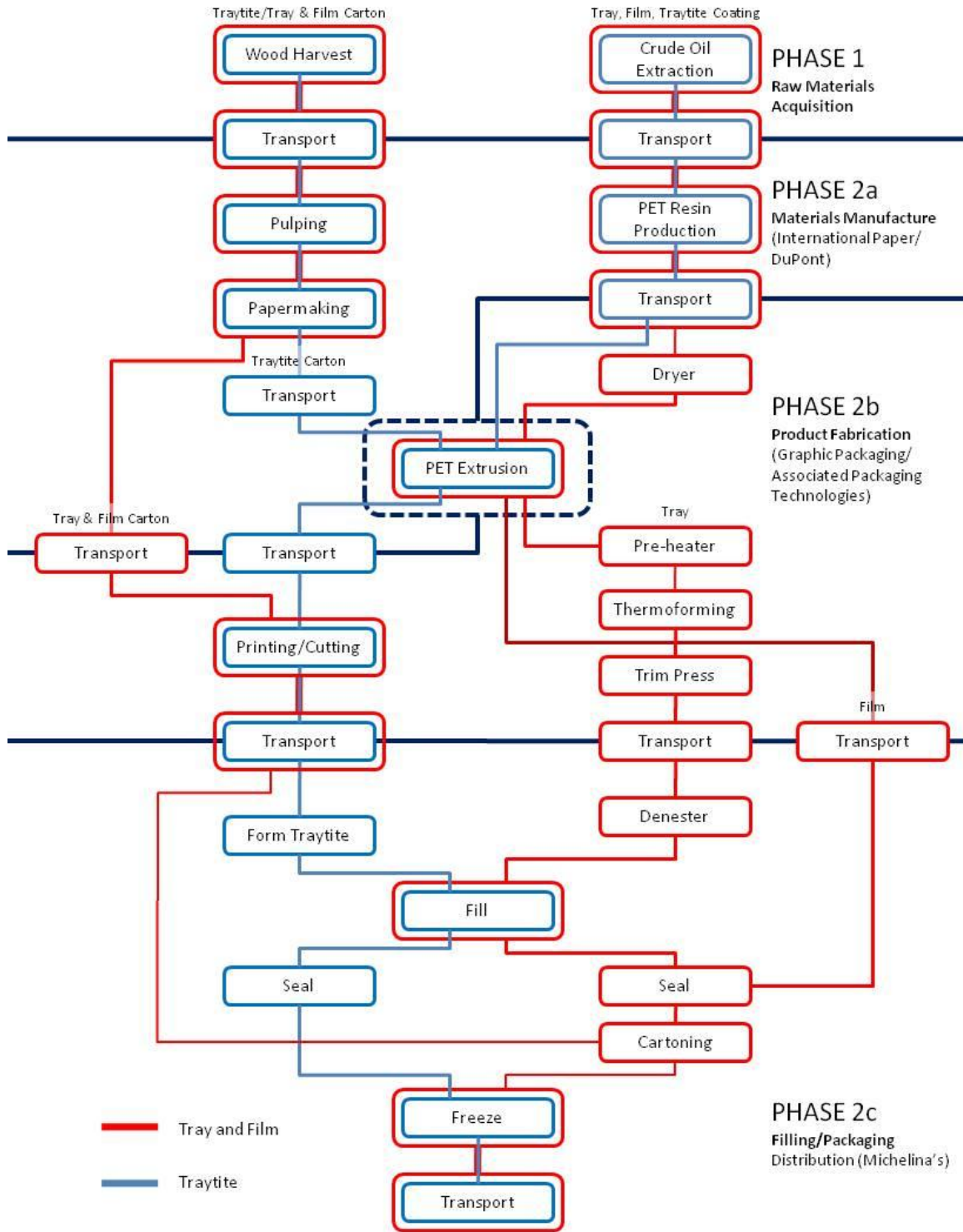


Figure 2: System boundaries of this LCA

The system boundary of this LCA begins at harvesting the raw materials, wood and crude oil. Energy consumed in growing the tree or forming the crude oil was not accounted for, but the energy used to harvest the wood and crude oil, which was primarily the energy use and emissions of the harvesting machinery, was included. The system studied in this LCA ends with the step of freezing the food and containers after food is deposited into the containers. By stopping with the freezing step, the system excludes warehousing, transportation to point of sale and to any intermediary points, consumer use and disposal. These processes were eliminated from the system because there is a large range of possible numerical values. Because of confidentiality agreements with their employers, none of our contacts were able to provide us with average values to use in the analysis. In addition, both products are often warehoused, transported, displayed and disposed of together, so the average differences in energy consumption and waste production between the two products are thought to be negligible in these processes.

In addition to the processes described above, three other processes were excluded from the system on the grounds that their impact on the system is thought to be negligible:

Capital Equipment: Capital equipment includes equipment used to manufacture buildings, motor vehicles and industrial machinery. Limited access to data on capital equipment resource consumption and outputs made data collection on capital equipment unreliable for this LCA. Moreover, according to the APC Report, "the energy and emissions associated with such capital equipment generally become negligible when averaged over the millions of pounds (or kilograms) of product manufactured over the useful lifetime of the capital equipment."²

Space Conditioning: Energy used to heat, cool, light and maintain manufacturing spaces is not accounted for in this LCA because this amount of energy is very small in comparison to the amount of energy the product-manufacturing machines in the factory consume. Franklin Associates attributes less than one percent of total energy consumption for the manufacturing process to space conditioning requirements.³

Support Personnel Requirements: the energy consumed by and wastes associated with providing for employees of the factory has not been accounted for in this LCA because it is assumed to be small in comparison with the energy used to produce the products.

Technical assumptions made in this LCA are detailed in Appendix C.

The inventory analysis (IA) is conducted after defining the scope of the LCA. For this step in the analysis, numerical data on inputs and outputs for each process is collected from primary and secondary sources. Detailed information about how each step in the production process works was gathered through interviews with industry experts. Comprehensive flow charts for each step were made and the numerical information, the

² Franklin Associates, 1-22.

³ Franklin Associates, 1-22.

inputs and outputs for each system process, to match the processes was researched and found in published LCA reports and databases.

After data on all processes was collected and organized in Microsoft Excel files, the data were analyzed. One package served as the unit of analysis for raw material consumption, air and water emissions, solid waste production, and total energy consumption. We chose to use one unit of packaging (i.e., a single Traytite® or tray-and-film package) because it most easily lends itself to conversion into other units. Also, this small functional unit serves just as well for the purposes of comparison as a larger unit.

The impact of the calculated waste and energy consumption on the environment in terms of several general environmental impacts was calculated and is presented later in this report. Finally, this data is used to conclude that Traytite® packaging has less of an impact on the environment and recommendations for modifications to reduce the environmental impact of both packaging types are made.

Data Acquisition and Calculation

Because data for this LCA is derived primarily from secondary sources, a detailed account of data sources is provided below.

Traytite® Package Data Acquisition:

Traytite®s are composed of solid bleached sulfate (SBS) paperboard coated in a clay coating and a thin layer of PET. Information about SBS production processes was gained through interviews with Dr. Chris Parks of MeadWestvaco. Dr. Parks was also helpful in providing the group with further contacts in paperboard industry, in particular Andy Johnson of Graphic Packaging International.

Mr. Johnson provided detailed information on the steps involved in making SBS and solid bleached sulfate (SBS). This process information was used to map out flow charts for SBS production.

Though several other contacts were helpful in detailing the various processes in making the paper used in packaging Traytite® and Tray-and-Film, most of the numerical data included in this LCA is taken from "White Paper No. 10c: Environmental Comparison-Manufacturing Technologies for Virgin and Recycled Coated Paperboard for Folding Cartons"⁴ This data source was used for all data on papermaking and pulping processes, excluding wood harvesting.

⁴ Environmental Defense Fund Paper Task Force, "Paper Task Force White Paper 10c: Environmental Comparison-Manufacturing Technologies for Virgin and Recycled Coated Paperboard for Folding Cartons," *Environmental Defense Fund*, Dec 19, 1995, http://www.edf.org/documents/1631_WP10C.pdf (accessed Nov 2008).

Wood harvesting data was taken from "White Paper No. 3: Lifecycle Environmental Comparison: Virgin Paper and Recycled Paper-Based Systems"⁵

Data on film PET was used as PET coating data for Traytite® packages because the process of making PET film and making PET coating are negligible in energetic and emissions differences, according to Dr. Parks. Detailed discussion of PET film data is provided below in the "Tray-and-Film Package Data Acquisition" section. Dr. Parks provided typical coating weights of PET used on Traytite® type boxes.

At the factory where they will be filled with food and frozen, Traytite® s are also formed into boxes from flat cutouts and sealed after being filled with food. The energy used of the machines used to form and seal Traytite® boxes was provided by Kurt Naas of A-line Corporation and is detailed in Appendix B.

Once the energy used to produce one Traytite® was calculated, the emissions associated with that energy was calculated using eGRID.⁶

Tray-and-Film Package Data Acquisition:

The paperboard cartons used in the tray-and-film package are made of SBS in exactly the same process as SBS manufactured for Traytite®. Tray-and-film paperboard packages are not coated with a layer of PET, however. Only a clay coating is applied. Therefore, all SBS data from the Traytite® section was also applied to the SBS used in the tray-and-film package, according to the weight of SBS used in the tray-and-film package.

Mr. John Giordani of Associated Packaging Technologies provided our group with information about the production of the plastic trays used in tray-and-film packaging, which are made of PET. Mr. Giordani's information was used to make the PET process flowcharts.

Numerical data for PET was calculated for two stages of PET production: synthesis of amorphous PET and forming of PET trays and PET film from this amorphous PET.

Data on the synthesis of amorphous PET was derived from an LCA prepared for the Plastics Division of the American Chemistry Council, "Cradle-to-Gate Life Cycle Inventory of Nine Plastic Resins and Two Polyurethane Precursors."⁷This data was used in the

⁵ Environmental Defense Fund Paper Task Force, "Paper Task Force White Paper No. 3: Lifecycle Environmental Comparison of Virgin Paper and Recycled Paper-Based Systems," *Environmental Defense Fund*, February 2002, http://www.edf.org/documents/1618_WP3.pdf (accessed Nov 2008).

⁶ eGRID is a comprehensive inventory of environmental attributes of electric power systems which contains air emissions data for nitrogen oxides (NOx), sulfur dioxide (SO₂), carbon dioxide (CO₂), mercury (Hg), methane (CH₄) and nitrous oxide (N₂O). It is available from: <http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html>

⁷ Franklin Associates, "Cradle-to-Gate Life Cycle Inventory of Nine Plastic Resins and Two Polyurethane Precursors," *American Chemistry Council: Life Cycle Study Sheds Light on Environmental Performance of Everyday Plastics*, Dec 2007,

inventory for the PET used in the tray and the PET coating on the Traytite® paperboard box.

Because the American Chemistry Council PET LCA covered PET resin in general, but not specifically PET film, LCA data specifically on PET film from an LCA of PET Film conducted by Plastics Europe was used.⁸ Differences between European and American data on PET production are addressed in the APC report⁹ and in the assumptions section of this report. Our own calculation of the data is as follows:

The energy and emissions values from a Plastics Europe report on APET were subtracted from the energy and emissions values for PET film given in the Plastics Europe report in order to calculate the amount of extra energy and emissions resulting from production of PET film from APET. This data contains emissions data about European emissions, which are 13-18% higher than US emissions for the same amount of energy, according to the APC report. These emissions data cannot be separated and accounted for in another way, so using this data introduces some inaccuracy into the report results, but the level of inaccuracy introduced is acceptable given the larger inaccuracy that would be introduced by not using it.

Data on the energy used to form APET into the trays used in the tray-and-film package was estimated from data provided by the manufacturers of the machines used to produce the trays.¹⁰ Mr. Giordani and Mr. Tony Gallo of APT provided names of companies which made the machines, but were unable to tell us exactly which machines were used. From the machine manufacturer's websites, we chose the machines which, according to our interviews and other data, we believed were used in the process. All machines used in our calculations are detailed in Appendix B.

Once the energy used to produce one tray was calculated, the emissions associated with that energy was calculated using eGRID.

Other Technical Assumptions:

The general nature of this LCA and limited access to plant-specific data forced us to make many technical assumptions to derive usable numerical data for this report. All such assumptions are detailed in Appendix C.

http://www.americanchemistry.com/Plastics/sec_content.asp?CID=1930&DID=7832 (accessed Nov 2008).

⁸ I Boustead, "Eco-Profiles of the European Plastics Industry: PET Film," *Plastics Europe*, Mar 2005, <http://lca.plasticseurope.org/petf5.htm> (accessed Nov 2008).

⁹ Franklin Associates, AD-1.

INVENTORY ANALYSIS

Data was compiled and analyzed using Microsoft Excel. A tabular summary of the inputs and outputs for the cradle-to-gate manufacture of Traytite and tray-and-film packaging is provided below. Graphical summary of the tabular data is provided in later figures.

	Traytite®	Tray-and-Film
Raw materials (g)		
Water	2019.95	4714.23
Wood	80.73	130.41
Air	10.56	120.26
Latex binder	1.54	2.48
Paraxylene	1.34	15.28
Starch	1.07	1.72
Ethylene Oxide	0.65	7.44
Acetic acid	0.10	1.09
Methanol	0.09	1.03
Air Emissions (g)		
CO ₂	140.39	291.52
SO _x	0.44	1.05
NO _x	0.25	0.41
Particulate Matter (PM)	0.16	0.26
CH ₄	0.22	0.87
VOC	0.12	0.14
N ₂ O	0.10	0.36
CO	0.06	0.49

Water emissions (g)		
COD	1.08	1.81
BOD	0.08	0.17
AOX	0.02	0.03
Suspended Solids	0.14	0.45
Sulfate	0.00	0.01
Solid Waste (g)		
Landfilled	3.82	7.01
Incinerated	0.34	0.58
Waste-to-energy	0.00	0.02
Fuel	0.27	3.11
Total	7.02	14.89
Total energy (kJ)	1269	3821

Figure 3: Tabular summary of inputs and outputs for per one package

GRAPHICAL INVENTORY ANALYSIS: Materials and Water Consumption

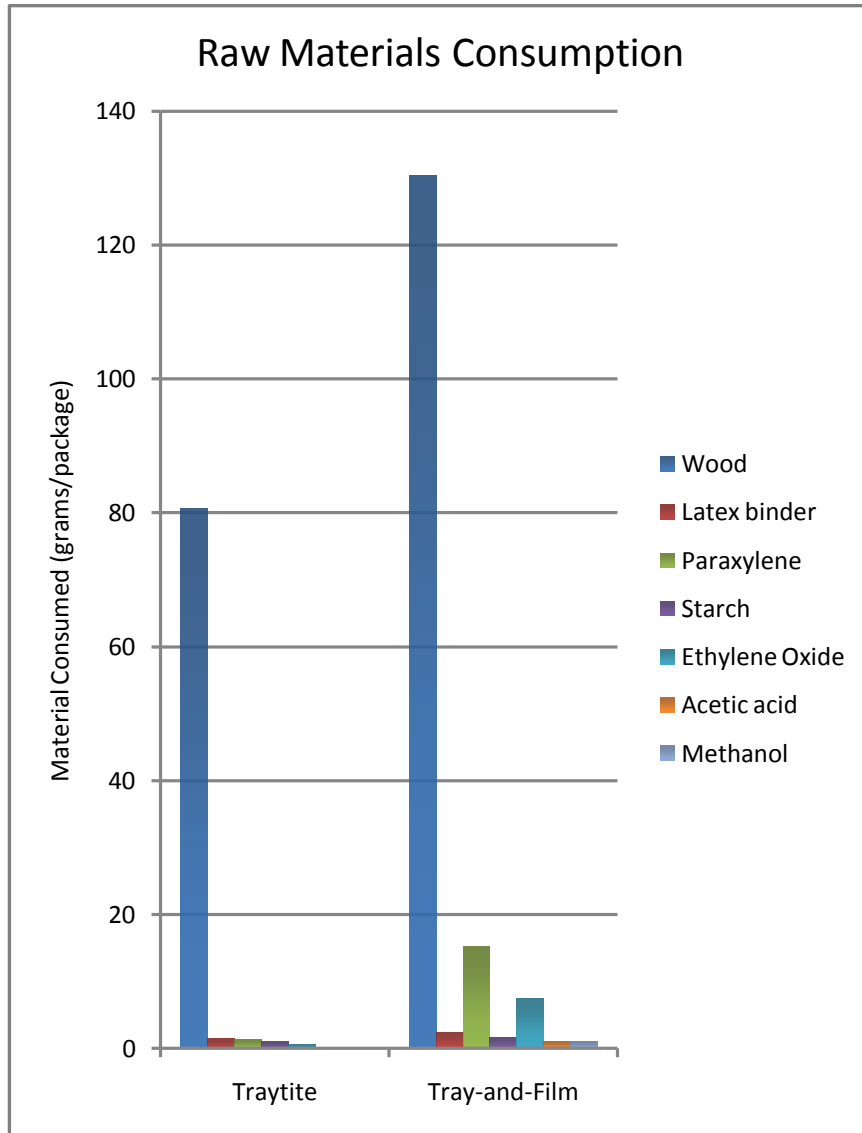


Fig. 4: Raw materials consumed in the production of Traytite and tray-and-film

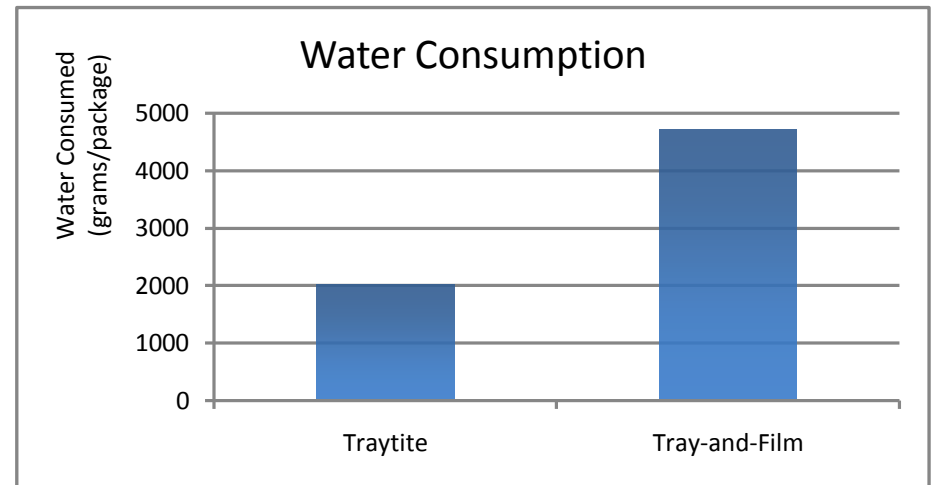


Fig. 5: Water consumption in production of Traytite and tray-and-film packaging

Figures 4 and 5 demonstrate that Traytite® consumes overall less raw materials, water and total energy. Fig 4 shows that wood is the most significant raw material used for Traytite®, which requires 80.7 grams of wood per box. The tray-and-film package consumes 62% more wood than Traytite at 130 grams per box.

Figure 4 also shows that tray-and-film packages require significantly larger amounts of many chemicals used to manufacture PET, particularly paraxylene and ethylene oxide. This difference is due to the greater quantity of PET used in tray-and-film packages.

Water use for the tray-and-film package (4700 ml) is more than twice as great as the water use for Traytite® (2000 ml) production. This is due to the extra water involved in the production of PET resin tray, as well as the greater weight of paper in the tray-and-film which proportionally increases water demand.

GRAPHICAL INVENTORY ANALYSIS: Energy Consumption

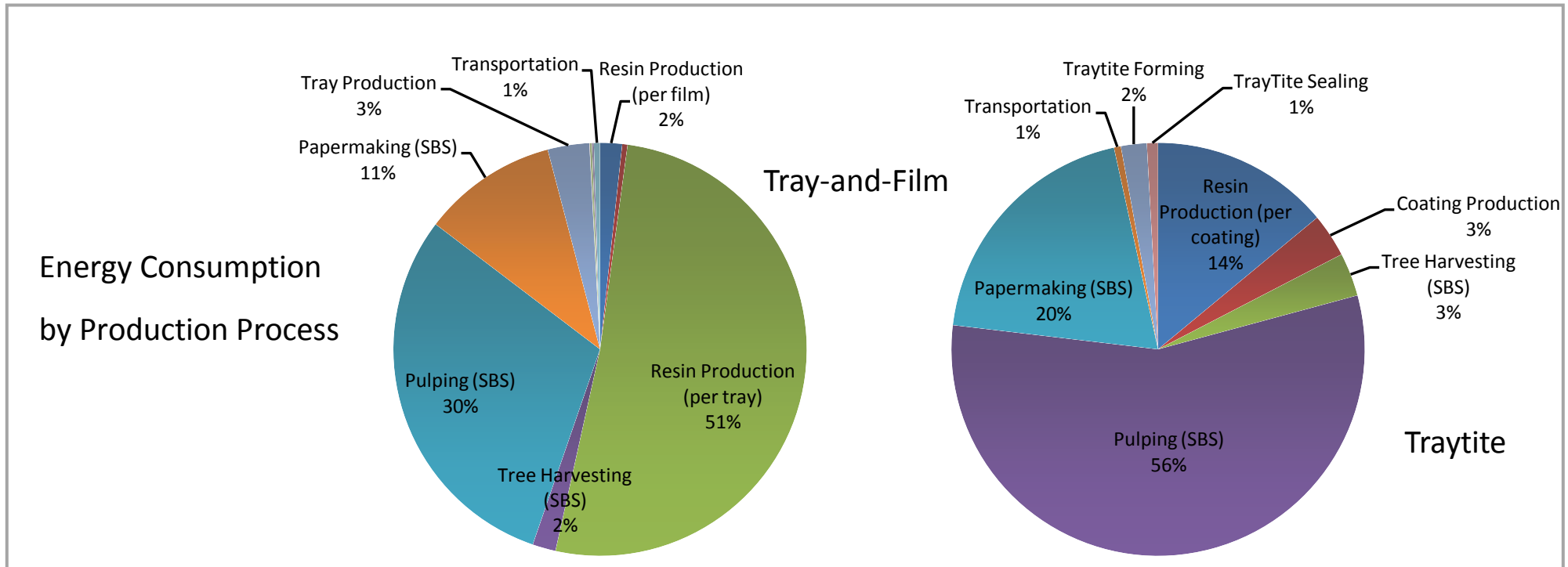


Fig. 6: Traytite and tray-and-film energy consumption by process

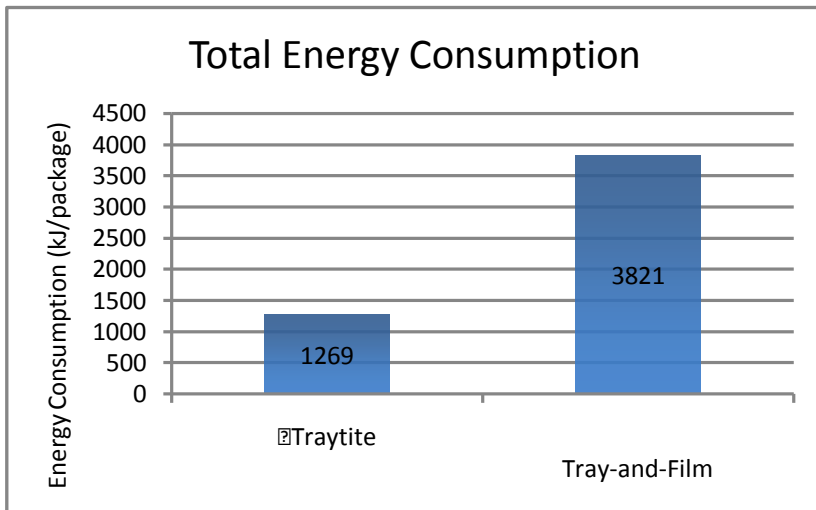


Fig. 7: Total energy consumption of Traytite and tray-and-film

Differences in total energy consumption between tray-and-film and Traytite®, displayed in Fig 7, are similar to the differences in water use between the two packaging types. The tray-and-film package requires about 200% more energy than Traytite® to produce. This discrepancy is likely due to the larger amounts of PET and paperboard used in the tray-and-film package.

Figure 6 breaks down the energy consumed in each step of producing both packaging types. The production of PET resin comprises half the energy needs of tray-and-film packaging, with paperboard-related processes consuming 43% of the rest. Traytite® energy consumption is dominated by paperboard-related processes, which together comprise 79% of Traytite® energy demand.

The following processes have been omitted from Fig 6 for tray-and-film because their contribution to total energy consumption is only slightly larger than zero percent: denesting, tray sealing, cartoning and film production.

GRAPHICAL INVENTORY ANALYSIS: Emissions to Air and Water and Solid Waste Generation

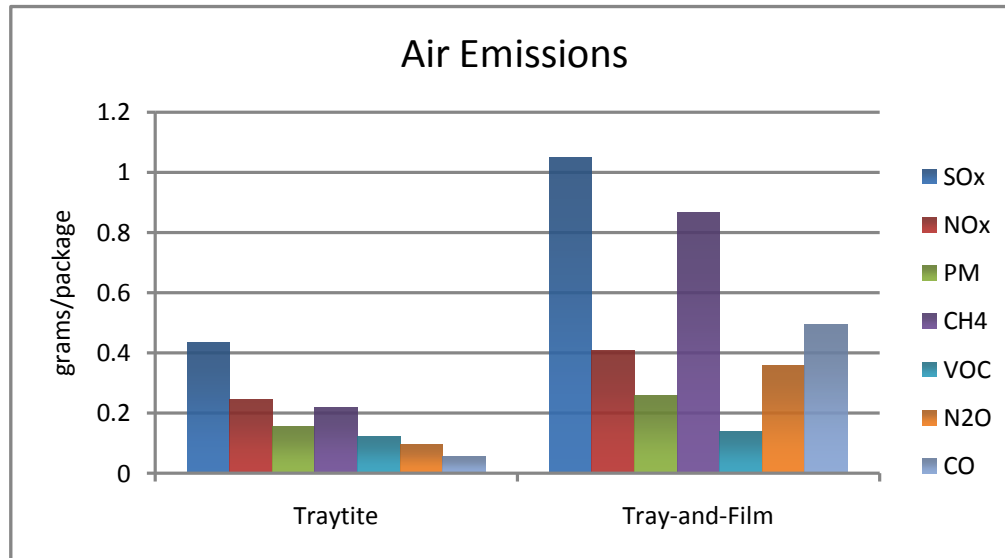


Fig. 8: Emissions to air from manufacture of Traytite and tray-and-film

Figures 8 and 9 display emissions to air and water produced from the manufacture of both packaging types.

Fig 8 shows that Traytite® emits less pollutants to the air than tray-and film. The two biggest differences in emission are in SOx, where tray-and-film produces 140% more than Traytite® and CH₄, where tray-and-film emissions are 300% greater than Traytite®.

Tray-and-film emissions to water, shown in Fig 9, are greater than Traytite®'s in every category. The differences in COD are the most dramatic: tray-and-film is 68% greater than Traytite®.

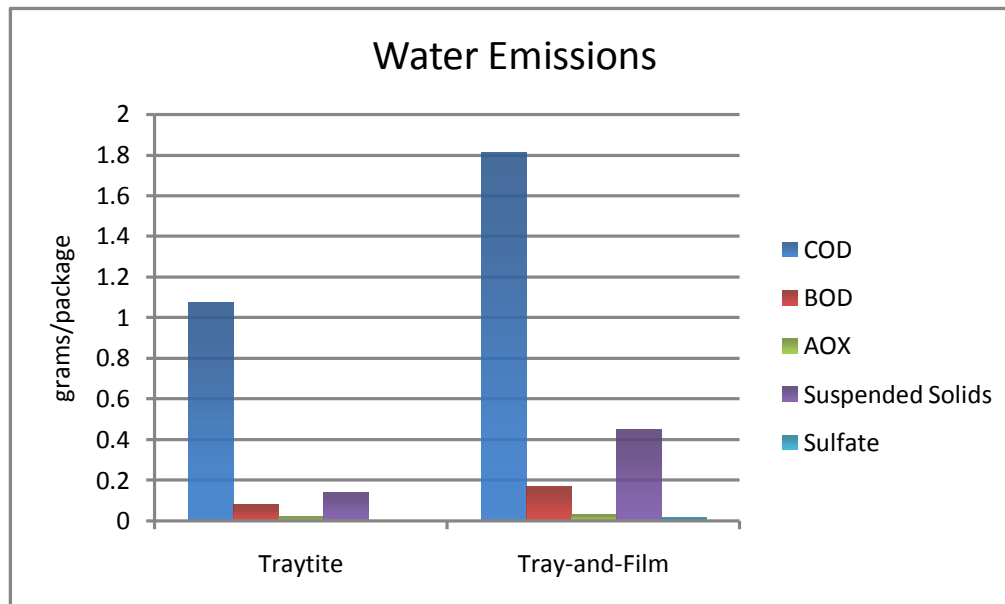


Fig. 9: Emissions to water from manufacture of Traytite and tray-and-film

ENVIRONMENTAL IMPACT ANALYSIS

Based on the most significant waste products produced in the manufacture of Traytite® and tray-and-film, three environmental impacts were chosen for evaluation: solid waste generation, acidification potential, eutrophication potential and climate change potential.

Solid Waste Generation

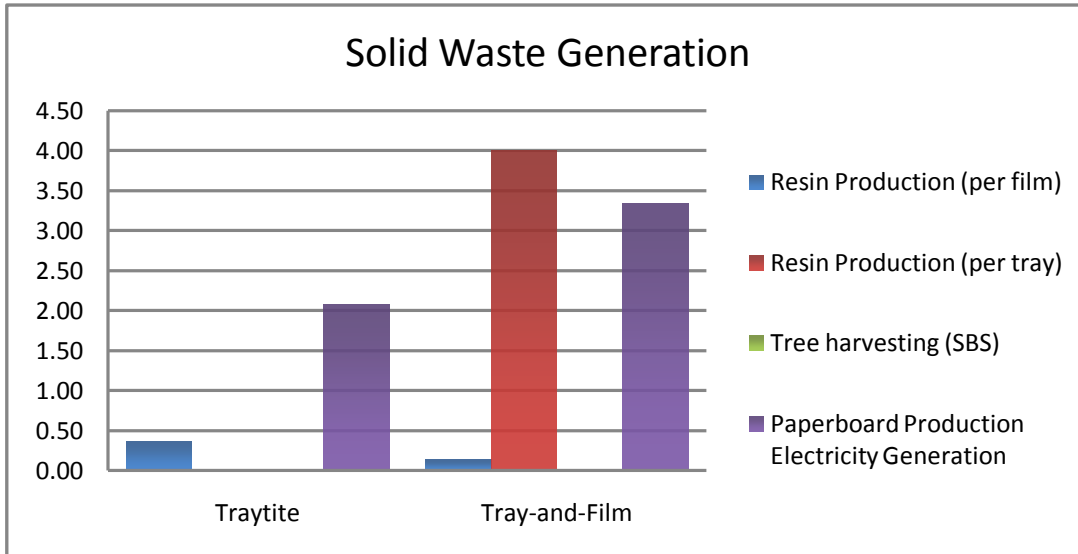


Fig. 10: Solid waste generated from manufacture of Traytite and tray-and-film

Solid waste generation, given in Fig 10, is greater overall for tray-and-film. Resin production (per tray) displays the solid waste generated by producing one tray-and-film tray. This is the largest source of solid waste generation for tray-and-film, followed closely by paperboard production electricity generation. This is also the most waste-intensive category in Traytite® production, though it is 60% less than paperboard production for tray-and-film. Total solid waste production for tray-and-film is about 200% greater than Traytite®.

The environmental impact of solid waste is extremely variable, depending on the method of waste disposal. Solid waste may be landfilled, incinerated or recycled, often by the manufacturing plant itself. Landfilling generally produces the most harmful effect on the environment. Incineration of some materials is an excellent method of disposal. Some manufacturing plants, for example, combust waste wood, on site and use the energy from incineration to help power the plant. Incineration does produce emissions to air, however, and is not appropriate, or possible, for all materials.

Recycling of solid waste reduces the impact of that waste on the environment. Materials may be reused, or reprocessed into a product of lesser quality. Most recycled materials are eventually landfilled because continual reprocessing degrades the quality of the product to a point where it is no longer useful. Recycling waste products as much as possible is an excellent strategy to avoid producing more waste from virgin materials.

Figure 10 covers only the solid waste produced in the manufacture of both types of packaging because that accounts for all of the waste produced inside they system boundary of this LCA. In a general discussion about the environmental impact of these products, however, it is important to remember that after the consumer has consumed the food in the package, the entire package itself becomes waste. This is discussed in a later section, “Recycling of Traytite® and Tray-and-Film Packaging.”

Acidification

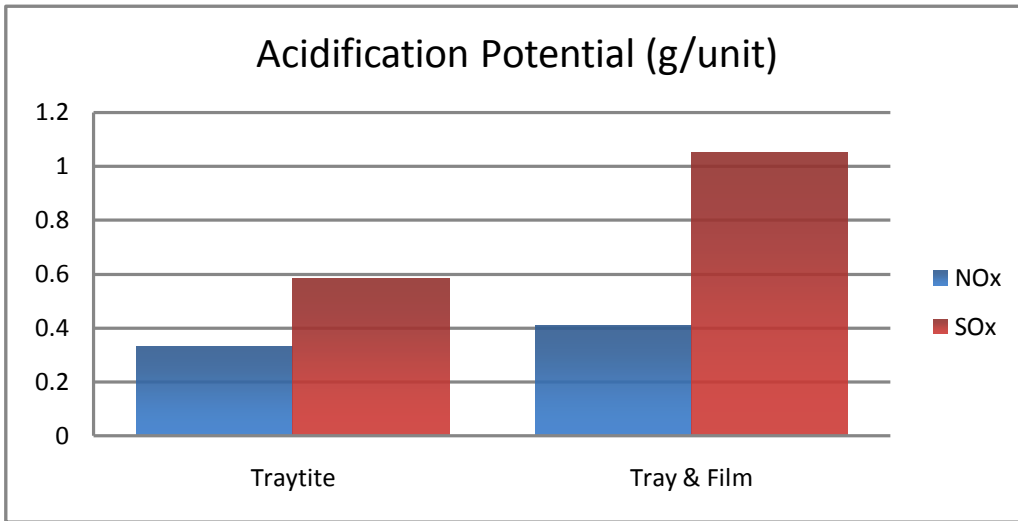


Fig. 11: Acidification potential of Traytite and tray-and-film packaging

NOx and SOx emissions from electricity production are common sources of acidification in the environment. These gases are released into the atmosphere where they are converted to nitric acid (HNO_3) and sulfuric acid (H_2SO_4) respectively. The acids are spread to land and water, often as acid rain. Acid rain damages vegetation and built infrastructure, and acidification of surface waters has consequences for many aquatic species.

Ammonia (NH_3) emission from landfills is another significant cause of acidification, but our system boundary does not include disposal of the products. Figure 11 shows that acidification potential for tray-and-film for SOx is 80% greater than Traytite® and acidification potential from NOx is 24% greater for tray-and-film than for Traytite®.

Eutrophication Potential

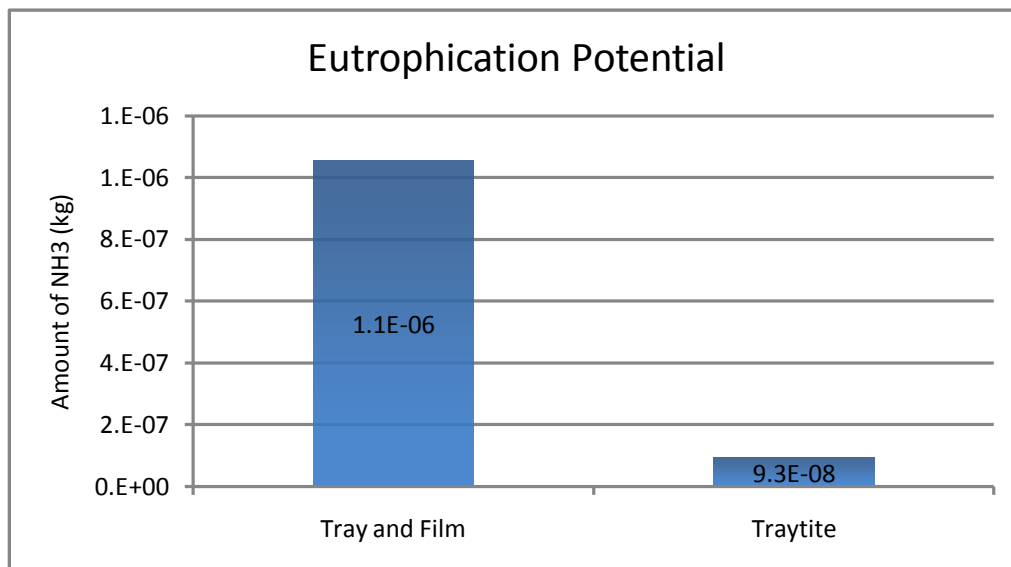


Fig. 12: Eutrophication potential of tray-and-film and Traytite packaging

Eutrophication is the blooming of unusually large and unhealthy amounts of algae, which is caused by the addition of excess nutrients to water bodies such as lakes and estuaries. Nitrogen and phosphorus are the main nutrients which cause eutrophication. Compounds containing nitrogen or phosphorus may be directly discharged into waterways, where their effect on systems is more immediate and easier to quantify.

Nitrogen-containing compounds in the air may also deposit nitrogen into the water and onto land, where it may run off into water, by precipitation. This impact of this deposition is less than if the nitrogen were discharged directly into a water body because some of the nitrogen deposited on land remains in the soil and is absorbed by plants.

Fig 12, above, is a graph of the eutrophication potential based on NH₃ emitted to the air in the manufacture of tray-and-film and Traytite® components. Though there are miniscule amounts of nitrate discharged directly to the water in the production of both tray-and-film and Traytite® products, the effect of this miniscule amount directly discharged to the water is far less than the impact of the deposition of gaseous ammonia by precipitation.

Climate Change Potential

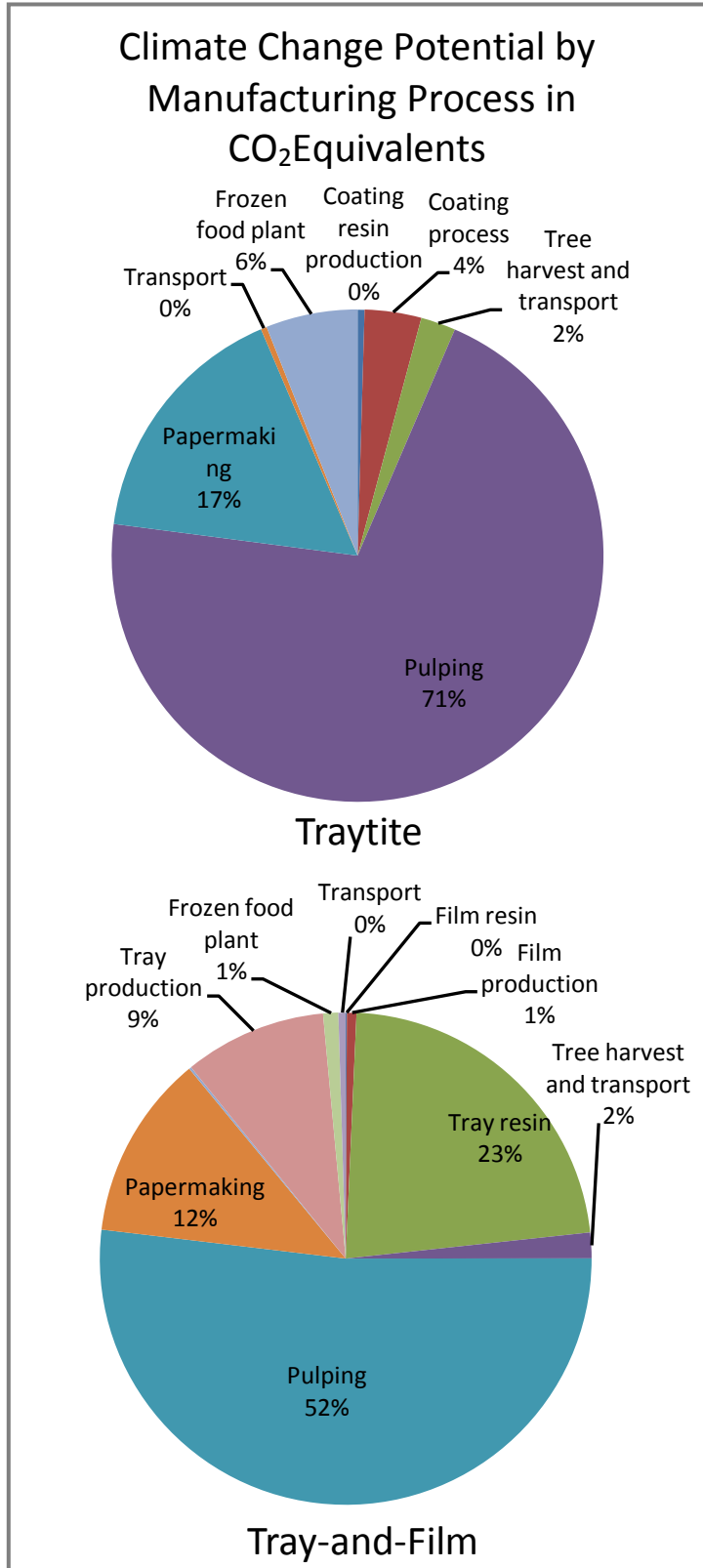


Fig. 13: Climate Change Potential by Manufacturing Process in CO₂Equivalents for Traytite and tray-and-film

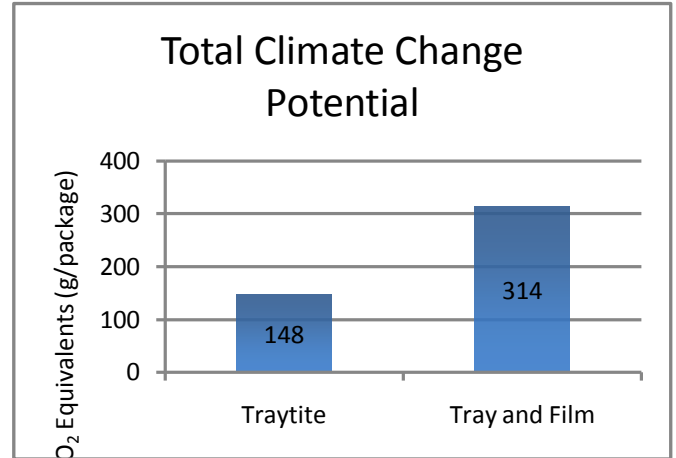


Fig. 14: Climate Change Potential by Manufacturing Process in CO₂Equivalents for Traytite and tray-and-film

Figures 13 and 14 show the potential impact on climate change from the manufacture of Traytite® and tray-and-film products as measured in carbon dioxide (CO₂) equivalents. The two greenhouse gases produced in the manufacture of Traytite® and tray-and-film packaging are methane (CH₄) and CO₂, both of which come from the generation of electricity used in various manufacturing steps and in transportation. Because methane is 21 times more effective greenhouse gas than carbon dioxide, according to the United Nations Convention Framework on Climate Change, methane emissions were converted into CO₂ equivalents in order to better represent the combined impact of both gases.

Fig 14 demonstrates that total climate change potential for the tray-and-film product is 112% higher than the Traytite® and figure 13 shows that the greatest percentage of climate change impact for both packaging types in the paper pulping process. Transport is given as 0% in both packaging types because the fraction of greenhouse gases produced per tray before the product is warehoused and shipped to the consumer is very small. Long shipping distances to the point of sale would increase this percentage.

Recycling of Traytite® and Tray-and-Film Packaging

While our analysis of Traytite® and tray-and-film packaging ends at the “gate,” the total environmental impact of both types of packaging is significantly impacted by what happens to it when the consumer is done with it. After consumption, a product has one of two fates: it is either recycled or permanently disposed of. Landfilling is an energetically inexpensive process of permanent disposal, but it has a large environmental impact because new materials must be created to replace those which have been landfilled.

If the product is recycled, the materials are reprocessed and either incorporated into the production of new, equivalent products, or they are transformed and incorporated into the production of another, lesser product. In some way they re-enter the production flow and replace the use of virgin materials. If Traytite® and/or tray-and-film packages were widely recycled, their environmental impact would be lessened.

Consumer participation in recycling depends upon 1) whether the product is able to be recycled in their area and 2) how convenient recycling the product is, including incentives to recycle the product. Recyclability is, broadly, the capacity in which a product is recycled after its intended use. The recyclability of a particular product depends on the degree to which materials in the product can be reused and technological capability for integrating or transforming the used product into another good.

Traytite® Recycling

The Traytite® package is a combination of paper and plastic components: an SBS paperboard container and lid coated in PET.

It is possible to separate PET coating from paperboard fiber during the pulping step of the paper recycling process, but only the fiber can be reused while the PET must be discarded.¹¹ However, most municipalities have not yet adopted the appropriate technology to separate the two layers, and so do not accept coated paperboard.¹² This lack of suitable recycling facilities means that a negligible percentage of Traytite®s are recycled.

Tray-and-film Recycling

The tray-and-film package is also composed of a combination of paper and plastic components—an SBS paperboard carton containing a PET tray sealed with a PET film—

¹¹ Andy Johnson, Graphic Packaging International, Inc.

¹² Heldman, Dennis R., and Daryl B. Lund. *Handbook of Food Engineering*. CRC Press, 2006.

but the separation of these components in the package leads to a greater percentage of this type of packaging being recycled.

Historically, PET recycling in the U.S. merely added another step in the fate of the resin, instead of closing the loop. PET products were transformed into fibers used in carpeting. However, since the early 1990's, technological developments in PET recycling have allowed for closed loop recycling, returning PET food packaging products to their original use, reducing the need for virgin PET in food contact packaging manufacturing.

While PET products such as beverage bottles are widely recycled, the PET trays used in tray-and-film packaging are accepted by relatively few recycling centers. This is because the black dye which makes the trays opaque is prohibitively expensive to separate from the resin and there is little demand for black-colored recycled PET.

The paperboard carton of the tray-and-film packaging is recyclable and recycled at significant rates in the United States. According to studies by Franklin & Associates¹³ and the American Forest & Paper Association, the fate of these products is divided mainly into three management possibilities: landfilling; recovery for recycling, reuse or export; or incineration with energy recovery.¹⁴ Based on these studies, an average of 46.5 percent of used paperboard is landfilled, 12.5 percent is incinerated, and 36 percent is recovered (Figure 14).

¹³ Franklin Associates. "Cradle-to-Gate Life Cycle Inventory of Nine Plastic Resins and Two Polyurethane Precursors." *American Chemistry Council: Life Cycle Study Sheds Light on Environmental Performance of Everyday Plastics*. Dec 2007.
http://www.americanchemistry.com/Plastics/sec_content.asp?CID=1930&DID=7832 (accessed Nov 2008).

¹⁴ Duke University, Environmental Defense Fund, Johnson & Johnson, McDonald's, The Prudential Insurance Company of America, Time Inc. *White Paper No. 3 Life cycle environmental comparison: Virgin paper and recycled paper-based systems*. Environmental Defense Fund, 1995, 2002.

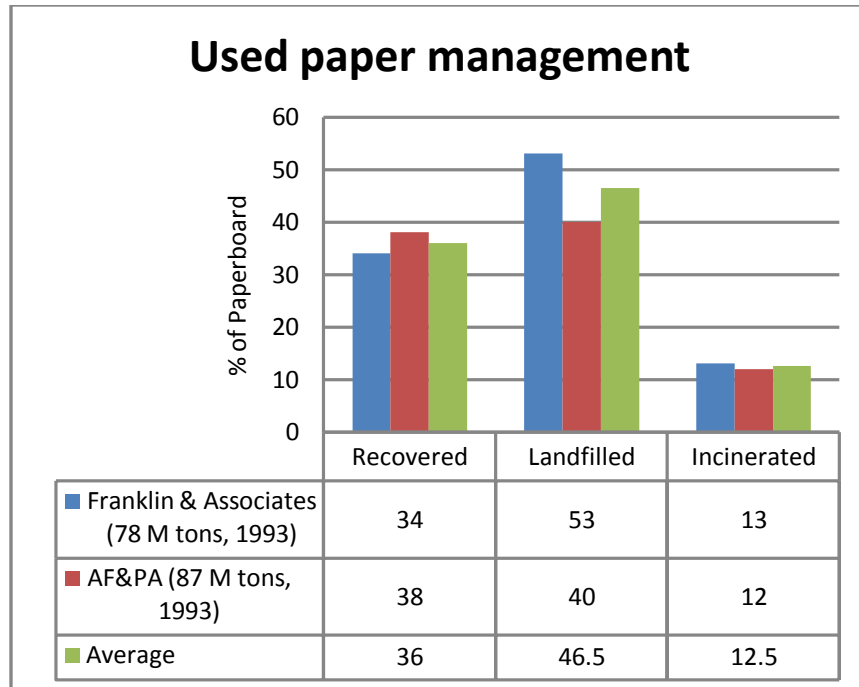


Figure 14: Allocation of used paperboard within waste management based on studies by Franklin & Associates and the American Forest & Paper Association

In summary, the only packaging component that may be recycled at a significant rate is the paperboard carton of the tray-and-film system, at a slightly greater than one third of the paperboard waste stream. Traytite[®] trays and PET components of tray-and-film systems are generally not recycled, but for the black PET of the tray-and-film system, the greatest barrier to recycling is lack of demand rather than lack of recycling technology.

The flow chart below (Figure 15) summarizes the most common waste pathways for packaging components of the LCA.

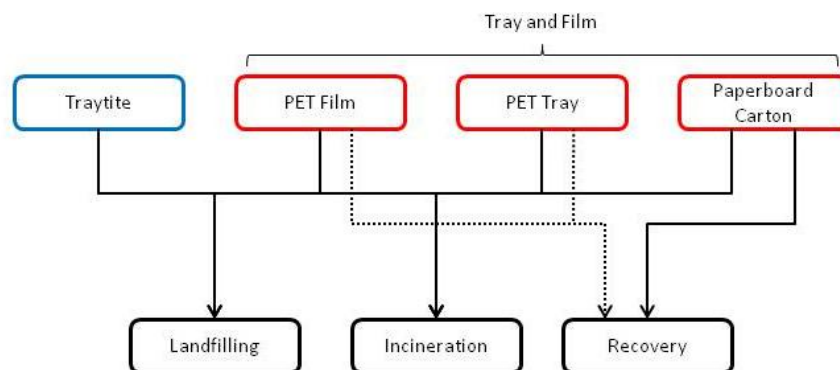


Figure 15: Dominant waste pathways for Traytite[®] and tray-and-film packaging components

RECOMMENDATIONS

Based on the results of this LCA, the following modifications to the packaging design of Traytite® and tray-and-film packaging may lead to reductions in their environmental impact.

Use of recycled paperboard

A modification that would lessen the environmental impact of both Traytite® and tray-and-film packages would be to use recycled paperboard content instead of the virgin paperboard from which the cartons are currently manufactured. For the tray-and-film package, using recycled paperboard presents no technical problems. Traytite®, however, must use virgin paperboard.

Like PET recycling, paperboard recycling does not completely recover the functionality of the recycled material, in this case, the paper fibers. Recycled fibers are generally softer, shorter and weaker, due to the breakdown and pulping required to recover them from used paper. Consequently, paperboard that contains greater recycled content has lower tear strength and stiffness.¹⁵ As the fibers are recycled multiple times, they lose their integrity (Figure 16) and are eventually excluded from reuse by separation procedures in the recycling process.

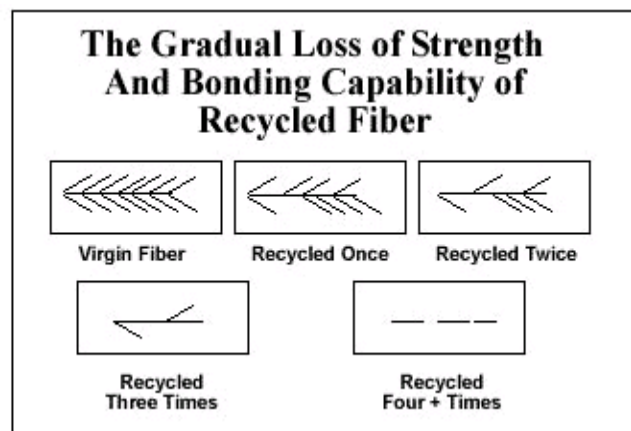


Figure 16: Degradation of paper fiber integrity through recycling¹⁶

Because of the resulting decrease in quality, recycled paperboard cannot be used for roles that require virgin-produced paperboard. These include packaging systems that

¹⁵ Dummit, Heather. *All about paperboard from Graphic Packaging International, Inc.* Macon: Graphic Packaging International, Inc., 2008.

¹⁶ All Packaging Company. *Paperboard Terms Defined.* Convey Studio. 2007. http://www.allpack.com/packaging_school/apc_guide_paperboard_terms_defined.html (accessed Decemeber 2007).

require a certain amount of strength or come in contact with food, such as the Traytite® packaging.

Use clear PET or a different material for the tray-and-film tray

The demand for recycled clear PET is much higher than for black PET. While recycling levels of clear PET trays might not reach the recycling levels of clear PET bottles (many municipal recycling programs stipulate that only plastic bottles, not other shapes of plastic, are acceptable), a modest increase in recycling would lessen the environmental impact of the tray.

Alternatively, a different material could be used for the tray. There are now disposable tray and bowl products on the market that are safe to heat food in and are also biodegradable. Using biodegradable material for the tray would dramatically decrease environmental impact of the tray when it is disposed of. If, however, the energy used and waste generated in producing these trays is large, it may offset some of the benefits of using the biodegradable tray.

Use of renewable energy

Most of the emissions to air and water in this LCA come from the generation of the electricity used to manufacture the paperboard and PET components. Using energy sources that emit less energy would lessen the negative environmental impact of the products. This can be accomplished at the manufacturing plant itself, by installing solar panels on the premises, for example, or by obtaining electricity from renewable sources such as wind power.

CONCLUSIONS

Based on the results of this LCA, Traytite® packaging has a lower level of environmental impact than traditional tray-and-film frozen food packaging. Traytite® packaging requires less energy to produce and generates less solid waste and fewer emissions to water and air. The most significant factor in these differences between tray-and-film packaging and Traytite® is the large amount of PET used in the PET tray.

Though the Traytite® package is less environmentally harmful to produce, there is little room for environmentally beneficial improvements in its design. There are several modifications that could be made to the tray-and-film design, including using recycled paperboard and modifying the PET trays, which would reduce its environmental impact. The magnitude of this impact reduction would depend both upon the modifications made to the packaging design and consumer behavior in disposal of the product.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Elizabeth Shay and Dr. Daniel Arneman for guidance and editing throughout the process of creating this LCA and Kurt Naas of A-line Corporation for suggesting the project and assisting us in finding contacts to interview. We would also like to thank the many industry contacts who generously provided us with information about frozen food packaging and manufacture. Without them, this LCA would not have been possible.

Appendix A: Industry Expert Contacts

Contact	Company	Information
Chris Parks	MeadWestvaco	Paperboard statistics (weight, content ratio) PET coating extrusion on Traytite®
Andy Johnson, sustainability VP	Graphic Packaging International	Paperboard production process Further contacts
Allen Fontaine, engineer	GPI	Machine names and companies Details of production process specific to Michelina's cartons and Traytite®s
Sam Keller, R&D	International Paper	Details on production process
Rick Gould	Rock-Tenn Paper	Details about PET coating extrusion
John Giordani	Associated Packaging Technology	PET thermoforming process
Tony Gallo, Sustainability	APT	PET thermoforming process
Adam Pawlick	Conagra	Frozen food plant process details for tray-and-film
Steve Meschke	Michelina's	Packaging machine data and transportation data

Appendix B: Manufacturing Machines Used in Traytite® and Tray-and-Film Energy Calculations

Tray & Film

Machine name	Manufacturer	Functions	Utilities	Notes
Resin Dryer	Conair	Dries resin	8 kW, 150 cpm	Single Hopper model
Pre-heater Oven	Brown	prepares amorphous PET (APET) for thermoforming	262.5 kW, 280 cpm	
Thermoformer	Brown	forms the tray, converts APET resin to crystallized PET	252 kW, 280 cpm	
T-series Horizontal Trim Press	Brown	cuts and separates trays	10.2 kW, 280 cpm	
Folder-gluer	Bobst	folds paper into carton and glues box edges		
Denester	Waldrop	separates trays so they can be filled	1.991 kW, 125 cpm	
Platen heat sealer	Pathway Solutions, Inc.	seals film on tray	220 V, 15 A, 60 cpm	
Cartoner	Kliklok	inserts tray in box and glues closed	11.95 kW, 125 cpm	

Traytite®

Machine name	Manufacturer	Functions	Utilities	Notes
MP-HT carton former	Arenco	forms and seals carton sides and base	53.5 kW, 45 stokes per minute	Triple head model
ES-S carton sealer	Arenco	seals paper lid after filling	23 kW, 125 cpm	

Appendix C: Technical Assumptions of this LCA

LCA Assumptions:

PET products

- PET film data was calculated using APC (US) data up to the film production process. The data about film production was found by subtracting PlasticsEurope amorphous PET data (an intermediate of film) from the total film production data. This data was then added to the APC APET data.
 - There are several differences in these two data sets
 - Total energy calculated by the two reports for PET production differed from 13.6-18% (APC report, AD-1)
 - *Transportation differences. Distances for some transportation steps are higher in North America compared to Europe.*
 - *Different feedstock mixes. Differences in the mix of crude oil and natural gas used as resin material feedstocks in the U.S. and in Europe lead to different feedstock energy (energy of material resource). This comes about due to the difference in calorific values for natural gas (54 MJ/kg) and crude oil (45 MJ/kg).*
 - *Different material sources. Differences in the source of an intermediate chemical/material may make a difference in raw materials, energy, and/or emissions. One example is the glycerine used in the polyols used in flexible foam polyurethane. It may be produced from a number of sources, including palm oil, animal fat, and from propylene.*
 - *Accuracy/types of collected data. The collected U.S. data (including a few Canadian and Mexican plants) was taken from a variety of sources within each company providing data (ranging from estimates to calculations from utility records).*
 - *Differences of the size and age of plants providing data. Production quantities were used to weight the provided data; therefore smaller plants were weighted lower than the larger plants.*
 - *Differences in plant sites. Coproducts that may be regarded as wastes on a small site or stand-alone plant may be regarded as inputs to other processes on large sites.*
 - *Differences in system boundaries. The European plastics LCI database includes waste incineration facilities within its*

system boundaries. No waste incineration facilities are included within the system boundaries of the U.S. plastics LCI database. Many U.S. plants had wastes sent to incineration facilities; however, these were commonly off-site and mixed with wastes from other plants, and so data were unavailable for the specific materials of interest. In some cases, large amounts of chemicals that were incinerated as wastes at European plants were actually coproducts (sold for profit) at corresponding U.S. plants. (APC, AD-2)

- Averaging data – APC used “horizontal averaging” opposed to “vertical averaging” which is less accurate (APC, AD-4 – AD-5)
 - Fuel infrastructure – APC used the electrical grid for the entire US as opposed to the Europe data which considered the specific grid of the plant’s country (AD-7)
 - Other differences include cogeneration of steam and electricity and coproduct allocation method (AD-6)
 - More information can be found in the Addendum of the APC report
- Assumed that the extrusion process to put the PET coating onto the Traytite® SBS was the same as the process to produce PET film (Chris Parks, MeadWestvaco).
 - Paperboard production
 - Assumed that the paperboard used to make Traytite® trays is 18-gauge paperboard. This assumption was needed to calculate the weight ratio of paperboard to PET coating.

Transport

- Diesel combination truck used for transport
- Each truck “weighed out” – filled to a max weight of 20 tons
- Transportation distance set at arbitrary 100 miles
- Diesel fuel consumption 10.5 gal/1000 ton-miles

Manufacturing Machines

- Assumed that the impact of the glue involved in assembling tray-and-film cartons are negligible
- Specific machine data from APT, GPI, and Michelina’s was confidential, so we approximated each machine’s energy consumption per product by taking averages of models we found online based on whatever manufacturing machine details given to us by our contacts.
- Consequently, we assumed that the energy used to produce the PET trays, Traytite® boxes and tray-and-film cartons come only from the machines that manufacture them, and their associated emissions come only from the production of the electricity to power them.

- In order to calculate the energy consumption per unit (Traytite[®] , PET tray, tray-and-film finished product), we made assumptions about the machine speeds based on:
 - Uniform production line speed limited by the slowest machine
 - Capacity of machine based on average of listed machine capacity specifications
- The assumptions about packaging manufacturing machines are tabulated on Table X:

Process	Contributing machine data	Assumptions made
Traytite [®] former	Arenco MP-HT	Assumed machine was triple head model, in order to reach a uniform 125 cpm for the production line
Traytite [®] sealer	Arenco ES-S	Assumed production line speed of 125 cpm
Resin dryer	Conair models: RWH39-35, RWH39-42, RWH44-58	Assumed single larger hopper rather than several small parallel hoppers. Took average of utilities and capacities.
Pre-heater oven	Brown models: PH-33, PH-43, PH-58, PH-74	Took average of utilities and capacity information. Unit capacity was set as the Thermoformer speed, because it was the lowest speed in the line.
Thermoformer	Brown CS series: CS-2100, CS-3036, CS-4500, CS-5500, CS-5050	Took average of utilities. The average of the maximum resin sheet dimensions was used to set the speed of the entire tray production line. The thermoforming speed was based on an average of a range of seconds per cycle given by Koester et. al (1).
Horizontal trim press	Brown T-series: T-125, T-130-L, T-340-L, T-350-L	Took average of utilities and set the speed to the lower thermoformer speed.
Folder-gluer	Bobst Domino 85-M	Assumed a production speed of 1200 cpm, based on a production speed of 1000 lineal ft/min, based on information from GPI.
Denester	Waldrop Model 125	Assumed speed of 125 cpm to run the tray-and-film production line at the same speed as the Traytite [®] line.

Platen heat sealer	Pathway Solutions RBF6-1520	Assumed two machines running in parallel at 60 cpm to approximate production line speed.
Cartoner	Kliklock-Woodman Captain 125	Original specifications were used at the max listed speed of 125 cpm

Table X: Assumptions made to calculate energy used per Traytite® or tray-and-film during manufacturing processes

Transportation

- Assumed an arbitrary dummy transport distance of 100 miles between PET plant, PET tray manufacturer and frozen food plant; between PET plant, film producer and frozen food plant; between paperboard producer, paperboard converter and frozen food plant; and between PET plant to frozen food plant.
- Assumed diesel combination trucks (tractor trailers) were used to carry goods.
- Assumed that each truck carried 20 tons (20,000 kg), which is the weight limit of a combination truck, according to Chris Parks.
- Assumed that trucks were filled by weight rather than volume, based on information from Steve Meschke at Michelina’s.

Excluded steps

Certain steps were excluded from the inventory analyses of both types of packaging because they would have had a minimal effect on a comparison between their impacts.

- We did not include glue in our inventory analysis because this would have been a negligible part of impact and materials use.
- We excluded Traytite® and tray-and-film paperboard carton printing, scoring and cutting steps. These steps are performed by the same “roll to cut” machine (Komori or Hamilton Stevens) in the same paperboard conversion plant (Graphic Packaging International), so we assumed that energy differences in processing the two configurations of board would be negligible.
- Excluded food filling and freezing processes at the frozen food plant because the same machines are used for both types of packaging (Adam Pawlick, Conagra).
- Excluded the ink used for printing Traytite® s and tray-and-film cartons from our inventory analysis because we assumed the same type of ink was used for both packaging types and differences in their application would be negligible.
- We did not include transportation from the frozen food plant to the distributor because these trucks carry both Traytite® and tray-and-film packaging systems together, in amounts specified by the distributor. In order to exclude this step, we assumed that an equal amount of both types of packaging are in each truck.