EXECUTIVE SUMMARY

Recently, a great deal of attention has been directed at packaging by a variety of interest groups including environmentalists, consumers, manufacturers, commercial and retail business and legislators. Before decisions are made regarding individual packaging materials, a full evaluation of available packaging materials should be made. Due to this ICPE (Indian Centre for Plastics in the Environment, New Delhi) decided to carry out a Life Cycle Analysis (LCA) of milk packaging materials (glass bottles and plastic pouches) with a packaging capacity of 1 litre or below. It was thus particularly necessary to discover the "Cradle to Grave" input of these packaging materials. This report documents the journey of these packaging materials from the time they are born to the end of their utility in the hope that environmental safe guards could be incorporated without hampering plastic's progressive role that it has been playing in sustainable development.

Life cycle analysis is an effective tool to measure the impact of a product or process on the environment. In this study, it covers the environmental and resource impact of plastic pouches vis-à-vis glass bottles used for packaging milk from the stage of raw material extraction, production, use and disposal, taking into account all the inputs such as materials, energy, capital equipment, man-hours, etc.) and the outputs like products, by-products, waste materials, emissions at every stage.

The basis of this study has been considered as one lakh litre (LLit) of milk in keeping with the view of the consumption in order of magnitude.

THE TOTAL IMPACT ASSESSMENT

The study discloses that for producing packaging with plastic pouches for one lakh litre of milk, the raw material required is only 0.40 Mt. But for the same quantity of packaging with glass bottles require 45.4 Mt of glass. The results of this analysis are organized in two categories: resource utilization and atmospheric emission.

Energy Consumption

The analysis by steps identifies the production of glass (Table – I) and subsequently manufacture of bottles (Phase I and Phase II) as being responsible for the greatest consumption of energy (~1202 GJ per one lakh litre of packed milk) as compared to plastic pouches(~37 GJ per one lakh litre of packed milk). Energy consumption related to transportation (Phase III) of milk shows that transportation in glass bottles requires significantly major amount of energy, being about ~115 GJ per one lakh litre of packed milk where glass is being used as packaging material, compared to ~ 63 GJ per one lakh litre of packed milk for transportation in plastic pouches.

Table I: Life Cycle Data for Different Materials Used for Packaging One Lakh Litres of Milk

	Glass		Plastic Pouches	
Material Required (Mt)	45.4		0.40	
	Energy*	Water*	Energy*	Water*
Phase I: Production of Raw Material	671.92	1608.0	32.22	25.6
Phase II: Production of Bottles/Pouches	530.27		4.56	
Total	1202.19	1608.0	36.78	25.6

Phase III: Filling and Distribution	Glass		Plastic Pouches	
	Fuel*	Energy* Single [Return]	Fuel*	Energy* Single [Return]
	2049	114.75 [213.43]	1120	62.73 [106.64]

Phase IV: Waste Management	Glass		Plastic Pouches	
Recycling Percent	Energy Consumption*		Energy Consumption*	
100%	501.67		4.56	
80%	401.34		3.65	
60%	301.00		2.74	
50%	250.83		2.28	
Reuse (Including Transportation)	Energy Consumption	Water Consumption	Energy Consumption	Water Consumption
95%	277.8	509.1	143.4 (New Plastic Pouches)	25.6 (New Plastic Pouches)
80%	457.5	675.4		
60%	697.0	897.2		
Incineration	Energy Recovered		Energy Recovered	
100%	Not Applicable		20.73	
80%			16.58	

*Units: Energy (GJ), Water (Thousand Litres), Fuel (Litres)

Atmospheric Emission: About ten components dominate the category of atmospheric emission for glass bottles and plastic pouches: CO, CO_2, SO_x, NO_x, CH_4, HCl, dust, heavy metals, suspended solids and chlorides. For all of these, the plastic pouch produces less of each emission than that produced by glass bottle. Tables II and III list atmospheric emissions.

Table II: Emissions during Phase I and Phase II for 1 Lakh Litre of Milk

		Glass	LDPE
Air Emissions			
CO	kg	**54.3**	**0.6**
CO_2	kg	**6610.2**	**760.0**
SO_x	kg	**134.8**	**5.2**
NO_x	kg	**68.1**	**4.8**
CH_4	kg	**39.5**	**3.2**
HCl	kg	**5.3**	**0.0**
Dust	kg	**67.6**	**1.4**
Water Emission			
Suspended Solids	kg	**352.3**	**0.2**
Chlorides	kg	**4535.5**	**0.1**

Table III: Emissions during Phase III

Emission	gm/km	kg/lakhlitres		Excess for Glass Bottles
		Bottles	Pouches	
CO_2	781	**4881.3**	**2668.7**	**2212.6**
CO	4.5	**28.1**	**15.4**	**12.7**
HC	1.1	**6.9**	**3.8**	**3.1**
NO_x	8	**50.0**	**27.3**	**22.7**
HC+ NO_x	9.1	**56.9**	**31.1**	**25.8**
Particulates	0.36	**2.3**	**1.2**	**1.1**
Total Regulated Tail Pipe Emission	13.96	**87.3**	**47.7**	**39.6**

Another major resource utilization is being demonstrated in terms of consumption of water. The manufacture of glass bottles is found to be responsible for the overall greatest consumption of water; ~1608 (thousand litre/ lakh litre of packed milk) in case of glass bottles production. This is about 63 times higher than that for plastic pouches for same amount of packed milk.

Reuse of glass bottles has also been considered as one of the option to reduce waste. It has been found that even for 95% reuse of glass bottles (95000 bottles) the energy consumption is double than that consumed in making new plastic pouches. Another important point during reuse of glass bottles is the issue of hygiene. It has been found in the past that bottles were not cleaned properly, which leads to contamination of milk as well. Also the water consumption in case of 95% reuse of glass bottles is 20 times to that used in new plastic pouches. More importantly, attention is also to be given to two end-of-life cases i.e.,100% incineration (waste to energy, energy recovery) and/or 100%-50% recycling (energy usage). According to this phase, energy recovery due to incineration is about 15.8 MJ/kg for plastic pouches, while there is no incineration for waste glass. Similarly energy consumed during recycling is found to be ~500 GJ for100% recycling and ~250GJ for 50% recycling for Glass Bottles. While for plastics recycling requires very small amount of energy i.e., 4.5GJ for 100% recycling and 2.28 for 50% recycling. It should also be noted that in case of recycling of glass bottles and plastics the waste enters into a new life and if this waste management technique is considered the life cycle analysis of plastics/glass bottles can be termed as ***"Cradle to Cradle"*** approach instead of "Cradle to Grave".

Emission to Air

The emission of CO_2 for the materials has approximately the same profile. However, the analysis of input effects indicates remarkably high emission of CH_4 emission in case of production of Glass. The comparative study on emission during transportation also shows significantly excess generation of CO, CO_2 and NO_x as compared to that in case of plastic pouches.

Emission to Water

As shown in the tables II, BOD and COD to water are unmistakably of higher amount in case of production of glass bottles. While these values are negligible for plastic pouches. The COD and BOD values are atleast 15-20 times larger in the case of glass bottles leading to dangerous environmental impact apart from health hazards.

CONCLUSIONS

Though plastics are relatively newcomers, their use in packaging of milk commodities adheres to the basic tenets of sustainable development more than glass, if one considers the consumption of energy and emission of gases. An analysis of the comparable life cycle with glass clearly tells that plastics are economically affordable, socially acceptable and environmentally effective.

The recording of the stages of production of glass bottles and plastic pouches give a complete picture of the consumption of energy, water and gases in these materials and remove the prevailing notion that glass bottles are more environment- friendly than plastic pouches.

Managing waste helps to produce more from fewer resources, while generating less pollution and waste. The measures to reduce the amount of solid waste produced, either as industrial, commercial or domestic waste, in essence are improvements in efficiency. Glass as milk packaging material causes more stress on waste management than plastic pouches. The residual plastics at less than 10 per cent by weight of municipal solid waste can provide 20 per cent of the fuel value for a local WTE plant.

From this study we can claim that the overall loss to environment from plastic pouches is less that that from glass bottles the difference seems significant. The choice of product end-of-life (work) management even strengthens this assessment.

Another sensitivity in the study results in discovering the effects of the weight of the glass vis-à-vis plastic pouches on the overall loss to environment through transport of packed milk in first use as well as reuse. Recycling of the glass bottles also leads to burden on environment by consuming more energy and water.

Instead of banning its production, the need of the hour is educating the public of – what to do with the waste pouches and where to throw them for recycle. After all, these polymers perform dutifully the role of a carrier effectively from the doors of producer to consumer.

PREAMBLE

Packaging may be defined as 'a means of ensuring the safe delivery of product to the ultimate consumer in sound condition at the minimum overall cost. Packaging represents one of the most widespread activities of modern society. The primary role of packaging is to protect the nutritional and sensory properties of milk from the processing stage till it is consumed. Packaging has become an integral part of the processing, preservation, marketing and even the cooking of the foods. In the early days of emergence of food industry, packaging was mainly done to reduce spoilage and to facilitate transportation. In contrast, packaging has today become essentially a convenience based to make it fancier and more fascinating. In food industry, packaging plays the dominant role in marketing and in the total manufacturing activity. Food packaging is a growing activity the world over and is the fastest growing in the developing countries like India. Some of the very important packaging considerations are product protection, shelf life, strength of package, packaging machinery, material availability, convenience, sales appeal, package decoration, product-package compatibility, package sealing efficiency, statutory requirement and cost. The criteria by which a package is judged are usually the following:

- It must protect and preserve the commodity from the time it is packed to the point of consumption.
- It must be suitable for the chosen selling and distribution system.
- It must be attractive to the consumer, easy to open, store and dispose.
- It must cost no more than the market can bear.

Functions of Packaging

Package has a three fold functions of containing, protecting and merchandising:

a. To contain the product

Package should be large one with proper constructional features so as to avoid leakage and spoilage. It should be as compatible as possible with the product and finally it should have enough strength to withstand handling, transportation and storage hazards.

b. To protect the product

Protection of the product against contamination or loss and damage or degradation due to microbial action, exposure to heat, light, moisture and oxygen, evaporation etc.

c. To help in selling the product

The shape of the package should be favourable to dispensation and reclosure, and to its disposal and reuse.

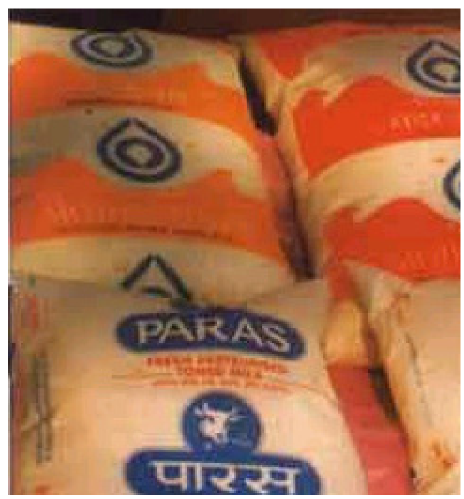
The packaging must be:

- Most economical
- Easily chilled, heated or micro-waved
- Environment friendly
- Priced correctly

Packaging is both a symbol of society's consumption habits and reflection of its progress. The user expects it to have easier handling, to be lighter, more aesthetic or safer from a hygiene point of view, etc. The factors governing the choice of an appropriate material for a given dairy product are

- The specific sensitivities of the contents (moisture and oxygen)
- Factors changing the content (temperature, relative humidity etc.)
- Weight and shape of the container
- Effect on filling and scaling speed
- Contamination of food by constituents of packaging materials
- Storage condition and for how long the product needs to be protected
- Biodegradability and recycling potential

Milk is generally available in sterilisable crown corked glass bottles, glass bottles with aluminium foil lid or snap-on plastic lid and plastic pouches. Generally glass bottles and plastic pouches (made of low density polyethylene) are used for milk packaging. The most suitable packaging size for milk in India is currently 500 ml and 1000 ml.



Environmental packaging considerations now seem to be as important as brand image. Matters relating to the environment and especially those concerned with disposal and recycling of milk containers, appear to have become as important as the containers themselves.

Current Scenario of Milk Production:

India is the world's largest producer of milk with 81 million tonnes production in the year 2000-01. This has been achieved due to the white revolution, which commenced prior to 1947 and was subsequently driven by the Co-operative Movement at Anand (Gujarat). This involves over 70 millions farmers and 100 millions milch cattle. The milk is collected through a very vast network of village collection centers. It is duly tested, transported to chilling centers and pasteurized.

In spite of the very vast distribution network of milk, only 778 out of 3750 cities and towns currently have access to packaged milk. Even today, almost 3000 cities and towns have to depend on loose, un-pasteurized and often adulterated milk. Over 204 Government dairies as well as smaller private dairies pack 30 lakh litres of milk per day. A number of dairies pack an average of 4-6 lakh litres of milk per day. It is estimated that there are approximately 300 brands of milk in poly-packs, which are supplied across India.

Approximately 46 percent of the total milk production is consumed in liquid form while the rest is converted into ghee, khoa, powder milk, ice-cream, cheese etc. Once milk reaches the dairies, it is pasteurized and packed in Form-Fill-and-Seal machines (FFS) which have the ability to pack continuously an average of 35-50 pouches per minute. The polyethylene film roll is placed on the top of the machine and it forms a pouch, fill it with the milk and seals and drops into a holding tray. The entire operation lasts barely 1.5 seconds. The duly filled pouches are then kept in a cold room at 4^0C for 8-10 hours in plastic crates before being loaded and transported to the various milk outlets.

India is unique in making available fresh milk twice a day at the doorstep in all the major towns and this is possible only due to milk being packed in pouches. This is the easiest and cheapest option available as each pouch of ½ liter weighing barely 4 grams costs only 25-28 paise and this holds and helps transport of milk to homes across India. Even in the year 2001, only 26 percent of liquid milk was branded, packed and sold to consumers. A large percentage is still sold loose. Of the total milk packed in India, almost 95 percent is packed in polyethylene pouches as these provide the most convenient and least cost option as compared to glass bottles. Milk is packed in polyethylene and after use, this can be duly recycled into good quality films for packing and any other products except cooked food. The challenge to India is to greatly expand the dairy network, so that hygienic, convenient and inexpensive packaged milk can be made available to the vast population that still procures loose and often adulterated milk.

SOURCE OF THE DATA

- The data (energy and emission) on raw Glass and Glass bag manufacture is taken from the various research papers mentioned in the text collected with the help of ***"Tata Energy Research Institute", New Delhi*** libraries**.** After collection of data weighted fraction of energy has been taken for Life Cycle Inventory purposes.

- The data on LDPE/LLDPE granules and film manufacture is taken from the ***"Eco-Profiles of Plastics and related Intermediates"*** by, **I. Boustead**, published by *The European Centre for Plastics in the Environment* of *The Association of Plastics Manufacturers in Europe (APME)*, Brussels and ***"Tata Energy Research Institute", New Delhi*** library. The data has been averaged for Life Cycle Inventory purposes.

- The data relating to the manufacture of Plastic Pouches was taken from ***"Industrial Energy Thrift Scheme: Energy Used in Plastics Industry"*** by The Rubber and Plastics Research Association for The Department of Industry and also from Agreni Polymers Ltd., Noida.

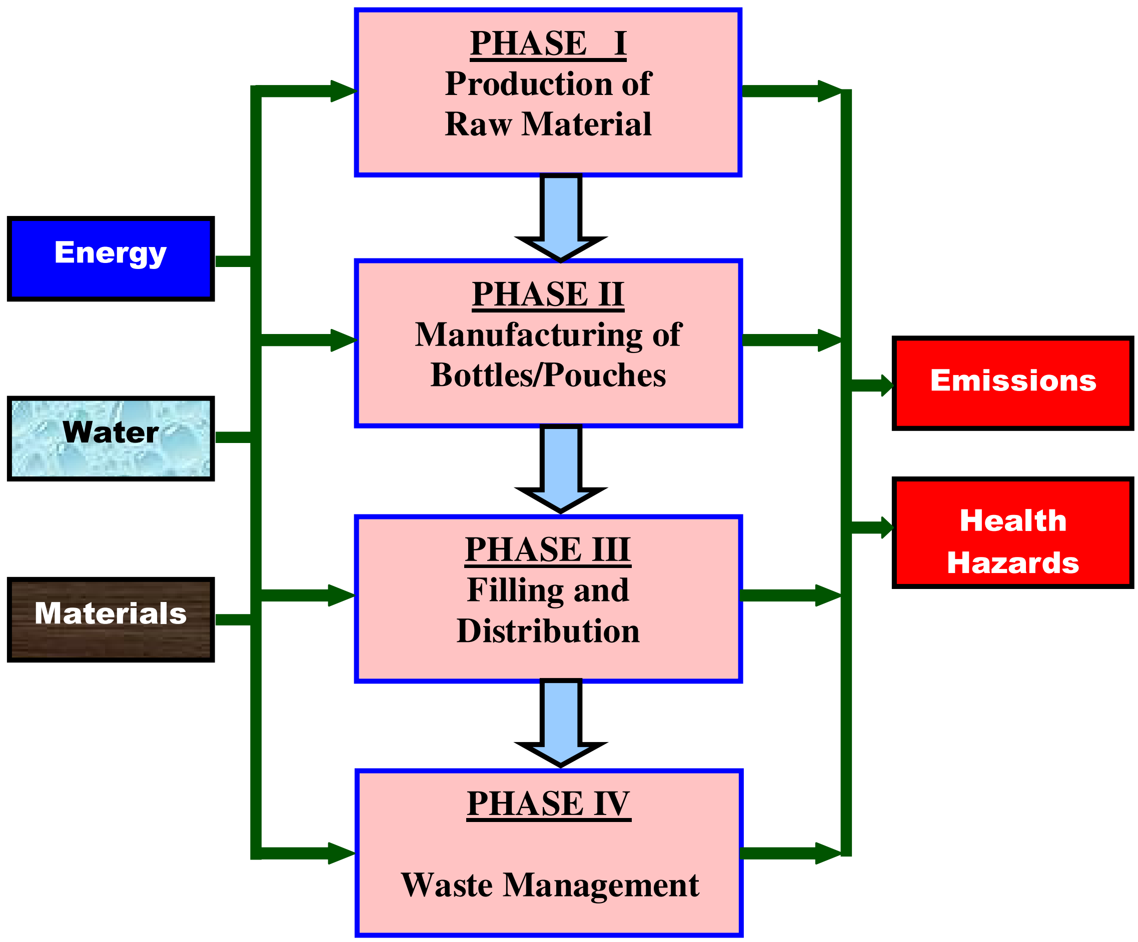
- The data of refrigerated cabin lorries, energy requirements in packaging, transportation has been taken during the onsite visits to **Mother Dairy** and **Paras Dairy** plants. After collection of data weighted has been taken for Life Cycle Inventory purposes.

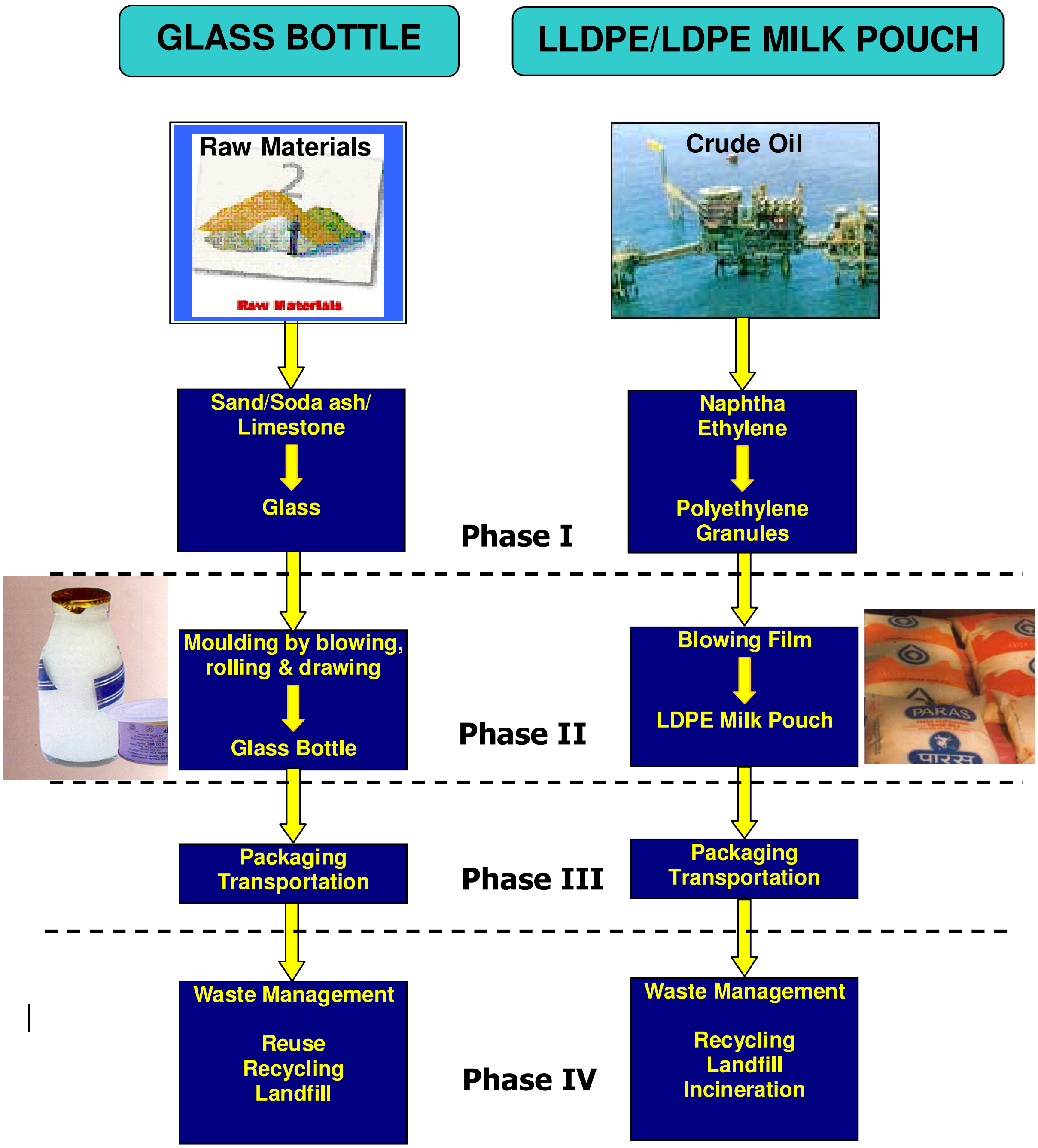
- The transport distances were estimated. Energy consumption and emissions due to transport were calculated based on the standard data available for transportation and ***"Environmental Rating of Indian Automobile Sector"*** published by *Centre for Science and Environment, New Delhi*. The basic production of fuel and energy associated were obtained from "***Energy and Packaging***" by **I. Boustead & G.F. Hancock** published by Ellis Horwood Publishers.

- The source of the data on waste management were taken from ***"Integrated Waste Management: a Life Cycle inventory"***, by *F. McDougall, P. White, M. Franke and P. Hindle, published by Blackwell Science*.

Goal and Scope

This project aims to provide a comprehensive environmental model for domestic packaging & waste management using a life cycle assessment methodology. The main focus of the project would involve producing lifecycle inventory data for plastic packaging during manufacturing, usage (both primary and secondary) and disposal and comparing the same in case of glass and plastic. As a case study having down to earth applications 1 litre milk plastic pouch vs. glass bottle has been considered in this report. The study has been divided in four phases as shown below:





Flow chart of glass bottle and milk pouch during the life cycle analysis

Packaging of Milk

To treat the subject of milk packaging, it would be better to look at the history, which is relatively short. Milk only really became a readily safe product at the turn of the century, so we will look at the period from 1900 to the present to see the trends which have taken place to bring this product to the marketplace and to the consumer.

At the end of the 19th century, milk was almost exclusively packed in glass bottles. The reason for this was most of the milk was distributed by breweries, and hence the bottle being chosen as the packaging vehicle for beer, became that for milk as well. The glass bottle was a good choice. It was sanitary. It was capable of being cleaned, sanitised and reused. It presented the product well. The white milk showed up very well in the glass bottle and the cream present in the milk would rise to the top and form a different coloured cream line allowing the customer to assess the quality of the milk based upon butter fat content.

It wasn't until much later, that it began to be recognised that glass bottle had shortcomings. The weight of the bottle relative to the product was great. Thus, its transportation costs were high. The effect of light on milk damaging the nutritive components was great. The cost of rewashing the bottle was high in terms of energy, and chemicals used *in washing the* bottle were to become an environmental hazard.

It wasn't until 1937 that a proper single use container became available. The package was mostly paper, and the bottom was glued together, and then dipped in wax to seal it. It was then filled with milk, and the top stapled closed. There was no opening for pouring. The stapled top had to be opened with a knife. Still, consumers liked the new disposable package when they were able to buy it. And, of course, the dairy received a package, which was already clean, did not have to worry about returned milk bottles, and did not have to worry about breakage or recontamination of the product's stream by returning dirty bottles to a plant. However, the wax process did leave a lot to be desired since it did impart a flavour to the milk. Secondly, little bits of wax would break away from the surface of the carton and cause an unpleasant mouth feel when drinking the product. In the late 1950's and early 1960's, it was discovered that polyethylene coating of the paper would allow a paper carton to be formed and scaled on a machine without damage to the product. The benefits of the carton were then becoming obvious.

1. The dairy received a clean sanitary package in which to package the milk.
2. The carton was opaque; thus, damage of the nutrients due to light was much slower.
3. The weight of the carton compared to the product was small, thus making distribution costs very reasonable. As time progressed, the shelf-life of milk could be increased by use of this carton allowing it to be purveyed through supermarkets with great ease.
4. Much information could be added to the carton in terms of printing, making it a source of information, about not only the product, but also how to utilise the product in cooking and various drinks. Of course, since

much of the milk was fed to children, as a fine nutritive source, the cleanliness of the product was of paramount importance.

The next step forward was the use of asepsis to process and package milk. This was based again on a single use paper package that utilised polyethylene combined with an aluminium foil membrane, to stop the ingress of oxygen into the package. Certainly milk was a product, which was available not only from refrigerated sources but also from non-refrigerated sources and particularly in the countries, which had a very hot climate, it was the ideal mode of package and transport of milk to the customer.

In the late 1970's, it became apparent that the polyethylene membrane in the paper carton really did all the work, and the paper was just, there to support it. The blow moulded milk bottle became a reality. This particular container was utilised on sizes from quarter litre through to a gallon size (3.74 litres). It could be fitted with a screw top and a handle could be moulded onto the package. It became a very convenient package to use, particularly for the growing elderly population in some countries. However, along with improvements, there were some negative factors with the plastic bottle, which are still being argued today. It is not readily biodegradable; it takes a huge amount of space because it is difficult to collapse the bottle; so its volume, in terms of disposal, is a factor. In addition, it is transparent; so the nutritive value of the milk is degraded in a very short period. This can be overcome by colouring the bottles and making them opaque. Recycling of plastic bottles becomes a cost factor since the bottle is still a single use container. Thus, if it has to be recycled, it has to be washed and sterilised, and broken down into a size, which can be fed into an extruder. Even then, regulatory authorities in many countries will not accept the reuse of plastic material to handle a food product.

All things being considered the paper carton with polyethylene coating is undoubtedly the best method of purveying milk there is. It is a single use, the carton can be incinerated, and power can be generated from the heat from the incineration. Polyethylene breaks down readily into non-toxic gases, and the ash from paper is just returning to the earth what was taken from it,

The aseptic package, though it is from the same components, does have the extra component aluminium foil, which makes disposal difficult and recycling nearly impossible. Incineration, of course, would reduce aluminium-to-aluminium oxide, which can be returned to the earth,

Other products, which are conveniently handled in paper polyethylene lined containers, are a full range of dairy products - cottage cheese, sour cream, yoghurt. Of course, a plastic container with a slip lid is utilised for packing these foods also.

The paper polyethylene type container is a wonderful conveyance to pass on information. Recipes for use of the product, nutrition, its suitability of feeding infants and information of disposal of the container can be printed on the carton.

Since economics are a factor, polyethylene film has been utilised in the form of a pouch where the milk forms the stuffing for a pillow. This pouch, though, suffers from the same shortcomings, as any plastic material which isn't coloured, light will affect the nutritional value of the product. Since milk is consumed for its nutritional value, this should be of paramount importance when we consider a package for milk.

Milk, being a perfect food is rarely sold unpacked. (Any bacteria in the atmosphere could find home in the product and grow to an alarming rate since the nutrients are present, the water activity is right and it could become a lethal product.) Hence, the packaging of milk is designed to maintain whatever quality of milk is supplied to the filling machine and package. The machine cannot improve the microbial quality of the product supplied to it. Raw milk or unprocessed milk is a product, which is not recommended to be consumed by humans since it contains potentially *danger*ous micro-organisms. Therefore, we could sum up the above statements by saying fresh or pasteurised milk should always be packaged to maintain its microbial quality and it should always be stored at a temperature of less than 45^0F. Some processing, which is commonly called UHT (Ultra high temperature) or aseptic, is capable of being packaged under aseptic conditions and sold at ambient temperature. The contrast between pasteurised milk and aseptic milk is sometimes difficult for the populous to understand fully. Pasteurised milk, generally speaking has a shelf-life of up to 14 days, though it can be, processed and packaged and held at refrigerated temperatures to maintain a shelf-life of 21 days. Much work has been carried out over the last few years to increase the shelf-life of pasteurised products by ultra-clean packaging, the use of modified atmospheres to restrict the growth of bacteria, and the use of packages with barrier properties which inhibit the transfer of oxygen, which is essential for most bacteria to propagate. Aseptic milk is processed and packaged so that it requires no refrigeration and has a non-refrigerated shelf life of up to 180 days.

Present status of the packaging industry

In developed countries packaging industry has met with tremendous advances. With newer marketing systems like super markets, self services stores etc packaging technology in these countries has risen to great heights. Newer and better packaging materials, development of packaging machinery and appliances have all advanced in an integrated manner. In developing countries like India, packaging is still in its infancy.

Consumption of milk

India has attained the first rank in milk production in the world. The first five countries in the world producing maximum milk are India, USA, Russia, Germany and France.

India produced 13.1 per cent of the total milk produced in the world. Last year produced 750 lakh ton of milk valued at about Rs.75,000 Crores. National Dairy Development Board (NDDB) milk production is increasing at one percent per annum in the world, while it is increasing at 4 percent in India. Per capita per day consumption of milk has increased to 212 gm.

Total milk production

In India, the milk industry may be said to have started in 1950-51 when the Central Dairy of Aarey Milk Colony was commissioned and went into stream.

The industry is still in its infancy and barely 10 per cent of our total milk production undergoes organized handling.

Table 1.1: India's position in relation to milk producing countries of the world (Source: F.A.O, 1970)

Country	Animals in milk (millions)	Milk yield/milking cow/annum (kg)	Total milk production (1000 tonnes)
U.S.S.R	41.2	2200	82,900
U.S.A	14.1	4154	52,800
France	8.7	3130	30,413
India	53.0	B – 450 C – 157	21,360
W. Germany	5.9	3779	22,545
Poland	6.2	2361	14,860
U.K	5.3	3950	13,000

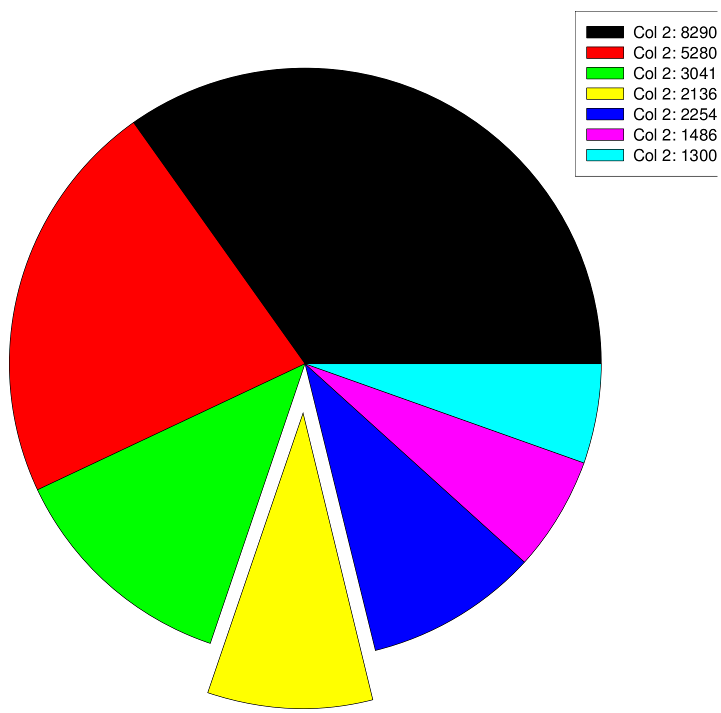


Figure 1.1: India's contribution in milk producing countries of the world

Milk production in India

The total milk production in the country for the year 1996-97 was estimated at 68.6 million MT. At this production, the per capita availability was 200g per day against the minimum requirement of 250g per day as recommended by ICMI. Thus there is a scope for increasing the production. The population of breeding cows and buffaloes in milk over three years of age was 62.6 million and 42.4 million respectively.

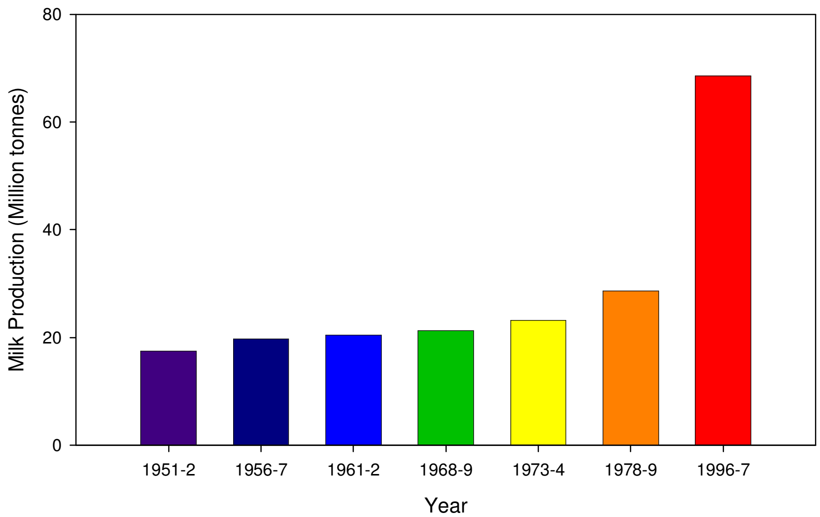


Figure 1.2: Milk Production in India

Table 1.2: Species contribution to total milk production in India

Type of milk	Total production	
	Per cent	Amt. (1000 x tonnes)
Cow	33.6	8,400
Buffalo	63.6	15,900
Goat	2.8	681

Table 1.3: Density of milk production in India

Category	Per village	State	Per sq. km
Min.	11 kg	Assam	2.1 kg
Ave.	88kg	Indian Union	15.6 kg
Max.	472 kg	Delhi	98.0 kg

Table 1.4: Summary of utilization of milk in India

Items	Percentage in relation to	
	Total milk production	Total quantity converted into milk products
Fluid milk	44.5	-
Manufactured milk	55.5	(100)
Ghee	32.7	58.9
Dahi	7.8	14.0
Butter	6.3	11.4
Khoa	4.9	8.8
Ice cream	0.7	1.3
Cream	1.9	3.4
Other products (Mainly chhana)	1.2	2.2

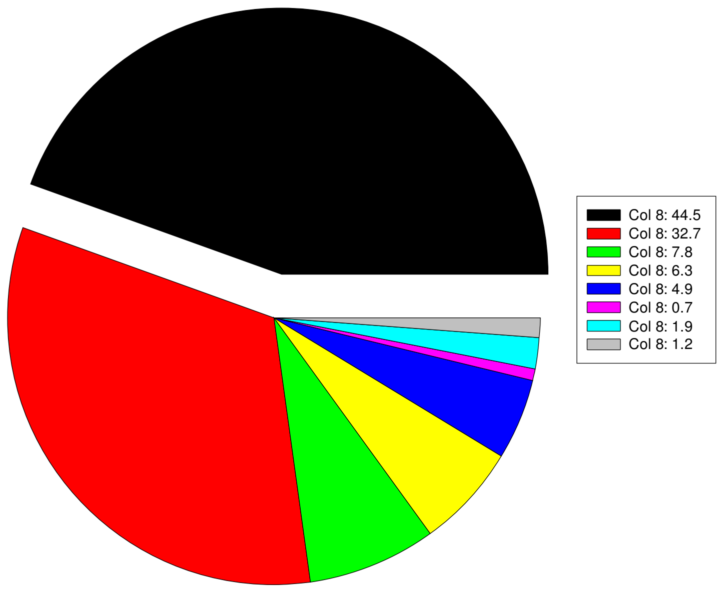


Figure 1.3: Utilization of milk (in percentage) in India

Statistics of Milk Consumption and Packaging in Delhi

Total Milk Consumption in Delhi ~ 40 lakh litres per day
Milk Supplier

Unorganized Sector	**50%**
Organized (Mother Dairy, Paras, DMS, Parag etc.)	**50%**

Survey of Mother Dairy

Pouches Filled per day	**~2,40,000 of one litre capacity**
	~80,000 of half litre capacity

Table 1.5: Milk Production in India

Year	Production (Million Tonnes)	Per Capita Availibilty (gms/day)
1950-51	17	124
1955-56	19	124
1960-61	20	124
1968-69	21.2	112
1973-74	23.2	112
1979-80	30.4	127
1980-81	31.6	128
1981-82	34.3	136
1982-83	35.8	139
1983-84	38.8	147
1984-85	41.5	154
1985-86	44	160
1986-87	46.1	164
1987-88	46.7	163
1988-89	48.4	166
1989-90	51.4	173
1990-91	53.9	176
1991-92	55.7	178
1992-93	58	182
1993-94	60.6	187
1994-95	63.8	194
1995-96	66.2	197
1996-97	69.1	202
1997-98(Prov.)	70.8	204
1998-99(Prov.)	74.7	211
1999-00(Anti.)	78.1	214

Prov. : Provisional ; Anti. : Anticipated; ***Sources :*** Basic Animal Husbandary Staststics, GOI, 1999,. Economic Survay,GOI, 2000-01.

Table 1.6: Milk Production by States

Milk Production by States ('000 MT)					
State	**1993-94**	**1994-95**	**1995-96**	**1996-97**	**1997-98**
Andhra Pradesh	3,766	4,221	4,261	4,470	4,510
Arunachal Pradesh	21	22	42	44	44
Assam	676	698	699	740	775
Bihar	3,215	3,250	3,321	3,399	3,475
Goa	33	36	37	39	39
Gujarat	3,935	4,459	4,608	4,831	4,860
Haryana	3,850	4,062	4,055	4,204	4,082
Himachal Pradesh	654	663	676	698	707
J & K	780	641	862	900	938
Karnataka	2,736	3,003	3,184	3,460	3,970
Kerala	2,001	2,118	2,192	2,258	2,348
Madhya Pradesh	4,975	5,047	5,125	5,224	5,378
Maharashtra	4,250	4,812	4,991	5,127	5,209
Manipur	84	64	60	62	62
Meghalaya	53	54	56	58	59
Mizoram	9	9	9	9	20
Nagaland	45	43	44	45	46
Orissa	565	584	648	687	670
Punjab	5,970	6,215	6,424	6,755	7,350
Rajasthan	4,958	5,103	5,449	5,873	5,500
Sikkim	30	32	33	34	35
Tamil Nadu	3,524	3,695	3,791	3,976	4,000
Tripura	35	38	39	40	47
Uttar Pradesh	10,991	11,321	11,878	12,387	12,934
West Bengal	3,095	3,250	3,341	3,376	3,415
A&N Islands	25	25	21	21	22
Chandigarh	38	39	41	42	43
D&N Haveli	7	8	5	4	4
Daman & Diu	1	1	0	1	1
Delhi	252	257	261	264	266
Lakshadweep	1	1	1	1	1
Pondicherry	32	33	33	37	37
All India	**60,607**	**63,804**	**66,187**	**69,066**	**70,847**
Source: Basic Animal Husbandry Statistics, 1999, GOI.					

Table 1.7: Per Capita Availability of Milk by States

Per Capita Availability of Milk by States (gms/day)					
State	**1993-94**	**1994-95**	**1995-96**	**1996-97**	**1997-98**
Andhra Pradesh	148	163	162	167	166
Arunachal Pradesh	62	64	119	121	118
Assam	78	79	95	80	82
Bihar	96	95	101	95	95
Goa	73	72	73	81	80
Gujarat	249	277	229	290	287
Haryana	605	625	618	621	592
Himachal Pradesh	330	324	329	332	330
J & K	261	210	276	282	288
Karnataka	160	173	185	193	219
Kerala	181	190	198	196	201
Madhya Pradesh	195	199	199	193	196
Maharashtra	140	156	163	159	158
Manipur	118	88	80	81	79
Meghalaya	77	77	83	78	78
Mizoram	32	32	31	30	64
Nagaland	93	91	88	85	84
Orissa	47	47	49	53	51
Punjab	776	797	847	841	880
Rajasthan	292	280	294	325	299
Sikkim	186	192	204	192	191
Tamil Nadu	168	175	180	184	184
Tripura	33	35	35	34	40
Uttar Pradesh	207	209	216	231	227
West Bengal	119	123	130	123	123
A&N Islands	223	215	173	167	169
Chandigarh	145	142	143	140	138
D&N Haveli	129	144	87	68	66
Daman & Diu	26	25	25	24	23
Delhi	67	66	69	63	61
Lakshadweep	50	53	54	46	45
Pondicherry	103	98	90	112	106
All India	**188**	**191**	**197**	**202**	**204**
***Source* :** Basic Animal Husbandry Statistics, 1999, GOI					

Table 1.8: Standards of different milk in India

Class of milk	Designation	Locality	Minimum % MF	Minimum % MSNF †
Buffalo milk	Raw, pasteurized, boiled, flavoured and sterilized	Assam; Bihar; Chandigarh; Delhi; Gujarat; Maharashtra; Haryana; Punjab; Uttar Pradesh; West Bengal	6.0	9.0
	- do -	Andaman and Nicobar; Andhra Pradesh; Dadra and Nagar-Haveli; Goa, Daman and Diu; Kerala, Himachal Pradesh; Lakshadweep; Tamilnadu; Madhya Pradesh; Manipur; Karnataka; Nagaland; NEFA; Orissa; Pondicherry; Rajasthan; Tripura	5.0	9.0
Cow milk	- do -	Chandigarh; Haryana; Punjab	4.0	8.5
	- do -	Andaman and Nicobar; Andhra Pradesh; Assam; Bihar; Dadra and Nagar-Havali; Delhi; Gujarat; Goa, Daman and Diu; Himachal Pradesh; Kerala; Madhya Pradesh; Maharashtra; Tamilnadu; Karnataka; Manipur; Nagaland; NEFA; Pondicherry; Rajasthan; Tripura; Uttar Pradesh; West Bengal; Lakshadweep; Orissa	3.0	9.0
Goat or sheep milk	Raw, pasteurized, boiled, flavoured and sterilized	Chandigarh; Harayana; Kerala; Madhya Pradesh; Maharashtra; Punjab; Uttar Pradesh	3.5	9.0
	- do -	Andaman and Nicobar; Andhra Pradesh; Assam; Bihar; Dadra and Nagar-Haveli; Delhi; Goa, Daman and Diu; Gujarat; Himachal Pradesh; Lakshadweep; Tamilnadu; Karnataka; Manipur; Nagaland; NEFA; Pondicherry; Orissa; Rajasthan; Tripura; West Bengal	3.0	9.0
Standardized milk		All India	4.5	8.5
Recombined milk		All India	3.0	8.5
Toned milk		All India	3.0	8.5
Double toned milk		All India	1.5	9.0
Skim milk	- do -	All India	Not more than 0.5	8.7

Packaging Trend

Glass bottles
Since the early 1970s, glass packaging for milk has diminished, so much so that by 1983 milk was simply not found in glass bottles. Attempts are underway to make its surface scratch resistant either by surface or plastic shields, to make light weight bottles useable and to develop: unbreakable glass bottles. Brown tinted glass bottles have been fabricated to protect the milk from UV light and is getting acceptance in the market.

Plastic packaging
Plastic materials have made great inroads into the food packaging field due to (a) availability of a wide range of materials, (b) developments in various forms and ancillary materials, (c) low energy costs involved in its production, and (d) versatility in functional properties, product usage and package disposability (Kumar, 1988).

Characteristics of an Ideal Package

The ideal package should have the following characteristics (Nielsen, 1997):

1. Protection from moisture, oxygen and light,
2. Enable the product to retain aroma,
3. Should have distribution strength,
4. Tamper evidence,
5. Printability and machinability,
6. Impact on sale,

7. Extend the product shelf life,
8. Low cost,
9. Environment friendly and
10. Carry information about the product such as its identification and its manufacturer, the volume and weight of the products, its ingredients, additives used, its composition and nutritional information in terms of recommended daily intake.

Materials

In today's highly competitive marketplace, packaging is as vital to success as actual product. Selecting and developing the right container to effectively market product requires an understanding of packaging materials, advantages and disadvantages, and how materials can be used as innovative tools for creating distinction.

Beverage manufacturers use packaging as a primary tool to open new markets and appeal to different target audiences. To position milk as a beverage, dairies must keep pace by providing consumers with packaging that drives sales. Processors no longer can afford to view packaging as merely an expense. Keep in mind that innovative packaging represents risk in terms of capital investment, increased costs and consumer acceptance. However, most dairies that have made significant packaging changes don't view it as risk, rather, as a step in the right direction.

Material matters

Size, shape, custom or stock, and shelf-life requirements are among factors that influence container costs, as well as manufacturing and warehousing needs. Small, relatively inexpensive changes in graphics generate new consumer enthusiasm. This impulse buy is important, but doesn't represent sustainable growth. This is achieved by providing consumers with a reliable, performing package. The first issue a dairy must address when deciding on packaging material is if the milk beverage will be refrigerated or shelf-stable. e.g., In the United States, only FDA-approved containers can be used to package shelf-stable, low-acid beverages such as milk, coffee-milks and dairy-based chocolate drinks.

Next, dairies must determine their desired length of shelf-life e.g. 2 days, 7 days etc. If it's going to be longer than the traditional 14 days that's achieved by high-temperature short-time (HTST) pasteurization, it's wise to choose added-protection packaging materials to ensure high-quality milk through the code date. Lastly, dairies need to identify any manufacturing and warehousing restraints. A big decision, if using plastic bottles, is to buy pre-formed bottles or blow mold on-site.

Basic Package Types

As more beverage processors, including dairies, convert their packaging operations to plastic containers, it's important to understand that not all plastics are the same. In addition, aluminium, flexible film, glass, paperboard and combinations of these materials remain innovative options, with each offering processors, retailers and consumers different benefits.

• Flexible pouches

Flexible pouches can be as simple as large volume plastic bags of HTST-processed milk to shelf-stable, single-serve containers of UHT (ultra-high temperature) milk. The film used for pouches can be foil or metalized material for added barrier properties, or simply an all-plastic design. Pouches can be block-style or stand-up and even include a reclosable plastic spout that contains an integral straw. Flexible pouches enable innovation in shape, size and graphics. They are especially appealing to kids because of their interactive nature and fun look.

• Glass

Glass is the most inert container available to dairy processors. Because it has no impact on taste whatsoever, many consumers find glass to be the most "all-natural" container for fluid milk. It is reminiscent of home-delivery days. Glass is also the only material (except for steel) suited to retort packaging of milk. Not only is it able to withstand the high heat of retorting, it also adequately protects product quality. Glass bottles are economically available in stock sizes and shapes. They can also be customized to include features such as logos and textured surfaces.

Single-serve bottles are resealable, however, like aluminum cans, the popularity of glass continues to decline as the marketing advantages of plastics improve. When it comes to glass vs. plastic, glass's breakable nature makes it undesirable, particularly for distribution in public venues. Clear glass provides shelf stability to UHT-pasteurized dairy drinks but minimal protection from UV light, which means that full-body labels or tinting are very important for maintaining product quality. Because it's inert, glass is the preferred package for nutritional and highly fortified beverages that contain vitamins, minerals and other reactive ingredients. Glass usage in the beverage industry is relatively flat, with whatever new business coming from niche, value-added products.

Dairy plastic evolution

When it comes to plastics, HDPE (high-density polyethylene) continues to be the most common container for fluid milk, particularly with larger volume packages such as gallons and half-gallons; however, PET (polyethylene terephthalate) is trying to take over the single-serve business, with plans to move into larger sizes as it becomes more economical. Plastic containers made with the right combination of barriers and used in combination with ESL processing, can provide milk a lengthy refrigerated shelf-life. The limiting word here is refrigerated, because FDA has not approved plastic for low-acid, aseptic beverages such as milk.

For dairies to take full advantage of value-added features that plastics offer, marketers should look outside of dairy to see what other drink manufacturers are doing. Go a step further and look at liquid laundry detergent to see how these companies have designed containers that are easier for consumers to manage.

• HDPE – original milk plastic

HDPE dominates the jug business because it is low-cost, durable and lightweight. Standard HDPE resin produces a translucent container, which offers some protection against UV light. UV protection ingredients can be added to resin to further prevent oxidative flavors from developing in milk, as well as protect light-labile vitamins and minerals.

Pigments can be added to HDPE resin to provide even greater protection to milk from destructive elements in the environment. Almost any color is possible, but transparent, yellow and white are dominant with fluid milk. Unlike most dairies that have simply added single-serve bottles to their fluid milk line, Schroeder Milk converted its entire line to white resin. "We wanted to extend our personality to the entire line, not just single-serve as we have seen with other dairies," adds Schroeder. Most dairies using pigmented jugs purchase them preformed, rather than blow mold them on-site, even if the dairy has blow-molding equipment. This eliminates the possibility of contaminating non-pigmented packaging with color. When pigmented HDPE is used for bottling ESL milk, blow molding is often done on-site as part of the ESL-controlled environment. Either way, turning HDPE resin into a milk container is a single-step process that involves blow molding melted resin beads. Color helps sell beverages. Expect to see more colors very soon such as coffee-milk brown and raspberry fuchsia.

• PET – the trendy resin

Even though it's more expensive than HDPE, PET's glass-like clarity and very low oxygen transmission rate makes it an extremely attractive container to beverage manufacturers. PET also has considerable mechanical resistance, is lightweight and is very versatile for designing unique shapes with sharp and contrasting profiles.

According to research conducted at Virginia Polytechnic Institute and State University, Blacksburg, Va., milk packaged in traditional HDPE containers showed higher levels of oxidative off flavor than milk packaged in PET bottles with UV additive, but not higher than clear PET or glass. Interestingly, amber-colored PET had developed the least amount of oxidative off flavor. In fact, it gave complete protection to UV light, comparable to the control, which was glass wrapped in tin foil. Researchers concluded that amber-tinted and/or UV-treated PET bottles are competitive packaging choices for high-quality milk (*Journal of Dairy Science* 84:1341-1347).

Turning PET resin into a milk container is a two-step process. Resin is melted and converted into a preform through an injection-molding process. These preforms can either be blow molded by the packaging company, which then ships pre-formed containers to the dairy, or dairies purchase the preforms, and blow mold on-site. Below a certain size bottling operation, it's not economical for dairies to install their own in-line PET bottle blow-molding machine, especially if there are a number of sizes involved or elaborate designs. Both preforms and finished bottles are available from suppliers in stock shapes and sizes; however, customization is the trend in today's beverage industry. Like with HDPE, if the bottle is being used for ESL milk, it's best that it be formed as part of the ESL operation.

Because of PET's smooth finish, it's possible to use innovative caps and closures on bottles. This smooth finish is a major advantage over HDPE, which can leak when no inner seal is used. Milk can dry on the threading, which most consumers find to be very objectionable. With PET bottles, the opening's threads are so defined and smooth that inner seals are not necessary. While most glass bottles can be replaced with PET, if the PET bottle is to have the same fill volume, it needs to be designed slightly smaller than its glass counterpart because its walls are thinner than glass. Because PET bottles weigh only about 10% of comparably sized glass bottles, PET reduces freight costs.

Qualitative material environmental characteristics

Glass

Glass containers have been used for hundreds of years and, whilst having encountered strong competition in a number of its prime markets, the material still dominates many of them, particularly for returnable/refillable applications- the first milk bottle was reportedly used in 1884 (Hanlon, 1984). Its market is predominantly for food and beverages. Because of the special characteristics of the material and of the manufacturing processes, it is a good example of the systems mentioned earlier, which do not fit in our tidy pattern for production operations. In this case, the raw material producer is also the packaging manufacturer. The raw materials are basically sand, limestone and soda ash, plus small quantities of aluminium oxide, magnesium, lead or arsenic, depending on the properties required.

The bottle making process essentially comprise in producing glass in a large furnace, at a temperature of about 1500^0C and feeding the molten material to a container-making machine. A 'gob' of the molten material, now typically at a temperature of about 700^0C, is blown to the required shape and a variety of annealing and surface treatments may follow. It is, of necessity an in-line process because of the heating and cooling requirements involved and the lengthy start-up time needed for the glass furnace. Environmental effects principally relate to the energy and the atmospheric emissions associated with the furnace. Care must obviously be exercised in milk packing, handling and transporting the containers to minimize breakage's.

Plastics

Compared to other materials, plastics are relatively new comers. Although thermosetting resins, whose molecular structure is cross-linked, have been used since the last century and are still extensively used in coating formulations for packaging, contemporary use of plastics for primary, secondary and tertiary packaging is almost entirely based on thermoplastic materials. Today, about one third of all plastic manufactured are used in packaging.

The breakthrough for thermoplastic was the discovery and development of polyethylene by Imperial Chemical Industries in 1935. Significant use of polyolefins, and of vinylpolymers, was being made to support the war efforts by 1945 and, with the onset of peace, alternatives uses for the materials, as packaging, were rapidly developed. The term plastics cover a very broad family of different polymeric materials. Those commonly used for packaging include the polyolefins, principally polyethylene and polypropylene; PVC, (polyvinyl chloride); polystyrene and PET, (polyethylene terephthalate). About two thirds of this use is for foods and beverages, with much of the perishable foods in modern supermarkets being portion-packed in some form of plastics.

Manufacturing processes entail taking-in the plastic material as granules or powder, heating it (temperatures vary widely between the different polymers but are typically in the 150 to 300^0C range) and forming into shape. The forming can be blowing or injecting into a chilled mould or by pre-extruding sheet and then forming this into a mould. Sheet is also supplied direct to packers for use on form fill-seal machines. The process is reversible so that all unadulterated industrial scrap is collected by the packaging manufacturer, regranulated and reused in-plant, representing a significant cost saving, Many blown bottles and moulded tubs are also printed prior to delivery to the packer.

Environmental effects, specifically associated with plastics packaging manufacturer, are relatively benign. Impacts common to all manufacturing operations, such as nuisance for local communities, have to be controlled but apart from these, energy consumption, atmospheric emissions and incidence of solid waste are readily controlled.

A qualitative review of the five materials groups, in terms of what are perceived to be their environmental strengths and weakness, has been compiled for general guidance:

Table 1.9: Comparison of glass and plastics in terms of their strengths and weaknesses

	Glass	Plastics
Strengths	• Abundance of raw materials • Hygienic with foods and beverages. • Established capability to be returnable/refillable established bottle bank recovery systems in most developed countries • High public esteem and participation in recovery and recycling.	• The most versatile and diverse family of packaging materials • Efficient and economic use of material for individual packs • Hygienic packaging for foods and beverages • Excellent protection from physical damage provided by low mass of expanded materials • High energy recovery from incineration • Efficient in-plant industrial scrap reuse
Weaknesses	• Significant energy consumption in production • Pollution risks associated with production-furnaces • Relatively high pack weights compared to other materials • Safety hazards from breakage splintering • Reliance on voluntary action for recovery	• Derived from non-sustainable resources of fossil fuels • Highly visible contributor to litter • Difficult to recover, separate and recycle from post-consumer waste • Non-degradable-perceived as a weakness for plastics, but not for glass which is no more degradable • Some use in multi-layer materials which exacerbates recovery and reuse limitations

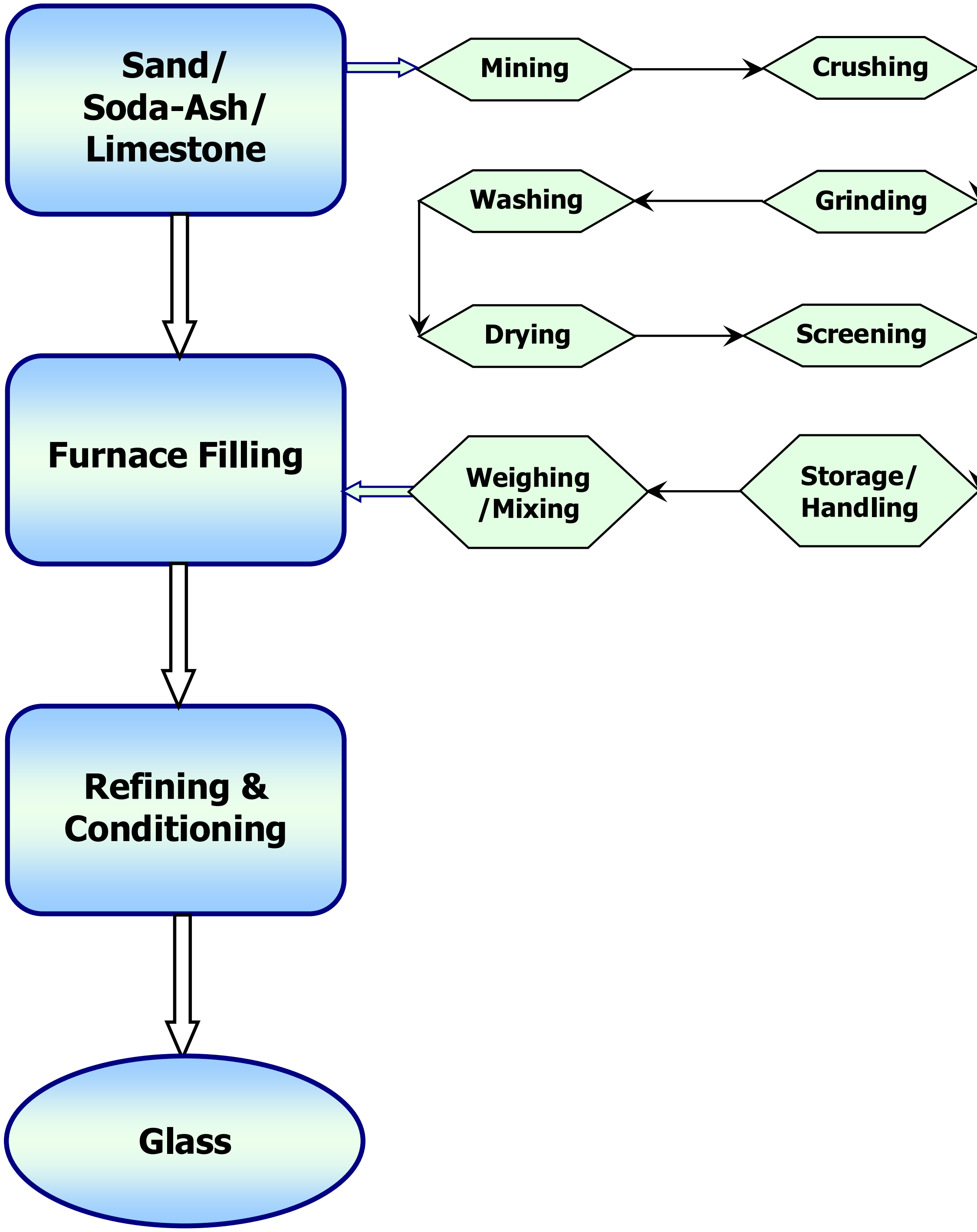


Figure 2.1: Flow chart for production of glass

DETAILED PROCESS OF PRODUCTION OF GLASS

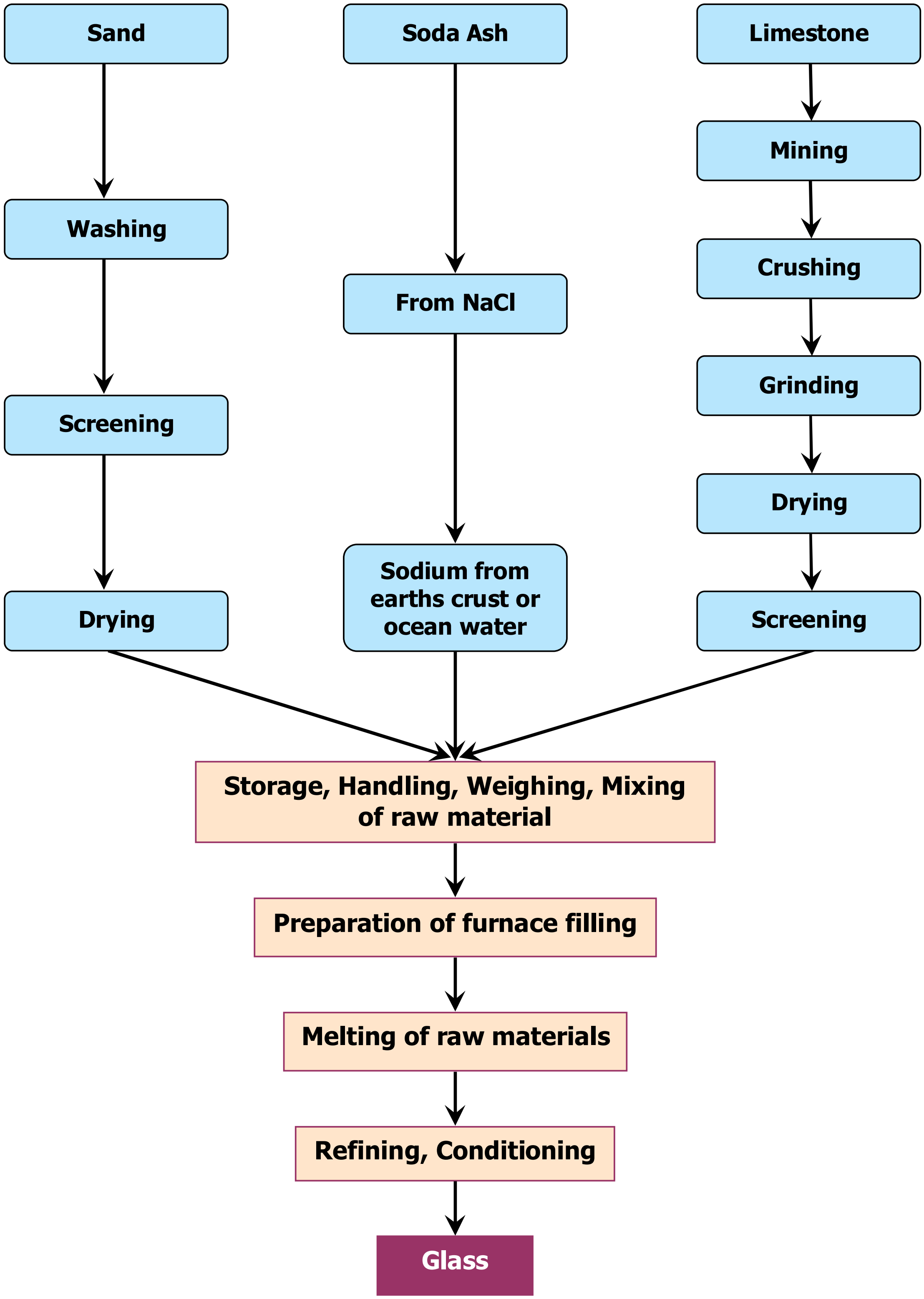


Figure 2.2: Detailed flow chart of processes for production of glass

Process details

The process for the production of glass bottles involves the following steps:

1. The extraction and processing of the raw materials;
2. The mixing of the raw materials;
3. The melting of the raw materials; and
4. The formation of the bottles.

Extraction of raw materials

Virgin glass is made up of 70% silica sand, 15% soda ash, 12% limestone, 2% feldspar and 1% other materials. These raw materials are available in vast quantities and are initially extracted from quarries. At this stage, the environmental impacts include the consumption of energy, air pollution (particles, dust) as well as the alteration of landscapes and wildlife habitats. The materials are usually loaded into silos pneumatically or by means of screw, bucket or belt conveyors.

Mixing of raw materials

During the mixing process, the materials are mixed in the proportions. The emission of dust is the main environmental consequence at this stage. Mixing can be regarded as being carried out at two locations – first in the mixer and secondly in the furnace. After mixing, they are transported to silos, or directly to the entrance of the melting furnace.

Melting

The process is carried out in a regenerative furnace in which the mixed raw materials combine at high temperature to form the molten glass. When the temperature rises, the mixture emits gases, liquid phases are formed and the mass became transparent. This is the step that consumes the most energy. Crushed glass is generally added at this stage to facilitate the transfer of heat through the material. The homogenized melt is then followed by a process of refining, which is carried out to eliminate all bubbles from the glass melt.

The melting process contributes significantly to the total environmental load. At this stage, atmospheric emission of dust, SO_2 and NO_2 as well as volatile organic compounds are recorded. Small quantities of $CO_{2,}$ lead and methane may also be present. In the furnace the melting process takes place, on other side of furnace the glass emerges as thin liquid. Then glass can flow unhindered from melting section to the conditioning section (adjustment of temperature before molding). During this process, all remaining bubbles are reabsorbed into the melt.

PRODUCTION OF GLASS BOTTLE

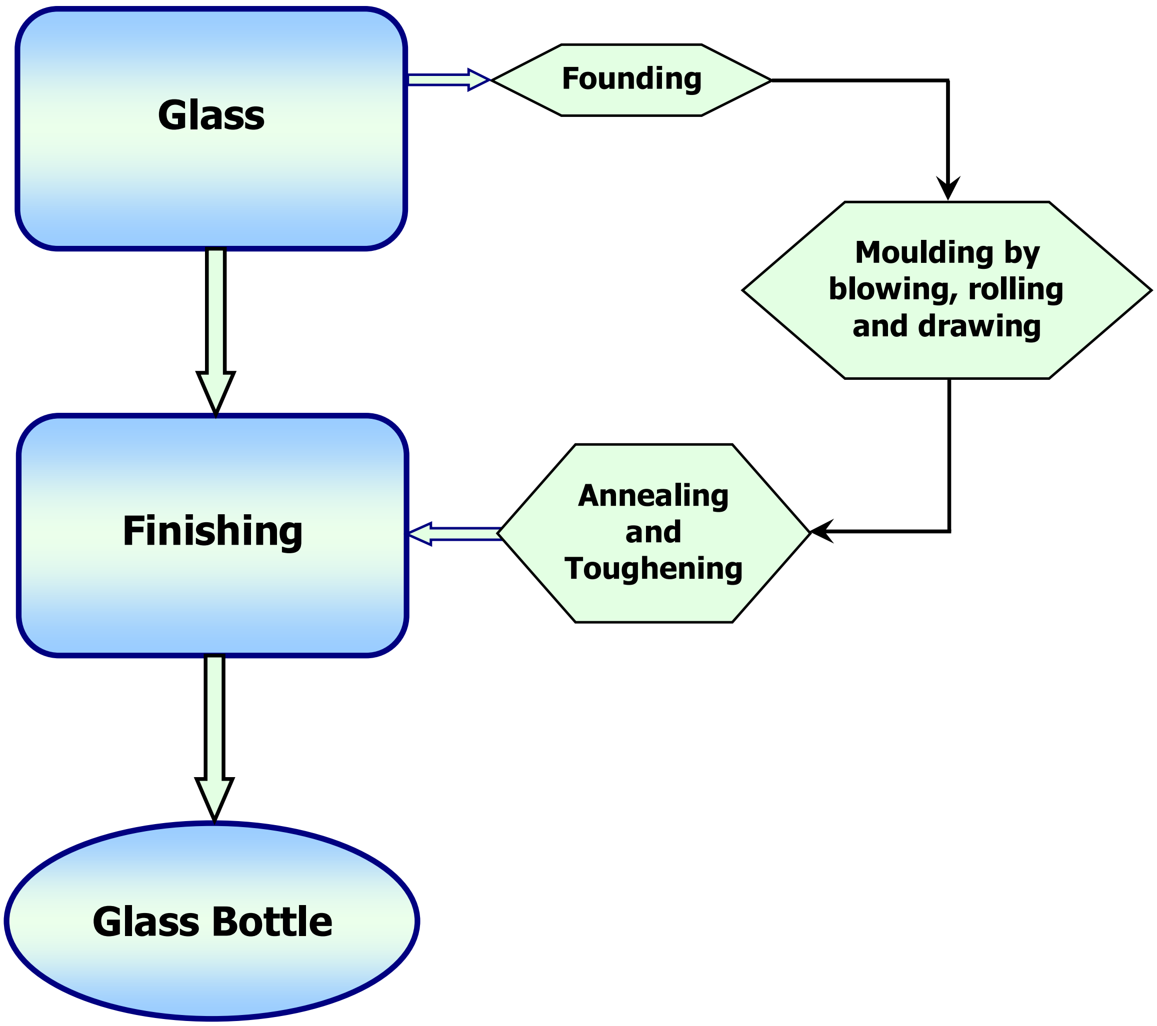


Figure 2.3: Flow chart for production of glass bottles

Process for the production of glass bottle

Raw materials

Most raw materials needed to manufacture glass are abundant throughout the world: silica sand, limestone, sodium carbonate and, of course, cullet. These materials are stored in compartments or silos where they are kept dry and clean. They are later weighted, mixed and poured into tanks that feed the furnaces. The average percentage of cullet used in the production of glass varies considerably from plant to plant. The average in the United States is approximately 35%.

Raw Materials

Founding

The melt of raw materials to produce glass requires constant monitoring and supervision, as well as sophisticated automated control systems. Depending on their size, furnaces have the capacity to produce anywhere from 50 to 600 tons of glass per day. Most furnaces use natural gas and reach temperatures of up to 2200-2400° F or 1200-1300° C. The molten glass flows out of the furnace through pipes into the bottle-forming machine.

Critical parameters

This overview of the life-cycle-inventory methodology as well as the descriptions of the manufacturing processes for each of the containers being studied makes it possible to identify certain critical life-cycle parameters of these containers that have a major impact on their environmental performance. The first of these critical parameters is the effective **number of refills** of the bottles. Not surprisingly, the more times a reusable glass bottle (RGB) is reused, the fewer the environmental consequences, since its reuse eliminates the need to manufacture a new bottle.

The **recovery rate** of the containers being studied is the second critical parameter that has a major impact on their environmental performance. It is important to emphasize that this rate is primarily dependent on the recovery system used in the jurisdiction being studied and on the habits of consumers. Not surprisingly, the higher this rate is for a given type of container, the less significant the environmental impacts associated with the use of the container will be, because the recovery of the container eliminates the impacts associated with its disposal. Instead, the container is recycled and can be used to manufacture a new container or another product.

The third critical parameter is the **recycling rate** of the various materials used to make a new container. For example, as has just been noted, the aluminum recycling rate can have a major impact on the quantity of energy used as well as on the amount of waste generated. Once again, the rates used in the referenced studies are generally those which prevail in the countries where the studies were conducted. The **transport distance** of RGBs is the fourth critical parameter. Certain studies conclude, for example, that beyond a certain average number of kilometres of transportation, RGBs become less environment friendly than other containers (Saphire, 1994; Fraunhofer-Institut, 1993).

Glass forming and annealing

During the bottle formation stage, the melted glass enters a cooling zone where it is cut, molded and water-cooled. This step involves the introduction of certain waste products into the water; suspended solids, oils and effluents that create a biochemical oxygen demand (BOD). After this so much heat is extracted that the object can no longer be deformed. The process of glass forming aims at giving a desired shape to the glass. It requires a definite amount of energy, which is assumed to be around 10% of the total energy requirements. Once formed, the glass containers undergo a thermal treatment for enhancing the physical properties of the glass product. The process requires a certain amount of energy, which is assumed to be 10% of the total energy requirements.

These are essential stages in automatic bottle making:

Gathering: The required quantity of glass is obtained from the furnace.

Forming the parison: This shaping process may be carried out by pressure, and/or suction, or by a metal plunger.

Transfer: The parison, held by its neck, is transferred from the blank mould to the blow mould. All the moulds are made in two halves, which open on hinges to allow the transfer to occur.

Finishing: Finishing of glass is carried out by grinding, polishing, etching and matting by sand blasting. For the decoration of glass varnishes are used often consisting of pigmented inorganic oxides and a flux of glass with a lower melting point (Frit). Then treated glass is put in the annealing furnace where the frit combines with the original glass. The production of glass containers is basically a two-stage operation. A precisely measured quantity of molten glass, the 'gob', is delivered automatically into the blank mould. The first stage involves the formation of the neck and rough shape of the bottle or jar.

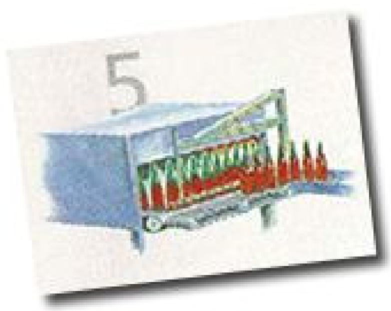
In the second stage the 'parison' is transferred to the finishing mould where the container is fully blown to its final dimensions. Although the container is still visibly glowing hot, the temperature has dropped to about 550°C. On leaving the machine the containers are transferred into a large tunnel called the annealing lehr. With the rapid reduction in temperature, tension or 'residual stress' as it is called, builds up in the glass surface making it unable to withstand normal handling. The annealing lehr solves this problem by again raising the temperature of the containers passing through, and then allowing them to cool at a controlled rate over a period of 3 hours. Most containers have special coatings applied making the glass surface more resilient to scratching and scuffing.

Bottle forming machines

From the furnace, the molten glass flows into the bottle-forming machines, which can carry one, two, three or four glass loads to form bottles. The number of machines connected to the furnace can vary from 1 to 8 depending on its size. The bottle is manufactured in two stages, as described below.

Bottle-forming machines

The first stage consists in forming a parison or preliminary mold of the container, which is then transferred to the final mold. Compressed gas is injected into the parison to fill the container and expand it towards the walls of the mold. The new container is detached from the mold and conveyed to the annealing station. These machines can produce over 700 small bottles and over 100 large bottles (such as Champagne bottles) per minute.



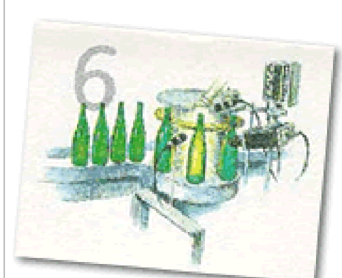
Annealing station

Although theoretically speaking glass is stronger than steel, its strength is reduced by the fact that it cools unevenly. It is therefore necessary to control the annealing process so that the bottle cools evenly.

The annealing station is similar to a very big furnace in which bottles are reheated to 1000° F or 550° C and then gradually cooled for 30 to 60 minutes. Upon leaving the station, the bottles are still warm but can be handled safely.

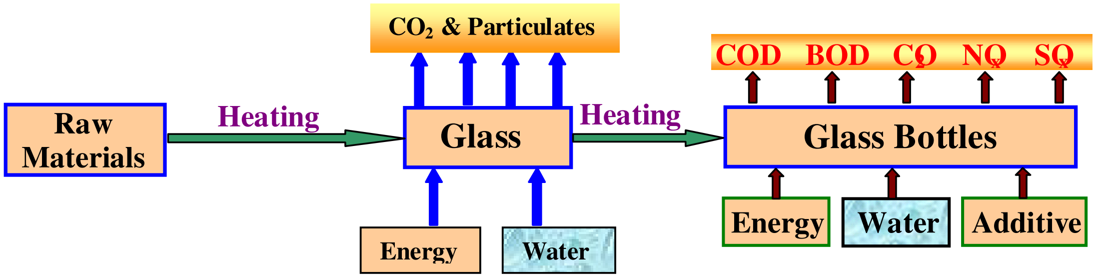
Inspection

After leaving the annealing station, the bottles are conveyed through electronic inspection machines that automatically detect imperfections. Rejected bottles are sent back to the raw materials section for recycling



Inspection

LIFE CYCLE INVENTORY DATA FOR PRODUCTION OF GLASS AND GLASS BOTTLE



Energy required

Energy requirement for making glass bottles can be considered in the following headings:

(i) Energy required to produce raw materials
(ii) Energy required to deliver raw materials
(iii) Energy required to operate the glass making factory

Energy required to produce 1 kg of glass(sum of (i) and (ii): 14.80 MJ

Energy required to convert 1 kg of glass into glass bottles (iii): 11.68 MJ

Total energy required to produce 1 kg of glass bottles: 26.48 MJ

Table 2.1: Distribution of energy consumption for typical glass bottle manufacture – Energy required to operate Glass Bottle Making Factory.

	Energy required **X 10^{-4} cal/kg glass**
Heavy oil	163.61
Kerosene	0.02
LPG	30.99
City gas	0.31
Electricity	56.74
Total	251.68

Source: Glass industry "Practical energy audit manual" Teri

Water Required

Water required to produce 1 kg of glass bottles: 35.42 Litres

Raw materials required

Table 2.2: Gross raw materials (in g) required to produce 1 kg of glass.

Raw material	Input (g)
Sand	757.20
Soda ash (including dolomite)	226.00
Limestone	173.20
Alumina	10.80
Calcium sulfate	6.60
Feldspar	14.50
Iron chromite	0.80
Calumite brand slag	23.60
Sodium nitrate	0.04
Nepheline syenite	11.30
Cullet	6.60
Sodium sulfate	2.30
Selenium	0.01
Cobalt oxide	0.0003

Source: Boustead and Hancock 'Energy and packaging'

Emissions

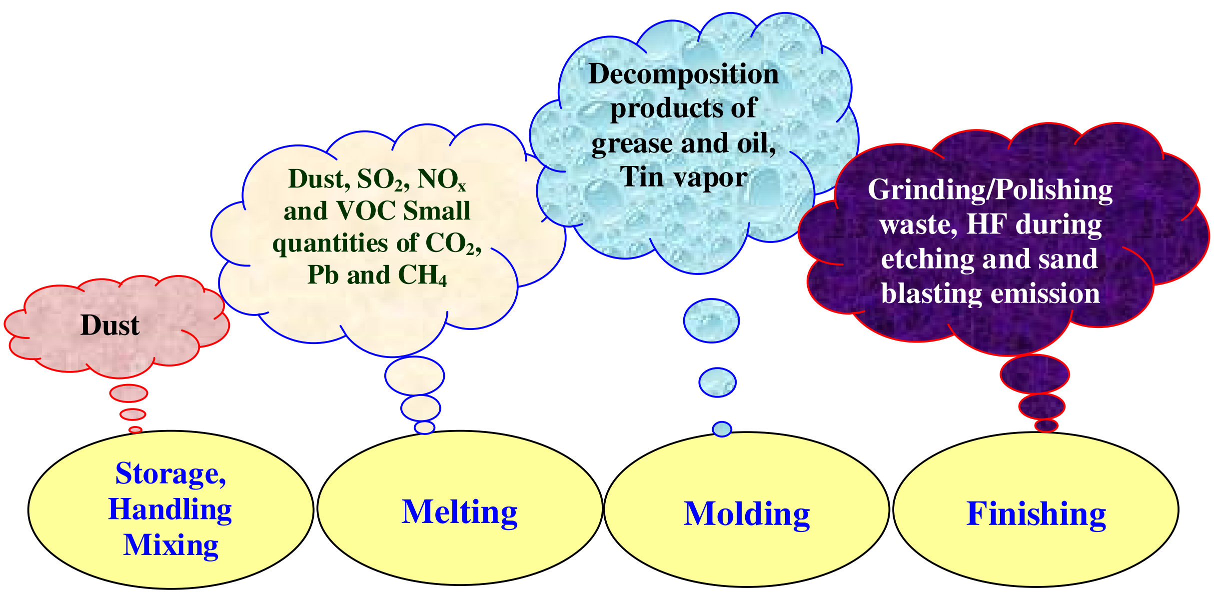


Table 2.3: Gross air emissions (in mg) arising from the production of 1 kg of glass.

Emission	Totals (mg)
Particulates	1488.0
CO	1197.0
CO_2	145600.0
SO_x	2970.0
NO_x	1500.0
N_2O	2.1
Methane	827.0
HCl	117.0
HF	8.2
Lead (Pb)	-11.7
Arsenic	64.4
Mercury (Hg)	0.00172
Ammonia (NH_3)	25.5
Nickle	0.4565
Cadmiun	0.0118
Zinc	0.258

Source: Integrated solid waste management: a life cycle inventory by McDougall, F.R., White, P.R., Franke, M. and Peter Hindle

Gross solid waste in kg generated to produce 1 Kg of glass: 0.074 kg

Table 2.4: Gross water emissions (in g) arising from the production of 1 kg of glass

Emission	Totals (mg)
COD	11.64
BOD	0.57
Phenol	1.46
Chlorinated Hydrocarbons	0.00876
Suspended solids	7760.0
Total organic compounds	68.475
Al^{+++}	24.1
AOX	0.0358
Ammonium	42.0
Barium	28.2
Cadmiun	0.087
Chloride	99900.0
Chromiun	0.338
Copper	0.143
Cyanide	0.041
Iron	28.65
Lead	0.368
Mercury	-0.000001
Nickle	0.153
Nitrate	7.1
Phosphate	1.6
Sulfate	773.0
Sulfide	0.316
Zinc	0.346
Arsenic	0.0584

Source: Integrated solid waste management: a life cycle inventory by McDougall, F.R., White, P.R., Franke, M. and Peter Hindle

PRODUCTION OF POLYETHYLENE (LDPE) GRANULES

The process of manufacturing involves following steps:

- Extraction of Crude oil
- Production of Naphtha by fractionation from crude oil
- Cracking of Naphtha to produce ethylene/propylene
- Polymerization of ethylene to produce polyethylene (LDPE)
- Manufacturing of tapes from LDPE granules

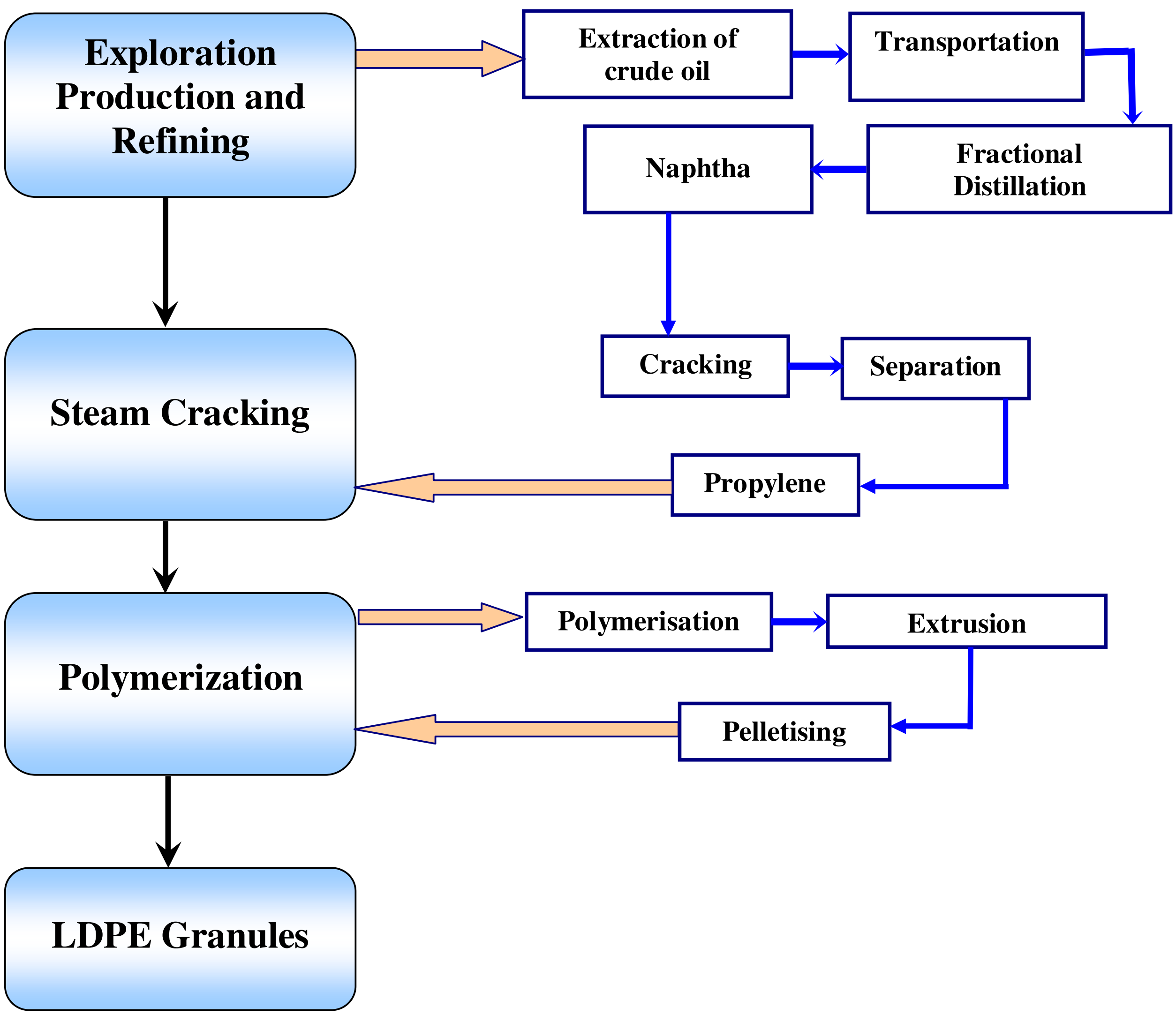
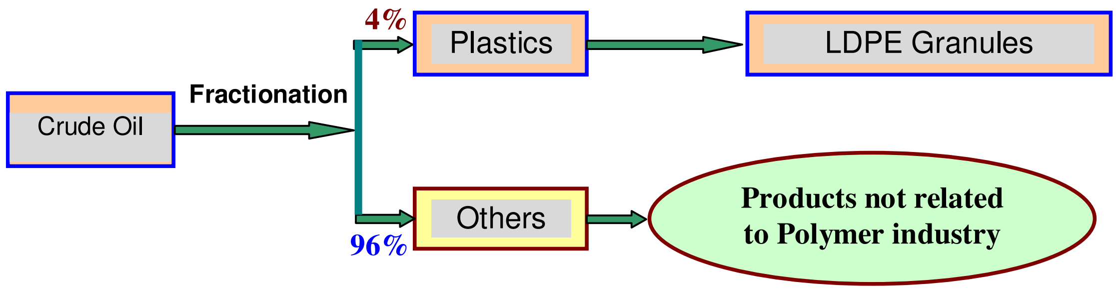


Figure 2.4: Flow Chart for Production of LDPE Granules.



EXTRACTION OF CRUDE OIL

The first step for production of LDPE/LLDPE is to extract crude oil. This industry has long presence and the extraction of crude oil is mainly carried out to meet the need of transportation and electricity sector. Only a small fraction (4%)of world's total oil consumption is used in plastic industry. Out of this 4%, 57% is used to make PP and PE, that amounts to ~2% of world's total oil consumption.

PRODUCTION OF NAPHTHA BY FRACTIONATION FROM CRUDE OIL

The crude unit functions simply to separate the crude oil physically, by fractional distillation, into components of such boiling range that they can be processed approximately in subsequent equipment to make specified products. A crude unit will resolve the crude into the following fractions:

(i) A light straight-run function, consisting primarily of C_5 and C_6 hydrocarbons.

(ii) A naphtha fraction having a nominal boiling range of 200-400^{0}F

(iii) A light distillate with boiling range of 400-650^{0}F

Wastes resulting from the production and handling of crude oil, include drilling muds, oil field brines, free and emulsified oil and tank bottom sludges.

However, it is important to note that extraction of crude oil is carried out mainly to supply the needs of transport and other sectors. Plastics only consume a small fraction - four percent - of the world's oil. This fraction is used so effectively that fossil fuel reserves last longer as a result. In fact, it is estimated that the use of plastics as a whole actually saves more oil than needed for their manufacture.

(Source: APC: Environmental Protection Agency)

CRACKING OF NAPHTHA TO PRODUCE ETHYLENE

Cracking is used in petroleum industry to reduce the molecular weight of hydrocarbon by breaking molecular bonds. Cracking is carried out by thermal, catalytic or hydro cracking. Thermal cracking depends on a free radical mechanism to cause scission of hydrocarbon carbon-carbon bonds and a reduction in molecular size, with the formation of olefins, paraffin and some aromatics. Side reaction such as radical saturation and polymerisation are controlled by regulating reaction conditions. In catalytic cracking, carbonium ions are formed on a catalyst surface, where bond scissions, isomerisations, hydrocarbon exchange and so on, yield lower olefins, paraffin, iso-olefins and aromatics.

Petroleum refining is a very developed process and every emission from refinery is highly controlled, so that it never exceeds the standard limits. Different types of emissions and their monitoring to guard emissions are given below.

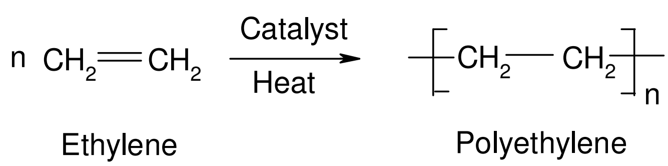
Combustion Related Emission

- *Nitrogen oxides control:* Nitrogen oxides from refineries are generated in the combustion process. A number of methods are there to reduce NO_x emissions, such as reducing the nitrogen in the feed, reducing the oxygen supply, but such an approach run the risks of increasing PM (Particulate Material) emissions- and reducing the combustion temperature. The most common method is by reducing the residence time, which, however, is the design feature of the burner.
- *Carbon dioxide control:* There is at present no treatment method for reducing CO_2 emissions.
- *Particulate control:* Particulate emissions from refineries come mainly from fuel combustion. Particulate emissions can be reduced by suitable changes to the burner or to fuel technology, or primary low cost techniques.
- *Process emission:* Particulate can be major emission from refinery process units. The main sources are catalytic cracking and cokers. In catalytic cracking, use of cyclones and electrostatic precipitators, and careful catalyst selection help to minimize the particulate emission. In coker process, the coke is maintained in a damp condition to minimize the condition of these fine particles.

- *Flare related emission:* Flares in refineries contribute to SO_x. NO_x and particulate emissions. These can be reduced by minimizing the hydrocarbons entering the flare at source and avoiding unnecessary flaring.
- *Fugitive emission:* These are volatile organic compounds that escape mainly from the process and off-site areas, such as tankage and oily water effluent treatment systems. Reduction in VOC emission can be achieved by using the technologies such as vapour recovery or internal floating decks in fixed roof tanks etc.
- *Control of aqueous emissions:* Refinery effluents can cause pollution of water by the release of contaminants, which are damaging to aquatic life. The major sources are process water, ballast water, rain water run-off and cooling water. The minimum treatment is to remove the free oil from the water.

Polymerization of Ethylene to produce LDPE

The polymerisation of ethylene or propylene is carried out using Zeiglar-Natta Catalyst or Metallocence catalysts. The reaction involved can be given as



Ethylene + Co-monomers → LDPE or LLDPE

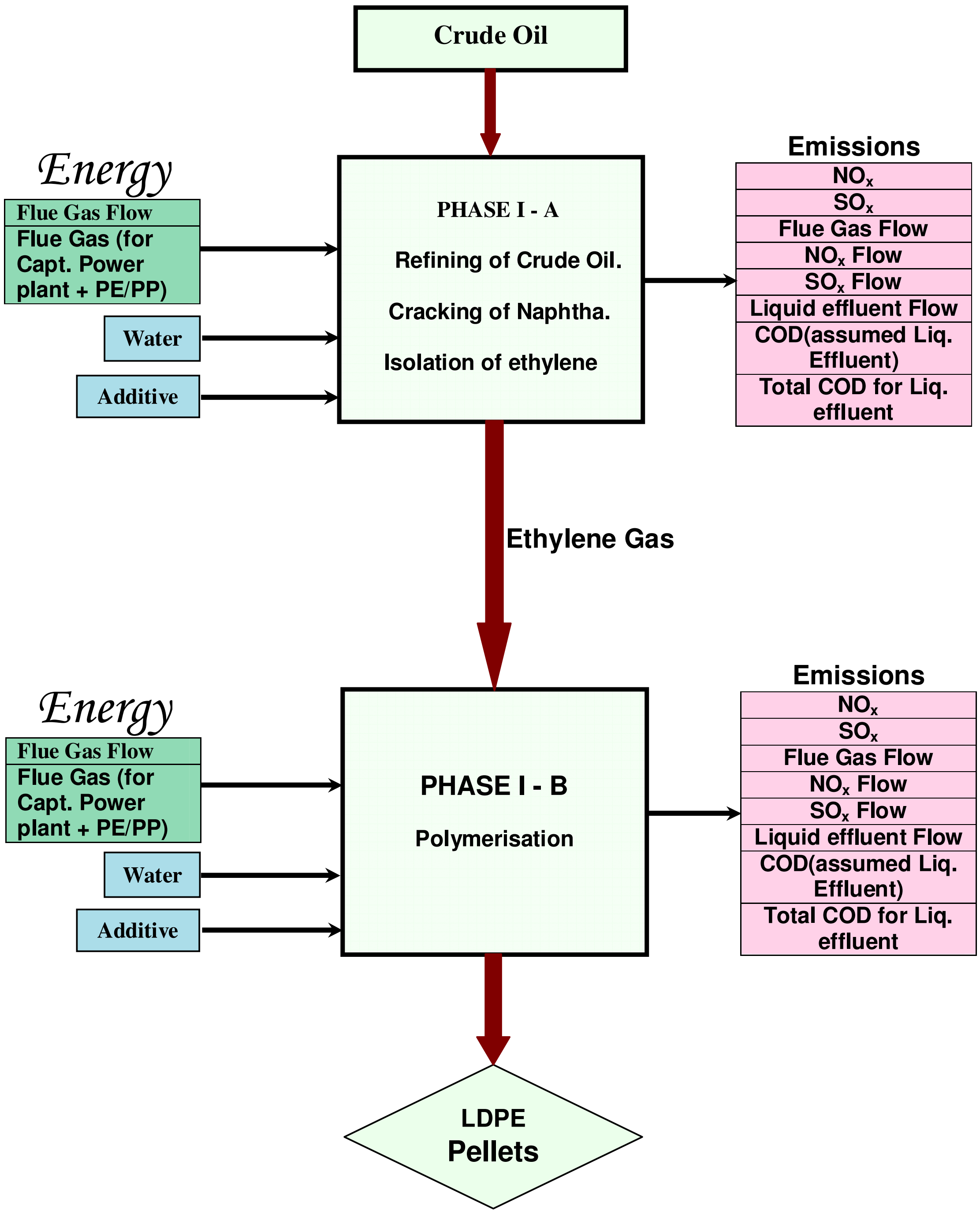


Figure 2.5: Flow Chart of input and output during Production of PE Pellets.

LIFE CYCLE INVENTORY DATA FOR PRODUCTION OF LDPE GRANULES

The values given in the inventory data are obtained for production of LDPE granules starting from the extraction of crude oil.

Energy Required

Energy Requirement for making LLDPE film can be considered in the following headings:

Energy required to produce/deliver raw materials (crude oil) = 48.30 MJ
Energy required to produce 1 kg LDPE/LLDPE resin = 32.27 MJ
Energy required to produce 1 kg LDPE/LLDPE film = 11.41 MJ

Gross energy required to produce 1 kg of LDPE/LLDPE Film: 91.98 MJ

Table 2.5: Gross energy in MJ required to produce 1 kg of low density polyethylene. (Totals may not agree because of rounding)

Fuel type	Fuel production and delivery energy (MJ)	Energy content of delivered fuel (MJ)	Energy used in transport (MJ)	Feedstock energy (MJ)	Total energy (MJ)
Electricity	10.83	5.77	0.05	<0.01	16.65
Oil fuels	0.77	9.36	0.21	22.47	32.81
Other fuels	1.97	7.90	0.09	32.56	42.52
Totals	13.57	23.03	0.35	55.03	91.98

Water Required

Water required to produce/deliver raw materials (crude oil) = 00.34 L
Water required to produce 1 kg LDPE/LLDPE resin = 45.66 L
Water required to produce 1 kg LDPE/LLDPE film = 18.20 L

Total water required to produce 1 kg of LDPE/LLDPE Film: 64.20 L

Table 2.6: Gross primary fuels and feedstocks in MJ required to produce 1 kg of low density polyethylene.

Fuel type	Fuel production and delivery energy (MJ)	Energy content of delivered fuel (MJ)	Fuel used in transport (MJ)	Feedstock energy (MJ)	Total energy (MJ)
Coal	3.50	2.02	0.01	<0.01	5.53
Oil	1.14	9.62	0.27	22.47	33.50
Gas	4.23	9.93	0.07	30.21	44.43
Hydro	0.66	0.79	<0.01	-	1.45
Nuclear	3.83	1.94	<0.01	-	5.77
Lignite	0.07	0.05	<0.01	-	0.12
Wood	-	-	-	2.35	2.35
Sulfur	-	<0.01	<0.01	<0.01	<0.01
Biomass	0.05	0.04	<0.01	<0.01	0.09
Hydrogen	<0.01	0.11	<0.01	-	0.11
Recovered energy	-	-1.53	<0.01	-	-1.53
Unspecified	0.06	0.03	<0.01	-	0.09
Peat	0.04	0.03	<0.01	-	0.07
Totals	13.57	23.03	0.35	55.03	91.98

Table 2.7: Gross primary fuels and feedstocks in mg to produce 1 kg of low density polethylene.

Fuel type	Input in mg
Crude oil	740,000
Gas/Condensate	840,000
Coal	200,000
Metallurgical coal	1,000
Lignite	7,900
Peat	7,400
Wood	530,000
Biomass	10,000

Raw Materials Required

Table 2.8: Gross raw materials in mg required to produce 1 kg of low density polyethylene.

Raw material	Input in mg
Air	110,000
Barytes	<1
Bauxite	920
Bentonite	48
Calcium sulfate	5
Clay	76
Dolomite	32
Feldspar	<1
Ferromanganese	2
Fluorspar	5
Granite	<1
Gravel	10
Iron	2,700
Lead	3
Limestone	2,000
Nitrogen	17,000
Olivine	24
Oxygen	74
Phosphate as P_2O_5	<1
Potassium chloride	1
Sand	230
Shale	13
Sodium chloride	1,400
Sulfur (bonded)	25
Sulfur (elemental)	56

Table 2.9: Gross water resources in mg required to produce 1 kg of low density polyethylene.

Source	Used for processing (mg)	Used for cooling (mg)	Totals (mg)
Public supply	5,100,000	-	5,100,000
River canal	2,000	130,000	130,000
Sea	74,000	25,000,000	25,000,000
Unspecified	440,000	33,000,000	33,000,000
Well	57	2,000	2,100
Totals	5,600,000	58,000,000	64,000,000

Emission:

Table 2.10: Gross air emissions in mg arising from the production of 1 kg of low density polyethylene.

Emission	From fuel production (mg)	From fuel use (mg)	From transport operations (mg)	From process operations (mg)	From biomass use (mg)	Totals (mg)
Dust	3,100	220	11	86	-	3,400
CO	610	730	130	72	-500,000	1,600
CO_2	1,300,000	1,100,000	18,000	7,000	-	1,900,000
SO_x	7,400	4,900	120	180	-	13,000
NO_x	7,700	4,000	180	58	-	12,000
N_2O	<1	<1	-	-	-	<1
Hydrocarbons	520	410	50	6,200	-	7,200
Methane	6,200	410	-	1,500	-	8,100
H_2S	-	-	-	3	-	3
HCl	110	1	-	1	-	110
Cl_2	-	-	-	<1	-	<1
HF	6	<1	-	<1	-	6
Lead (Pb)	-	<1	-	<1	-	<1
Metals	1	3	-	<1	-	4
F_2	-	-	-	<1	-	<1
Mertcaptans	-	<1	-	<1	-	<1
Organo-Cl	-	-	-	<1	-	<1
Aromatic HC	-	-	-	30	-	30
Polycyclic-HC	-	-	-	<1	-	<1
Other organics	-	-	-	19	-	19
CFC/HCFC	-	-	-	7	-	7
Aldehydes (CHO)	-	-	-	8	-	8
Hydrogen (H_2)	-	-	-	73	-	73
Mercury (Hg)	-	-	-	<1	-	<1
Ammonia (NH_3)	-	-	-	<1	-	<1

Table 2.11: Gross solid waste in mg arising from the production of 1 kg of low density polyethylene.

Type	From fuel production (mg)	From fuel use (mg)	From process operations (mg)	Totals (mg)
Mineral	37,000	-	5,600	43,000
Mixed industrial	410	-	1,700	2,100
Slags/ash	12,000	150	1,300	13,000
Inert chemical	1	-	530	530
Regulated chemical	25	-	1,500	1,600
Unspecified	<1	-	45,000	45,000
Construction	-	-	8	8
Metals	-		2,100	2,100
To incinerator	-	-	120	120
To recycling	-	-	6	6
Plastics	-	-	270	270
Wood waste	-	-	4,100	4,100

Table 2.12: Gross water emissions in mg arising from the production of 1 kg of low density polyethylene.

Emission	From fuel production (mg)	From fuel use (mg)	From transport operations (mg)	From process operations (mg)	Totals (mg)
COD	5	-	-	780	790
BOD	4	-	-	160	160
Acid (H^+)	1	-	-	63	65
Dissolved solids	74	-	-	91	160
Hydrocarbons	9	3	-	36	48
NH_4	1	-	-	7	9
Suspended solids	55	-	-	470	520
Phenol	4	-	-	1	4
Ca^{++}	-	-	-	1	1
Na^+	-	-	-	190	190
Metals-unspecified	<1	-	-	120	120
NO_3^-	-	-	-	5	5
Other nitrogen	<1	-	-	7	7
Cl^-	-	-	-	300	300
SO_4^{--}	-	-	-	89	89
CO_3^{--}	-	-	-	43	43
Phosphate as P_2O_5	-	-	-	5	5
Detergent/oil	-	-	-	180	180
Dissolved organics	-	-	-	38	38
Other organics	-	-	-	7	7
Sulfur/Sulfide	-	-	-	10	10

Table 2.13: Comparative Data for Phase I and Phase II in terms of Energy required to produce packaging material for 1 lakh litres of milk.

	Energy required (GJ)	
	Glass	**Plastic Pouches**
Phase I	671.92	32.22
Phase II	530.27	4.56
Total	1202.19	36.78

Although the energy required to produce 1 kg of glass is less than that required to make 1 kg of LDPE, it must be understood that for filling 1 litre of milk, we need 454 gms of glass, while in case of LDPE pouch, the weight will be only 4-5 gms. Thus, in terms of energy needed for a unit packaging – the energy needed for glass is 32 times more than that needed for plastic pouches.

Chapter3

FILLING

In this part of the report, initially brief description is given for filling/packaging of milk. The case studies involve filling/packaging of milk in polyethylene pouches and glass bottles. Comparison has been made in terms of total lorry load (trips) require to transport one lakh litre of milk in pouches and bottles. The total fuel, energy required and total emissions generated are compared.

One very important issue to be highlighted here is concern of hygiene, safety and handling during packaging and transportation of glass bottles. If during packaging any breakage takes place it leads to not only spillage of milk but also to injury to the persons involved. If it occurs during transportation or carrying it to home by the end-user, can lead to spillage of milk with glass on the streets and harms are well known. This was one of the main reasons that the glass bottles were replaced with plastic pouches, in which only loss of milk takes place and not personal injury. No quantitative data is available for breakage-injury in case of glass bottles

Materials and Inputs Associated with Filing Operations

<u>Inputs to the Filling Line</u>

Lubricating Oil and Grease: The use of lubricating oil and grease is in smaller amount. Moreover, their contribution to the overall system energy is small and remains approximately same in case of glass bottles and plastic pouches. Therefore consumption of lubricating oil has been neglected during calculations.

Water: Water is used in the filling line for the first time of glass bottles while no water is needed during filling of plastic pouches. But in the study this has been neglected during calculations.

Water used during returnable bottles is very high than compared to non-returnable plastic pouches. An average of … litres per 1000 bottles has been chosen in the present calculations involving reusable bottles. The energy associated with the washing of bottles has been found to be … These has been taken into account during reuse of glass bottles.

The energy and water associated with the washing of crates used in glass bottles or plastic pouches remains same and therefore has not been considered during calculations.

Detergent: Detergent is used for bottle washing and plant cleaning. Reused glass bottles are the major consumer although some detergent is used even during first time use. For the purposes of present study we have assumed that the detergent used during first use of glass bottles is negligible and during reuse glass bottles consume detergent (sodium hydroxide) at the rate of 1.75 kg per 1000 bottles. The energy associated with the provision of this caustic soda has been obtained from the literature.

No detergent is required in plastic pouches cleaning. Detergent used for cleaning crates remains same for glass bottles and plastic pouches and has been neglected during calculations.

Energy: It is obvious that the energy during packing of glass bottles will be higher because of their heavy weight, than that of plastic pouches. In the present study because of unavailability this energy difference has not been taken into account during calculations.

TRANSPORTATION

Road is a major mode of transportation of milk. Lorries are commonly used for distribution and at smaller level distribution is carried out in rickshaws. The energy requirements for road transport can be considered as the sum of the fuel directly consumed by the vehicle on its journey with two other sub systems responsible - (a) the construction and maintenance of the vehicle and (b) the construction and maintenance of the roads. The energy requirements associated with the fuel consumption comprise some 70% of the total, construction and maintenance of the vehicle has been estimated as a further 22% and construction and maintenance of routes as 7%. As the inclusion of vehicle-road construction and maintenance energy had been much debated, its contribution has been excluded from the calculation in this report.

Return Journeys: For return journeys three variations in practices are of particular importance.

(i) Lorries returning to filling plants after delivery of returnable bottles carry loads of empty bottles (weight of crates has not been considered). It is reasonable to assume that such lorries carry on average approximately half of their load and this attracts an energy which is typically only 0.86 that of a fully loaded vehicle. This is of importance during reuse of glass bottles and will be considered in the waste management section where reuse of glass bottles has been described in detail.

(ii) Lorries returning from delivery of plastic pouches will usually carry empty crates and the vehicle traveling with this load (almost empty) consume energy equivalent to 0.7 of the fully loaded vehicle.

(iii) When contract hire lorries are used to deliver glass bottles/plastic pouches, they would usually seek an alternative return load. In such circumstances no energy will be attributable to the packaging material for this return load. However, most of the time company owned or regular lorries are used for delivery of milk and hence this practice remains invalid for milk distribution.

In this report, a lorry with average fuel efficiency of 3.05 km/lit, has been considered as the standard vehicle for transportation of milk. The lorry runs on diesel fuel and can carry maximum of 9MT of load. Though the lorry of varying sizes are used to transport milk, in present study the lorry with the dimension of refrigerated cabin given in table 4.1 has been considered.

Table 3.1: The dimensions of lorry cabin and crate to transport the milk

	D(cm)	W(cm)	H(cm)	Volume(cc)
Cabin dimensions	210	150	180	5670000
Crate dimensions (Milk Pouches)	52.5	22.5	16.4	19373
Crate dimensions (Milk Bottles)	52.5	22.5	30	35438

Table 3.2: Comparison between raw material (plastic pouch and glass bottle) required to transport one lakh litre milk.

Packaging Material	No. of Crates	Milk (Ltrs)	Packing Material (Kg)	Wt. of crates (Kg)
Pouch	293	2927	12	351
Bottle	160	1600	726	368

The lorry causes pollution while the fuel burns in the engine and from evaporation of the fuel itself. The main pollutants contributed by the lorries are carbon monoxide (CO), unburned hydrocarbons (HC), oxides of nitrogen (NOx), lead and particulate matter (PM) etc. Diesel fuels, without any additives, are mixtures of hydrocarbon compounds, which contain hydrogen and carbon atoms. In a perfect combustion process, where time of combustion is not a factor, oxygen in the air would convert all the hydrogen in the fuel to water and all the carbon in the fuel to carbon dioxide. The nitrogen in the air would remain unaffected.

However, the state of ideal thermodynamic equilibrium is never achieved in an automobile engine. The use of additives like sulphur in the fuel, short combustion time for chemical oxidation processes, lack of homogeneity and heterogeneity and rapid variation in temperature leads to the formation of some unwanted compounds.

Added to these incomplete combustion products are oxides of nitrogen formed due to high temperature oxidation of the nitrogen present in the air fuel mixture. In simple terms, the combustion process in an automobile is never 'perfect' and thus leads to emissions of several types of pollutants.

Emissions from a typical lorry can be classified according to the sources of emission. The amount of emissions from a lorry is presented in figure 4.1 and health hazards are presented in table 4.3.

Hydrocarbons

Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn only partially. Hydrocarbons include a wide variety of compounds with varying impact on human health and with different reactivities in the tropospheric chemical conversions. In particular, unburnt hydrocarbon contains a large proportion of methane, which is inert in human health respect. Added to these are the oxygenated compounds, aldehydes, ketones, phenol, alcohol, nitromethane, esters etc., all of which are more reactive then methane. A number of these exhaust hydrocarbons are also toxic, with a potential to cause cancer. Hydrocarbon reacts in the presence of nitrogen oxides and sunlight to form ground-level ozone, a major component of smog. Ozone irritates the eyes, damages the lungs, and aggravates respiratory problems. It is one of the most widespread and intractable urban air pollution problems.

Nitrogen Oxides (NO_x)

Under high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides. Nitric oxide (NO) and nitrogen dioxide (NO_2) are the main oxides formed during this reaction and are collectively grouped together as NO_x, in which NO largely predominates. The main source of NO is molecular nitrogen in the air used as a comburent feeding the engine. Diesel fuels contain too little nitrogen for their contribution to NO formation to be significant. Like hydrocarbons, NO_x are precursor to the formation of ozone. They also contribute to the formation of acid rain.

Carbon Monoxide

Carbon monoxide (CO) is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidised rather than fully oxidised to carbon dioxide (CO_2). The main parameters governing CO emissions is the fuel-air ratio. In a rich mixture, the CO concentration increases steadily with the fuel-air ratio and the lack of oxygen causes incomplete combustion.

Carbon monoxide reduces the flow of oxygen in the bloodstream and is particularly dangerous to persons with a history of heart disease.

Carbon Dioxide

In recent years carbon dioxide a product of 'perfect' combustion, is becoming a major pollution concern. Carbon dioxide does not directly impair human health but it is a 'green house gas' that traps the earth's heat and contributes to the global warming.

Suspended Particulate Matter (SPM)

Particulates are present in exhaust emission of CI engines (diesel engines) only and they are virtually absent in SI engines. Diesel particulates are composed of carbonaceous material (soot) generated during combustion. SPM is emerging as one of the most serious problem in India with regard to air pollution. There is a growing concern all over the world about particulate matter of size 10 micron and 2.5 micron or less. WHO has classified these as thoracic particles because these are respirable and lodged into the respiratory tracts.

Evaporative Emissions

Hydrocarbon pollutants also escape into the air through fuel evaporation. With today's exhaust emission controls and fuel formulation, evaporative losses can account for a substantial amount of the total hydrocarbon pollution from the vehicles on hot days. Evaporative emissions account for 15 to 25 % of total hydrocarbon emission from a fuel engine. The two main sources of evaporative emissions are the fuel tank and the carburetor. These occur in several ways:

Diurnal Fuel evaporation increases as the temperature rises during the days, heating the fuel tank and venting fuel vapours.

Running Losses The hot engine and exhaust system can vaporize fuel when the lorry is running.

Hot Soak The engine remains hot for a period of time after the lorry is parked and fuel evaporating continues.

Refuelling Fuel vapours are always present in fuel tanks. These vapours are forced out when the tank is being filled with liquid fuel.

The following graph shows the amount of different pollutants generated from a lorry:

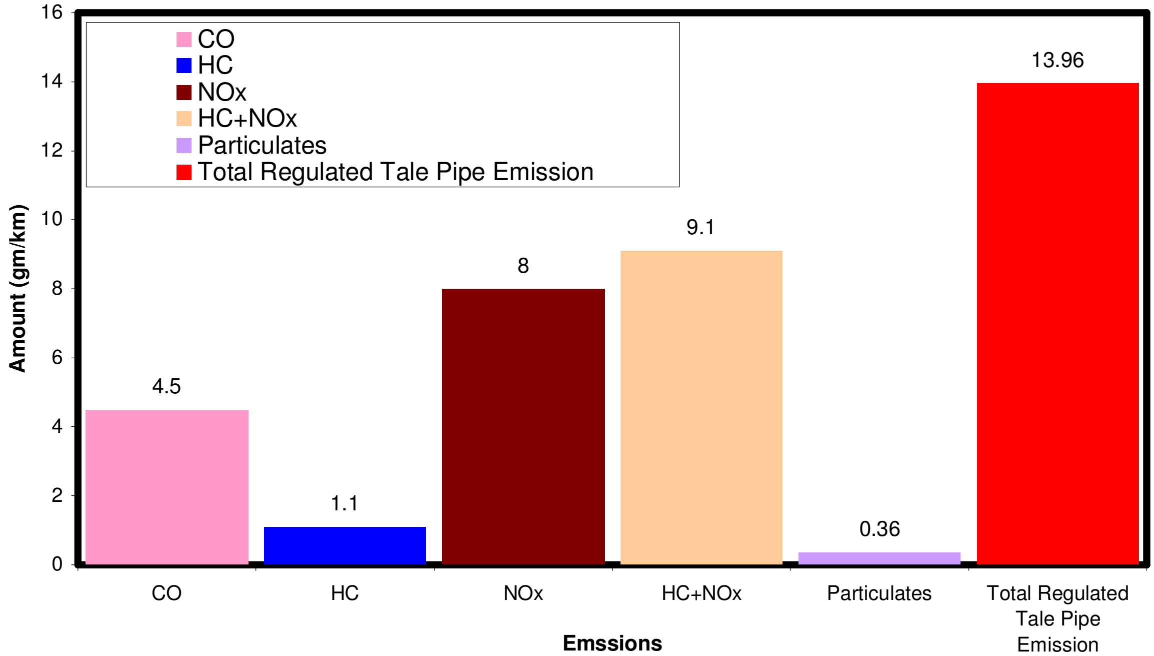


Figure 3.1: Different emissions from a lorry

Table 3.3: Health Implications of Automobile Pollution

Agent	Health/environmental implications
Oxides of Nitrogen	Respiratory tract irritation, bronchial hyperactivity, impairing lung defenses
Hydrocarbons	Lung cancer
Ozone	Cough, substantial discomfort, bronchoconstriction, decreased exercise performance, respiratory tract irritation
Sulphur dioxide	Exacerbation of asthma and COPD, respiratory tract irritation, hospitalisation may be necessary and death may result in cases of severe exposure
Lead	Impaired mental growth in children. Lead can affect mental development, blood chemistry, kidneys, nervous, reproductive and cardiovascular systems.
Particulates	The World Health Organization has concluded that, on a worldwide basis, suspended particulate matter is the most serious air pollutant which is resulting in a total excess mortality per year of about 4,60,000 additional deaths every year of which 1,35,000 are because of chronic obstructive pulmonary disease (COPD) or chronic asthma and about 90,000 due to cardiovascular diseases (CVD). Scientists also point out that it is not all particles that are equally dangerous. It is particles that are respirable (that is, less than 10 microns in size), that cause the major damage. Diesel vehicles are the biggest contributor to the particulate pollution.
Source: Dieter Schwela 1996, Health Effects of and Pollution Exposure to Air Pollutant: Global Aspects, Keynote Speech, World Congress on Air Pollution in Developing Countries, San Jose, 21-26 October, 1996, mimeo	

Life Cycle Inventory Data for Transportation of Milk

Table 3.4: Number of lorryloads (trips) required, excess fuel and energy consumption during transportation of Milk

For 1 lakh ltrs of milk		distance for trips	Diesel (ltrs)	Energy (GJ)
no. of crates for 1 lakh ltr	**10000**			
No of lorries required (for Pouches)	**34**	3417	1120	62.73
No of lorries required (for Bottles)	**63**	6250	2049	114.75
Excess Distance (km)		**2833**		
Excess Fuel (Ltrs)			**929**	
Excess Energy (in case of transportation in glass bottles) because of Fuel (GJ)				**52.02**

Energy Required

The total energy requirements for transportation of one lakh litre of milk in different packaging materials are given in table 4.4. It can be seen from the table that the excess energy utilized by packaging milk in the glass bottles amounts to be 52.02 GJ/lakh litre of milk compared to packaging in pouches. This loss is only the 70% of the excess energy, rest 30% energy is utilized in road and vehicle maintenance and that has not been accounted here.

Excess Environmental Burden

Excess fuel required in the case of packaging of one lakh litres of milk in bottles will cause severe environmental problem in the transportation as the amount of emissions generated per day (considering the amount of milk production per day) will be very high. Following table presents the excess burden on the environment because of use of bottles.

Table: 3.5

Pollutants	**Emission from the lorry** gm/km	**Emission** kg/lakh litres		**Excess emission in case of packaging in Glass Bottles**
		Pouches	Bottles	
CO_2	781	2668.7	4881.3	2212.6
CO	4.5	15.4	28.1	12.7
HC	1.1	3.8	6.9	3.1
NO_x	8	27.3	50.0	22.7
$HC+NO_x$	9.1	31.1	56.9	25.8
Particulates	0.36	1.2	2.3	1.0
Total Regulated Tail Pipe Emission	13.96	47.7	87.3	39.5

**Only because of excess fuel used during the transportation phase. (Does not include emissions during fuel production phaseand the emissions during the maintenance of roads (40% additional)*

Ch.4

SCOPE OF WASTE MANAGEMENT

The issue of waste management has moved centre stage, both in public perceptions and in terms of national regulations. Until recent times, the principal means of waste management has simply been deposit in landfill. This is now understood as unsustainable practice, creating potential problems for the future generations. Processed in the appropriate manner, waste can be seen as a valuable resource, either to make new raw materials through recycling or recovered as useful energy. The total of all post-user plastic waste accounts for very low percentage of total waste by weight. No matter how small the proportion, the presence of plastics packaging in the waste stream is very important. There is growing interest in recovering energy/heat from the municipal waste using advanced combustion techniques. With its high calorific content, the portion of plastics packaging waste that is not separated out for recycling makes a key contribution to the success of these schemes.

There has been a perception that plastics packaging waste is a major problem, largely because of what people see in their domestic waste bin. Some people can recall the “good old days” when household waste that did not go on the compost heap was burned on the domestic fire. The waste collected each week was essentially the ashes from the fire which would go to landfill. As these appeared to be inert, the whole process tended to be viewed as environmentally friendly when compared with the handling of domestic waste today.

However, while composting of vegetable waste is highly encouraged, uncontrolled burning of domestic is definitely not! At low combustion temperatures in a domestic fire, unacceptable levels of dioxins and furans are produced.

Waste is an inevitable product of society. Solid waste management practices were initially developed to avoid the adverse affects on public health that were being caused by the increasing amount of solid waste being discarded without appropriate collection or disposal. Managing this waste more effectively is now a need that society has to address. In dealing with the waste, there are two fundamental requirements: less waste and an effective system for managing the waste produced.

Waste management in case of milk packaging materials involves four different routes:

- Reuse
- Recycle
- Landfill
- Waste to energy

In case of packaging material used in milk packaging, the plastic waste generated after one packaging goes to the mainstream of general waste that if collected properly can be recycled otherwise can be used for energy recovery.

The glass bottles are mainly reused or recycled (if broken or not suitable for use).

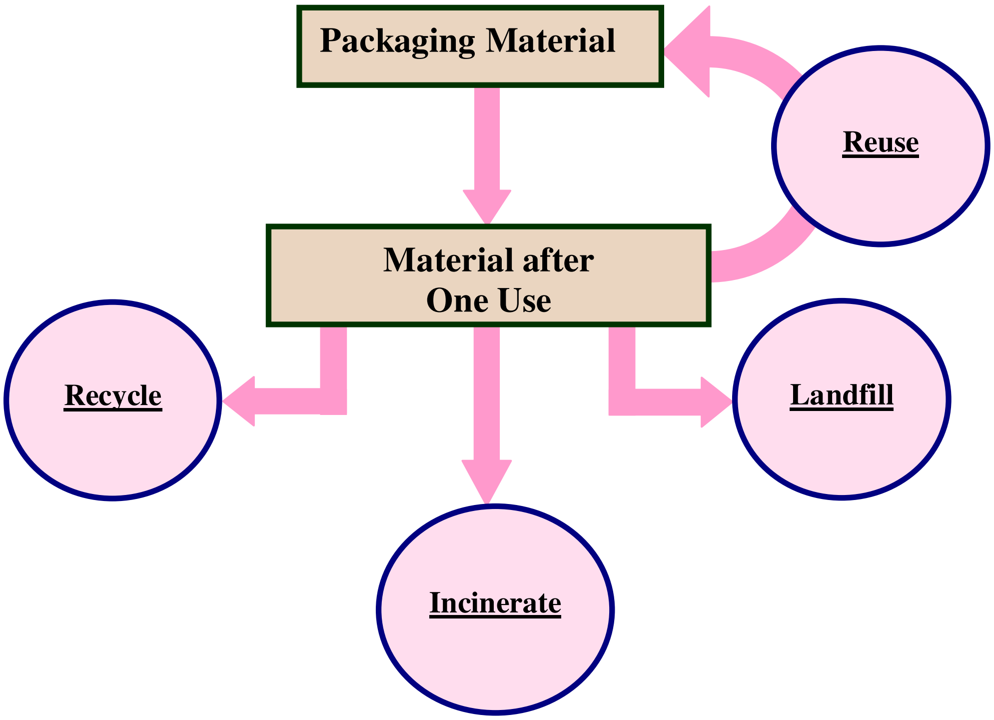


Figure 4.1: Different techniques of waste management

REUSE

Glass Reuse

Reused Glass Bottles when used to pack milk, not only result in a significant discharge of waste water with detergents but also is a concern for safety and health. The improper cleaning creates hygienic problems and sometimes makes them unsuitable to be reused after being used once. The different materials used during reuse of glass bottles and energy associated with the reuse process are given below:

Water consumption: During washing = **4536 L/1000** Bottles
Detergent Consumption: **1.45 kg/1000** Bottles
Energy consumption:
Lorries returning to filling plants = 0.86 x energy consumption of a fully loaded vehicle.
Energy Associate with Cleaning = **45.28 MJ/1000** Bottles*

*Includes energy for sourcing of water 0.04MJ/4.5L, production of detergent (NaOH) 28.87MJ/kg.

Statistics shows that 5% of the bottles generally get damaged during distribution and therefore maximum reuse possible is 95%. Calculations were made for 95%, 80%, 60%, 40%, 20% reuse. Comparative data for the reuse of glass bottles and new plastic pouches is given in the following tables in terms of water and energy consumption.

Table 4.1: Energy consumption during reuse of glass bottles compared to that with new plastic pouches

Reuse Percentage	Energy consumption (GJ) for Packaging of 1lakhlitre of milk					
	Glass Bottles					New Plastic Pouches
	Cleaning	New	One Side	Return Journey	Total	
100	4.528	0	114.75	98.68	218.0	143.4
95	4.3016	60.11	114.75	98.68	277.8	143.4
80	3.6224	240.44	114.75	98.68	457.5	143.4
60	2.7168	480.88	114.75	98.68	697.0	143.4
40	1.8112	721.32	114.75	98.68	936.6	143.4
20	0.9056	961.76	114.75	98.68	1176.1	143.4
0	0	1202.2	114.75	98.68	1415.6	143.4

Table 4.2: Energy consumption during reuse of glass bottles compared to that with new plastic pouches

Reuse Percentage	Water consumption (thousand litres) for Packaging of 1lakh litre of milk			
	Glass Bottles			New Plastic Pouches
	Reused Bottles	New Bottles	Total	
100	453.6	0	453.6	25.6
95	430.9	78.1	509.1	25.6
80	362.9	312.5	675.4	25.6
60	272.2	625.0	897.2	25.6
40	181.4	937.6	1119.0	25.6
20	90.7	1250.1	1340.8	25.6
0	0	1562.6	1562.6	25.6

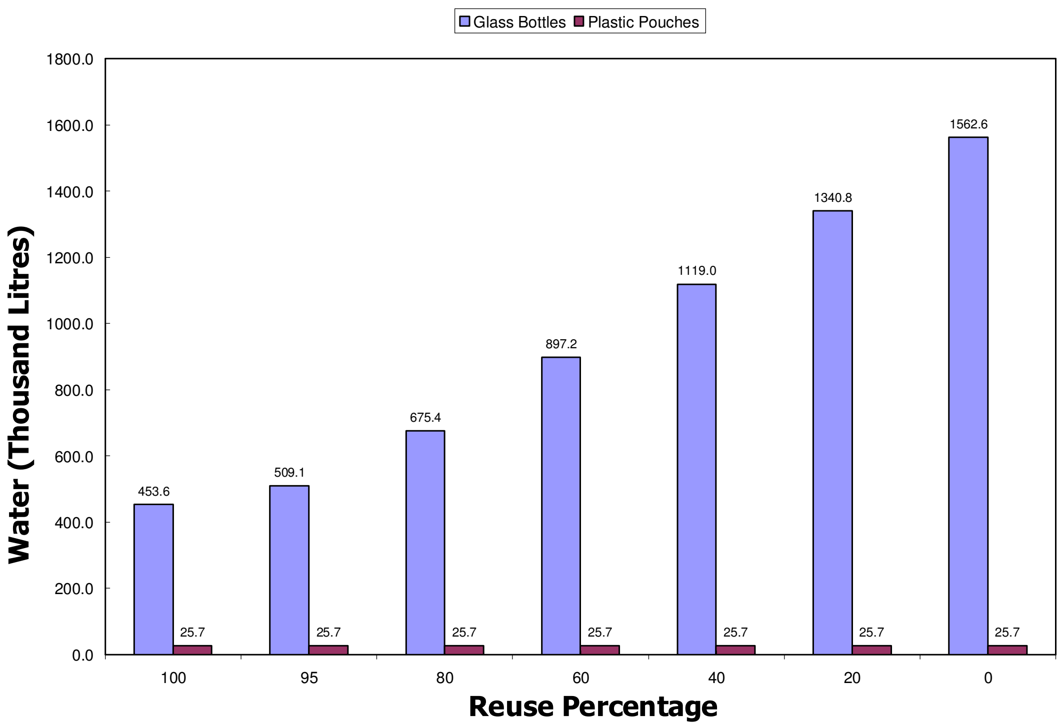


Figure 4.2: Comparative analysis of water consumption during reuse of glass bottles and new plastic pouches

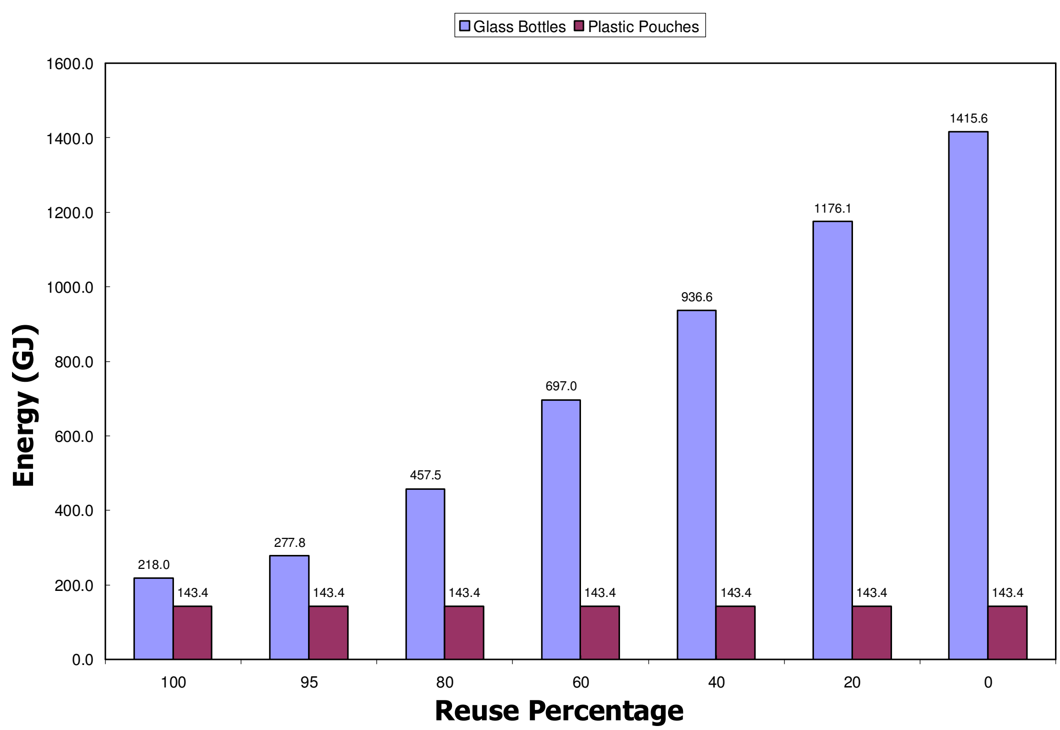


Figure 4.3: Comparative Analysis of energy consumption during reuse of glass bottles and new plastic pouches

RECYCLING

Glass Bottles ✓ **Plastic Pouches** ✓

GLASS RECYCLING

Glass was formed naturally from common elements in the earth's crust long before humans began experimenting with its composition. Most glass is now manufactured by a process in which raw materials are converted at high temperatures (1420-1600^{0}C) to a homogeneous melt that is then formed into products. Raw materials are selected according to purity, supply, pollution potential, ease of melting and cost. Sand is the most common ingredient, of which purity and grain size are important. Container-glass manufacture tends to use sand between 590 and 840 μm for the best compromise between the high cost of producing fine sand and melting efficiency. Transport costs are often three to four times the cost of the sand, so manufacturing plant siting should be close to a source of good raw materials. Common colourants for glass include iron oxides, chromium, copper, cobalt and nickel. Colour separation of recycled glass is necessary to avoid colour quality concerns upon remelting.

Cullet, or broken glass is used as a batch material to enhance glass melting. The input of recovered cullet to the furnace lowers the temperature needed to melt the virgin raw materials, thus leads to considerable energy savings (Ogilvie, 1992) and it reduces the amount of dust and other particulate matter that accompanies a batch made exclusively from virgin materials. Certain glass-forming operations generate as much as 70% waste glass, which must be recycled as cullet. More efficient manufacturing operations such as the container industry, may purchase cullet from recycled glass distributors. Typically between 10 and 50% of a glass batch is comprised of cullet, but operations at 70-80% cullet are not uncommon. For container glass, a 10% increase in use of cullet reduces the melting energy by 2.5%, particulate emissions by 8%, NO_x emissions by 4% and SO_x emissions by 10% (Gaines and Mintz, 1994).

The first stage of glass reprocessing usually consists of a manual sort to remove gross contaminants (plastic bottles, ceramics, lead wine bottle collars) followed by automatic sorting to remove ferrous contaminants and low-density materials (paper labels, aluminium bottle tops). The former is achieved by magnetic extraction, the latter by a combination of crushing, screening and density separation techniques. Around 5-6% of the recovered glass input is removed in this way (Ogilvie, 1992). The crushed cullet is then ready for mixing with virgin raw materials, prior to melting in the furnace and blowing or moulding of the final glass products. Recycled glass cullet is not only made into new containers such as bottles and jars, it is also used for secondary markets such as fibreglass and 'glasphalt', paving asphalt using crushed cullet replacing stone aggregate. Since the use of recovered glass cullet is integrated within the normal glass production process, in consideration of the environmental burdens, glass reprocessing will be considered up to the production of finished glass containers.

Energy consumption for Recycling (MJ)	11.04MJ/Kg

Table 4.3: Air emission during recycling of 1kg of glass

	Recycled glass (100%)/kg produced
Particulates	704
CO	222
CO_2	57000
CH_4	767
NO_X	2880
N_2O	1.66
SO_X	728
HCI	58.5
HF	23.4
H_2S	-
HC	-
Chlorinated HC	-
Dioxins/furans	-
Ammonia	16.5
Arsenic	2.61
Cadmium	0.009
Chromium	-
Copper	-
Lead	35.5
Mercury	0.002
Nickel	0.362
Zinc	0.155

Source: BUWAL (1998)

Table 4.4: Water emission during recycling of 1kg of glass

	Recycled glass (100%)/kg produced
BOD	0.374
COD	7.41
Suspended solids	796
Total organic compounds	80.7
AOX	0.0287
Chlorinated HC_S	0.0075
Dioxins/furans (TEQ)	-
Phenol	1.18
Aluminium	16.5
Ammonium	10.3
Arsenic	0.038
Barium	22
Cadmium	0.0099
Chloride	8410
Chromium	0.227
Copper	0.0918
Cyanide	0.032
Fluoride	-
Iron	19.2
Lead	0.0151
Mercury	0.000198
Nickel	0.102
Nitrate	5.64
Phosphate	1
Sulphate	480
Sulphide	0.253
Zinc	0.232
Solid waste (gm)	44.97

PLASTIC RECYCLING

Mechanical Recycling

Mechanical recycling is an excellent recovery method provided some important conditions are met. Producing products from recycled plastics pouches is a business like any other, including the need for guaranteed regular supplies of suitable raw material and the existence of economically viable end-markets. The types of products produced will depend largely on the homogeneity of the plastics pouches waste stream. Examples of some recycled products made from recycling of milk pouches are numerous and amount of energy consumed during recycling is given in table 4.5.

Table 4.5: Energy consumption and Air emission during recycling of LDPE

	Recycled LDPE/kg produced
Energy consumption (MJ)	25.4
Particulates (mg)	-
CO	-
CO_2	1,299,900
CH_4	-
NO_X	6390
N_2O	-
SO_X	13,870
HCI	-
HF	-

Source: Henstock (1992)

Table 4.6: Water emission during recycling of LDPE

	Recycled LDPE/kg produced
BOD	-
COD	-
Suspended Solids	-
Total organic compounds	-
AOX	-
Solid Waste (mg)	132.0

Source: Henstock (1992)

Table 4.7: Comparative Data for Phase IV in terms of Energy required to recycle packaging material for 1 lakh litres of milk.

Glass		**Plastic Pouches**	
Percent	**Energy (GJ)**	**Percent**	**Energy (GJ)**
100%	**501.67**	100%	**4.56**
80%	**401.33**	80%	**3.65**
60%	**301.00**	60%	**2.73**
50%	**250.83**	50%	**2.28**

WASTE-TO-ENERGY

Glass Bottles ✗ **Plastic Pouches** ✓

Energy Recovery from Plastic Pouches

Plastics pouches can be used to meet energy needs after serving a useful life as a plastic product. Where waste streams are such that eco-efficient mechanical recycling is not achievable, or after certain items have been removed for mechanical recycling, the remainder of high calorific value plastics pouch waste can be recovered as energy. This can take different forms:

a) Municipal waste combustion where the high calorific value of plastics, superior to that of other waste fractions, contributions to the safe combustion of waste and to generating valuable energy for heat and electricity;

b) Co-combustion, or mono-combustion, where plastics replace another fuel in varying proportions, thus saving finite, primary fossil fuels. Recovered fuel based on source separated, specifically prepared, plastics offer an attractive alternative to coal, for example, in the manufacture of cement or the generation of electricity in power plants.

Modern municipal solid waste combustions plants operating in accordance with the exacting environmental standards are in use in several European and western countries. The pollution controls on EFW plants are much more stringent than those applying to traditional energy generating plants. Plastics have high calorific value. The presence of plastics in the waste stream helps to achieve steady-state combustion conditions. This ensures complete combustion of the waste and a corresponding decrease in potentially harmful emissions that are associated with incomplete combustion. Emissions from combustions facility operating and standard values are given in table 5.8

Energy Generated **51.83 MJ/Kg**

Table 4.8: Emission factors based upon US standard and actual data from the incineration plant (kg/tonne waste component)

Emissions	Plastics	
	US Standard	***Actual***
SO_2	1.109	0.296
HCl	0.528	0.188
NO_x	2.604	2.361
Dioxins	1.68E – 07	-
CO	1.62	0.168
PM	0.311	0.051

The waste management debate

There is a large amount of healthy debate in India on the subject of the best methods of managing waste. Some feel that simple rules should be applied to all waste everywhere. Others argue that flexibility is the key, and that with the same end goals in mind of avoiding landfill and minimizing pollution, waste management decisions should be made on the basis of detailed local assessment, taking into account factors such as consumption patterns, collection and separation systems, and local infrastructure. Several studies conducted in India, including those conducted by this research group show that there is no single universally valid hierarchy, equally valid to every situation e.g., mechanical recycling is not automatically preferable to energy recovery. The objective should be the improvement of the eco-efficiency of local waste management systems, with a view to optimizing the mix of waste management options available locally. Plastic packaging waste can be managed with a highly diversified range of environmentally efficient recovery/recycling options.

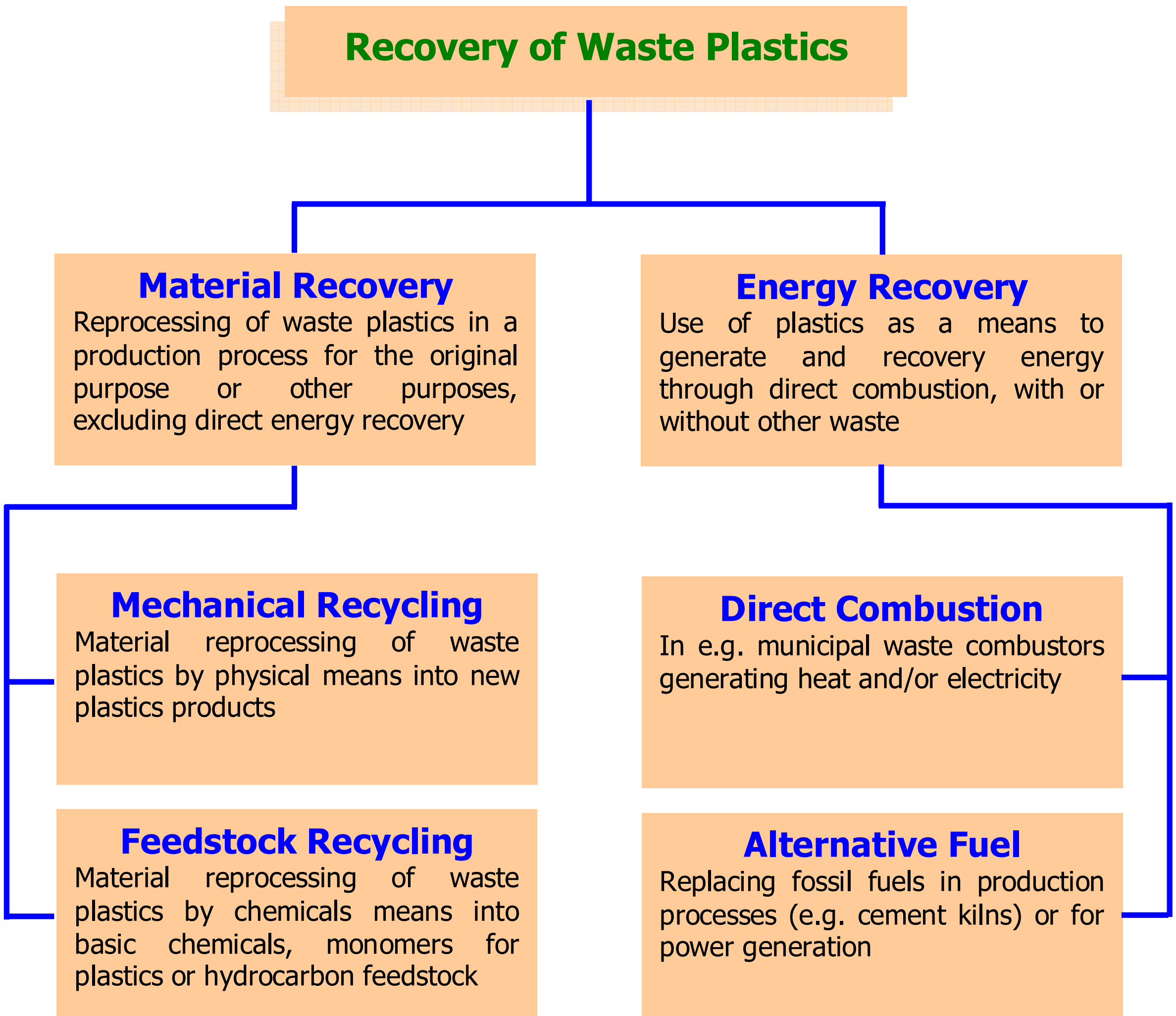
Litter

Changes in the management of waste will bring major environment benefits, particularly in avoiding environmental damage and recovering valuable resources. But environmentally sound recovery is only possible if the waste enters a suitable waste management system. This is unfortunately not the case with litter, which is waste that has simply been dropped on the ground.

Though most common items of rubbish are found on the streets, articles made from plastics are a significant proportion of litter and can be highly visible. It is important to recognize that litter is not a plastics issue but one concerning the behaviour of society. Sustainable development can all too easily be viewed as something to be dealt with at an intergovernmental level, for example when the discussion centres on international agreements on emissions. But litter provides a useful reminder that every member of society has an important part to play in the goal of sustainable development. Although industry creates packaging, and has some part to play in ensuring that is suitably recovered, society also must accept responsibility both by directing their used packaging materials to the designated collection schemes, and also by avoiding litter.

How to Manage Plastic Waste

Two principal recovery routes are available for the management of waste plastics: Material Recovery (recycling) and Energy recovery, and each route provides two recovery options. The availability of several recovery methods provides a flexibility of options which, combined with continuous improvements in waste collection methods and separation techniques can lead to more than 50% of plastic packaging waste being recovered.



Feedstock Recycling

Feedstock recycling is a form of material recovery that is particularly well suited to mixed plastics waste. These technologies break the plastics down into their chemical constituents. These can then be used as building blocks for a wide range of new industrial intermediate and consumer products. In effect, the plastics are reprocessed at the place of origin, the petrochemical complex. This can be compared to paper recycling in which the waste paper is converted back to pulp for reprocessing into new products.

A variant of feedstock recycling is the use of plastics as a chemical reactant in the production of steel. Here the products react *in-situ* with the iron ore, with a portion of the same plastics used, simultaneously, for their calorific value.

Conclusions

The present study examines the detailed scenario of use of glass bottles and plastic pouches as packaging materials for milk using life cycle analysis as the principal methodology. The coverage is based mainly on large amount of data collection and information as well as extensive literature survey. Life cycle analysis using cradle to grave approach is the only way to assess and compare the benefits for milk packaging material by identifying inputs and outputs in the different phases of the life cycle. In this study analysis has been carried out by dividing the total life cycle in four different phases and the energy consumed or recovered and emissions released or absorbed are considered in totality as much as possible.

It is to be noted a priori that a comparison of this nature can only be of real importance when contribution for each sector involved in the birth to death of a material is considered fully and without any bias. Hence the following issues become very-very pertinent:

- Crude oil which is the basic input to the plastic pouches is not processed only for making LDPE/LLDPE, it has to be fractionated anyway in order for the generation of various fuels and feedstocks for the interest of consumers mostly for transportation and energy generation. Moreover, only 2% of the total crude oil processing is required for the generation of feedstock for plastic pouches.
- Glass also requires chemicals etc. which involve number of other energy intensive processes and related health hazards because of air and water pollution.
- Glass and plastic both are non-biodegradable and therefore biodegradability is not an issue during milk packaging.

Keeping above facts in view, the conclusion arising out of the study can be listed as follows:

1. The basis of this study has been considered as one lakh litres of milk in keeping with the view of the consumption in order of magnitude.
2. Based on this, the relative weight of only packaging material itself amounts to a very high value for glass when compared with that on plastic pouches.
3. Consideration of various aspects related to Phase - I of this life cycle analysis shows that even the energy requirement is very high in case of glass. The plastic pouch manufacturing requires $1/20^{th}$ the energy of that of glass.

4. The life cycle analysis of Phase – II shows that the production of glass bottles is highly energy intensive and in this respect, glass bottles and plastic pouches follows similar trend.

5. The other input for these industries is water. It is to be noted that the water requirement for manufacturing glass bottles is significantly high as compared to that for plastic pouches.

6. Considering Phase – I and Phase – II together for packaging of 1lakh litres of milk the energy required to produce bottles/pouches can be assessed as:

   $Energy_{Glass} > Energy_{LDPE/LLDPE}$
   $Water_{Glass} > Water_{LDPE/LLDPE}$

7. The pollution of water in the production of plastic pouches is negligible while it is very high in case glass bottles.

8. The requirement of chemicals in manufacturing of these bottles/pouches needs also to be accounted for. There is a heavy requirement of chemicals in the glass bottle manufacturing. The requirement of chemicals in the case plastic pouch is negligible.

9. On the energy front there is considerable saving in the use of plastic Pouches for milk packaging as these are lighter in weight then glass bottles and the vehicles transporting them have to make lesser number of trips for moving the same amount of material, thereby reducing fuel consumption. The pollution associated with movement of transport vehicle is also reduced correspondingly.

10. Reuse of glass bottles in primary form has also been considered and it has been found that even for 95% of the glass bottles the overall energy requirement is high than that compared to the new Plastic Pouches. Also there is the issue of hygiene in reusing the glass bottles while plastic pouches are free of these.

11. There is a considerable amount of energy consumption in glass recycling than that compared with the plastic pouches. This is because of very high melting temperature of glass. Overall comparison shows that energy consumption is more than 100 times in case of glass bottles for different percentages of recycling than that compared to plastic pouches.

12. Plastic pouches goes through waste to energy process (~15.8 MJ/kg). This leads to good energy recovery at the end-of-life for plastic pouches.

13. Other than the above mention points there is more to be discussed in terms of breakage and safety associated with glass bottles. Also the

convenience of carrying leads to more inclination for the plastic pouch in the newly changing/developing society.