Analysis of Chewing Gum Packages

ENGS 171 Final Report

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Introduction

Chewing gum, or similar substances, has been chewed for pleasure since the ancient Greeks when it was used at least in part to sweeten the breath.[1] It was introduced and brought to its current state and level of popularity starting in 1869 when William F. Semple patented his chewing gum.[2] Around the same time Dr. Thomas Adams invented a new substance to chew while trying to devise a new form of rubber.[3] It was seen as a good substitute for chewing on pencils while concentrating.[4] During the 1930s and 1940s chewing gum grew immensely in popularity with the introduction of bubble gum cards for kids and GIs bringing American chewing gum to Europe, Asia and Africa during World War II. During the war, the soldiers used gum as currency to trade.[5]

Although it has always been a recreational substance, gum has become engrained in society over the course of its 5000 year life. Today most chewing gum is sugar free and identified with several health benefits.

Benefits of Chewing Gum

The benefits of chewing sugar-free gum are divided into four categories: oral health, diet management, stress relief, and concentration. Chewing gum helps improve oral health since it stimulates the production of saliva, helping to neutralize acids, fight cavities, re-mineralize enamel to strengthen teeth, and wash away food particles. A study done by Szoke et al. in 2001 revealed that children who chewed gum after meals reduced dental cavities by nearly 40% compared to non-chewers. Chewing gum also helps weight management since having a low-calorie snack such as gum instead of having one with more calories reduces daily caloric intake.

A study done by Hetherington (2007) showed that chewing gum before snacking helped reduce hunger, cravings for sweets, and decreased snack intake by 36 calories. Chewing gum may also improve concentration, as shown in a study by Wilkinson et al. (2002) where they concluded that chewing gum while performing memory tests appeared

[1] http://www.bbc.co.uk/dna/h2g2/A172342
[2] http://www.nacgm.org/consumer/funfacts.html
[3] http://www.bbc.co.uk/dna/h2g2/A172342
[4] Ibid
[5] http://www.nacgm.org/consumer/funfacts.html

to improve people's ability to learn, retain and retrieve information. Lastly, a study done by the FRC Research Corporation in 2006 showed that gum chewers were more calm and relaxed in dealing with life's everyday stresses.

Market Data: United States

The average American consumes 168 sticks of gum annually and the US gum market has total sales valued at 3.09 billion US dollars (National Confectioners Association). 80% of the US market is sugar-free gum and we decided to focus on that by only analyzing the packaging of sugar-free gum, but sugared gum packaging is similar and our results could easily be applied to this market. The largest gum manufacturer is Wrigley's with a market share of 59%, followed by Cadbury Schweppes who has a market share of 34.5% (National Confectioners Association). All four gums that we analyzed were produced by these two companies.

Assumptions

We made various assumptions in order to carry out the life cycle assessments for each of the four gum packages. Table 1 summarizes the numbers we used for energy consumption to manufacture the different kinds of packaging materials. The number for paper includes electricity and amount of oil needed. We assume that adhesive was insignificant in each of our packages, and that all paper is bleached. We also assume no energy is required during use, and that all of the materials are non-recyclable, ending up as solid waste. Due to current consumer behavior which is to throw out the gum wrapper, we decided to examine only virgin materials and assumed no recycling in our analysis. Transportation costs were calculated using truck transportation at a rate of 343 BTU per ton mile. Additionally, 1000 miles of transportation was accounted for in the delivery of gum packages. Data for end of life analysis varies from region to region. We used an average of rural and urban areas from North Carolina and assumed that this number of $95 per ton was representative of a national average.

Material	Energy Consumption (KJ/kg)
Paper	135,305
Aluminum	279,720
Polyethylene	98,000
Polystyrene	104,300
PVC	65,400
Polypropylene	74,300
Steel	40,000

Table 1- Energy Consumption for Different Materials
Source: http://engineering.dartmouth.edu/%7Ecushman/courses/engs171/UsefulNumbers.pdf

Specifications

Based on our life cycle analyses and current gum packaging, we compiled a list of new specifications for our redesign. First, the redesigned package should hold an amount of gum that is comparable to current packages. This criteria means that the package should hold at least twelve pieces of gum, possibly more. Recyclability is another important specification and the majority of the new package if not the entire package should be recyclable. Also, the possibility of using recycled materials to make the new package should be considered. To allow for easy recycling as few different materials as possible should be used and those with high recycling rates should be investigated. The new package shouldn't consume more materials than current packages. Material use also contains the possibility of the new package limiting or eliminating the use of adhesives, which often are produced in processes that use toxic materials. Another specification related to material use is that of energy use and our redesigned package should require less energy input than the current models. Our final specification involved the size and portability of the new package because consumers will not want a large, bulky package. Therefore, the redesigned package would ideally fit in a person's pocket, but must be feasible to carry in a purse or backpack.

Previous Investigation

We analyzed four different gum packaging for the midterm report: Dentyne, Eclipse Big-e-Pak, Extra and Orbit.

Dentyne 12-Pack Analysis

The package is comprised of an outer cardboard sheath in which a clear plastic package (assumed to be polyethylene) can easily slide in and out. The plastic acts as a housing for 12 pieces of hard coated gum, which are roughly .5” x .5” x .25” in size. A thin aluminum sheet covers the gum in conjunction with adhesive to create a tight seal (see Figure 1).

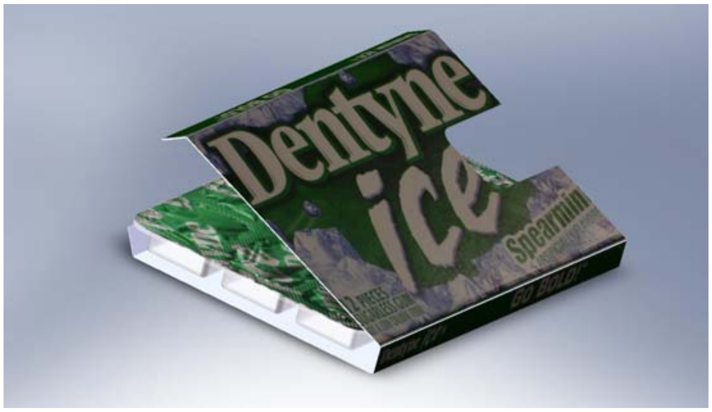


Figure 1 – A SolidWorks rendition of the Dentyne Ice package.

The outer surface of the cardboard is painted and has a waxy finish, while the inside of the cardboard is unpainted and appears heavily bleached. The plastic is easily manipulated which allows the user to push on one side and eject the gum through the foil. It does not contain any marking indicating that it is safe for recycling. The combination of adhesive, foil and plastic likely makes this product difficult to recycle. A weight analysis was done to determine the amounts of materials used in a single package (see Table 2).

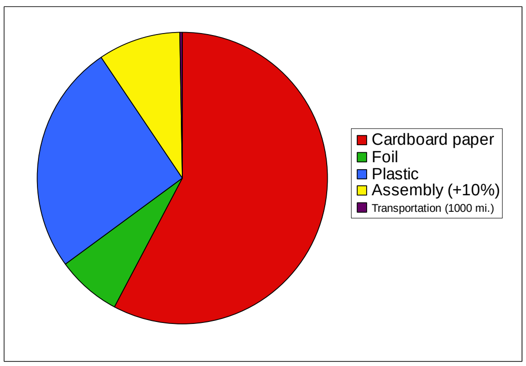
Weight Analysis (g)	
Overall weight	**22.0**
Cardboard paper	3.3
Gum package	18.7
Foil	0.2
Plastic	2.1
Gum (12 pieces)	16.4
1 piece	1.4
Overall weight of packaging	**5.6**

Table 2 – The above table illustrate the weight of individual materials used in a single 12-piece package of Dentyne Ice.

The materials were analyzed for energy used in manufacturing and transportation to ultimately determine the amount of energy used to package 1000 pieces of gum (see Table 3). For a further breakdown and comparison of materials, refer to figures 2 and 3.

Material	Weight (kg)	Materials used in US per year (kg)	Energy (MJ)
Cardboard paper	0.0033	1386000	1.88E+08
Foil	0.0002	84000	2.35E+07
Plastic	0.0020	840000	8.23E+07
Assembly (+10%)	0.0000	0	2.97E+07
Transportation (1000 mi.)			9.41E+05
Total		**2310000**	**3.24E+08**

Table 3 – The above table represents the energy used to manufacture and transport Dentyne Ice on an annual basis.



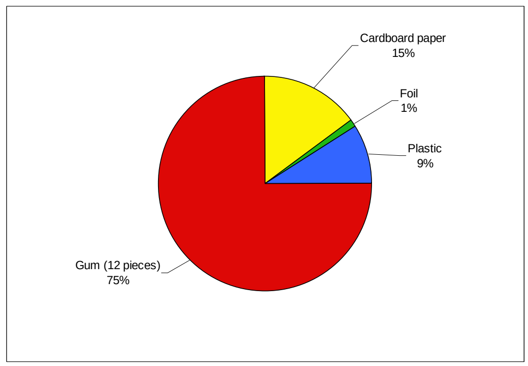


Figure 2 & 3 – The above graphs illustrate material properties of the Dentyne Ice package. The left graph represents the energy use of the different processes, while the left graph represents the percentage by weight of the different materials used in packaging.

Eclipse Big-e-Pak

Wrigley recently introduced the Eclipse Big-e-Pak, which is designed to hold sixty pieces of gum; significantly more than other competing packages. The Big-e-Pak is a circular contained made from HDPE plastic and is designed to sit in a car cup-holder. The lid is made from polypropylene and has two openings. The smaller opening allows for gum to be poured, whereas the second opening is much larger and allows the consumer to reach in and grab the gum one piece at a time. The first opening encourages the consumer to eat more than one piece, while the second opening encourages sharing with other people. The overall result is increased consumption of gum.

The container has both a freshness seal and a shrink-wrap plastic label. The freshness seal is made from cardboard paper, aluminum and glue, while the shrink-wrap label is made from PVC. Additionally, there is a polypropylene label glued on top of the container which identifies the brand of the gum. While the Big-e-Pak is marketed by Wrigley, the parts for it are produced by five companies, including Wrigley. The container is made by Silgan, the polypropylene lid is made by Rexam, the shrink-fit label is made by Sleevco, and the label on top is made by Deco. As a result, transportation costs associated with bringing all these parts to a central location could significantly increase the energy used to produce the Big-e-Pak. Transportation costs were calculated based on the assumptions previously mentioned and the energy input for transportation is .011MJ/package or .18MJ/1000 pieces of gum. A life-cycle analysis was done on this package and its takes 42.8 MJ to produce enough packaging for 1,000 sticks of Eclipse gum. Table 4 and Figure 4 illustrate the results of the LCA.

Material	**Mass (kg/package)**	**Energy (MJ) per 1000 pieces**
Cardboard paper	0.0003	0.68
Aluminum Foil	0.0007	3.27
Plastics	0.0268	34.68
Assembly		4
Transportation		0.18
total energy		42.81

Table 4: Lists the weight and energy input of the components of a BigEpak

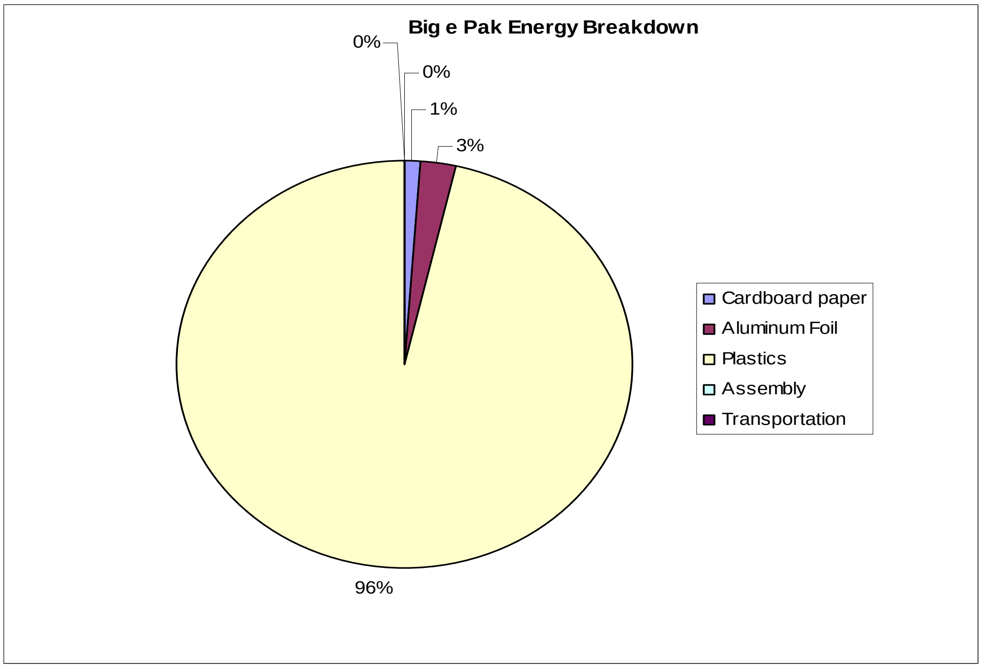


Figure 4: Breakdown of the energy consumed in the production of the BigePak

The vast majority of this energy was consumed in the production of the plastics, specifically the HPDE that is used to make the container. Recycling could reduce the environmental impact of the Big-e-Pak, but consumer behavior and other factors may result in low recycling numbers.

Extra Gum 15-gum

Wrigley's gum was introduced in the market in 1984 as the first sugar-free gum in the United States. It is currently the number one sugarless gum in the country due to its variety and long lasting flavors. Each pack of gum weighs 47.1 grams, holding 15 sticks, and 17% of its weight is due to packaging. Each pack has three distinct packaging layers: outside package, paper wrappers, and individual wrappers. Table 5 summarizes each packaging layer, its materials, and its weight composition.

Part	Material	Amount	Weight (kg)
Outside Package	Aluminum	50%	0.0006
	Polyethylene	40%	0.00048
	Paper	10%	0.00012
		Total:	0.0012
Paper Wrappers	Paper	100%	0.003
Individual Wrappers	Aluminum	20%	0.0006
	Paper	80%	0.0024
		Total:	0.003

Table 5 – Materials and weight composition per pack of Extra

As it can be seen, there are three materials used in each pack of gum: aluminum, paper, and polyethylene. Table 6 shows the amount of material present in each pack and the energy required to manufacture, assemble and transport packaging for 1000 pieces.

Material	Mass (kg/package)	Energy (MJ/1000 pieces)
Paper	0.00552	49.79
Aluminum	0.0012	22.38
Polyethylene	0.00048	8.95
10% assembly		8.11
Transportation		0.20
TOTAL		89.43

Table 6 – Materials and energy required to manufacture and transport 1000 gum pieces

Figure 5 shows the energy breakdown for 1000 pieces of gum:

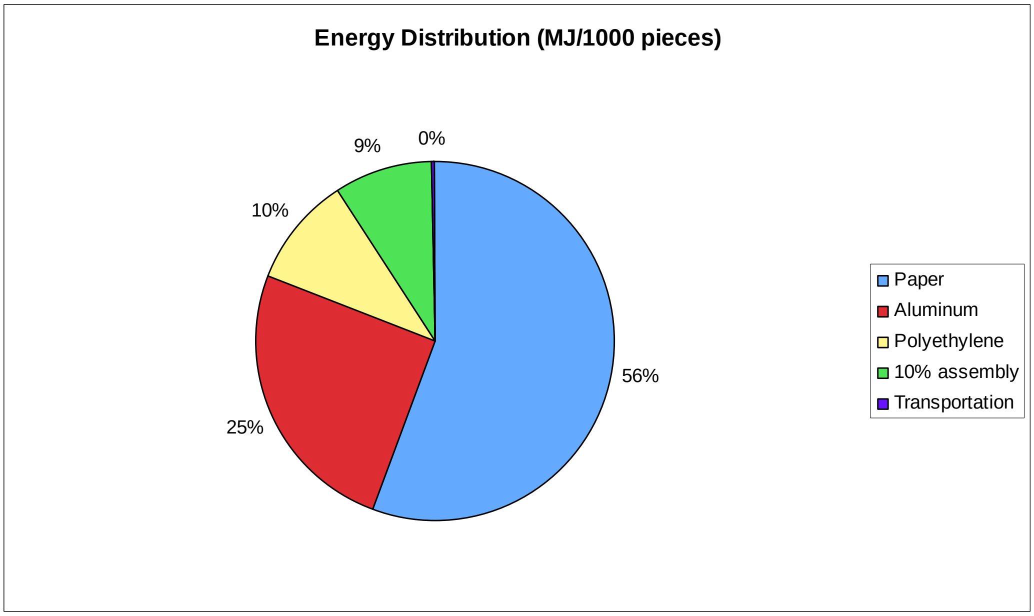


Figure 5 – Energy Breakdown for the packaging required for 1000 pieces of gum

Orbit

Orbit Gum comes in packages of 14 pieces. It was introduced in 2001 and with its distinctive wrapper and size of each stick, Orbit quickly became one of the top 5 gums in the United States.

There is a thin plastic wrapper that holds the packaging together which is easily removed. Underneath is a thin, folded cardboard container and then a flap for reclosing after the package is opened. Inside this paper there is a folded aluminum/paper divider that also protects the gum from moisture and going bad. From there, the gum is split into two rows of seven each in its own paper wrapper. The paper wrapper which holds an individual piece of paper is very fibrous in order to wick away moisture from the gum. Figure 6 shows the percentages of each material by energy to make.

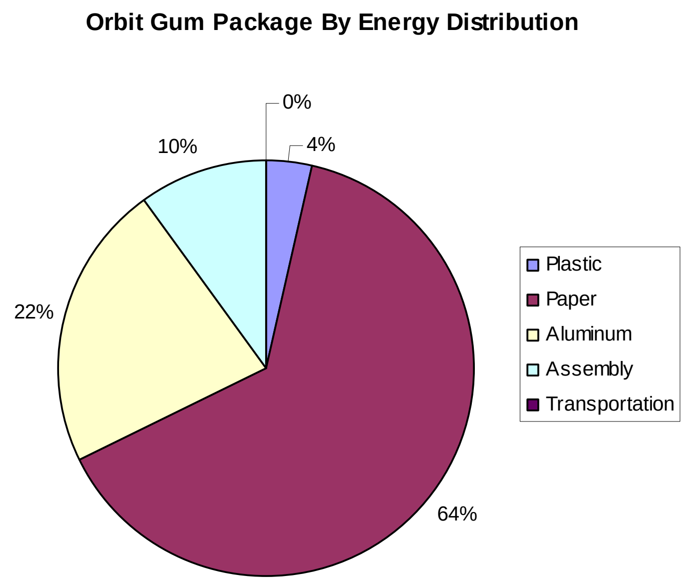


Figure 6 – Energy Distribution for Orbit

The entire package weighs 34.2 grams and of that only 6.6 grams is packaging. It is a fairly well packaged container with volume of 5.0875 x 10^-5 cubic meters giving it a very high density. As a result of this and the use of only three materials the package is easy to make. Orbit requires 79.6 MJ/1000 pieces of gum to produce when including assembly and transportation (see Table 7).

Part	Weight (kg)	Energy for the Part (MJ)
Plastic	0.0004	2.98
Paper	0.0053	51.22260714
Aluminum	0.0009	17.982
Assembly		7.218460714
Transportation		0.196639929
Total		79.59970779

Table 7 - Materials and energy required to manufacture and transport 1000 gum pieces

Finding Better Alternatives

Redesign

Due to the nature of gum, the type of packaging is very important to keep it away from the elements which might spoil the product. As a result, our redesigns focused on three of the top four items of the Design for Environment triangle.

Since we felt that avoidance was beyond the scope of this project we focused more on reduction, reuse and recyclability of materials. Additionally we tried to minimize the number of steps and materials required for the product. This meant that after our analysis of our alternatives we went with a deeper redesign.

We felt that there is significant room for improvement in the gum industry. Although we did not have a specific solution in mind going into the project, possibilities developed as we conducted our analyses. Our initial inspection of the different package types indicated that some companies use more materials than others. When examining the redesign options for gum packaging, materials were a large factor.

Our group came up with the following redesign options (see Table 8), beginning with the most extreme solutions and ending with less drastic options such as labeling materials better.

Deep	
Stop chewing gum	Behavioral
Develop longer lasting gum	Product Change

Moderately Deep	
Get rid of packaging	Product Change

Moderate	
Reusable container	Product Change
Recycling incentives	Behavioral

Moderately Shallow	
Use recycled paper	Dematerialization
Non-bleached paper	Product change/Behavioral
Edible Paper	Product change/Behavioral

Shallow	
Get rid of unnecessary/extra packaging	Dematerialization
More eco-friendly material	Dematerialization
Label materials better	Product Change

Provide material database	Information Sharing

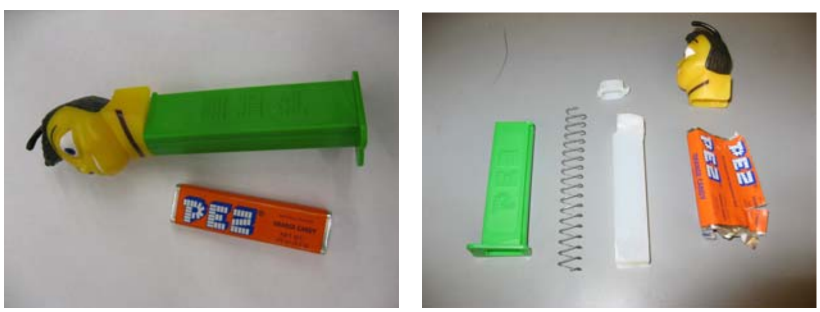
Table 8 – Redesign options

Afterwards, we brainstormed several potential implementations for these redesigns. The first possibility is a reusable container, similar to a PEZ dispenser, that would reduce the need for packaging down to a single layer to keep gum fresh before it is bought and transferred to the dispenser.

An alternative implementation would be to modify a current product, Bubble Tape produced by Wrigley, which uses a single plastic package to contain a 6 foot piece of gum that can be torn into individual pieces. If the pieces were pre-perforated into single piece sizes, perhaps traditional flavors of gum could be marketed to adults and general gum customers.

PEZ Dispenser

The dispenser is made up of several plastic pieces and a steel spring (see Figure 7 & 8). It is designed for reusability in conjunction with disposable packages of 12 pieces of PEZ candy. After unwrapping and loading the dispenser, one piece can be dispensed at a time. The container holds 12 pieces and is roughly 3” long x .5” wide.



Figures 7 & 8 – Photos of the PEZ dispenser used in the analysis

Weight Analysis (g)	
Overall weight	**20.5**
Plastic	19.9
Steel Spring	0.6
Overall weight of packaging	**20.5**

Weight Analysis (g)	
Aluminum	0.3
Overall weight of packaging	**0.3**

Table 9 & 10 – The above tables illustrate the weight of materials used in the dispenser and an individual wrapper.

The materials were analyzed for energy used in manufacturing and transportation to ultimately determine the amount of energy used to produce one container (see Table 11).

Weight Analysis (g)		Weight (kg)	energy (MJ)
Plastic	19.9	0.0199	1.95E+00
Steel Spring	0.6	0.0006	2.40E-02
Assembly (+10%)	0.0	0.0000	1.97E-01
transportation			8.55E-03
Overall weight of packaging	20.5	0.0205	
Total			2.18E+00

Table 11 – The above table represents the energy used to manufacture and transport one PEZ dispenser

We extrapolated this data to account for 1000 pieces of PEZ and the wrappers associated with them. This came out to be 9.9 MJ/1000pieces. Although this is for hard candy, and not for gum, the two are roughly similar is size and shape. This finding helped to make a decision for the proposed solution.

Bubble Tape

Bubble tape gum dispensers have many of the features that we were looking for in a redesign (Figure 9). It is made of only two materials, paper and plastic; the gum is not individually wrapped. As shown in Table 12, the energy to make 1000 pieces of gum is substantially lower than any of the four gum dispensers originally chosen. Because the packaging is so light, the transportation of the packaging is almost nothing in comparison to the rest of the manufacturing (see Figure 10).

Figure 9 - Bubble Tape package, made by Wriggly

Bubble tape	Weight (kg)	Energy for part (MJ)
Plastic	0.0143	35.04741319
Paper	0.0004	0.178527431
Plus assembly		3.522594063
Transportation		0.202257326
Total:		38.95079201

Table 12 - Materials and energy required to manufacture and transport 1000 gum pieces

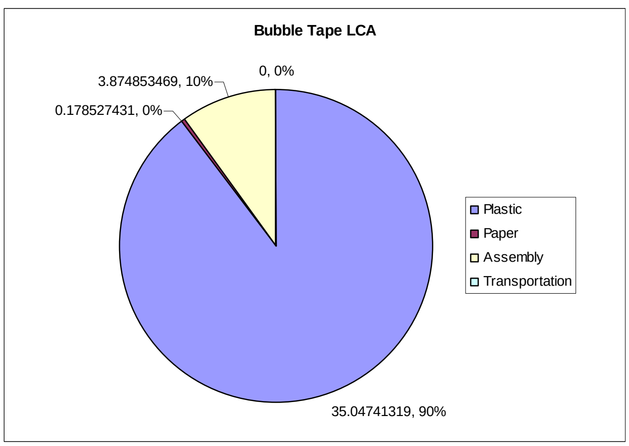


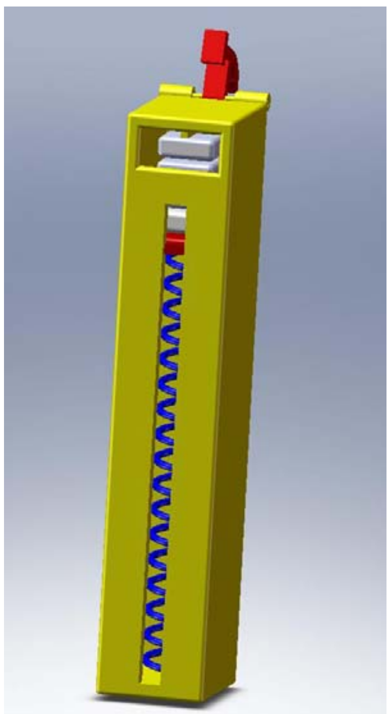
Figure 10 - Energy Distribution for Bubble Tape

Solutions

After going through the decision process (see decisions matrix in Appendix A), we settled on two alternative designs, one for "soft-shell" gum, and another for "hard-shell".

Hard-Shell Gum Alternative

As mentioned earlier, we investigated the energy consumption of a typical PEZ dispenser and the associated wrappers used to package PEZ. We chose this type of design to address our "hard-shell" redesign. By slightly altering the dimensions of the dispenser and eliminating unnecessary plastic, we were able to improve on the good performance of the PEZ dispenser. We were able to reduce the amount of plastic used for our dispenser from 19.3g down to 16g by eliminating the large plastic character head from the dispenser and redesigning the mechanism (see Figures 11 & 12). The larger dimensions necessary to fit hard-shell gum in the dispenser slightly offset these gains, but not enough to increase the overall weight.



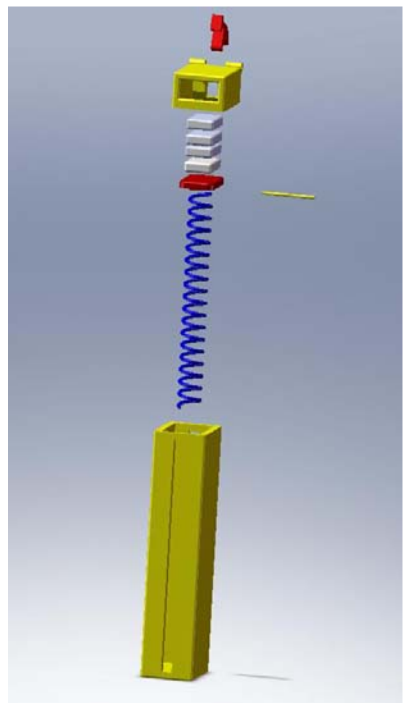


Figure 11 & 12 – The above figures illustrate our new reusable hard shell gum dispenser. Based on the PEZ dispenser, our container holds 12 pieces of hard shell gum and uses a pin-joint hammer mechanism to dispense of the gum.

We analyzed our new design using the same criteria that we used for the existing products. Next, we looked at the individual container rather than the entire market. The analysis was conducted using the same metric as before, MJ per 1000 pieces. After analyzing the weight of each solution in SolidWorks we obtained the following data (see Table 13).

Our Dispenser Weight Analysis (g)		Weight (kg)	Energy (MJ)
Overall weight	**20.5**	0.0205	
Plastic	16.0	0.0160	1.57E+00
Steel Spring	0.6	0.0006	2.40E-02
Assembly (+10%)	0.0	0.0000	1.59E-01
transportation			6.92E-03
Overall weight of packaging	**16.6**	0.0166	
Total			**1.76E+00**

Table 13 – The above table illustrates the energy analysis associated with production and transportation (1000 mi.) of our new product.

We extrapolated this data to obtain our desired metric of MJ/1000 pieces. Considering that the design is reusable, there is only one container necessary for 1000 pieces. Additionally, there are 83 aluminum wrappers that hold 12 pieces each (see Table 14 for analysis of these wrappers).

Weight Analysis (g)		Weight (kg)	energy (MJ)
Aluminum	0.3	0.0003	8.39E-02
Assembly (+10%)	0.0	0.0000	8.39E-03
transportation			1.25E-04
Overall weight of packaging	**0.3**	0.0003	
Total			**9.24E-02**

Table 14 – The above table illustrates the energy analysis associated with production and transportation (1000 mi.) of disposable wrappers.

The total energy needed for the combined production and transportation of the dispenser and associated wrappers comes out to 9.4MJ/1000 pieces, by far the smallest energy figure of all the analyses we conducted (compared with ~65 MJ for Dentyne).

Soft-Shell Gum Alternative

For the "soft-shell" alternative, we decided to pursue a container similar to Bubble Tape. In order to improve on the environmental impacts of the container, we eliminated the use of paper and incorporated the labeling of the product into the plastic itself, which could easily be done during the molding of the container. We also changed the material from type 5 plastic to a more easily recyclable type 2 plastic. The result: Green Tape (see figure 13 & 14).

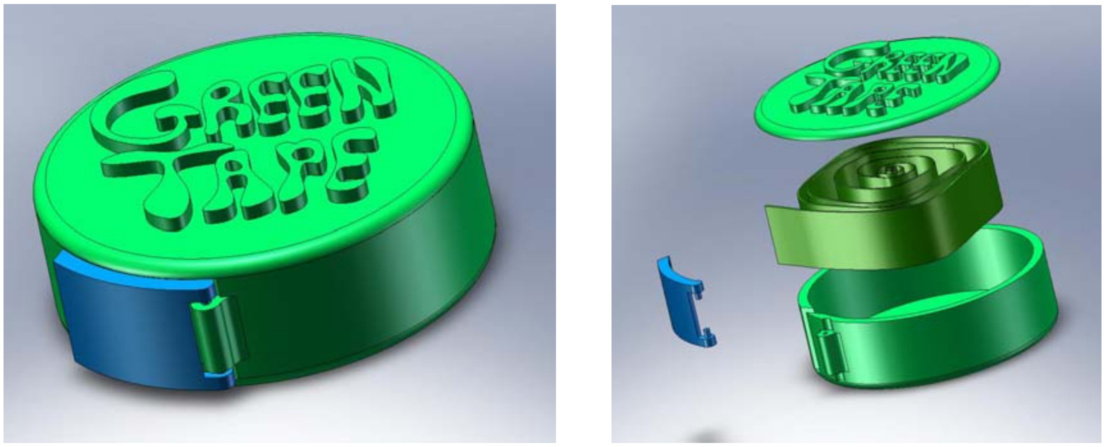


Figure 13 & 14 – The above figures illustrate our new design for a soft shell gum dispenser. The container houses a continuous roll of gum that come pre-perforated for easy portioning of 35 pieces. The container was designed to appeal to "green-conscious" consumers.

The recyclable container houses 6 ft. of soft-shell gum that is pre-perforated into 35 pieces so that it can be mass market to a more general customer base. As with our other solution, we analyzed the energy consumption of this solution on a per-container basis (see Table 15).

Tape Dispenser Weight Analysis (g)		**Weight (kg)**	**energy (MJ)**
Overall weight	**20.5**	**0.0205**	
Plastic	**14.3**	**0.0143**	**1.40E+00**
Assembly (+10%)	**0.0**	**0.0000**	**1.40E-01**
transportation			**5.96E-03**
Overall weight of packaging	**14.3**	**0.0143**	
Total			**1.55E+00**

Table 15 – The above table illustrates the energy analysis associated with production and transportation (1000 mi.) of our new product.

When extrapolated to our metric of MJ/1000 pieces, the new design consumes 44MJ for manufacturing and transportation, which is slightly higher than the existing Bubble Tape container; however our material is recyclable HDPE, while the current Bubble Tape container is not recyclable.

Greenhouse Gas and Pollutant Emissions

The amount of gas and pollutants released by the different kind of materials were determined to better assess the environmental impact of the various kinds of gum packaging. We were concerned with the four greenhouse gases with higher global warming potential: carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The following common pollutants were also monitored: sulfur dioxide, carbon monoxide, nitrogen oxides, volatile organic compounds, lead, and particulate matter of 10 micrometers or less. Table 16 shows these emissions per kilogram of materials used.

Emissions (g/kg)								
	Paper	Aluminum	Steel	Polystyrene	Polyethylene	PVC Plastic	HDPE	Polypropylene
CO_2	3850.00	1700.00	2020.00	2340.00	1440.00	1820.00	1120.00	990.00
CH_4	272.80	0.06	0.85	18.00	20.30	13.50	18.30	17.00
N_2O	116.16	0.00	0.00	0.04	0.03	0.04	0.02	0.02
CFC	29.70	0.12	0.00	0.00	0.00	0.00	0.00	0.00
SO_2	7.02	18.50	0.74	15.00	11.70	14.20	8.72	7.26
CO	36.30	67.80	23.80	12.40	5.08	3.16	4.98	6.13
NOx	7.83	0.00	2.23	5.69	2.61	3.31	2.35	2.56
VOC	5.52	0.00	0.20	0.97	1.11	0.75	0.99	0.90
Lead	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00
PM10	4.09	17.50	0.06	0.20	0.18	0.19	0.17	0.09

Table 16 – Emissions (in grams) per kilogram of amount used

Appendix B includes all the tables detailing the different materials and emissions associated for the different gum packaging. Figure 15 and 16 show the emissions of the four different kinds of packaging for soft shell gum. Our alternative for this kind of gum emits lower amounts of greenhouse gases and common pollutants.

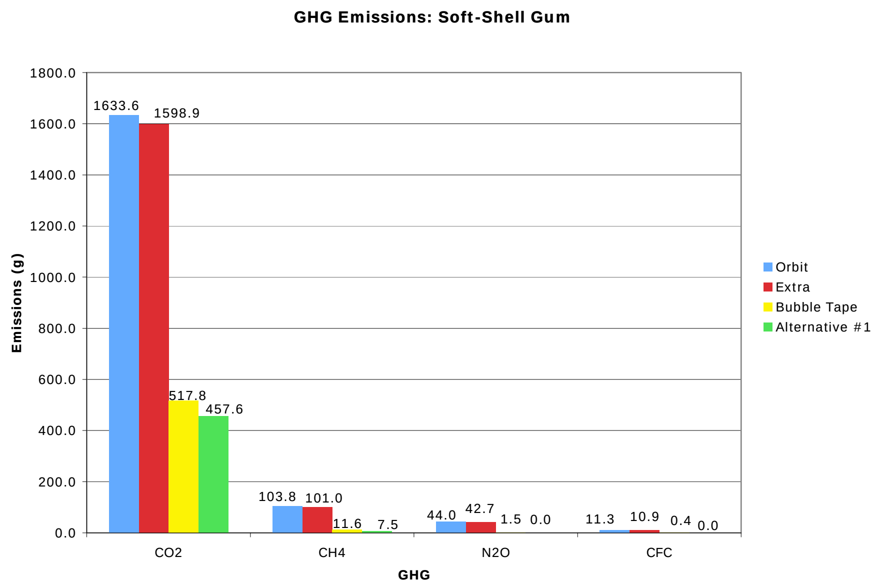


Figure 15 - GHG emissions for soft-shell gum

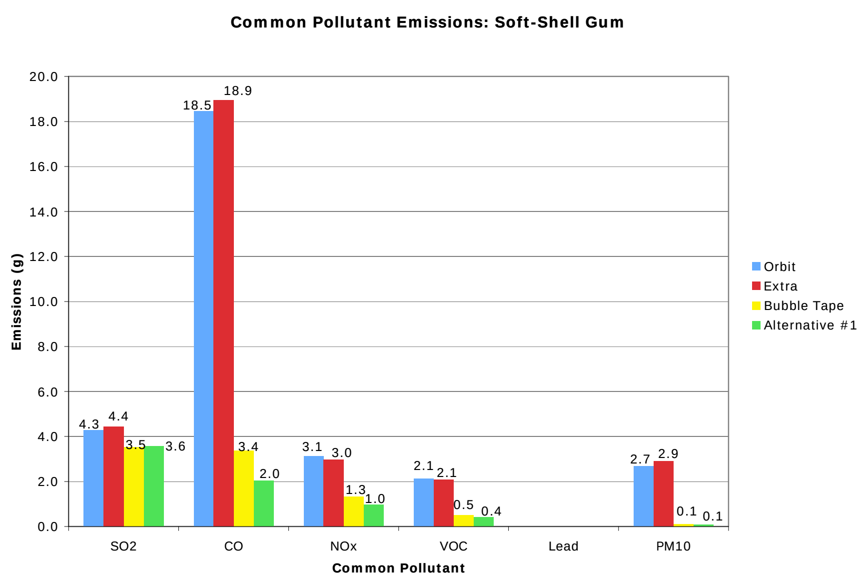


Figure 16 - Common pollutant emissions for soft-shell gum

Figures 17 and 18 illustrate the emissions of the different kinds of packaging for hard-shell gum. Our alternative proves to be slightly better than the PEZ container since our design is simpler and requires less plastic.

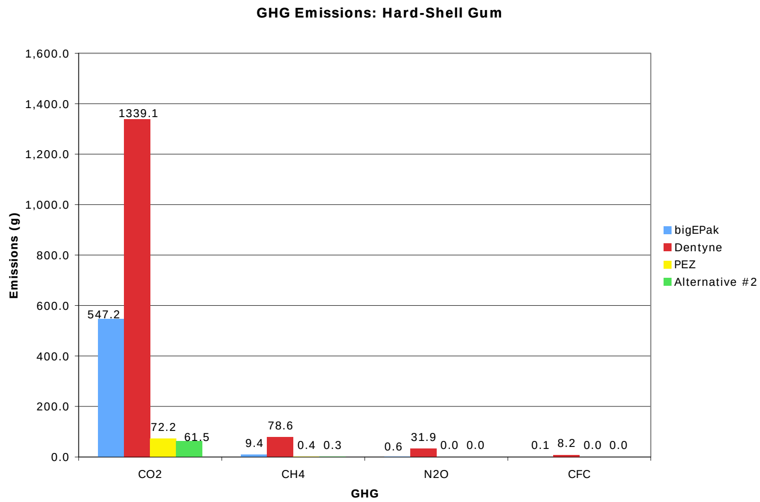


Figure 17 - Greenhouse gas emissions of hard-shell gum

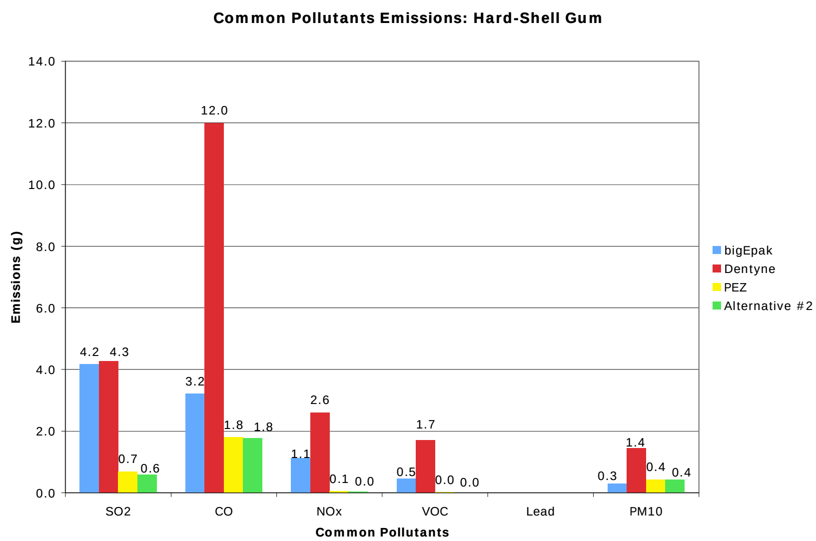


Figure 18 - Common pollutant emissions of hard-shell gum

End-of-life

Unfortunately, due to the nature of the materials and size of the packaging for most of the products investigated, recycling is not a viable option. Much of the paper is bleached and combined with wax making it difficult to recycle. Therefore, we examined costs associated with solid waste disposal. This value varies widely throughout the country depending on region and proximity to large cities. For an approximation, we relied on a study from North Carolina that looked into the costs of solid waste collection and disposal in cities and counties throughout the state and averaged the costs for urban and rural solid waste. We found that on average, the cost is $95/ton of waste. This value allowed us to estimate the overall cost of solid waste collection and disposal for each brand of gum on a yearly basis (see Table 17a).

Brand	Package Weight (g)	number of sticks sold	stick per package	packages	waste (kg)	waste in lbs.	waste in ton
Extra	8.1	6.30E+09	15	4.20E+08	3.40E+06	7.50E+06	7.50E+03
Eclipse Big-E	27.8	5.04E+08	60	8.40E+06	2.34E+05	5.15E+05	5.15E+02
Dentyne	5.6	5.04E+09	12	4.20E+08	2.35E+06	5.19E+06	5.19E+03
Orbit	9	6.30E+09	14	4.50E+08	4.05E+06	8.93E+06	8.93E+03

Table 17a – The above table represents the cost ($) associated with solid waste collection and disposal associated with each brand of gum over a single year.

Brand	average cost for collection and disposal	Cost per pack	Cost per stick
Extra	$681,968.76	$0.0017	$0.00011
Eclips big-e	$48,907.73	$0.0058	$0.00010
Dentyne	$492,595.82	$0.0012	$0.00010
Orbit	$811,867.57	$0.0019	$0.00013

Table 17b – The above table summarizes the overall costs, cost per package, and cost per stick of gum for each of the four products examined.

It is interesting to note that while on a yearly basis, the Eclipse Big-E pack requires the least amount of money for disposal (see Table 17b), on a per package basis, it is the most expensive. This difference can be explained by its recent introduction to the market earlier this year. For this reason, it has a very small market share and does not contribute as much to overall waste. On a per stick basis, the Big-E pack is actually one of the least expensive due to the fact that a single package holds over 60 pieces of gum.

Our proposed solutions included a reusable concept and a recyclable concept. However, for this portion of the analysis, we assumed worst case scenario that both were disposed of as solid waste. We compared the cost for solid waste disposal based on our above figures and assumptions for all of the packages investigated (see Table 18).

Brand	g	sticks per package	Cost per pack	Cost per stick
Extra	8.1	15	$0.0017	$0.00011
Eclipse big-e	27.8	60	$0.0058	$0.00010
Dentyne Ice	5.6	12	$0.0012	$0.00010
Orbit	9	14	$0.0019	$0.00013
PEZ	20.5	12	$0.0019	$0.00016
Bubble Tape	14.3	31	$0.0014	$0.00004
HS Dispenser	16	12	$0.0015	$0.00013
SS Dispenser	14.3	35	$0.0014	$0.00004

Table 18 – The above table summarizes the cost per pack, and cost per stick of solid waste disposal for each of the packages investigated. The yellow rows represent the four packages we looked into during the first half of the project. The green rows represent the packages we looked following the midterm report, and the blue rows represent the proposed solutions.

Bubble Tape and our soft shell solution had the smallest cost per stick associated with disposal, while the PEZ dispenser had the largest cost. It should be noted that this is an extreme case in which the PEZ dispenser is used once for 12 pieces and then discarded. This principle also applies to our hard shell dispenser. If reuse is considered, and a ceiling for the lifetime of the packages is set low at 1000 pieces, both the PEZ and hard shell containers drop by a factor of about 80 to become by far the lowest cost alternative.

Sources

FRC Research Corporation. "The Impact of Chewing Gum on Consumers' Stress Levels." Survey conducted in June, 2006 among 280 male and female respondents aged 18-49.

Hetherington MM, Boyland E. "Short term effects of chewing gum on snack intake and appetite." Appetite. 2007 May; 48(3):397-401.

National Confectioner's Association. "US Confectionary Gum". January 2008. http://www.ecandy.com/ecandyfiles/BG_Gum.pdf. last visited May 4, 2008.

Shelf Impact. "Eclipse Goal: Build Consumption with Stationary Pack". November 10, 2006. http://www.shelfimpact.com/archives/2006/11/eclipse_goal_build_consumption_1.php

Szoke et al. "Effect of After-Meal Sucrose-Free Gum-Chewing on Clinical Caries." J Dent Res 80(8): 1725-1729. 2001

Wilkinson L., Scholey A., Wesness K. "Chewing gum selectively improves memory in healthy volunteers." *Appetite.* 2002 June; 38 (3): 235

Appendix A-

	Specification						
Product	**Capacity**	**Recyclability**	**Materials Used**	**Energy Use**	**Portability**	**Sanitation**	**Total**
Dentyne	1	1	2	3	4	4	15
Big E Pak	4	4	3	4	0	2	17
Extra	3	2	2	1	3	4	15
Orbit	3	3	4	2	4	3	19

	Specification						
Redesigns	**Capacity**	**Recyclability**	**Materials Used**	**Energy Use**	**Portability**	**Santiation**	**Total**
Soft Gum							
Bubble Tape	4	4	4	2	3	3	20
Big League Chew	3	1	1	3	3	0	11
Hard Gum							
mint dispenser	1	3	3	3	4	3	17
Push Pop	1	2	3	2	1	2	11
Pez	3	4	4	3	3	4	21

Appendix B

The tables below show the materials and emissions for the eight different gum packages.

Soft-Shell Gum:

Orbit: Greenhouse Gas Emissions (per 1000 pieces)					
	Mass (kg)	CO_2 (g)	CH_4 (g)	N_2O (g)	CFC (g)
Polystyrene	0.029	66.86	0.51	0.00	0.00
Paper	0.379	1457.50	103.27	43.97	11.24
Aluminum	0.064	109.29	0.00	0.00	0.01
TOTAL:		**1633.64**	**103.79**	**43.98**	**11.25**

Orbit: Common Pollutant Emissions (per 1000 pieces)							
	Mass (kg)	SO_2	CO	NOx	VOC	Lead	PM10
Polystyrene	0.029	0.43	0.35	0.16	0.03	0.00	0.01
Paper	0.379	2.66	13.74	2.96	2.09	0.00	1.55
Aluminum	0.064	1.19	4.36	0.00	0.00	0.00	1.13
TOTAL:		**4.27**	**18.46**	**3.13**	**2.12**	**0.00**	**2.68**

Extra: Greenhouse Gas Emissions (per 1000 pieces)					
	Mass (kg)	CO_2 (g)	CH_4 (g)	N_2O (g)	CFC (g)
Paper	0.368	1416.80	100.39	42.75	10.93
Aluminum	0.080	136.00	0.00	0.00	0.01
Polyethylene	0.032	46.08	0.65	0.00	0.00
TOTAL:		**1598.88**	**101.04**	**42.75**	**10.94**

Extra: Common Pollutant Emissions (per 1000 pieces)							
	Mass (kg)	SO_2	CO	NOx	VOC	Lead	PM10
Paper	0.368	2.58	13.36	2.88	2.03	0.00	1.51
Aluminum	0.080	1.48	5.42	0.00	0.00	0.00	1.40
Polyethylene	0.032	0.37	0.16	0.08	0.04	0.00	0.01
TOTAL:		**4.44**	**18.94**	**2.97**	**2.07**	**0.00**	**2.91**

Bubble Tape: Greenhouse Gas Emissions (per 1000 pieces)					
	Mass (kg)	CO_2 (g)	CH_4 (g)	N_2O (g)	CFC (g)
Polypropylene	0.472	466.98	8.02	0.01	0.00
Paper	0.013	50.80	3.60	1.53	0.39
TOTAL:		517.78	11.62	1.54	0.39

Bubble Tape: Common Pollutant Emissions (per 1000 pieces)							
	Mass (kg)	SO_2	CO	NOx	VOC	Lead	PM10
Polypropylene	0.472	3.42	2.89	1.21	0.42	0.00	0.04
Paper	0.013	0.09	0.48	0.10	0.07	0.00	0.05
TOTAL:		**3.52**	**3.37**	**1.31**	**0.50**	**0.00**	**0.10**

Alternative #1: Greenhouse Gas Emissions (per 1000 pieces)					
	Mass (kg)	CO_2 (g)	CH_4 (g)	N_2O (g)	CFC (g)
High-density polyethylene	0.409	457.60	7.48	0.01	0.00
TOTAL:		**457.60**	**7.48**	**0.01**	**0.00**

Alternative #1: Common Pollutant Emissions (per 1000 pieces)							
	Mass (kg)	SO_2	CO	NOx	VOC	Lead	PM10
High-density polyethylene	0.409	3.56	2.03	0.96	0.41	0.00	0.07
TOTAL:		**3.56**	**2.03**	**0.96**	**0.41**	**0.00**	**0.07**

Hard-Shell Gum:

BigEPak: Greenhouse Gas Emissions (per 1000 pieces)					
	Mass (kg)	CO_2 (g)	CH_4 (g)	N_2O (g)	CFC (g)
Paper	0.005	19.25	1.36	0.58	0.15
Aluminum	0.012	19.83	0.00	0.00	0.00
Polyvinyl chloride	0.022	39.43	0.29	0.00	0.00
High-density polyethylene	0.368	412.53	6.74	0.01	0.00
Polypropylene	0.057	56.10	0.96	0.00	0.00
TOTAL:		**547.15**	**9.36**	**0.59**	**0.15**

BigEPak: Common Pollutant Emissions (per 1000 pieces)							
	Mass (kg)	SO_2	CO	NOx	VOC	Lead	PM10
Paper	0.005	0.04	0.18	0.04	0.03	0.00	0.02
Aluminum	0.012	0.22	0.79	0.00	0.00	0.00	0.20
Polyvinyl chloride	0.022	0.31	0.07	0.07	0.02	0.00	0.00
High-density polyethylene	0.368	3.21	1.83	0.87	0.37	0.00	0.06
Polypropylene	0.057	0.41	0.35	0.15	0.05	0.00	0.01
TOTAL:		**4.18**	**3.22**	**1.12**	**0.46**	**0.00**	**0.30**

Dentyne: Greenhouse Gas Emissions (per 1000 pieces)					
	Mass (kg)	CO_2 (g)	CH_4 (g)	N_2O (g)	CFC (g)
Paper	0.275	1058.75	75.02	31.94	8.17
Aluminum	0.017	28.33	0.00	0.00	0.00
Polyethylene	0.175	252.00	3.55	0.01	0.00
TOTAL:		1339.08	78.57	31.95	8.17

Dentyne: Common Pollutant Emissions (per 1000 pieces)							
	Mass (kg)	SO_2	CO	NOx	VOC	Lead	PM10
Paper	0.275	1.93	9.98	2.15	1.52	0.00	1.13
Aluminum	0.017	0.31	1.13	0.00	0.00	0.00	0.29
Polyethylene	0.175	2.05	0.89	0.46	0.19	0.00	0.03
TOTAL:		**4.29**	**12.00**	**2.61**	**1.71**	**0.00**	**1.45**

PEZ: Greenhouse Gas Emissions (per 1000 pieces)					
	Mass (kg)	CO_2 (g)	CH_4 (g)	N_2O (g)	CFC (g)
Polyethylene	0.020	28.66	0.40	0.00	0.00
Steel	0.001	1.21	0.00	0.00	0.00
Aluminum	0.025	42.33	0.00	0.00	0.00
TOTAL:		**72.20**	**0.41**	**0.00**	**0.00**

PEZ: Common Pollutant Emissions (per 1000 pieces)							
	Mass (kg)	SO_2	CO	NOx	VOC	Lead	PM10
Polyethylene	0.020	0.23	0.10	0.05	0.02	0.00	0.00
Steel	0.001	0.00	0.01	0.00	0.00	0.00	0.00
Aluminum	0.025	0.46	1.69	0.00	0.00	0.00	0.44
TOTAL:		**0.69**	**1.80**	**0.05**	**0.02**	**0.00**	**0.44**

Alternative #2: Greenhouse Gas Emissions (per 1000 pieces)					
	Mass (kg)	CO_2 (g)	CH_4 (g)	N_2O (g)	CFC (g)
High-density polyethylene	0.016	17.92	0.29	0.00	0.00
Steel	0.001	1.21	0.00	0.00	0.00
Aluminum	0.025	42.33	0.00	0.00	0.00
TOTAL:		**61.46**	**0.29**	**0.00**	**0.00**

Alternative #2: Common Pollutant Emissions (per 1000 pieces)							
	Mass (kg)	SO_2	CO	NOx	VOC	Lead	PM10
High-density polyethylene	0.016	0.14	0.08	0.04	0.02	0.00	0.00
Steel	0.001	0.00	0.01	0.00	0.00	0.00	0.00
Aluminum	0.025	0.46	1.69	0.00	0.00	0.00	0.44
TOTAL:		**0.60**	**1.78**	**0.04**	**0.02**	**0.00**	**0.44**