Lube oil EXECUTIVE SUMMARY

The evolution of packaging material has been incremental and gravitated towards more durability. The Industrial Revolution that was born almost 250 years ago adopted the concept of packaging from nature to ensure that the goods produced reaches customers without mutilation in quality. The importance of the art of wrapping grew with the proliferation of goods and packaging became sibling to the goods that the industries produced. For, the goods would loose their value, if they don't reach in the condition they are expected to be. This benign symbiotic relationship catalyzed the evolution of packaging to meet the rising expectation of consumer and the spread of distribution chain of products.

Recently, it was decided by ICPE (Indian Centre for HDPE in the Environment, New Delhi) to carry out Life Cycle Analysis (LCA) of commodity packaging materials such as materials used in packaging of milk, atta and lube oil. In this volume 'Lube Oil' packaging materials (tin cans and HDPE cans) with a packaging capacity of 5 lt (4.35 kg) has been considered for life cycle analysis. 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 plastics' 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. This study covers the environmental and resource impact of HDPE cans vis-à-vis tin cans used for packaging 'Lube Oil' 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 million metric ton of 'Lube Oil' in keeping with the view of the consumption in order of magnitude.

THE TOTAL IMPACT ASSESSMENT

The study discloses that for producing packaging with HDPE cans for one million ton of 'Lube Oil', the raw material required for packaging is only 63218 Mt. But for the same quantity of packaging with tin cans require 86207 Mt of packaging material. The results of this analysis are organized in two categories: resource utilization, water and atmospheric emission.

Energy Consumption

The analysis by steps identifies the production of Tin (Table – I) and subsequently manufacture of cans (Phase I and Phase II) as being responsible for the higher consumption of energy (~7485 thousand GJ per one million metric ton of packed 'Lube Oil') as compared to HDPE cans (~3277 thousand GJ per one million metric ton of packed 'Lube Oil'). Energy consumption related to transportation (Phase III) of 'Lube Oil' shows that transportation in tin cans requires significantly excess amount of energy, being about ~4691 GJ per one million metric ton of packed 'Lube Oil', compared to that in HDPE cans.

Table I: Life Cycle data for Different Materials used for Packaging One million ton of 'Lube Oil'

	Tin cans	HDPE cans
Material Required (Mt)	**86207**	**63218**
	Energy (Thousand GJ)	**Energy (Thousand GJ)**
Phase I: Production of Raw Material	3846.02	5052.87
Phase II: Production of Cans & Liners	3638.54	1472.99
Total	7484.55	6525.86

Phase III: Distribution	Tin cans		HDPE Film Bag	
	Fuel (Tons)	**Energy (GJ)**	**Fuel**	**Energy**
	83770.49	**4691.1**	**Taken as Basis**	

Phase IV: Waste Management	Tin	**HDPE cans**
Recycling Percent	**Energy Savings** (Thousand GJ/86207 ton)	**Energy Savings** (Thousand GJ/63218 ton)
100%	1602.586	1620.287
80%	1282.069	1296.230
Incineration	**Energy Recovered**	**Energy Recovered (Thousand GJ/63218ton)**
100%	**Not Applicable**	3276.61
80%		2621.29

Table II: Emissions during Phase I for Packaging One Million ton of 'Lube Oil'

For 1 Million ton of 'Lube Oil'		Tin	HDPE
Air Emissions			
CO	Ton	**1352.997**	**51.839**
CO_2	Ton	**21721.094**	**107470.6**
SO_x	Ton	**453.435**	**885.052**
NO_x	Ton	**333.495**	**625.858**
CH_4	Ton	**789.858**	**372.986**
HCl	Ton	**6.318**	**3.034**
Dust	Ton	**102.389**	**183.332**
Water Emission			
Suspended Solids	Ton	**28.888**	**132.757**
Chlorides	ton	**1038.517**	**21.494**

Table III: Emissions during Phase III for Packaging One Million ton of 'Lube Oil'

Emission	gm/km	Excess Emission for Tin cans (kg)	HDPE Cans
CO_2	781.0	199545.5	Taken as Basis
CO	4.5	1149.75	Taken as Basis
HC	1.1	281.05	Taken as Basis
NO_x	8	2044.00	Taken as Basis
$HC+NO_x$	9.1	2325.05	Taken as Basis
Particulates	0.36	91.98	Taken as Basis
Total Regulated Tail Pipe Emission	13.96	3566.78	Taken as Basis

Atmospheric Emission: About ten components dominate the category of atmospheric emission for tin cans and HDPE cans: CO, CO_2, SO_x, NO_x, CH_4, HCl, dust, heavy metals, suspended solids and chlorides. For all of these, the HDPE can produces less of each emission than to the Tin can. Tables II and III list atmospheric emissions.

More importantly, attention is also 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 3277 thousand GJ/63218 ton (for 100% incineration) and 2622 thousand GJ/63218 ton (for 80% incineration) for HDPE cans, while there is no incineration for waste Tin. Similarly energy savings during to recycling is found to be ~1620 GJ/63218 ton (for 100% recycling) for HDPE cans and

~1603.287 GJ/86207 ton (for 100% recycling) for tin cans. It should also be noted that in case of recycling the waste enters into a new life and if this waste management technique is considered the life cycle analysis of plastics/tin cans can be termed as *"Cradle to Cradle"* approach instead of "Cradle to Grave".

Emission to Air

During the transportation phase excess weight of the tin cans leads to consumption of excess fuel resulting in severe atmospheric pollution. The emission of CO_2 for HDPE cans is higher is phase I but leads to overall less CO_2 emission because of its light weight during the transportation phase. The analysis of input effects indicates remarkably high emission of CH_4 emission in case of production of Tin. The comparative study on emission during transportation also shows significantly excess generation of CO, CO_2 and NO_x in case of tin cans as compared to that in case of HDPE cans.

Emission to Water

As shown in the different tables, BOD and COD to water are of a slightly higher amount in case of production of tin cans than in case of HDPE cans.

CONCLUSIONS

Though plastics are relatively newcomers, the use of it in packaging of 'Lube Oil' commodities adhere to the basic tenets of sustainable development more than tin, if one considers the consumption of energy, emission of gases and the use of chemicals. An analysis of the comparable life cycle with tin clearly tells that plastics are economically affordable, socially acceptable and environmentally effective.

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

Managing waste help 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. Tin as 'Lube Oil' packaging material cause more stress on waste management than HDPE cans. 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 due to HDPE cans is less than that of tin cans and 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 Tin vis-à-vis HDPE cans on the overall loss to environment through transport of packed 'Lube Oil' in first use. Tin leads to more burden on the environment. Recycling of the HDPE cans also decreases the burden on environmental by saving energy as compared to making the products by virgin plastics.

Instead of banning its production, the need of the hour is educating the public of what to do with such waste cans 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. 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:

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

Functions:

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
- Environmentally 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

The most suitable packaging size for 'Lube Oil' in India is currently 5 kg and 10 kg. The types of cans generally used for packaging of 'Lube Oil' are:

- Tin cans with LDPE liner
- HDPE cans with LDPE liner

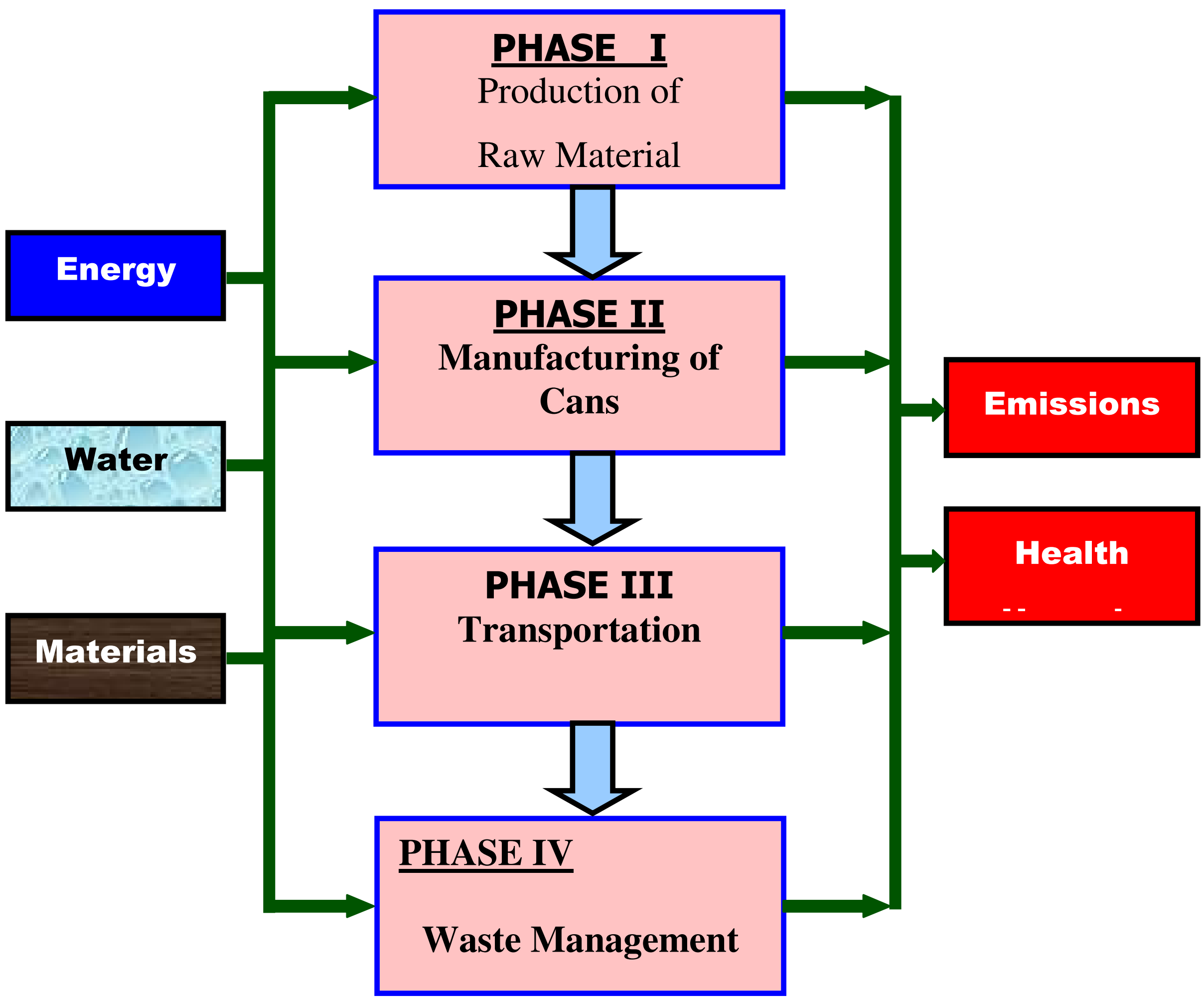
Environmental packaging considerations now seem to be as important as brand image. Matters relating to the environment and especially those concerned with disposal and recycling of 'Lube Oil' cans, appear to have become as important as the containers themselves.

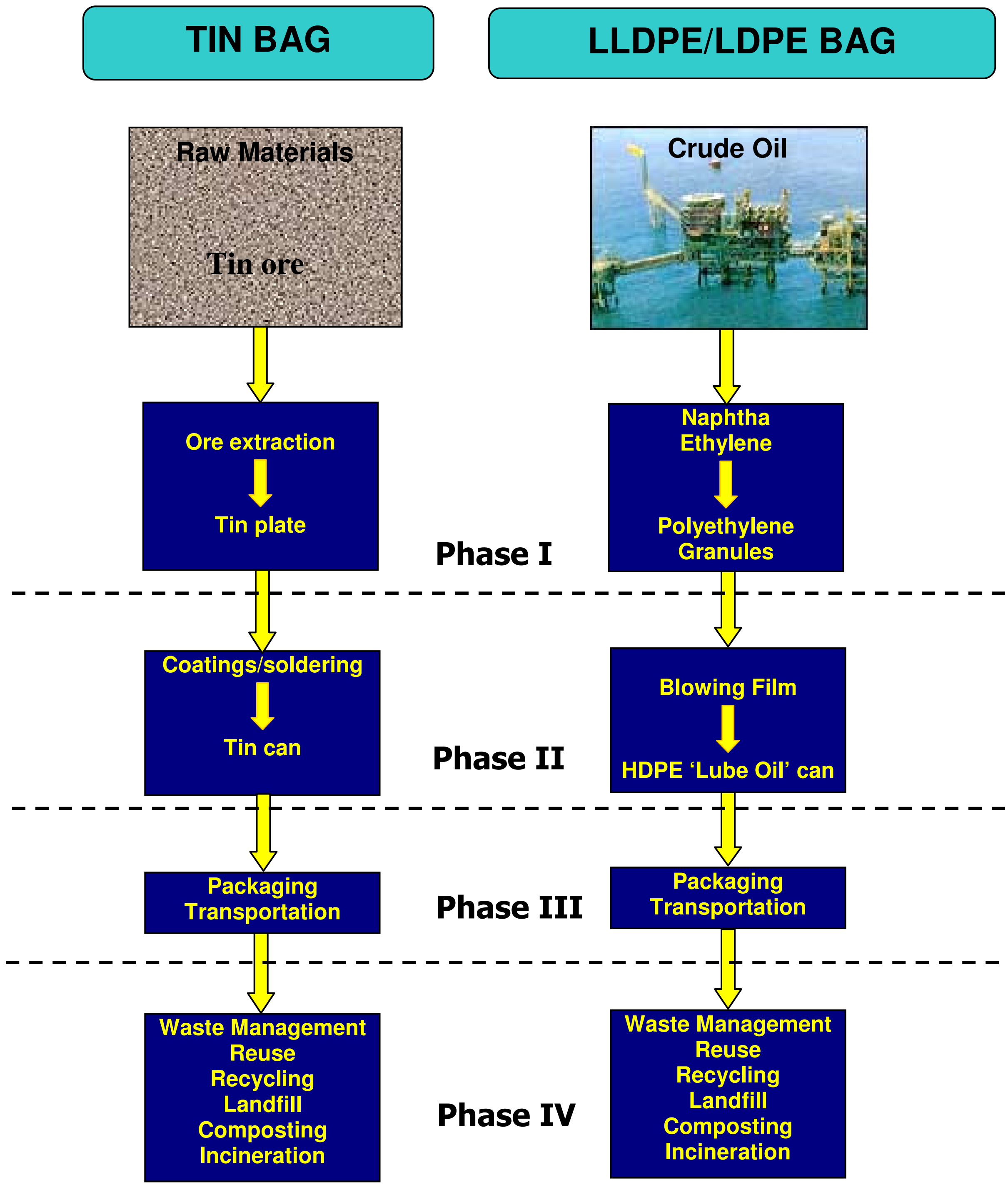
Table 1.4: Comparison of Different Packaging Material in Terms of Their Strengths and Weaknesses

Packaging Material	Strengths	Weaknesses
Tin cans	• Efficient and economic use of materials for individual packs. • High pack safety and minimal secondary packaging requirements. • Easiest materials to recover from the waste stream due to its magnetic properties. • High reuse capacity.	• Significant energy consumption in raw materials. • Pollution risks in materials production-furnaces. • Low residual value of recovered material. • Less public awareness of environmental merits than for some other materials.
HDPE Cans	• The most versatile and diverse family of packaging materials • Efficient and economic use of material for individual packs • Hygienic packaging for foods and beverages • High energy recovery from incineration • Efficient in-plant industrial scrap reuse • Non-degradable perceived as a weakness for plastics • Amenable to recycling	• Raw material derived from non-sustainable resources of fossil fuels, though only 4% of the world's oil consumption used in total HDPE products.

Goal and Scope

This project aims to provide a comprehensive environmental model for domestic packaging and waste management using a life cycle assessment methodology. The main focus of the project would involve producing lifecycle inventory data for HDPE packaging during manufacturing, usage (both primary and secondary) and disposal and comparing the same in case of tin. As a case packaging of 1 million ton 'Lube Oil' in cans (5 litre capacity) made of HDPE and Tin has been considered in this report. The study has been divided in four phases as shown below:





Flow Chart of Tin Bag and HDPE Bag during the Life Cycle Analysis

PACKAGING ASPECTS

The first forms of packaging were made from leaves, animal skins, bamboo, reeds, wicker and gourds and used by ancient hunter-gatherer communities. Later, as people continued to live near the source of their food, packaging was simply a means of containment. Various simple containers were used to store fresh products, which had been preserved by drying, salting or smoking. But despite such efforts at preservation, it was often attacked by animals, insects and microorganisms. By the eighteenth century, most of the goods sold in shops at that time were wrapped in parcels or wooden boxes and displayed around the shop walls.

The history of packaging is intimately connected with foodstuffs. Until the nineteenth century, packaging was mainly used to transport goods from their place of production to the customer. Further, as people gravitated away from living near their sources of food to the rapidly expanding towns during the period of early industrial growth, the role of packaging expanded from one of essentially containing products to one of protecting them as well. With the onset of industrialization, the search began for better methods of preserving foodstuffs and packaging became a key ingredient for the successful development of enhanced shelf life preserved foods.

There are several myths and public perception of packaging:

- **It fills the dustbin and the amount of waste is growing.**
- **It is disposed off by methods that harm the environment.**
- **It wastes scarce materials and energy.**
- **It is not recycled or reused.**
- **It should be returnable for reuse.**
- **It is a cause of litter.**
- **It should be biodegradable.**
- **It contributes to pollution.**

Unfortunately, the misconceptions, frequently get more attention than the service and essential benefits that packaging provides.

One needs to be sustainable in packaging the bulk commodities. Sustainability has been defined as 'development, which meets the needs of the present without compromising the ability of future generation to meet their own needs'. This identifies the synergy between economic development, social equity and the environment. Therefore, sustainable packaging must be:

- Economically affordable
- Socially acceptable (Human Health)

- Environmentally effective

Equal consideration of each is necessary; otherwise the whole system will be become unbalanced. There is need to produce more value from goods and services with less raw material and energy consumption and less waste and emission production.

Functions of Packaging

Containment and protection:

Protecting the product from spoilage is the most important function of packaging. It must create a barrier between the product and the hazards of the environment. Packaging protects products from light, dirt, bacteria, fungi, insects and animals, and is a major factor in determining the shelf life of the product.

Preservation:

By acting as a protective barrier to foodstuffs, packaging slows their rate of deterioration. As consumers demand more natural foods, so the packaging takes on the role of the preservative previously added to the food itself. An example of this is 'modified atmosphere packaging' where the ratio of gases in the air space inside the pack is modified to produce conditions that are not conductive to enzymatic changes or microbial growth.

Communication:

Packaging also serves as means of communications between the manufacturer and the consumer. Self-service retailing has led to lower prices through economies of scale and reductions in labour, but the product now has to sell itself, often against competition from other similar products.

Packaging Reflects a Changing Lifestyle

Today, typical supermarket stocks in excess of 15000 different product types, six times more than it did in 1960. Consumer choice has never been greater. The rising affluence has made consumers more adventurous in the foods they eat and in the way they spend their leisure. Consumers can only choose from the products available to them, but with the vast amount of choice today, the power of consumer to influence what is stocked by retailers has also increased for market research to understand, what customers actually want.

Packaging plays a vital role in the world today; without it much food would become unavailable to the consuming public or would be spoilt, many non-food products would become damaged and wasted and the distribution of goods would be much more expensive and difficult to carry out. There are not likely to be too many major changes in the way that packaging performs its role in the future; packaging designers and technologists will continue to develop more resource-efficient, more economical, more convenient and more environmentally responsible packaging.

The function of containment, protection and preservation in packaging are paramount, and many of the communication functions will always be necessary. However, the relative amount of resource and effort that is put into the development of the convenience, service and presentation and selling functions of packaging may well change, but the overall costs of delivering such packaging products to consumers will be the major criterion for dictating change.

Finally, there is a growing demand for the products, which are seen as environment-friendly, and here the packaging is often challenged, sometimes above the product itself. It is important that, consumer are made aware of all these functions.

Types of Packaging

The early uses of packaging were concerned with survival and this highlights basic principles that are just as important today. Around two-thirds of packaging is used for food grains and sugar. Many non-food products, as well as food products, require protection during their distribution from factory to customer, and none more so than the enormous range of pharmaceutical, toiletries and household products that are now a necessary part of modern life.

The choice of suitable packaging involves a number of considerations would the pack provide the optimum protection for the contents throughout their distribution and shelf life, will it contain the product adequately, keeping harmful outside influences out and will it adequately describe and market the product?

Primary, Secondary and Tertiary Packaging:

The primary packaging of a product is the first and main line of protection, the material that is in direct contact with the product. It represents the barrier between the product and the hazards of the external environment. Although it is convenient to consider the different types of primary packaging as distinct material sectors (metals, glass, plastics, paper and board), they are seldom used singly. Glass containers need closures of cork, metal or HDPE and usually at least one paper or plastics label. Paper or thin board is often used in combination with plastics and/or foil to provide sufficient product protection to ensure 'fitness for use' with the minimum use of resources.

Primary or sales packs are often delivered in some forms of secondary packaging. Secondary packaging utilizes the primary packaging providing both the retailer and the consumer with a more convenient means of handling the product. It also helps in protecting the primary packages and thus the product.

Transport or tertiary packaging must ensure the safe and efficient delivery of products from their point of manufacture to the next point in their distribution chain. Integrated design of tertiary packaging, together with products' primary and secondary packaging, can reduce transport costs and the environmental impact of transport. Today many of the wooden and metal systems have been replaced by lighter and often more durable HDPE ones, which reduce the total amount of energy, used in the system.

Returnable, Non-Returnable and Recoverable Packaging:

The role of packaging in protecting products and helping to make them readily available to consumers can be served by both returnable and non-returnable packaging. Returnable has come to mean, refillable and reusable 'multi-trip' packaging, while non-returnable usually means disposable 'one way' packaging. Recoverable packaging is now widely acknowledged as any packaging for which the raw material can be recycled and reused for the original purpose or other purposes, composted, regenerated or for which the energy value can be utilized as a source of energy generation.

Commodity Packaging:

The roles of packaging are many and varied. Amount and complexity of the packaging used in a product depends to a large extent on the type of product being packed. Therefore, a further categorization of primary packaging type is as commodity, convenience and functional and luxury packaging. Commodity packaging for staple foodstuffs and household goods, such as flour, sugar, butter and detergents, is usually kept as simple as possible, whilst still providing safe delivery of the product, in prime condition, from the manufacturer, through the distribution and retail chain, to the consumer. Each layer of packaging fulfils a different function, protecting against various hazards such as moisture, light, oxygen, pests or crushing.

Convenience and Functional Packaging:

Convenience and functional packaging for products, such as pre-packaged fresh foods, ready-to-eat meals, portion packs and multi packs, is usually more complex and sophisticated than that used for staple products. It reflects the needs of our changing lifestyles, where we spend less time shopping and preparing meals. These packs may be required to do more than simply provide basic protection for the product. They may for example:

- Extend the shelf life of perishable products through the use of modified atmosphere packaging;

- Be designed to be oven, microwave and/or table ready;
- Be tamper evident;
- Need to be child resistant, easy to open for the elderly, or to dispense measured amounts of the product.

The design of this type of packaging has to be a compromise between fulfilling specific consumer needs and minimizing the use of resources.

Environmentally Responsible Packaging Manufacture

There is a need for packaging and to concentrate on how best to satisfy that need whilst, at the same time, controlling and minimizing the resulting environmental impacts.

Impacts arising from any product system can be simplistically divided into three broad categories of environmental burden:

- Consumption of resources
- Pollution
- Solids waste

To be meaningful, any environmental assessment must consider these three effects at each stage in the lifecycle.

Packaging Design

For most design considerations, there is a fortunate coincidence of performance, cost and environmental virtue. Requirements for protecting the environment, such as minimizing use of materials, i.e. light weighting, efficient manufacturing and handling processes which restrict energy consumption, and avoiding waste through good product protection in storage and distribution, are now routinely practiced by the packaging industry. They represent efficient, cost-effective packaging systems and therefore, make good business sense.

The benefits achieved from the redesign and improvements of packaging, in reducing weight alone, are most impressive. Even the sophistication's of convenience in packaging design have their environmental merits and justifications. While some additional packaging resource may be incorporated into a design, producing a specification, which exceeds the minimum required for simple product protection and delivery, contributes significantly in environmental gain.

Convenience foods, for example, are, by their very nature, products that require little, if any, preparation in the home: for hot foods, re-heating in a microwave oven is highly energy efficient. The combination of bulk production by the food manufacturer, with minimal waste in the home, compensates for the increase in packaging.

There are, nevertheless, aspects of packaging design, which now receive much attention on purely environmental grounds. The almost universal acceptance of the need to maximize recycling and reuse of materials has placed new demands on the packaging designer. The importance and difficulties of post-consumer packaging material recovery, or reclamation, is a first step to recycling. Thought given to this requirement at the design stage, the 'cradle' or start of the lifecycle can facilitate reclamation and reuse at the end of the cycle, thereby avoiding the 'grave'. Correct design may tip the scales between economically and environmentally viable recycling and recycling that would be pointless due to more resource being used than was saved through the recycling.

Packaging Material Selection

In theory a choice can always be made from any one of the two main groups of packaging materials used in packaging lube oil:

- Tin
- HDPE

Tin: The manufacture of tinplate constitutes the most important application of tin. Modern tinplate consists of a thin sheet of low carbon steel covered with a very thin coating of commercially pure tin. Ordinarily, the thickness of the steel base is about one-hundredth of an inch, while the tin coating thickness is in the range 0.000015 to 0.001 in. Tinplate is an inexpensive "tonnage" material having the mechanical characteristics of steel and the ability to be soldered, corrosion resistance and good appearance of tin.

Records show that an early version, consisting of iron hammered into thin sheet and coated with tin by dipping in the molten metal, was available in Bavaria in the fourteenth century. The first record of a successful tinplate plant in the United Kingdom was of one set up in South Wales in the early part of the eighteenth century using rolls to produce the thin sheet. The adoption of steel in place of iron, coupled with rolling in place of hammering, and the development of machines to replace manual labour, particularly automatic tinning machines, led to a substantial increase in output and in improved quality.

The major expansion in production up to the current world output of some 14 million tones (estimated) has been achieved by substantial improvements to manufacturing processes, culminating in sophisticated steel making, precision high-speed rolling mills and tin coating methods, all controlling the product to fine limits.

Tinplate is principally used for the manufacture of containers and closures employed in the packaging and canning of foods, beverages and other merchandise. Its uses have changed considerably over the years; previously substantial proportions were used for general household articles such as plates and pots, miscellaneous boxes, etc., but in recent years the bulk has been used in the manufacture of hermetically sealed containers for packaging a wide range of food and beverages. Development of fast automatic can making and cannery equipment has resulted in rapid growth to the current very high rate of production. It is probable that over 90 per cent of tinplate is so used and one estimate suggests that some fifty thousand million tinplate containers are made each year.

Considerable quantities are also being used for aerosol containers for products ranging widely from air fresheners, fly killers and insecticides to toiletries; for containers for general products (paints, oils, polishes, etc.), a wide range of closures for glass jars, and a number of engineering components.

Although the wide acceptance of tinplate is due primarily to its rather special properties, the extensive development of new can manufacturing processes and designs has resulted in a considerable increase in the number of tinplate varieties being available. General products, such as paints and oils, can be widely distributed in convenient amount. The demand for effective packaging is always under severe cost pressure and also pressures from competitive material and methods, and there will always be a strong demand for improved quality and design at minimum increase in cost.

HDPE: Compared to other materials, plastics are the relative newcomers. 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 plastics 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 vinyl polymers 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 same happened in non-packing markets, e.g. nylon parachutes to nylon stockings. 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^{0}C 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, re-granulated 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 from these processes principally relate to the coating and printing operations. Storage, use and disposal of waste inks and coating must be controlled. Use of the actual paper and board is very efficient and scrap is collected and returned for recycling, often back into paper packaging itself. General processes to obtain different packaging materials are shown in the figure 1.4.

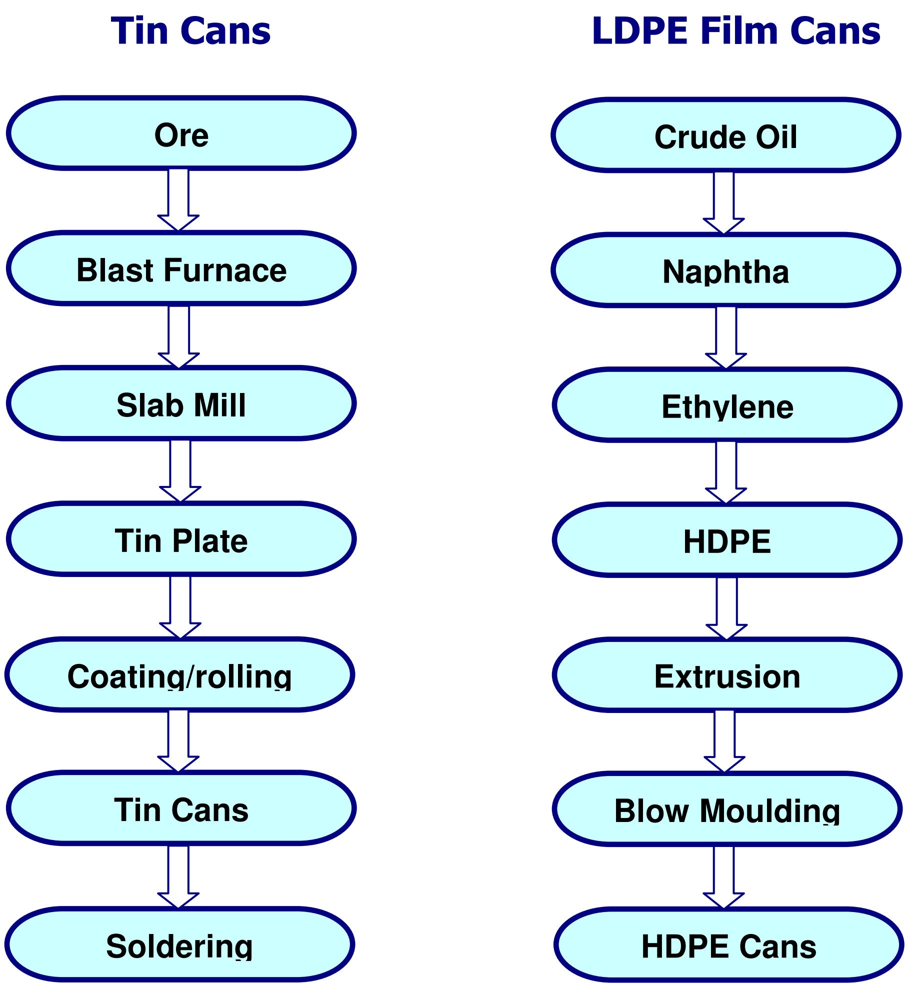
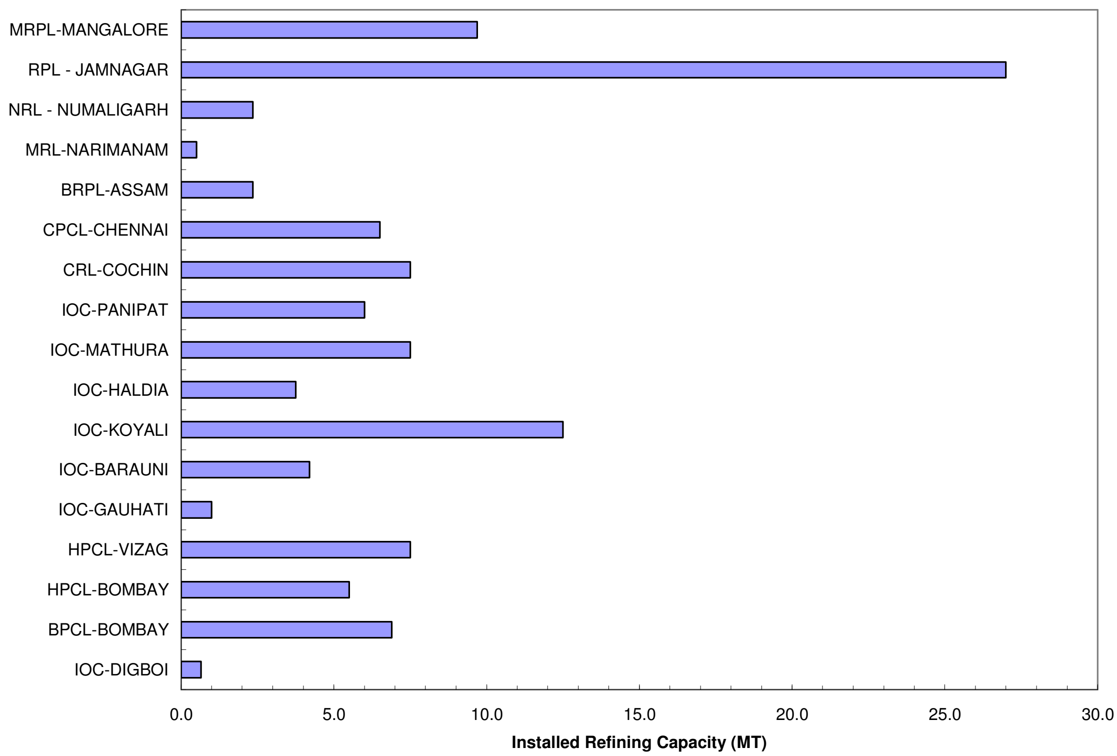


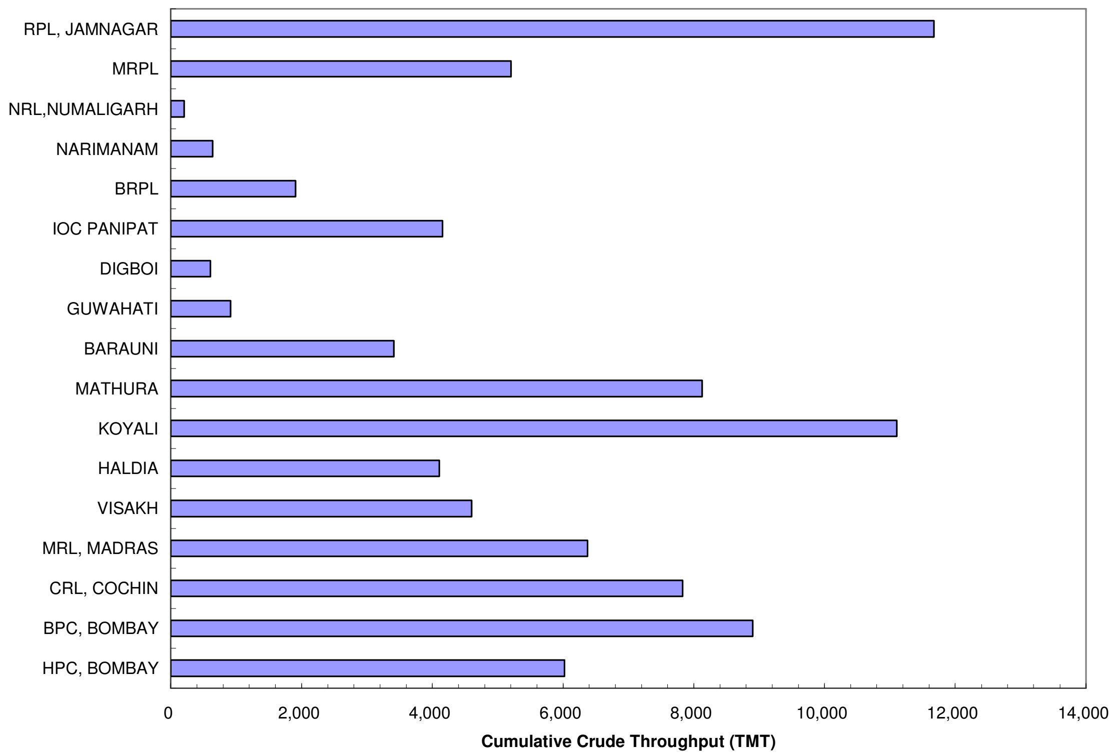
Figure 1.1: General Process to Obtain Different Packaging Materials.

According to the statistical reports available at the end 1997, the total proved oil reserves in the world is 140.9 TMT of which India has 0.6 TMT, a share of 0.4% of the total reserves available for utilization. Not all the reserves have been utilized as yet. The oil production is about 37 MT in India, which is 1.1% of the world's oil production (3474.7 MT). The crude oil excavated is transported to the refineries where they are refined to obtain different products. India has 12 refineries out of 705 of the total refineries in the world. These 12 refineries have the capacity to refine 10,86,371 tonnes of crude oil. The refinery capacity of India is about 1235 thousand barrels on a daily basis with a share of 1.6% in the total world refinery capacity. But the oil production of India is not sufficient prevent the oil imports as the consumption as of 1997 is 2.4% (83.1 MT) of the world's consumption as against to a production share of only 1.1% of the world. [source: world oil, excel]



According to the report on Indian refineries (MMTPA) in april 2000, there are 17 refineries with a total installed capacity of 111.39 MT with quite a few proposals for expansion of the existing refineries as well as installation of new refineries. The crude throughput from the existing refineries is about 85,772 TMT. [source: refineries, excel]

Lube oil, one of the crude oil/petroleum products, is produced by 3 major industries in India: Hindustan petroleum- Mumbai, MRL-Madras, and IOC-Haldia. Among them they produce 725.3 TMT of lube oil. The break up in terms of LVI and HVI of each company is shown in the Chart 1 (Lubprdn-excel).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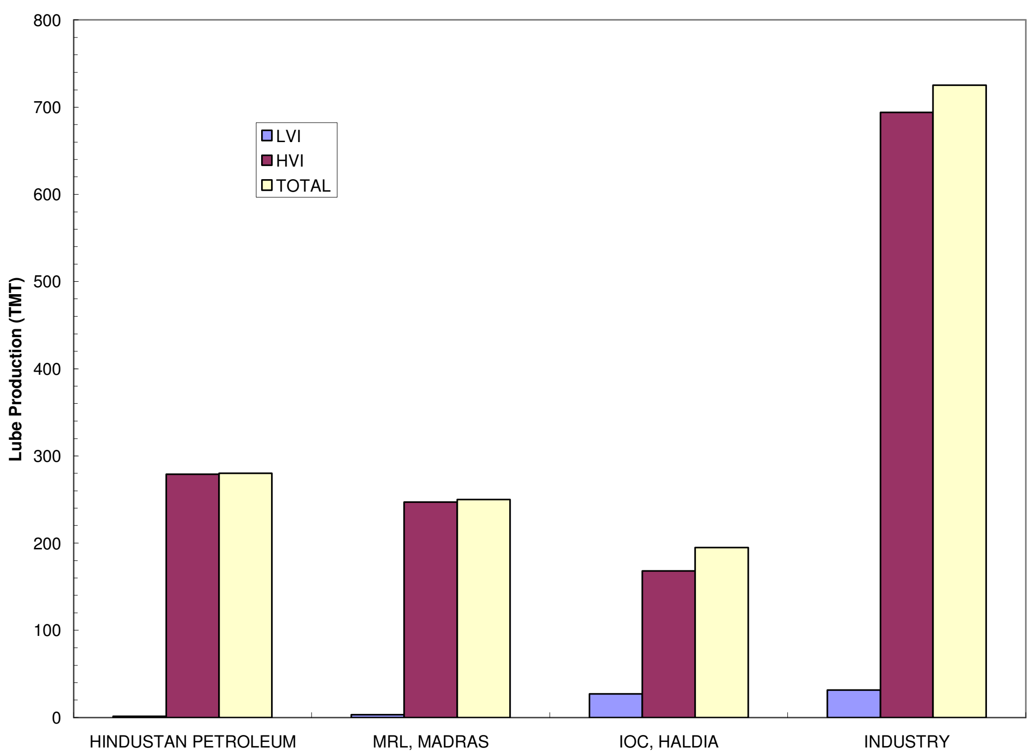
MRPL
NRL,NUMALIGARH
NARIMANAM
BRPL
IOC PANIPAT
DIGBOI
GUWAHATI
BARAUNI
MATHURA
KOYALI
HALDIA
VISAKH
MRL, MADRAS
CRL, COCHIN
BPC, BOMBAY
HPC, BOMBAY
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Cumulative Crude Throughput (TMT)


800
700
600
500
400
300
200
100
0
Lube Production (TMT)
LVI
HVI
TOTAL
HINDUSTAN PETROLEUM
MRL, MADRAS
IOC, HALDIA
INDUSTRY

PRODUCTION OF TINPLATE

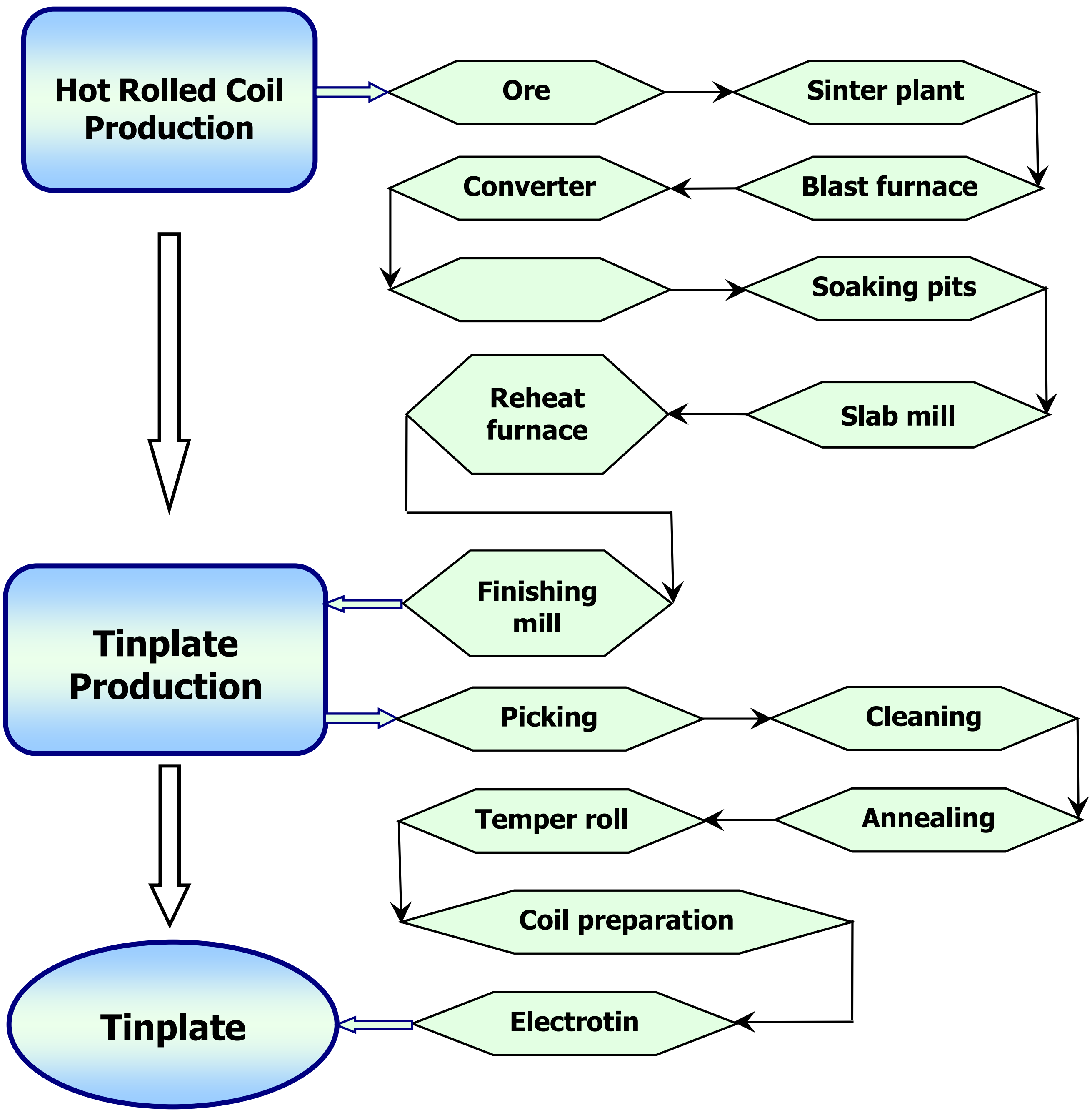


Figure 2.1: Flow Chart for Production of Tinplate

Process Details

Tinplate is essentially low carbon steel between 0.15 and 0.49mm thick coated with between 5.6 and 22.4 grams of tin per square meter. The flow chart for production of tinplate is given in figure 2.1.

Production of Steel

The production of steel from iron ore involves a number of processes. The first process involves the production of pig iron from the ore mined. The iron ores are generally hematite (Fe_2O_3) with some magnetite (Fe_3O_4). Coke is included to provide the reducing gas and heat needed for reduction of the ore and smelting. The pig iron thus obtained is then reduced to get steel.

Manufacture of Pig Iron

Iron ore is mined and it is fed directly to the blast furnace to get pig iron or it may undergo a preliminary treatment known as sintering to form a porous mass (Sinter) that is more easily reduce to iron in the blast furnace. In sintering, a mixture of 90-95% ore fines and 5% coke, sometimes with added limestone, is passed over a continuous moving hearth in a sintering machine. After ignition, the mass is caused to agglomerate by localized fusion, the heat being provided by combustion of the coke in air drawn through the charge. Temperatures of 1300-1400^{0}C are reached, and the product is broken into porous lumps. This is fed into the furnace, and a blast of hot air is blown continuously through tuyeres located above the hearth. The primary products – liquid iron and slag – are tapped frequently from the furnace – almost continuously in the large modern furnaces – through several tap holes near the base of the furnace. Liquid pig iron, also known as hot metal, will normally have the following composition:

Carbon	3.5 – 5.0%
Silicon	0.3 – 1.0%
Manganese*	upto 2.5%
Phosphorus*	upto 1.0%
Sulphur	upto 0.8% but generally lower

**Mn and P dependent on ore.*

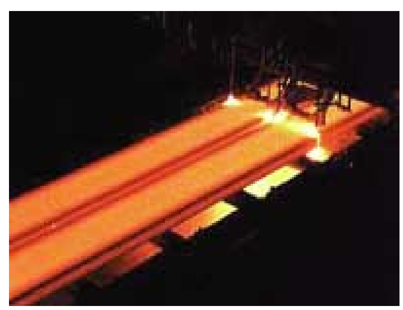
After tapping, the liquid iron is run into large insulated vessels fitted on rails cars for transport to the steel making plant.

Steel Making

The desired composition for tinplate will usually lie within the following range:

Carbon	0.03-0.12%
Manganese	0.20-0.60%
	(above 0.04% for rephosphorised steel only)
Phosphorus	upto 0.15%
Sulphur	upto 0.05%
Copper	upto 0.20%
Silicon	less than 0.10%
Nickel	upto 0.20%

The pig iron produced in the blast furnace contains metalloid contents far too high for steel sheet, and they must be substantially reduced in the steel making stage. The furnace is charged with 85-95% liquid pig iron and 10-15% scrap, together with about 5% by weight of lime**.** This charge reacts with elemental oxygen or iron oxide to remove excess carbon picked up in the blast furnace. Iron is charged to a pear shaped converter and oxygen is blown in. The metal, oxygen and slag form an emulsion in which the iron is rapidly refined to steel.



On completion of the refining operation, the liquid steel with specified C, Si, Mn, S and P, but also residual oxygen in excess, is poured into large ladles for casting into ingots. The "casting steel into ingots" route requires "soaking" to a comparatively high temperature, suitable for hot rolling into slabs in a primary mill, before hot rolling into strip can be carried out, a major and costly operation. Continues casting (CC) of the steel directly into slabs eliminates both of these operations.

Production of Tinplate

Continuous Casting:

Liquid steel must be cast into standard shape so that it can be rolled. The casting process is continuous because liquid steel is continuously poured into a bottomless mould at the same rate as a continuous steel casting is extracted. The continuous length of cast steel is then cut to length for processing.

Hot Rolling (Hot strip Mill):

Cast steel is relatively weak due to large and uneven metal crystals or grains. Rolling slab causes the coarse grain structure to recrystallise into a much finer grain structure giving greater toughness, shock resistance and tensile strength. Before hot rolling, the steel slab, bloom or billet is reheated in a furnace to1200^{0}C. This makes it easier to roll the steel. A slab 230 mm thick can be rolled to thickness of 1.5 mm by hot rolling process. The principle of rolling metal is that the two rolls rotate with the same angular velocity, but in opposite directions. The gap between them controls the thickness of the rolled product.

The molten steel is continuously cast into slab form and the slabs are hot rolled in the Hot Strip Mill into coils of steel strip with a thickness of 2 mm.

Steel Pickling:

Substantial layers of oxides are formed when the steel is heated to elevated temperatures for rolling, and these need to be removed completely before proceeding with the next stage, cold rolling, to avoid the defects that would occur. The steel leaving the hot strip mill is 1.5 mm thick, and needs to be cold rolled because the required thickness cannot be achieved by the hot rolling. The process widely used for the removal of these surface layers, also called scale, is termed "pickling". The pickling liquor used is a dilute aqueous solution of hydrochloric acid (5-10% HCl) and is carried out at ambient temperature. After use in the pickling process, the used HCl is returned for purification. Appropriate inhibitors are added to limit Lube oilck of the steel, giving a smoother surface and some economic advantage.

In each case, thorough rinsing and drying are essential to achieve acceptable surface quality.

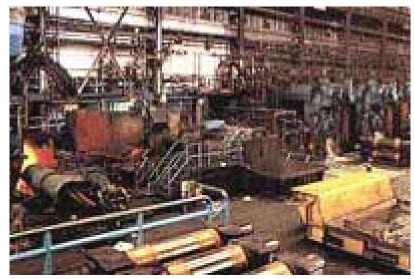
At the exit end, the strip is side trimmed to the exact width required. This trimming at the same time removes any serrations, cracks, or other bad edges that may have occurred during hot rolling. A film of oil is then applied to the surface to assist coiling, to help preserve the pickled coil during storage, and to act as a lubricant during rolling in the first stand of the cold mill.

Cold Rolling:

The final stage of thickness reduction is carried out by cold rolling**.** Cold rolling is carried out at a room temperature and at very high speeds using lubricants to reduce friction. Various lubricants are employed, usually dispersed in water, or the water may be applied separately on to the rolls.

In operation, the strip is loaded on to the uncoiler, and fed slowly through each stand and finally on to the recoiler mandrel (the wind-up reel); the mill is then run up to maximum speed, and finally decelerated as the tail end of the coil is reached. A new coil is then fed on to the uncoiler and the processes repeated; thus cold reduction is a batch process, and substantial operating time is lost in between coils due to the lower speed during run-up and run-down, and a significant length at the front and back ends of the coil will be outside gauge thickness tolerance.

Cold rolling increases the strength, make steel thinner and produce a smooth bright surface.



In the Tin Mill, 20 tonnes feed coils are cold rolled to final thickness, usually in the range of 0.16 to 0.30 mm for food cans.

Electrolytic Cleaning:

The effects of the heavy cold working (which is defined as HDPE deformation in a temperature range within which the strain hardening it causes is not relieved) of the steel during cold rolling (not less than 85% reduction in thickness) are substantially to increase its strength and hardness, but at the expense of ductility. Elimination of the harmful effects of cold reduction is vital and is done by annealing. The lubricant flooded onto the steel strip during cold reduction will decompose at the high annealing temperatures used and will interfere with the effective coating with tin in the final stage; it is vital, therefore, that this is thoroughly removed before annealing. The usual method of cleaning is by electrolytic treatment in an alkaline solution. As the amounts of lubricant to be removed are large, strong solutions of caustic alkalis with phosphates or silicates and wetting agents are used as the detergent. Generally, cleaning is carried out in two stages, the first consisting of either a dip tank or the detergent is sprayed on to the strip, followed by thorough scrubbing and rinsing, then a similar electrolyte is used in which bipolar electrodes are fitted, again followed by thorough scrubbing and rinsing, and finally drying by means of warm air.

Solution temperatures approaching boiling point are used, and close control of solution strength is exercised to ensure very effective cleaning.

Annealing:

There are two types of annealing used: batch and continuous annealing. In batch annealing, the annealing is done in three stages: heating, holding and cooling. The heating stage of the cycle must necessarily be very long, often up to 30 hours duration. Batches of coils are placed under covers and heated to recrystallization temperature to remove the strain, hardness and embrittlement induced by cold rolling. Soaking time will vary according to furnace design, chemical composition of the steel, and the temper grade desired, between say 5 and 12 hours; it is also the practice to use slightly higher peak temperatures for the softer grades, say about 650^0C and the order of 620^0C for the harder temper grades**.** By the same token, cooling times will be long, even though a form of accelerated cooling is employed. The total cycle times, therefore, are of the order of 4 days.

As batch annealing is slow, causing a relatively serious hold-up in throughput, the concept of continuous annealing emerged. Total cycle time in the continuous annealing process is less than 90 seconds. It incorporates four zones, heating, soaking, slow cooling and fast cooling. The peak temperature is usually 6500-6900C, but will be varied according to the earlier history of the steel, its composition and the temper grade required. The strip is rapidly heated to the recrystallization temperature in continuous strip form in protective atmosphere. The thin gauges obtained in tinplate practice allow the adoption of short soaking times, of the order of 20 seconds, and yet provide sufficiently complete crystallization. Slow cooling over 30 seconds, down to a little under 500^0C ensures uniform cooling free from variable stresses and distortion in the strip, and avoids any danger of quench aging. Beyond that temperature, it is rapidly cooled to a temperature at which oxidation will not occur, and re-coiled.

Temper Rolling:

After annealing the steel strip for single reduced tinplate is given a further reduction in thickness on a temper mill. After annealing, the steel strip will be a soft pliable state and will possess a rough "open" surface. This strip must be given a light cold rolling, termed temper rolling (or "skin passing") before proceeding to the final surface finishing treatment. Temper rolling is normally carried out in four-high mills. Rolling speeds will often be in excess of 1500 m/min, and the mill will be equipped with sophisticated instrumentation to provide control of rolling loads and strip thickness is minimal, and a rolling lubricant is not used; in fact a high standard of cleanliness is required, as it is vital to avoid contamination of the surface, which may be difficult to remove prior to tinning.

Coil Preparation:

This operation is aimed primarily at inspecting the surface quality of the strip and removing any faulty portions that may be present; this will include any off-gauge material detected by means of x-ray or nucleonic measuring units and pinhole detectors.

Standard practice will include rolling to a width at least 12.5 mm (0.50 in) greater than the ordered dimension, and the line will normally include a pair of accurate rotary knives to trim each edge of the strip to within the tolerance imposed on the ordered width dimension. The line will thus usually include uncoilers and recoilers, cutting, rejection and welding units, in addition to thickness gauges, pinhole detectors, side trim rotary knives and precise mechanism for location on the strip. This combination will provide large coils, up to20, 000 kg in weight, for the final coating line, depending on the number of welds which have to be made after rejection of portions; in view of interruption to fast operation caused by the presence of welds, can-makers normally lay down a maximum of four in any one coil.

Electrolytic Plating:

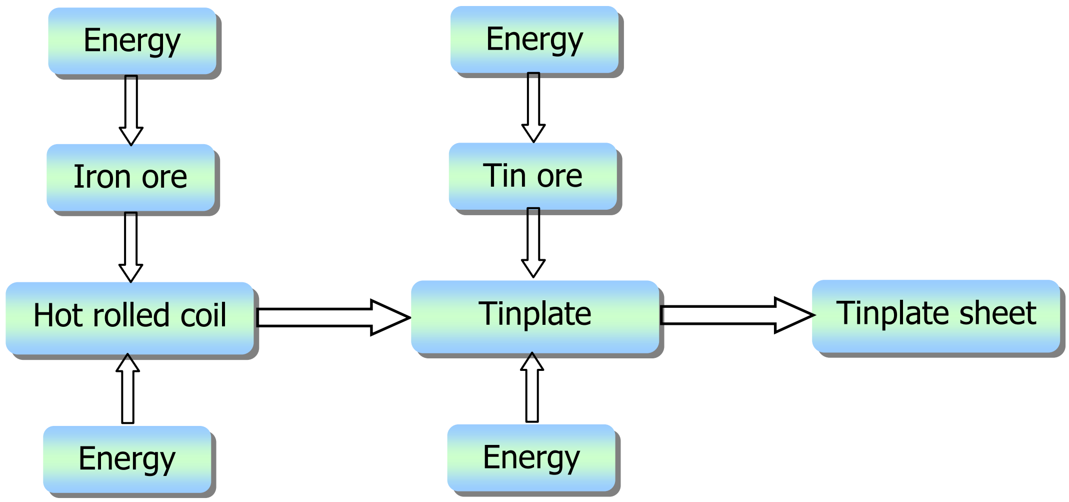
Electrolytic tinplate is produced by the continuous electro-deposition of tin as the strip moves through a high-speed line. The plating is accomplished by passing the strip through a bank of plating cells containing complex electrolyte and tin anode beds. After tin deposition on both sides of the strip it is then passed through re-flow tower.

Finishing:

The coating as deposited has a matt light gray appearance, i.e. it is not bright plated, but is readily converted into a lustrous bright appearance by momentarily raising its temperature above the melting point of tin and cooling rapidly. In the re-flow tower, heat induced in the moving strip melts the matt tin coating and surface becomes bright. Quenching in water follows re-flowing. Package and other specific processes follow the finishing process.

The tin coating is applied by continuous electro-deposition of tin on to thin steel strip, after which the tinplate thus obtained is either sold in coil form or cut into sheets for the can manufacturer.

LIFE CYCLE INVENTORY DATA FOR PRODUCTION OF TINPLATE



Energy required to produce 1 kg of Tinplate: 49.7 GJ

Table 2.1: Gross energy in MJ required to produce 1 kg of Tinplate

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	6.40	2.56	-	-	8.96
Oil fuels	2.10	10.09	-	-	12.19
Other fuels	3.68	24.87	-	-	28.55
Totals	12.18	37.52	-	-	49.70

Totals may not agree because of rounding

Air Emission

Table 2.2: Gross air emissions in gm arising from the production of 1 kg of Tinplate

Emission	Totals (gm)
Particulates	1.410
CO	18.500
CO_2	297.00
SO_x	6.230
NO_x	4.560
N_2O	0.0096
Methane	10.800
H_2S	0.0099
HCl	0.0864
HF	0.011
Lead (Pb)	0.00459
Copper	0.00026
Chromium	0.00014
Arsenic	0
Mercury (Hg)	0.00002
Ammonia (NH_3)	0.00197
Nickel	0.00179
Cadmium	0.00011
Zinc	0.00027

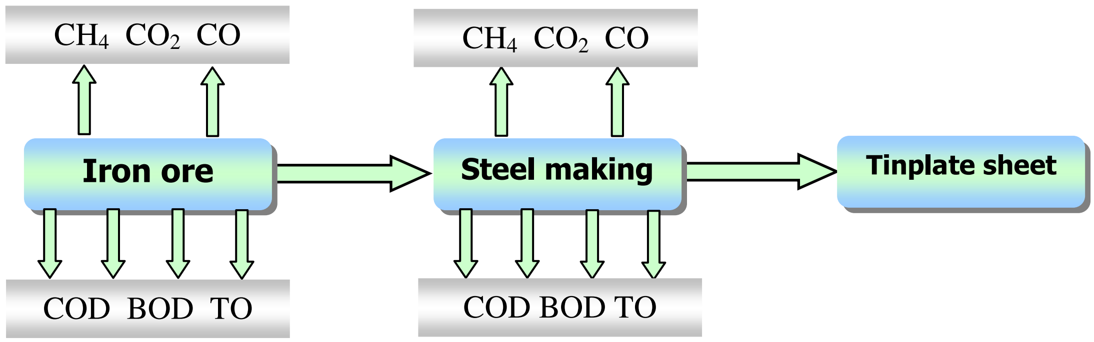
Source: Integrated solid waste management: a life cycle inventory by McDougall, F.R., White, P.R.,Franke, M. and Peter Hindle

Water Emission

Table 2. 3: Gross water emissions in gm arising from the production of 1 kg of Tinplate

Emission	Totals (gm)
COD	0.465
BOD	0.170
Phenol	0.00065
Chlorinated Hydrocarbons	0.00001
Suspended solids	0.395
Total organic compounds	0.150
Al^{+++}	1.920
AOX	0.00052
Ammonium	0.00801
Barium	0.165
Cadmium	0.0001
Chloride	14.200
Chromium	0.0196
Copper	0.00961
Cyanide	0.00003
Iron	0.790
Lead	0.00974
Mercury	0.00002
Nickel	0.00969
Nitrate	0.00608
Phosphate	0.146
Sulfate	8.950
Sulfide	0.00014
Zinc	0.0194
Arsenic	0.00385
Fluoride	0.032

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



Gross solid waste required to produce 1 kg of Tinplate: 67 gm

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

PRODUCTION OF TIN CANS

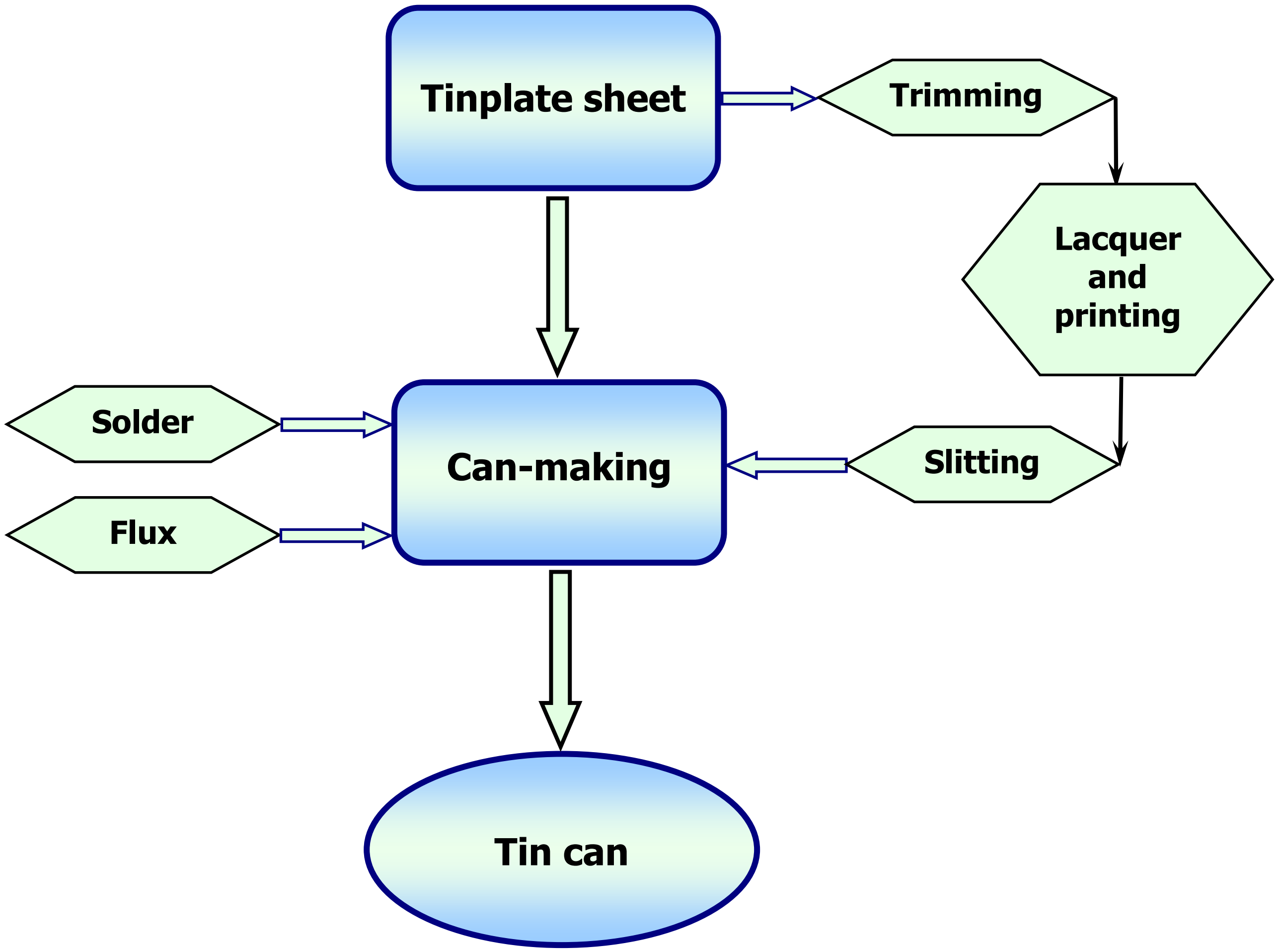


Figure 2.2: Flow Chart for Production of Tin Cans

Process Details

Production of plain ends

For economic plate usage, the strips cut from the tinplate sheet for feeding into the press are "scrolled" in shape. The scrolled sheet is first lacquered and then cured in oven. Coated sheets are rescrolled at right angles to the original scrolling to produce secondary scrolled strips. Circular blanks are then pressed from these strips and processed in two stages so that a curl is formed around the edge. Lining compound is sprayed on to the inside of the curl while the end is rapidly rotated. This spreads the lining compounds into a uniform coat. Finished ends are fed directly to a can making line.

The endplate may have been previously coated with lacquer, or used unlacquered ("plain"): in the former case a stamping lubricant is applied to minimize lacquer fracture on tooling, or alternatively an "internal" lubricant may be included in the lacquer prior to application, which often is considered adequate, particularly with good flexible lacquer types. External lubrication is usually done by fine spraying to the strips as they are picked up automatically with suction-cups from the hopper and fed into the press. Unlacquered plate is not normally lubricated on end stamping; the applied to the plate surface in the electrolytic tinning process is usually adequate.

Open frame (or "C") type presses are normally used, and although this type has a very rigid structure, the combined operation of blanking, drawing and coining sets up some frame deflection, with consequent effects on end profile. After stamping, the ends fall through the press into the curler, which consists of an inner rotating disc and an outer stationary tool, both suitable profiled, to form the outside curl and outside diameter. A lining or sealing compound is then applied into the seaming panel through closely matched nozzles.

Body Production:

As virtually all-open top can bodies require a rectangular blank for their fabrication, the waste arising from cutting up the rectangular sheet is minimal; it is confined to the narrow sheet edge trim taken off during the slitting operation. There is no real material saving, therefore, in purchasing coil, and it is the general custom to purchase body plate in sheet form. Some users' coil cut-up lines can be fitted with straight-cut knives as well as the "scrolled" type, to be in a position to cut rectangular sheets internally, should the need arise. If the bodies are required lacquered and/or printed, these operations are carried out before cutting up the sheet.

Production of two-piece cans:

Circular blanks, stamped directly from lubricated tinplate coil are fed to a cupping press that forms a shallow cup shape from the blank. The body-maker then draws the cup and irons out the walls to produce the body shape. The can walls are deliberately overdrawn so that the top may be trimmed to give a smooth, uniform rim. The body is then subjected to a vigorous washing to remove all traces of lubricant before being printed on the outside and cured in the oven. Tinplate bodies are then necked and flanged ready to receive the end and pressure tested to detect leaks. The untreated metal on the inside of the can body is then sprayed with an epoxy coat which is oven cured. A further vinyl coat is applied over this, and the can is again passed through the curing oven.

Production of three-piece cans

Sheets are lacquered and printed, with the exception of uncoated margins, which will subsequently become the edges of the body blanks. The sheets are then dried in an oven. A number of passes along the printing lines may be needed depending on the number of colors to be laid down. The print is protected by a final coat of varnish, which may be applied as the last operation during the final pass along the printing line. Printed and varnished sheets are trimmed, slit and fed to body-maker where they are bent around a mandrel and the side seam is formed. Solder is applied to the joint and any excess is wiped off. The ends of the cylinder are then necked in and flanged to provide the seating for the ends. To complete the internal can coating, lacquer is sprayed on to the inside of the can and oven cured. The finished body cylinder is then closed at one end by fitting either a plain end or any easy open end. This operation is known as seaming. Cans are then pressure tested for leaks before leaving the production lines.

There are both basic and optional steps in the can-making process. The latter depends on the weight of the tinplate, the size of the can, and the use for which it is intended.

Tinplate is delivered in multi-ton coils to the coil-cutting facility where it is cut into sheets, and for some products, enamel coated for shipment to the can manufacturing plant. The major machines in the can-making line and their operations are:

THE SLITTER: The first slitting operation produces strips as wide as the body circumference, including seam, and the second cuts these into blanks of the required height. Sheet edges are cut precisely square during these operations. Modern tandem slitters are fitted with carbide cutters, and are usually preset in a tool room to achieve maximum cutting accuracy; this is essential to maintain side seam and double seam standards, together with precise lacquer stenciled margins to allow efficient soldering of the side seam. The body blanks are checked for accuracy and loaded into feed hoppers of the bodymaker.

THE BODY-MAKER: The body blanks are fed into the body-maker in which they are first passed through a rolling unit which flexes the plate to prevent flutes being formed, and to provide an appropriate degree of bow to the blank which assists feeding through the bodymaker.

The blank is then fed through and, successively:

1. Notched at the corners to reduce the ultimate side seam from four to two metal thickness at its extremities, to form a lap joint.
2. The two edges parallel to the can axis are hooked to 90^0.
3. A second hooking operation reduces their angle to about 30^0 to the plane of the blank.
4. The final operation forms the blank into a cylinder by bending it around a mandrel using a pair of wing formers. These are then hammered flat on to a

contoured spline located in the mandrel. Accurate cutting of the blank, edging it and close control at the forming station ensure a well-formed seam, essential for good soldering. Immediately prior to body forming, the hooked edge is coated with a thin film of flux. If the body is to be beaded circumferentially, incipient beads are formed across the side seam, before soldering, by a suitably designed hammer and spline.

THE SIDE SEAMER: This stage is in continuous motion, synchronized with the bodymaker, and fitted with a magnetic or mechanical chain conveyor to transport the body securely through the following stages:

1. Controlled preheating of the side seam to equalize expansion on soldering.
2. The side seam contact the rotating roll carrying molten solder, causing a pool to form and by capillary action to penetrate fully into the side seam structure. Finely balanced preheating and close setting of the solder roll are particularly vital. This roll rotates in a both of the molten solder held usually at a superheat of about 50^0C, the bath being heated by gas flames. On leaving the soldering station a controlled reheating is applied to the side seam to effect good post-wiping by means of a rotating mop to remove excess solder and present an acceptable appearance. Minimal metals exposure along the internal side seam region can be achieved by applying a film of suitable lacquer from a spray nozzle. It may be applied before or after the solder operation. The interior can surface may be so treated to improve product/can compatibility; lacquer can also be sprayed externally to improved the atmospheric corrosion behavior of the soldered seam. The heat applied during soldering cures the lacquer.
3. The side seam is then cooled rapidly by powerful air jets to avoid solder disturbance on handling at high speed.

The side seam is sometimes welded together. Replacement of soldering by welding is done where good resistance to transitory high internal pressures during post-filling operations and danger of creep failure during higher temperature storage are vital. Two processes were developed for welding side seams in place of soldering.

The Conoweld Technique: This requires careful and thorough removal of the chrome/chrome oxide coating, to a width of about 2 mm along each of the blank edges that will form the lap seam, just prior to welding. It is vital to avoid contamination of the copper electrode rods. A specially designed square waveform of alternative current is employed to give sound, continuous, solid phase welds. High-precision body forming, with spot welding followed by seam welding, maintains an overlap of less than 1.3 mm, and rolling to significantly less than twice the plate thickness reduces welded lap thickness. The welding units are fitted into a modified bodymaker/side seamer assembly, and the process is operated at similar high speeds to those of modern soldering lines.

The Soudronic Process: To avoid the deleterious effect of electrode surface contamination on weld quality, Soudronic developed the use of copper welding rollers over which copper wire is passed. The wire serves as an intermediate electrode, and is moved along with the welding of each can. As the wire is not reused, tin pick-up, interfering with subsequent welds, is avoided, thus ensuring almost constant electrical resistance. The wire is not otherwise affected, and is readily sold for recovery at prices around 60% of its initial cost. The Soudronic welding technique employs a sine wave alternating power supply and controls the current and the pressure applied through the electrode wheels, and the time by the machine speed.

The following special grades of plate cannot, at present, be welded:

1. Tinplate coated on one surface only;
2. Fully alloyed, low tin coating grade (0.5/0.5 g/m^2);
3. Blackplate, if stored for a short while (except under special conditions) but if the surface is freshly cleaned it can be successfully welded;
4. Chrome/chrome oxide coated plate ("TFS"). (It can be welded, if freshly "edge cleaned", as in the Conoweld process.)

Although the welded seam is free from the danger of lead pick-up (which in the case of a soldered seam can only be eliminated by the use of pure tin), the weld has to be effectively coated to prevent traces of iron being picked up by some types of beverages and acidic foods. For this purpose, a driven roller-coating unit (DRC) is available to be fitted beyond the welding station for side striping the seam. It applies comparatively high solids lacquers to the internal weld line, which is then cured by post-solder heating. The actual welding process uses two threads of copper wire, one inside and the other outside the cylinder. The wire serves as a conductor for electricity that creates a heat so intense it fuses the sides of the cylinder together in a series of overlapping spot welds. The copper wire, having served its purpose, is ejected by the machine and returned to the factory for recycling.

THE CURING OVEN: On cans intended for certain products, protective enamel is sprayed on the welded seam inside and outside the cylinder. The cylinder must pass through an oven where the enamel is cured for a few seconds at high temperature.

THE PARTER: Most cans are formed individually, but some of the small cans start out two or more per cylinder (multi-high). In such cases, the body is then parted into its multiple lengths along the prescored lines.

THE FLANGER: The two ends of each body are finally flanged outwards for subsequent double seaming on the end; the flanging operation can be by means of dies or spinning. The flanger thus adds a curved lip at both ends of the can to allow the double seaming of ends to form a hermetic seal.

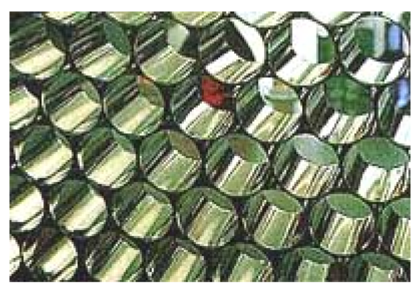
THE BEADER: Creates the rings that circle some cans for added panel resistance. Beading makes it possible to use slightly thinner tinplate

THE DOUBLE SEAMER: Puts on and seals one end of the can. Double seaming is carried out in two stages. In the first operation, after feeding the end on to the flanged body, the end curl is rolled gradually inwards radially, so that its flange is well tucked up underneath the body hook, to a final contour governed by the shaped roll. Seaming is completed in the second operation in which a shallower contoured roll is used to close up and tighten the "first operation" partial seam to the desired tightness rating. The interior periphery of the end is coated with a latex material called seaming compound that helps form the seal.

THE TESTER: Finally, the cans are individually tested for micro leakage under pressure in large wheel-type testers, each of which can carry up to 50 pockets per wheel. High-pressure air is used to test the cans. Tester rejects cans that do not have a tight seal.

THE PALLETIZER: The cans may be conveyed directly to the cannery for immediate use or they can be palletized and stretch-wrapped for storage.

Draw and Redraw (DRD(Process)



Deep drawing is used for producing a wide range and size of components. This introduction to the process will be related to the manufacture of cylindrical cups with a flat base, by means of a cylindrical punch and die set assembled in a power press.

As the tool assembly descends a circular cutter forms a blank which is then held down against the die by a cylindrical blankholder.

Further downward travel causes the punch to effect the following processes:

i. The peripheral flange is draw inwards radially over the face of the die, wrinkling due to the gradually decreasing circumference being prevented by the pressure exerted by the blank holder. At the same time the central portion of the blank is stretched around the end of the punch, to form the base of the can.

ii. The flange material is first bent around the die radius R_d and is then unbent to form the vertical cup wall.

iii. The cup wall is stretched and thinned under tension.

iv. The cup base is stretched over the face and around the radius of the punch.

Drawing and Wall-Ironing (DWI) Process

This was the first of the two modern canmaking processes to be developed, based on presswork only, and was aimed at the production of can having a large height: diameter radio for pressurized beverages.

The technology requires a circular blank for forming the cylindrical body, and internal post-lacquering, with usually external decoration for beverage cans. Use of metal in coil form is almost universal. The highly automated process produces up to 100 cans per minute, with closely controlled linked systems; modern installations are planned on multi-lines capable of producing 1 billion cans per year, equivalent to 2 million per day. The system consists of the following basic stages.

1. The strip is fed from an uncoiler onto an inspection/lubricating unit, which checks the material for pinholes, off-gauge portions, etc. to ensure minimum down-time and no danger of damage to expensive tooling, and then applies a controlled amount of the drawing lubricant, usually by a roll applicator.
2. A first-stage cup is drawn in a heavy duty high-precision double-action press fitted with combination tool (i.e. for blanking and drawing), multiple die – 6, 7 or even 8 cups may be produced in one press strike staggered across the strip. The cups are fully drawn through the die, i.e. without a residual flange.
3. The cup is then redrawn to the final can diameter either in a separate double or single-action press, or integrally at the beginning of the next stage. The first stage cup must be located precisely in the redraw tool to ensure even drawing; this is achieved by means of a cup locator. Cups are removed from the punch return stroke by means of a "sprung fingers" stripper.
4. Wall ironing, in which the redrawn cup wall thickness is reduced from its original gauge of 0.30 mm to 0.10 – 0.14 mm, normally be means of three ironing rings, of the form. Ironing is effected by the radial compressive stress acting on the material deriving from the tensile stress exerted by the punch; as a cold-worked thickness reduction of more than 50% is effected copious amounts of a good lubricant are needed, additionally to limit tool surface damage and provide a good can surface.

The substantial thickness reduction involved causes a corresponding substantial increase in body height, but with an irregular rim. Excess height is usually trimmed off in rotrary trimmers. Additional lubricant is applied at each of the three ironing stages. The substantial thickness reduction involved causes a corresponding substantial increase in body height, but with an irregular rim. Excess height is usually trimmed off in rotary trimmers. Additional lubricant is applied at each of the three ironing stages.

5. Before lacquering and decorating can be carried out, the heavy residual lubricant which will contain small particles of swarf must be very effectively removed; this can be carried out in hooded mat-conveyor type cleaning units employing water-based detergents or organic solvents (which are liberally sprayed inside and outside the cans) to ensure near absolute cleanliness, the final stage requires very thorough washing – generally with a final wash in deionised water – and quick drying, using hot air. If needed, a chemical surface treatment facility (chromate, phosphate type) can be incorporated as a final stage.
6. When required to be externally decorated, a base coat is first applied and oven dried, then the printed design, using up to four colours, by the rotary technique; finally, a varnish coat is applied, followed by stoving. To avoid damage to the print before it is dried, the cans are usually transported through the oven by means of "peg" conveyors.
7. The can rim is then flanged outwards to enable the top end to be seamed on after filling by the packer; flanging is almost always coupled with necking which reduces the overall diameter across the seamed end to below that of the can body wall. This is accomplished by die-necking and spinflanging, or combined roll flanging and necking-in. By this means, blows from the double seam on to adjacent can walls during transport can be avoided, thus reducing the danger of damage. It also provides a significant saving in endplate material resulting from the smaller diameter end needed, and also allows more effective packing methods to be adopted.
8. Finally, the internal surface is spray lacquered and then stoved.

As would be expected, the external tin coating is substantially damaged by wall ironing, even though it appears visually very lustrous and smooth. Scanning electron microscopic examination shows tin distribution to be very patchy, and when removed the underlying steel surface is found to be deeply scored in the ironing direction, the grooves appearing to be filled with tin. Extent of damage increases with each ironing stage.

Thus the residual tin coating cannot be expected to offer much protection, and general experience has shown that the products more aggressive to iron are likely to cause severe pitting or perforation without extra protection than in three-piece cans.

The Draw-Redraw (DRD) Steel Can

Two-piece draw-redraw cans, usually with a ring pull opener, are commonly used to can food. In this method, a cup is stamped or drawn out of a disc of tinplate. The principle of this method is that a "first operation" drawn cup is redrawn to one of smaller diameter, and thus of greater height; this may be achieved in one or two redraw operations.

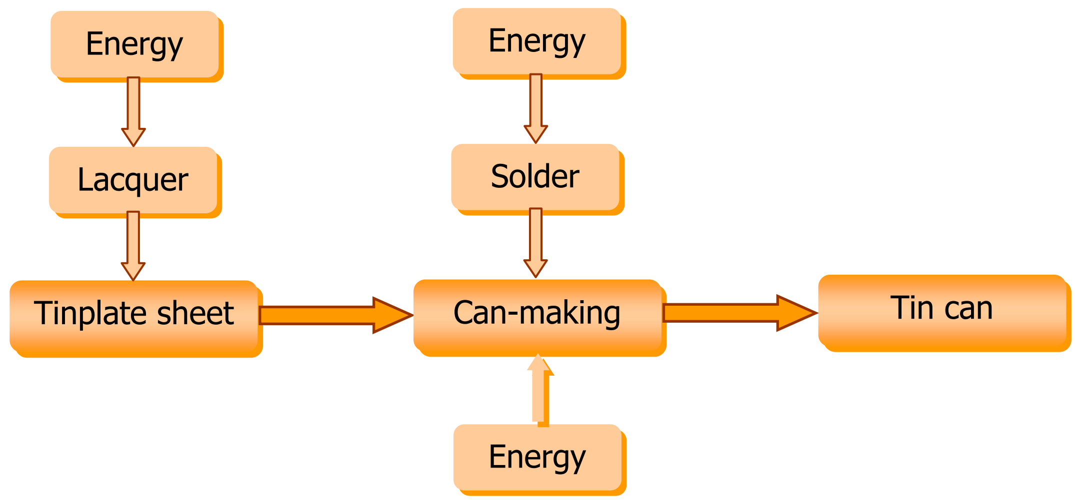
The greatest can height: diameter ratio that can be produced by multiple drawing is usually less that than by DWI; the DRD can is favored for the shorter food cans. As a deliberate change is gauge does not occur in this process, the base material will usually be strengthened to the level required by coining a profile into it.

The main stages of the DRD process can be summarized as follows. As the plate thickness will remain sensibly constant, the area of the circular blank required will be approximately equal to that of the untrimmed finished container. The optimum plate thickness will depend on can size and application required; it is usually within the range 0.20-0.22 mm. As a flat base at this thickness will not have adequate resistance to internal pressure, it will be profiled to an optimum contour at the end of the last drawing stroke, as in the DWI process, by attaching appropriate tooling to the base of the punch and die. Care must be taken to ensure that the coining tool radii are not too sharp, as this can lead to lacquer fracture. Separate presses are used for each stage, finally trimming the irregular flange.

The Metal Box DRD Process: It is a process that involves redraw close-coupled presses based on rotary continuous operation. The lacquered scrolled plate is fed directly into a standard cupping press, usually double-action type, in which the first stage cup is drawn; these are then fed directly into an eight-head rotary press in which the cup is redrawn into once of smaller diameter and greater height. If one redraw stage only is required for the particular can size, coining at the end of the punch stroke contours the base. The irregular flange is then trimmed in a second, similar rotary press to the width specified for later double seaming the top end. When two redraw stages are required for taller cans, the integrated line will usually contain three rotary presses; alternatively, flange trimming can be carried out as a final separate operation, using conventional high-sped trimmers.

This cup is then redrawn, trimmed and flanged to form the finished can. The cup has no separate bottom end, no side seam and, after lacquering, is ready for the canner to seal with an end.

LIFE CYCLE INVENTORY DATA FOR PRODUCTION OF TIN CANS



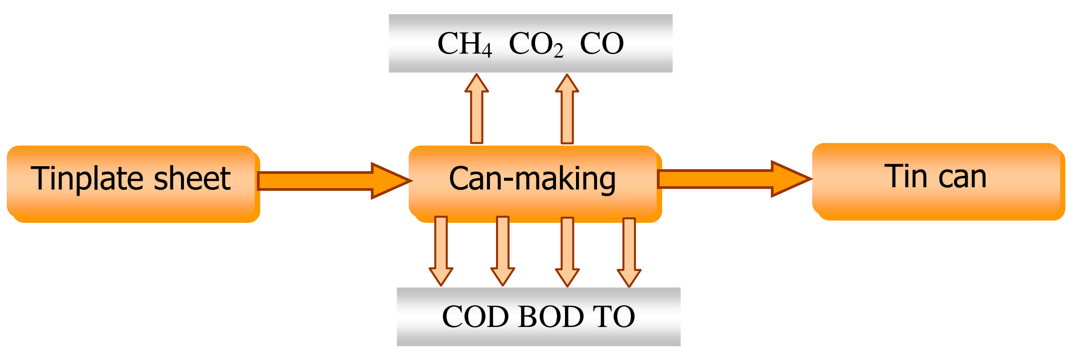


Table 2.4: Energy Consumption during Production of Tin Cans used for Packaging one Million ton of "Lube Oil"

Phase	Material required (tonnes)		Energy (GJ)	
	Per Can (5 lts)	For 1 mT lube oil packaging	Per Can (5 lts)	For 1 mT lube oil packaging
Phase I: Production of tinplate	**375×10^{-6}**	73135.158	16.7×10^{-3}	3846019.56
Phase II: Production of tin cans	**375×10^{-6}**	86206.897	15.8×10^{-3}	3638535.421
Total	-	-	32.5×10^{-3}	7484554.981

Total Energy Required To Produce 1 Kg of Tin Cans: 91.19 MJ

Table 2.5: Total Emissions during production of tinplate required to manufacture tin cans needed for packaging of 1 million ton of "Lube Oil"

Emissions (kg)	Tinplate production
Total air emissions	25765466.01
Total water emissions	2009022.79
Total solid waste	4900055.585

PRODUCTION OF POLYETHYLENE (HDPE) GRANULES

The process of manufacturing involves the following steps:

- Extraction of crude oil
- Production of naphtha by fractionation from crude oil
- Cracking of naphtha to produce ethylene
- Polymerization of ethylene to produce HDPE
- Manufacturing of cans from HDPE granules

Flow chart for the production of PP-HDPE granules is shown in Figure 3.2.

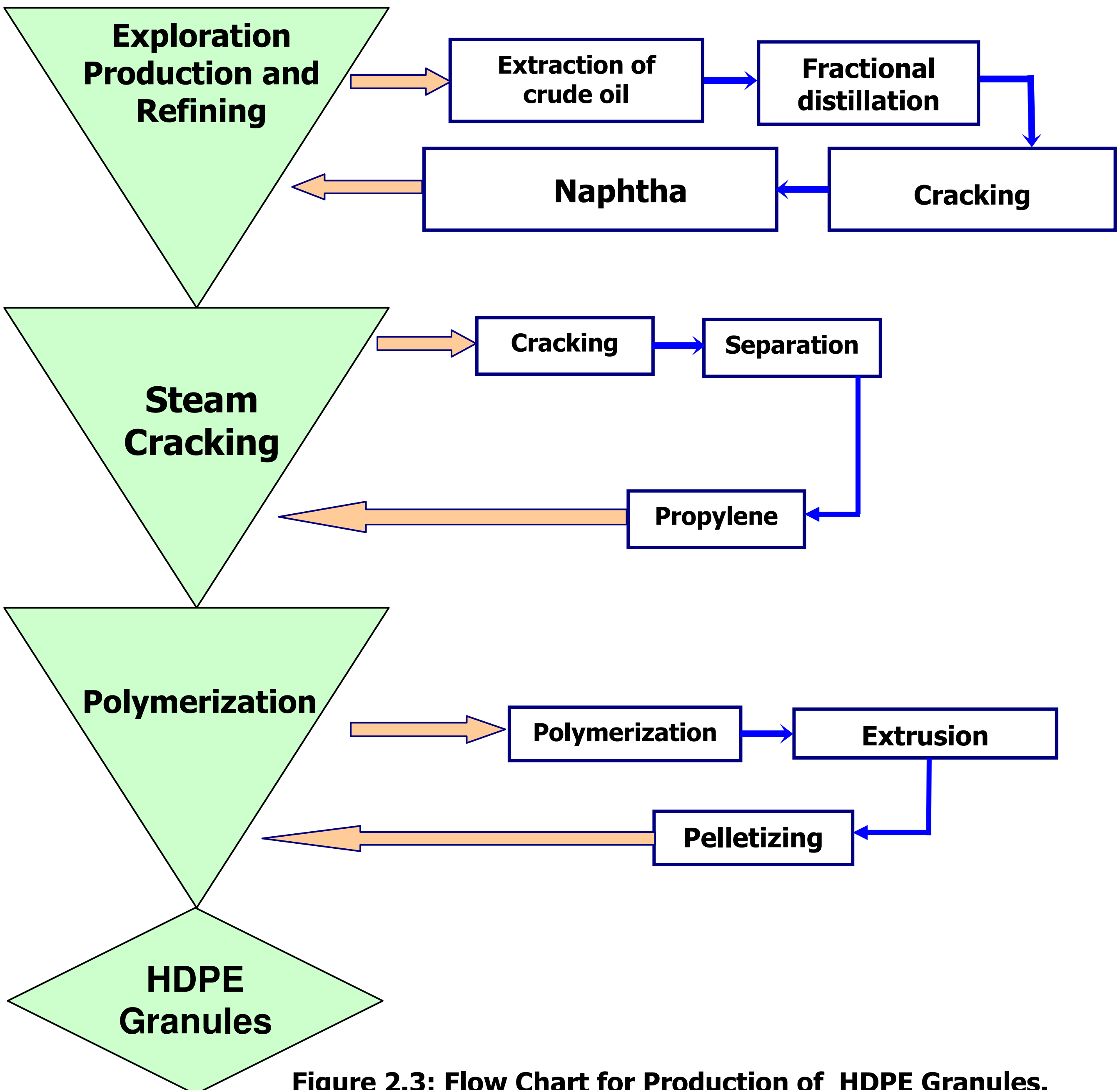
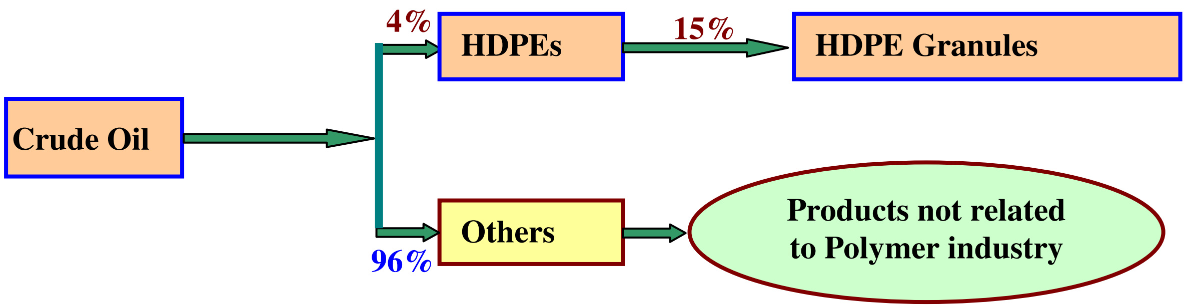


Figure 2.3: Flow Chart for Production of HDPE Granules.



EXTRACTION OF CRUDE OIL

The first step for production of PP-HDPE 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 per cent) of world's total oil consumption is used in HDPE industry (Figure 3.3). Out of this 4 per cent, 57 per cent is used to make PP and PE; that amounts to about 2 per cent 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:

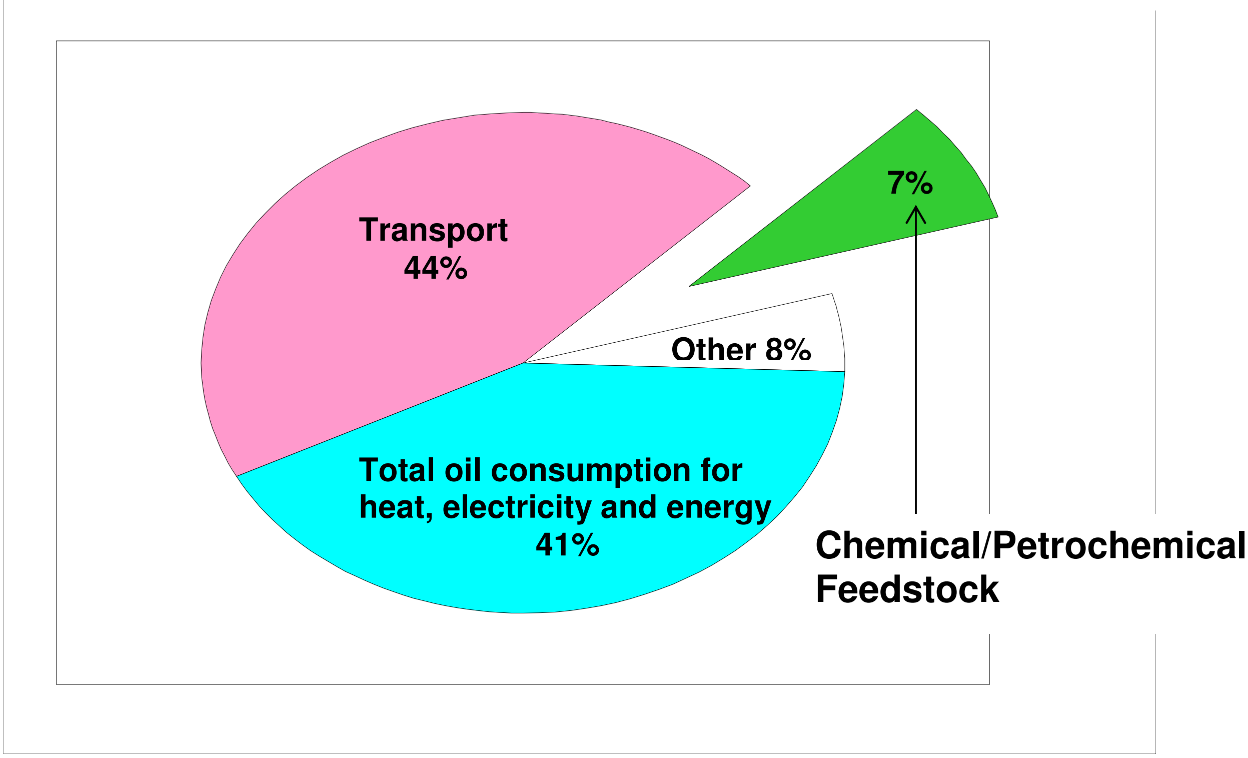
(i) A light straight-run function, consisting primarily of C_5 and C_6 hydrocarbons.

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

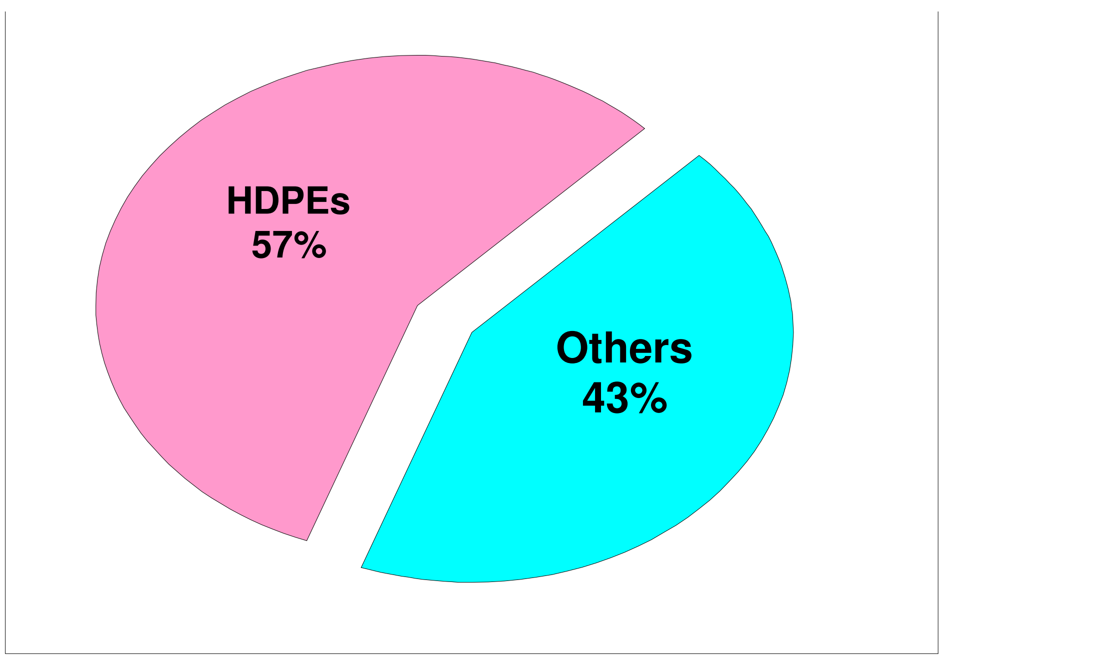
(iii) A light distillate with boiling point range of 400-650^{0}F

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

World’s Oil Consumption



World’s Chemical and Petrochemical Feedstock



Total 4% of the World’s Oil Consumption used in HDPE Products

Figure 2.4: Consumption of world’s total oil in making HDPE products

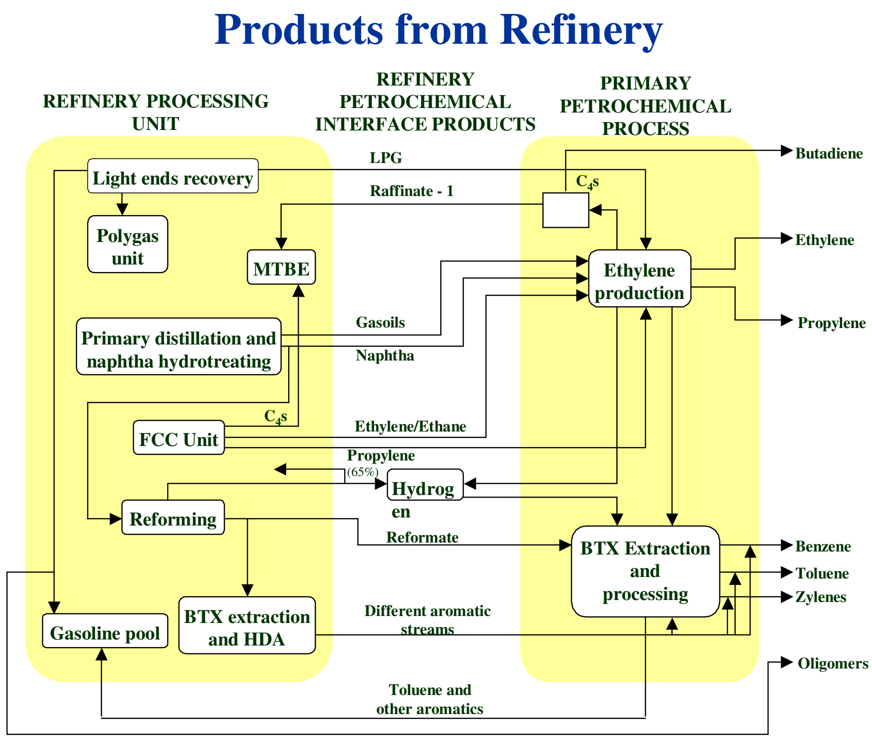


Figure 2.5: Different products obtained during refining process

> ***.....However, it is important to note that extraction of crude oil is carried out mainly to supply the needs of transport and other sectors. HDPEs only consume a small fraction - four per cent - 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 HDPEs 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 hydrocarbons by breaking molecular bonds. There are three different methods for cracking: thermal cracking, catalytic cracking, and hydrocracking. Thermal cracking depends on a free-radical mechanism to cause scission of carbon-carbon bonds of the hydrocarbon and a reduction in molecular size, with the formation of olefins, paraffin and some aromatics. Side reactions such as radical saturation and polymerization are controlled by regulating reaction conditions. In catalytic cracking, carbonium ions are formed on a catalyst surface, where bond scissions, isomerizations, hydrocarbon exchange and so on, yield lower olefins, paraffin, iso-olefins, and aromatics.

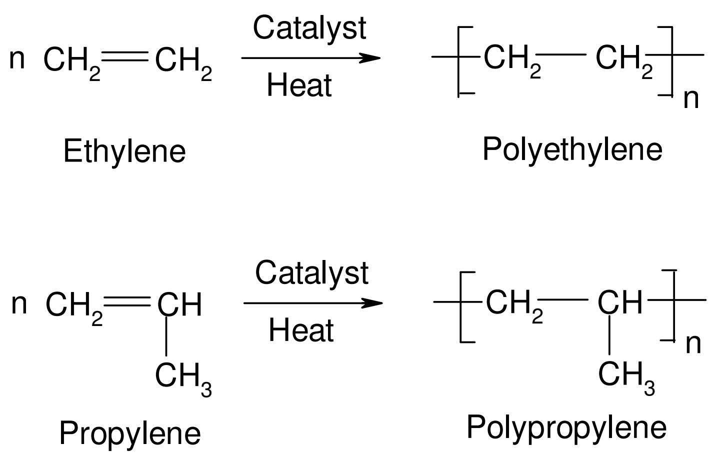
Petroleum refining is a very developed process and every emission from refinery is highly controlled, so that it never exceeds the standard limits. Different types of emissions and their monitoring and control measures are discussed below.

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 etc.; but such an approach runs the risks of increasing Particulate Material (PM) 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*: Particulates can be a 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 generation 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 (VOC) 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, rainwater run-off, and cooling water. The minimum treatment is to remove the free oil from the water.

Polymerization of Ethylene to Produce HDPE

The polymerization of ethylene or propylene is carried out under heat and pressure using Zeiglar-Natta oil catalysts or Metallocene catalysts. The reaction involved can be given as



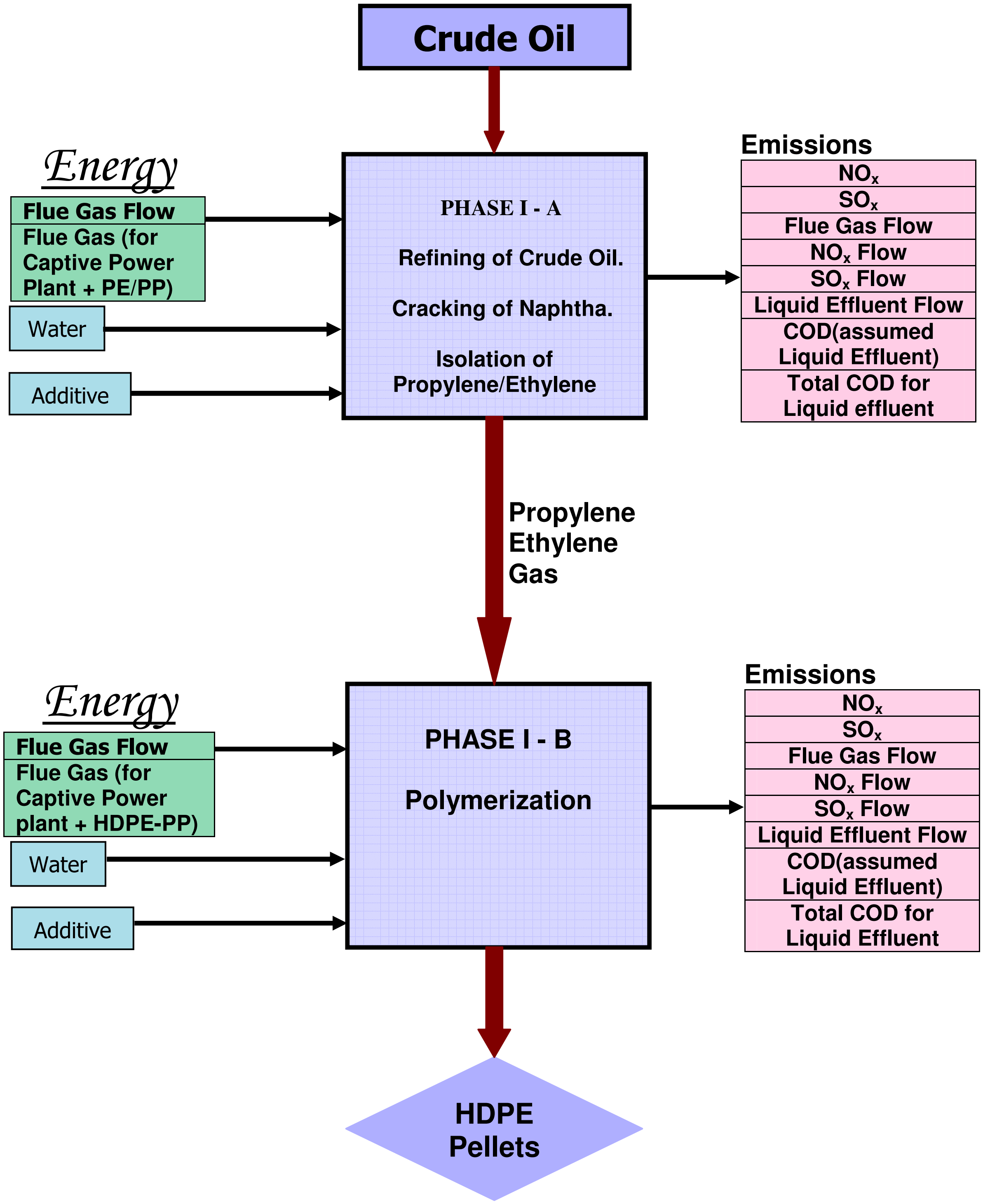
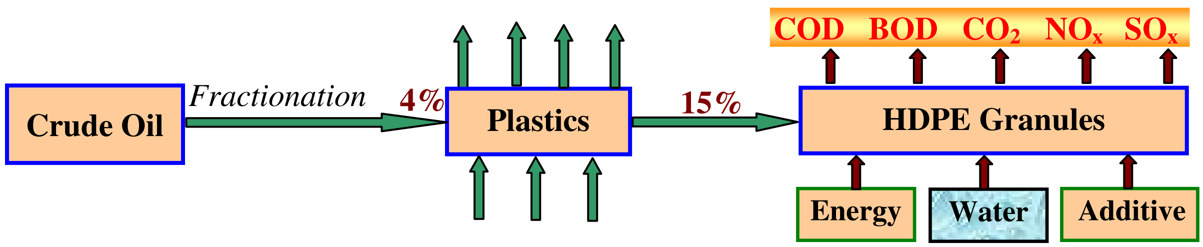


Figure 2.6: Flow chart of input and output during production of PP-HDPE Pellets.

LIFE CYCLE INVENTORY DATA FOR PRODUCTION OF HDPE GRANULES

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



Energy Required

The energy requirement at different stages of production and distribution of HDPE granules and types of fuel used to generate such energy are listed in Table 2.6.

Table 2.6: Gross primary fuels required to produce 1 kg of HDPE (Totals may not agree because of rounding)

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	1.42	1.04	<0.01	<0.01	2.46
Oil	0.69	13.93	0.09	34.82	49.53
Gas	3.54	6.41	0.24	13.70	23.88
Hydro	0.53	0.47	<0.01	-	1.00
Nuclear	2.17	1.16	<0.01	-	3.33
Others	0.13	-	-	-	0.13
Total	8.48	22.59	0.33	48.52	79.92

Gross energy required to produce 1 kg of PP/HDPE: 79.92

Water Required

Gross water resources required to produce 1 kg of PP-HDPE: 55

RAW MATERIALS REQUIRED

The requirement of gross feedstocks and primary fuel for the production of HDPE is given in Table 2.6 and the gross raw material requirement in Table 2.7

Table 2.7: Gross raw materials in mg required to produce 1 kg of HDPE.

Raw material	Input in mg
Air	120,000
Bauxite	36,00
Bentonite	25
Iron	180
Limestone	960
Nitrogen	65,000
Oxygen	39
Sand	130
Sodium chloride	33,000
Sulfhur (bonded)	160
Sulfhur (elemental)	330

Table 2.8: Gross feedstocks and primary fuels to produce 1 kg of HDPE.

Fuel type	Input in g
Crude oil	1,100
Gas/Condensate	450
Coal	88

Emission

The data on air, solid, and water emissions in the process of production of HDPE are presented in Tables 2.9, 2.10, and 2.11 respectively:

Table 2.9: Gross air emissions in grams arising from the production of 1 kg of HDPE. (Totals may not agree because of rounding)

Emission	From fuel production (g)	From fuel use (g)	From transport operations (g)	From process operations (g)	From biomass use (g)	Total (g)
Dust	1.50	0.33	0.002	1.1	-	2.9
CO	0.31	0.49	0.023	0.005	-	0.820
CO_2	640	1100	5.900	13.00	-3.40	1700
SO_x	3.70	9.90	0.081	0.020	-	14.00
NO_x	4.80	5.10	0.044	0.038	-	9.900
Hydrocarbons	0.49	0.77	0.013	4.600	-	5.900
Methane	4.40	1.20	-	0.110	-	5.700
HCl	0.05	0.001	-	<1	-	0.048
Metals	0.001	0.007	-	-	-	0.008
Aromatic HC	-	-	-	0.140	-	0.140
Hydrogen (H_2)	-	-	-	0.100	-	0.100

Table 2.10: Gross solid waste arising from the production of 1 kg of HDPE.

(Totals may not agree because of rounding)

Type	From fuel production (g)	From fuel use (g)	From process operations (g)	Totals (g)
Mineral	17.00	-	57.0	74.00
Mixed industrial	0.330	-	2.60	2.90
Slags/ash	4.70	0.17	0.98	5.80
Inert chemical	-	-	0.54	0.54
Regulated chemical	0.090	-	7.70	7.80
To incinerator	-	-	0.29	0.29

Table 2.11: Gross water emissions arising from the production of 1 kg of HDPE

(Totals may not agree because of rounding)

Emission	From fuel production (mg)	From fuel use (mg)	From transport operations (mg)	From process operations (mg)	Totals (mg)
COD	4	-	-	200	200
BOD	3	-	-	150	150
Acid (H^+)	1	-	-	46	47
Dissolved solids	260	-	-	84	350
Hydrocarbon	6	<1	-	45	51
NH_4	1	-	-	10	11
Suspended solids	25	-	-	2000	2100
Phenol	3	-	-	1	4
Ca^{+++}	-	-	-	21	21
Fe^{++}/Fe^{+++}	-	-	-	3	3
Mg^{++}	-	-	-	3	3
Na^+	-	-	-	370	370
Metals - unspecified	<1	-	-	48	48
NO_3^-	-	-	-	6	6
Other nitrogen	<1	-	-	8	8
Cl^-	-	-	-	340	340
F-	-	-	-	18	18
SO_4^{--}	-	-	-	49	49
CO_3^{--}	-	-	-	25	25
Phosphate as P_2O_5	-	-	-	1	1
Detergent/oil	-	-	-	68	68
Dissolved organics	-	-	-	27	27
Other organics	-	-	-	2	2
Sulphur/ Sulphide	-	-	-	5	5

PRODUCTION OF HDPE CANS

The production process of HDPE cans is schematically presented in Figure 2.7.

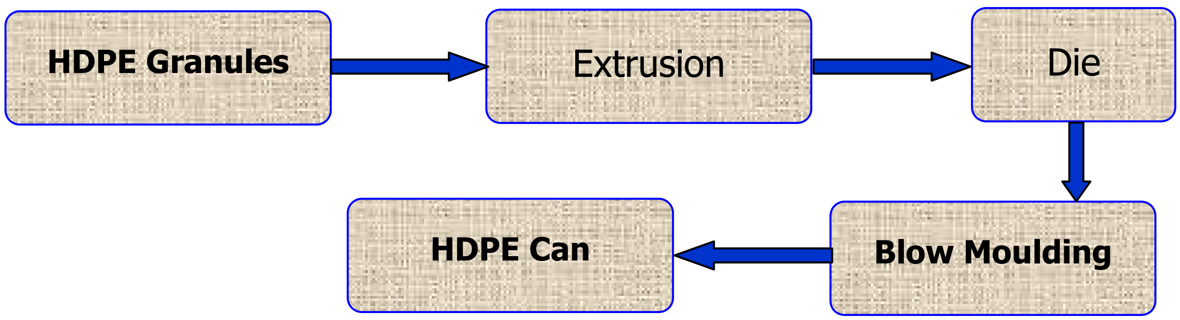


Figure 2.7: Flow Chart for Production of HDPE Cans from Granules.

Process for Production of HDPE Cans

Blow moulding is a method of forming hollow articles out of thermoplastic materials.

Blow moulding is a process of forming a molten tube of thermoplastic material, then with the use of compressed air, blowing up the tube to conform to the interior of a chilled blow mould. The most common methods are extrusion, injection, and injection-stretch blow moulding.

The continuous-extrusion method uses a continuously running extruder with a tuned die head that forms the molten plastic tube. The tube is then pinched between two mould halves. A blow pin or needle is inserted into the tube and compressed air is used to blow up the part to conform to the chilled mould interior. Accumulator-extrusion is similar, however, the molten plastic material is accumulated in a chamber prior to being forced through a die to form the tube.

Injection blow moulding is a process of injection moulding a preform (similar to a test tube), then taking the tempered preform to a blow mould to be filled with compressed air to conform to the interior of the blow mould. Injection-stretch blow moulding can be a single-stage process similar to standard injection blow moulding, by adding the element of stretch prior to blow forming. Also, a two-step process is possible, where a preform is made in an injection moulding machine, then taken to a reheat-stretch blow moulding machine for preform reheating and final blow forming in a blow mould.

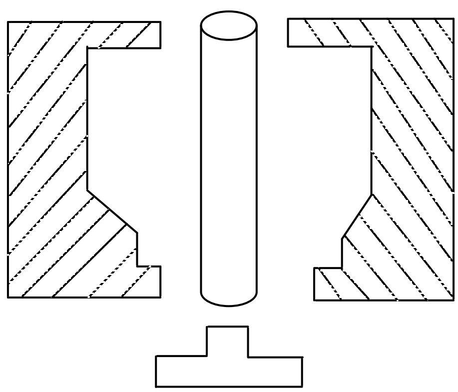
Blow Moulding Process

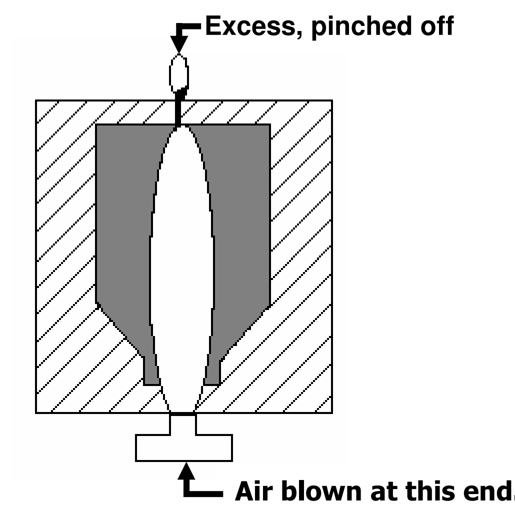
Blow moulding is an important processing method for making hollow articles and those with curves such as bottles, cans, etc.

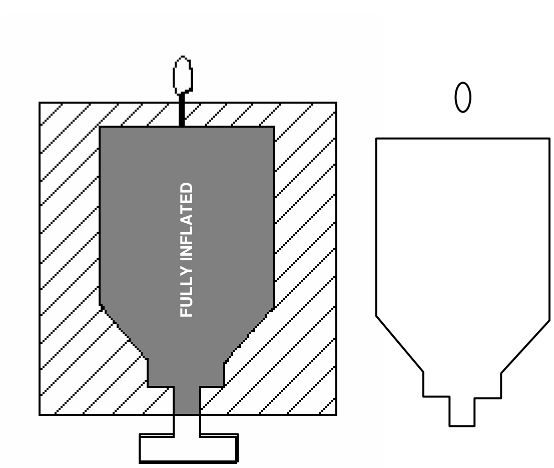
The process involves the formation of a parison – which is a preshaped sleeve usually made by extrusion.

- The parison is engaged between two mould halves and air is blown into it (like a balloon), which causes the parison to expand and take the shape of the mould.
- The polymer solidifies in the cold mould since the mould walls are kept cold.
- The finished article, which is hollow, is rejected.

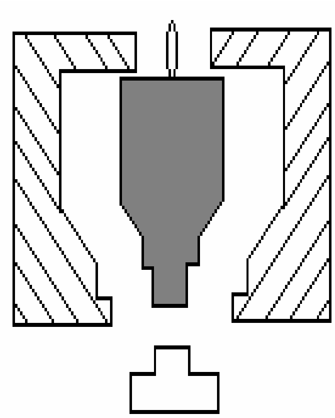
The size of the bottles can range from 1 ml to over 2000 liters.





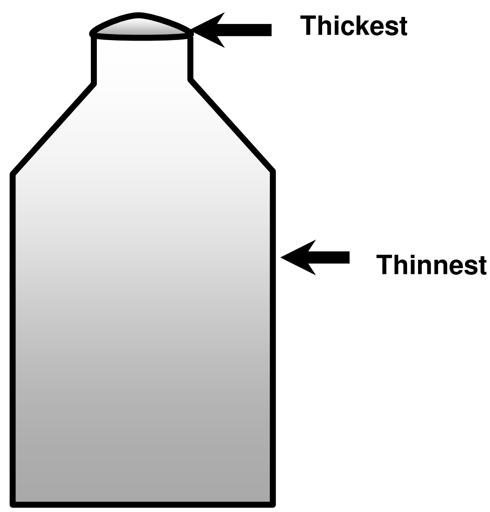


Inflated & Cooling With Air Pressure



Some points to note:-

1. The wall thickness of the bottle wall varies due to differences in the diameter of the hollow bottle.

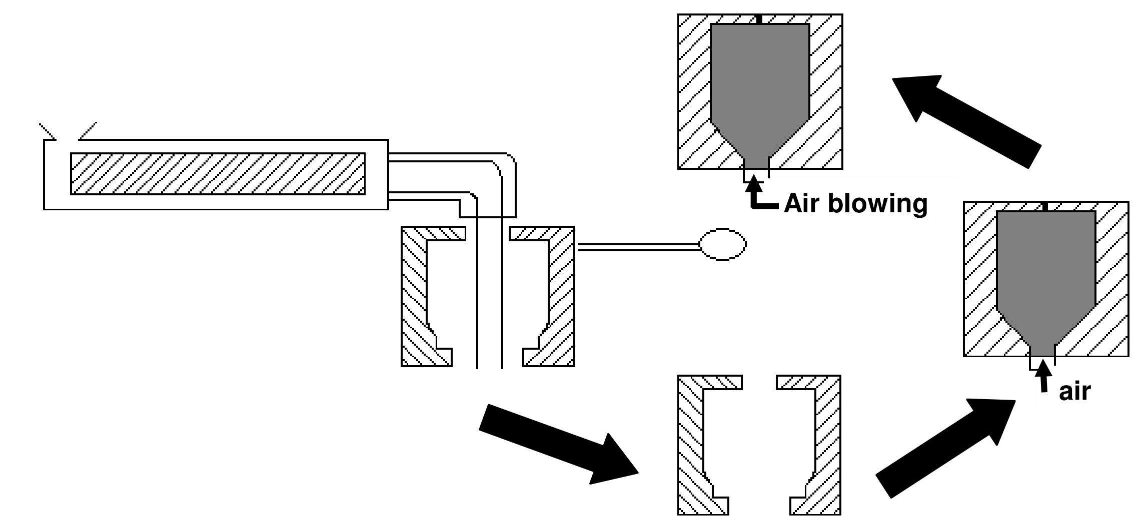


The parison should be designed to give strength to the thinnest section. Strength can be improved by ribbing along the bottle wall – keeping the wall thickness low.

2. Temperature should be chosen to give a good adhesion at the pinching place. Pinching causes a weld line, making it the weakest point for failure.
3. Blowing process is fast but cooling is slow. Injecting liquid CO_2 or high-pressure air after blowing can enhance rate of cooling.
4. Free hanging parison formation is limited in length due to sagging and parison deformation.
   Parison forming is very sensitive to rheological properties and hence to temperature.
5. The matching of the moulds must be excellent otherwise one gets a mould line and another place for possible failure – especially when wall thickness is low.
6. Practically all thermoplastics can be blow molded.

Extrusion Blow Moulding

a. **Intermittent:** One parison is extruded at a time with discontinuous extrusion.
b. **Continuous:** Parison(s) are extruded in a continuous tube form. The mould moves up as the parison extrudes into it and then pinches it and moves away making room for the next mould.

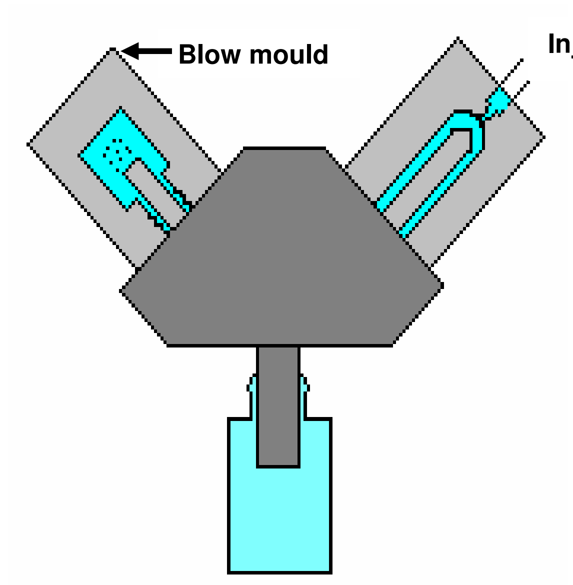


Rate of extrusion can be programmed to result in a parison of varying thickness to give a bottle of devised uniform thickness.

This can also be done by varying the die gap and extruding the polymer at a constant rate.

Injection Blow Moulding

- Parison is formed by injection of the polymer around a hollow steel rod mandrel. The parison is moulded with the threading.
- This then is blown to produce a bottle with no scrap at either side.
- This parison thickness distribution is determined in the injection mould without need for additional control.
- The hollow mandrel along with the parison can move from the injection moulding to blow moulding.
- The parison is sometimes made of a length smaller then that of the bottle - Mandrel pushes it to the required length along with blowing – can get biaxial orientation.

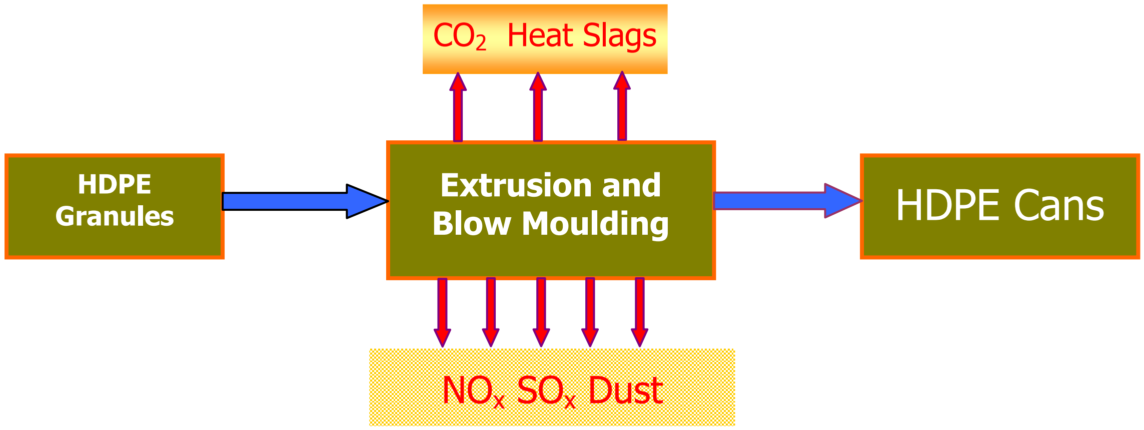


Comparison between Extrusion and Injection Blow Moulding:-

EXTRUSION	INJECTION MOULDING
1. Pinch Mark	1. No Pinch Mark
2. Weld line	2. No weld line
3. One Directional stretching.	3. Biaxial stretching possible.
4. Difficult to control thickness variation.	4. Easy to control thickness variation.
5. Fast process.	5. Relatively slow
6. Less expensive	6. More expensive
7. Lower/Medium quality bottles PE, PP, PVC.	7. High quality bottles PET.
8. Large articles possible.	8. Small articles/bottles
9. Cost of moulds etc. low	9. Cost of moulds high.
10. Adjustable weight control.	10. Fixed weight
	11. More accurate neck finish dimensional.

HDPE - Stiff bottles, toys, cases, drums
LDPE - Flexible bottles
PP - High Temperature bottles and cases such as Hose used for sterilization.
PVC - Clear bottles, oil resistant container

LIFE CYCLE INVENTORY DATA FOR PRODUCTION OF HDPE CANS



Energy Required

Table 2.112: Gross primary fuels required to produce 1 kg of HDPE cans (Totals may not agree because of rounding)

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	4.44	2.13	<0.01	<0.01	6.57
Oil	0.87	-0.2	0.19	-4.46	-3.6
Gas	2.16	9.7	-0.22	5.69	17.33
Hydro	-0.13	-0.09	<0.01	-	-0.22
Nuclear	2.76	0.1	<0.01	-	2.86
Others	0.02	-2.03	-	2.5	0.36
Total	**10.12**	**9.61**	**-0.01**	**3.59**	**23.3**

Gross energy required to produce 1 kg of HDPE cans: 23.3 MJ/kg

Raw Materials Required

Table 2.13: Gross primary fuels required to produce 1 kg of HDPE cans.

Fuel type	Input in mg
Crude oil	-1,00,000
Gas/Condensate	2,70,000
Coal	2,32,000

Table 2.14: Gross raw materials required to produce 1 kg of HDPE cans.

Raw material	Input in mg
Air	1,30,000
Bauxite	33,600
Bentonite	3
Iron	2400
Limestone	240
Nitrogen	30,000
Oxygen	61
Sand	-10
Sodium chloride	30,000
Sulfur (bonded)	130
Sulfur (elemental)	260

Gross water resources required to produce 1 kg of PP-HDPE woven sacks: 233

Emissions

Table 2.15: Gross air emissions in mg arising from the production of 1 kg of HDPE cans.

Emission	From process operations (mg)
Dust	-1029
CO	67
CO_2	2800
SO_x	89
NO_x	27
Hydrocarbons	-3300
Methane	1290
HCl	<1
Metals	<1
Aromatic HC	-137
Hydrogen (H_2)	50

Table 2.16: Gross solid waste in mg arising from the production of 1 kg of HDPE cans

Type	From process operations (mg)
Mineral	-49,600
Mixed industrial	-700
Slags/ash	220
Inert chemical	-10
Regulated chemical	3300
To incinerator	261

Table 2.17: Gross water emissions in mg arising from the production of 1 kg of PP-HDPE woven sacks

Emission	From process operations (mg)
COD	290
BOD	88
Acid (H^+)	10
Dissolved solids	3
Hydrocarbons	1
NH_4	-1
Phenol	0
Al^{+++}	18
Na^+	-70
NO_3^-	13
Other nitrogen	1
Cl^-	1060
SO_4^{--}	9
CO_3^{--}	7
Phosphate as P_2O_5	3
Dissolved organics	39
Other organics	0
Sulphur/Sulphide	-4

Table 2.18: Energy consumption during production of tin cans used for packaging one million ton of "Lube Oil"

Phase	Material required (tonnes)		Energy (GJ)	
	Per Tin Can (5 lts)	For 1 mT lube oil packaging	Per Tin Can (5 lts)	For 1 mT lube oil packaging
Phase I: Production of HDPE	**275×10^{-6}**	63218.391	21.98×10^{-3}	5052873.58
Phase II: Production of HDPE cans	**275×10^{-6}**	63218.391	6.41×10^{-3}	1472988.51
Total	-	-	32.5×10^{-3}	6525862.09

USAGE (PACKAGING AND TRANSPORTATION)

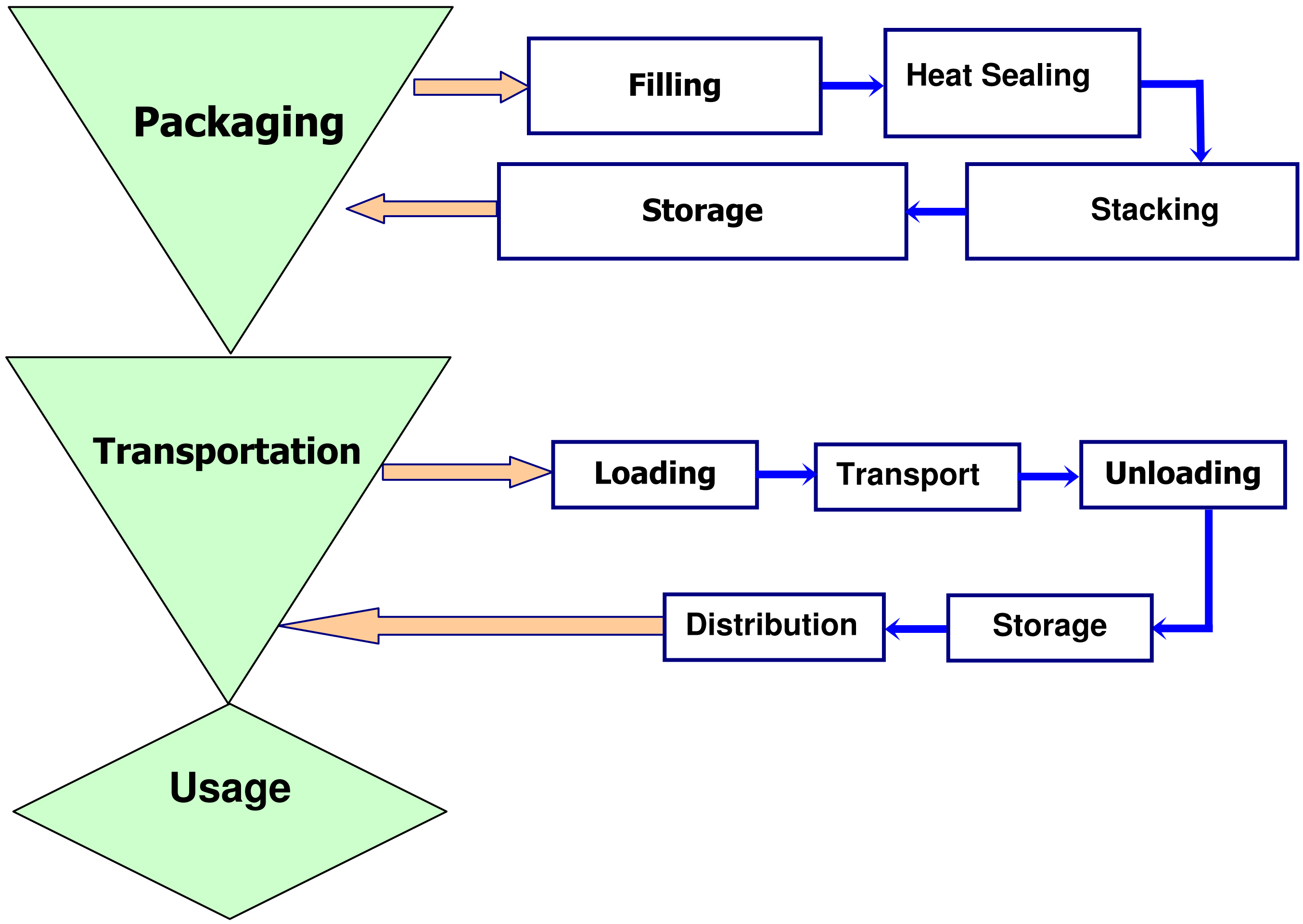


Figure 3.1: Flow Chart for Usage (Packaging & Transportation)

In this part of the report, initially brief description is given for production of lube oil in India and the calculation are carried out for packaging of packed Lube oil produced/manufactured per annum. The case studies involve packaging Lube oil in tin cans and HDPE cans. Comparison has been made in terms of excess truckload (trips) require to transport packed Lube oil in different packaging materials. The total fuel, energy required and total emissions generated are compared.

Packaging

In case of lube oil packaging, the basic requirement for packaging material should be

- To prevent contamination of the oil from the packaging material (or its constituents)
- Water resistance
- Good Strength
- Should not impart colour to the Lube Oil.
- Should not react with Hydrocarbon and other constituents of Lube oil

Other factors deciding the choice of the packaging materials are

- Better cost economics
- Easy availability of the packaging material
- Reusability to improve overall cost economics

Tin was a choice, when alternative packaging options did not exist. HDPE cans on the other hand provide the most cost effective and functionally superior alternative to traditional packaging alternatives.

Life Cycle Inventory Data for Packaging of 'Lube oil'

Table 3.1: Amount of Packaging Material required

	Tin cans	HDPE cans
Material required (tonnes)	86206.897	63218.391
	Energy (GJ)	**Energy (GJ)**
Phase I: Production of raw material	3846019.56	5052873.58
Phase II: Production of cans	3638535.421	1472988.51
Total	7484554.981	6525862.09

Transportation

Road is a major mode of Packed Lube oil transport. Besides truck for long distances, for local distribution is done in a variety of sizes ranging from small petrol driven pick-up to large diesel powered vehicles. Not surprisingly, the energy requirements of these vehicles vary considerably. 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 requirement 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.

In this report, a truck with average fuel efficiency of 3.05 km/lit, has been considered as the standard vehicle for transportation of bulk commodities. The truck runs on diesel fuel and can carry 9MT of load.

The truck causes pollution while the fuel burns in the engine and from evaporation of the fuel itself. The main pollutants contributed by the trucks 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 truck can be classified according to the sources of emission. The amount of emissions from a truck is presented in Figure 4.2 and health hazards are presented in Table 4.2.

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 problem.

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 parameter 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 carburettor. 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 truck is running.

Hot Soak: The engine remains hot for a period of time after the truck 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 Truck:

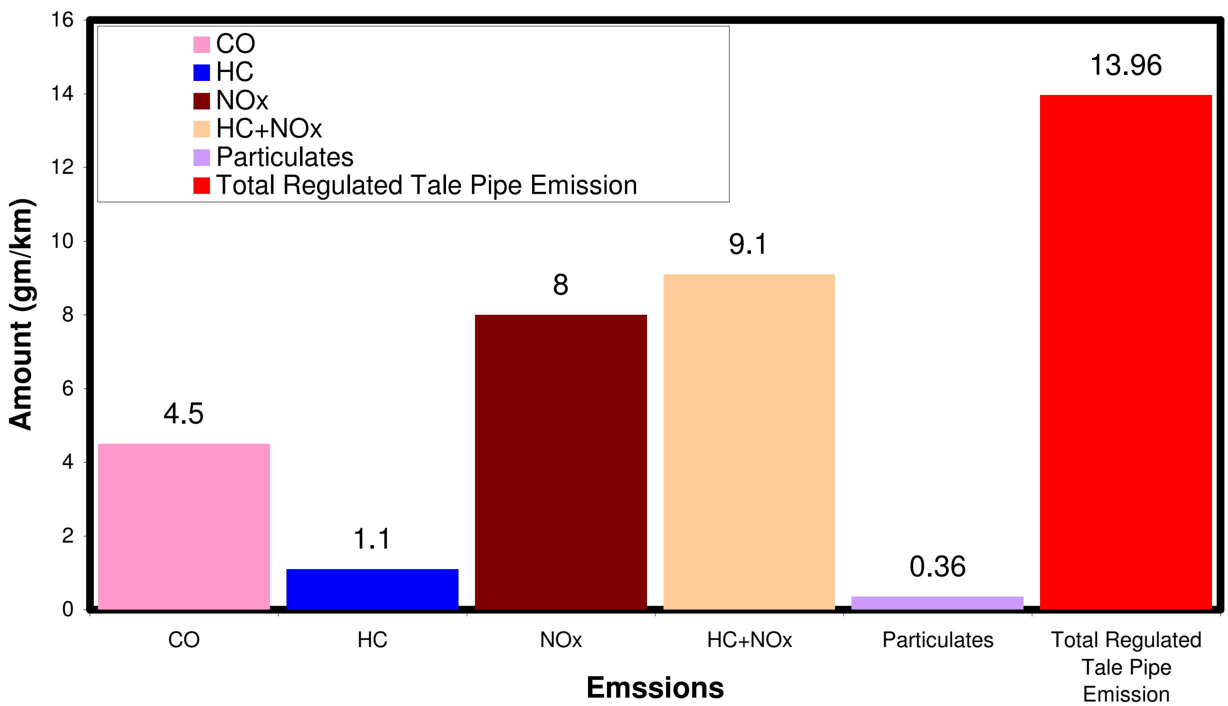


Figure 3.2: Different emissions from a truck

Table 3.2: 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 Bulk Commodities

Table 3.3: Number of truckloads (trips) required, excess fuel and energy consumption during transportation of 'Lube oil'

Lube oil 1Mt	Wt. of Packaging Material Required	Total weight to be carried (Wt of Food grains + Wt of Cans)	Total number of Trucks (truckloads) required
In case if the total packaging is carried out in Tin Cans			
5 lt lube oil (4.35 kg) in 375 g tin can	86206.897 ton	1086206.897 ton	120690
In case if the total packaging is carried out in HDPE			
5 lt lube oil (4.35 kg) in 275 g HDPE can	63218.391	1063218.391	118135

Energy Required:

The total energy requirement for transportation of all the bulk commodities in different packaging materials are given in the following table. It can be seen from table the total loss of energy because of packaging in tin cans comes to **4691147 MJ** in excess than compared to that of HDPE cans.

Table 3.4: Excess Energy and Fuel Required for Transportation

Lube oil 1 million tonne	Total number of truckloads required	Excess fuel required* (liters)	Excess energy required* (MJ)
Tin cans	120690	**83770.49**	**4691147.5**
Plastic cans	118135	Taken as basis	Taken as basis

*per 100 km distance

Excess Environmental Burden

Excess fuel required in the case of packaging of all the bulk commodities in tin or paper cans will cause sever environmental problem in the transportation as the amount of emissions generated per annum will be very high. Figure 5.16 presents the excess burden on the environment because of use of tin or paper cans.

Table 3.5: Excess Emissions during Transportation of 1million metric ton of 'Lube oil'

Emissions	Amount* gm/km	Total* (kg/lakhtonne)	
		Tin Cans	HDPE Cans
CO_2	781	199545.5	Taken as basis
CO	4.5	1149.75	Taken as basis
HC	1.1	281.05	Taken as basis
NO_x	8	2044.00	Taken as basis
HC+ NO_x	9.1	2325.05	Taken as basis
Particulates	0.36	91.98	Taken as basis
Total regulated tail pipe emission	13.96	3566.78	Taken as basis

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

Excess Distance Covered: 255500 km
Excess Fuel Consumed: 83770.49 liters
Excess Energy Consumed: 4691.148 GJ

WASTE MANAGEMENT

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.

The Organization for Economic Cooperation and Development (OECD) defines waste in general terms as: 'Unavoidable material for which there is currently or no near future economic demand and for which treatment and/or disposal may be required'. The United Nation Environment Program (UNEP) defines waste as: 'objects which the owner does not want, need or use any longer, which required treatment and/or disposal'. The European Community broadly defines waste as: 'any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of the national law in force'.

Waste management in case of bulk commodity packaging materials involves four different techniques:

- Reuse
- Recycle
- Landfill
- Waste to energy

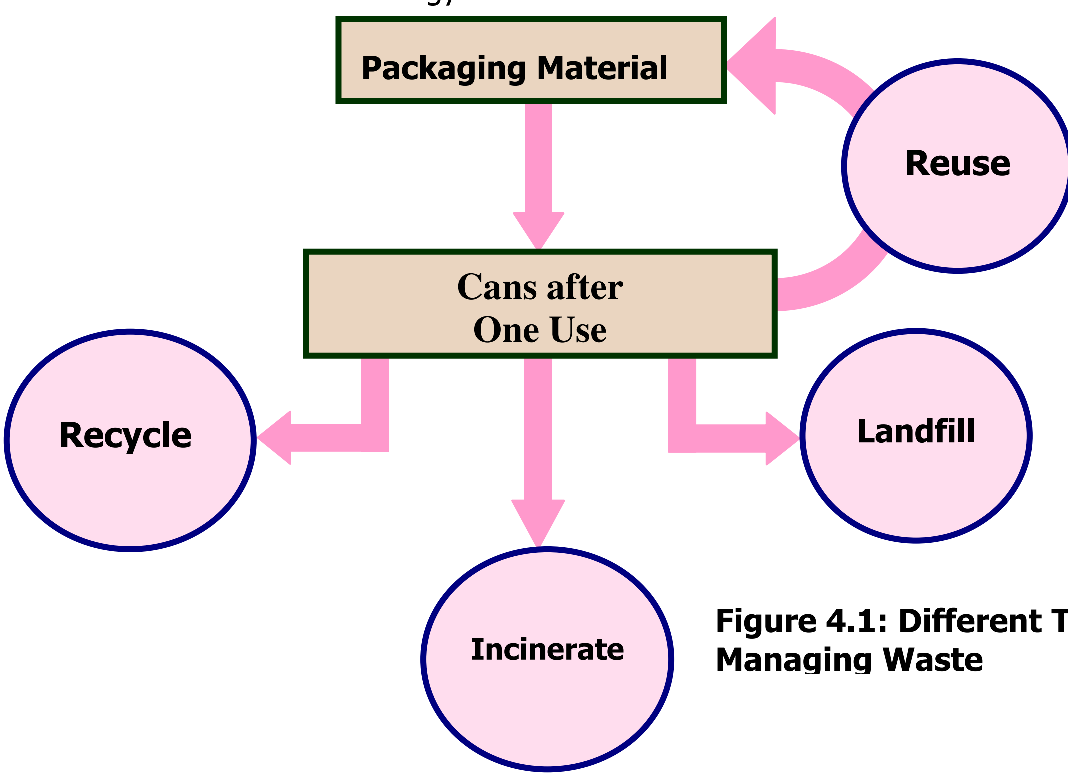


Figure 4.1: Different Techniques of Managing Waste

In case of packaging material used in bulk commodities, the waste generated after one packaging does not go to the mainstream of general waste. The bags are reused, recycled or can be made to go for landfilling or incineration.

Generation of Less Waste: Concept of 'More with Less'

The Brundtland report of the United Nations, Our Common Future (WCED, 1987), clearly explained how sustainable development could only be achieved if society in general and industry in particular, learn to produce 'more from less'; more goods and services from less of the resources, while generating less pollution and waste.

In this era of 'green consumerism' (Elkington and Hailes, 1988; Elkington, 1997), this concept of 'more from less' has been taken up by industry. This has resulted in a range of concentrated products, light-weighted packaging, reduction of transport packaging and other innovations (Hindle et al, 1993; IGD, 1994; EPU, 1998). Production as well as product changes have been introduced, with many companies using internal recycling of materials as part of solid waste minimization schemes.

All of these measures help to reduce the amount of solid waste produced, either as industrial, commercial or domestic waste. In essence, they are improvements in efficiency, i.e., 'eco-efficiency', whether in terms of materials or energy consumption. The cost of the raw materials and energy and rising disposal costs for commercial and industrial waste will ensure that waste reduction continues to be pursued in industry for economic as well as environmental reasons.

'Waste minimization', 'waste reduction' or 'source reduction' is usually placed at the top of the conventional waste management hierarchy. In reality, however, source reduction is a necessary precursor of effective waste management rather than part of it. Source reduction will affect the volume and to some extent the nature of the waste, but there will still be waste for disposal

As shown in the previous chapter on usage, the amount of packaging material required per MMT of Lube oil is much higher in case of use of Tin cans than compared to HDPE cans. This extra amount of material used will put extra burden on the waste management at the end of the life of packaging material. The use of tin cans goes against the concept of 'More with Less', as one is required to use more packaging material packed with lesser commodities.

REUSE

Tin Cans

HDPE Cnas

Tin cans and HDPE cans after first use, cannot be reused to pack lube oil, as they will result in a significant contamination by the oil and dust left (residue). These cans cannot be used for packaging any other type of oil or material.

Waste Disposal Techniques

The three principal disposal methods - recycling, incineration and landfill - are not so much alternative options, dealing with the totality of the waste arising, as complementary techniques, each being most effective with a specific part of the total waste. Hence, to employ the techniques in parallel is to produce the most effective economic and environmentally sensitive solution to the specific needs industry and society at large. This is the basis of an integrated waste strategy.

Recycling

Tin Cans

HDPE Cans

The availability of long-term outlets for the sale of recycled material is prime requirement for the adoption of this technique. Materials collected for recycling into new products is often of relatively low bulk density, when collected, and transportation costs can be prohibitive if the reception points are not suitably located. The quantity of material to be sold is very relevant and this is best achieved by the collection of community source separated waste in order to avoid contamination. The materials to be recycled are best handled and processed in a central plant catering for communities of between 250000 and 500000 people. Only at this level can effective tonnages of each material be brought together and scale benefit be obtained from mechanization of the sorting processes. Depending on the market for paper and cardboard, the recycled materials could amount to between 20% and 40% of the total waste arising.

Recycling of Tin Cans

On account of its magnetic property, packaging steel can easily be separated from lightweight packaging and other materials. In Germany, this takes place by means of magnetic sorting in the sorting plants managed by the Dual System and is in general a fully automated, and therefore cost-efficient and highly reliable process. 98 % of the packaging steel collected is separated out from other waste types and supplied to steelworks for recycling.

The packaging steel collected through the Dual System is compressed and transported to steel manufacturers, who melt down the tinplate scrap, together with other types of packaging steel scrap and pig iron depending on the particular manufacturing process, turn this raw product into new, high-quality steel.

The tin coating does not pose a problem as far as recycling is concerned, for the tin content in tinplate can scrap is exceptionally low, i.e. in the order of thousandths (approx. 2 g per m^2 steel sheet). Moreover, the half a million metric tonnes of packaging steel recycled each year only constitute a tiny amount of the total annual volume of scrap used in the steel industry, which is between 15 and 17 million metric tonnes. Packaging steel scrap is generally mixed with other sorts of scrap in the steelworks. Indeed packaging steel scrap is actually sought after as an alloying agent in the production of tin-alloyed steel goods (e.g. for transformer sheets).

The aluminium lid on tinplate beverage cans is not a problem during the recycling process. The aluminium oxidizes as the steel is melted down and blends with the resulting slag, which is used in the construction industry. During this process, energy is released and, in turn, used to melt down more scrap.

Paints and lacquers on packaging steel pose no problems when it comes to tinplate recycling. This is partly attributable to the fact that the recycling process takes place at approximately 1600°C and at such temperatures dyes and lacquers are completely burnt away.

In 2001, 78 % of all packaging steel in Germany was recycled. The total consumption of tinplate amounted to 707,000 metric tonnes. The total volume recycled was 549,000 metric tonnes. By recycling beverage cans, food cans and other steel products, the use of raw materials can be minimized and energy saved. As a result, the savings that can be made, per metric tonne of recycled steel scrap, include 1.5 metric tonnes of iron ore, 665 kg of coal and approximately 200 kg of limestone.

Tinplate recycling

The process involves three steps:

- The delivery of scrap from can maker to treatment plant
- The treatment of scrap
- Delivery of de-tinned scrap to the point of use

The scrap is shredded and the tin coating removed chemically leaving a high-grade steel scrap that is washed and baled. The tin bearing solution is electrolyzed to recover the tin metal that is then melted and cast into ingots. The tin stripping agent is an aqueous solution of sodium nitrite and sodium hydroxide.

The amount of recovered material input that is lost in the reprocessing of tinplate is reported as 8.2% by Habersatter (1991); Porteous (1992) suggests a loss of 5% in the process up to the production of de-tinned washed steel. Taking the former value would mean that each tonne of recovered tinplate delivered to the reprocessors would produce 918 kg of recycled tinplate. The typical energy saving (when compared to the use of virgin materials) of around 18.59 GJ per tonne (using the BUWAL data). Comparisons of the amounts of emissions (including solid waste) associated with the processing of 1 tonne of recovered tinplate scrap versus production of an equivalent amount of tinplate from virgin are also presented.

Energy Saving per tonne of Tin Plate Recycled 18.59 GJ

Air Emission

Table 4.1: Gross air emissions in gm arising from the production of 1 kg of Tinplate from recovered materials

Emission	Totals (gm)
Particulates	1130
CO	4330
CO_2	1090000
SO_x	2730
NO_x	1730
N_2O	4.55
Methane	1920
H_2S	0
HCl	130
HF	14.8
Lead (Pb)	9.47
Copper	0.53
Chromium	0.19
Arsenic	0
Mercury (Hg)	0.024
Ammonia (NH_3)	1.81
Nickel	0.24
Cadmium	0.009
Zinc	0.17

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

Water Emission

Table 4.2: Gross water emissions in gm arising from the production of 1 kg of Tinplate of recovered materials

Emission	Totals (gm)
COD	170
BOD	460
Phenol	0.08
Chlorinated Hydrocarbons	0.499
Suspended solids	175
Total organic compounds	127
Al^{+++}	285
AOX	0.0013
Ammonium	2.65
Barium	23.4
Cadmium	0.0168
Chloride	4500
Chromium	3.14
Copper	1.71
Cyanide	0.0064
Iron	567
Lead	1.65
Mercury	0.02
Nickel	1.73
Nitrate	7.03
Phosphate	47.9
Sulfate	2970
Sulfide	0.01
Zinc	2.85
Arsenic	0.57
Fluoride	32

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

Recycling of HDPE Cans

There are two types of plastics recycling systems:

Primary recycling:

It involves using uniform, uncontaminated plastics waste to manufacture plastic products of same or similar types. Much fabricator scrap, commonly blended with virgin resin in various ratios, is used in primary recycling but sometimes used alone.

Secondary Recycling:

Postconsumer plastic bags are used for this type of recycling. This involves granulation, cleaning and sometimes recompounding and palletizing to form different products such as small packaging, brushes, scrubbers and twines (Figure 6.2). Other useful products that can be made from recycling of plastic bags are toys, detergent bottles etc.

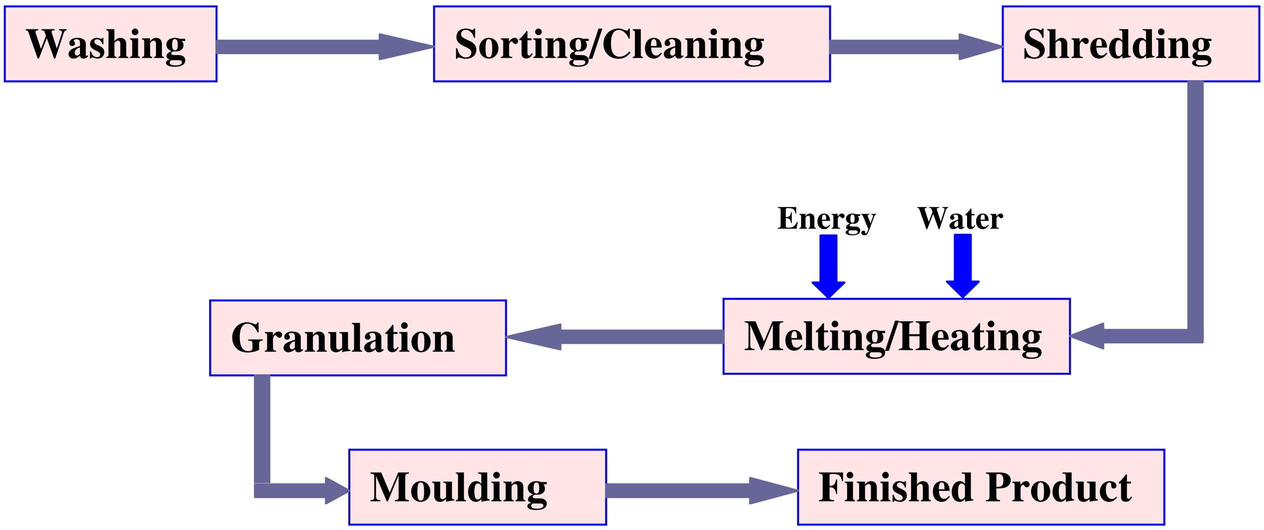


Figure 4.2: Different operations involved during Recycling of HDPE Cans

Incentives for using recycled plastics include ecological reasons, consumer demand, recycle content legislation and lower cost. Until recently, these incentives have had to be weighted against variable material composition, possibility of contamination, loss of mechanical properties due to degradation, lack of standards and variations in the supply. Now many of these problems have been solved through such measures as the use of sophisticated automated sorting, restabilization, implementation of recyclate quality standards and integrated collection networks. The three essential elements of plastics recycling are: (i) a stable supply source which involves reliable collection and sorting; (ii) an economical, proven and environmentally sound recycling process; and (iii) end-use applications for the recycled plastics which yield economic market values and capture consumer confidence. ***For all recycled products, a separate life cycle starts and therefore new cradle to plastic bags. The correct term to describe the life cycle analysis of plastic bags can be "cradle to cradle" as there is no grave for the bags.***

Table 4.3: Recycling of 1 kg of Packaging Material

	Recycled HDPE cans
Energy Saving* (MJ)	25.63
Emissions (g)	
CO_2	353
NO_x	0.98
SO_x	2.00
Solid waste (kg)	0.13
BOD	2.36
COD	4.62
Suspended Solid	-
Total Organic Compounds	-

** Compared to making the product by Virgin Material*

Table 4.4: Energy Savings in Recycling of Tin cans and HDPE cans used for Packaging of One Lakh Ton of 'Lube Oil

Phase IV: Waste Management	**Tin Cans**	**HDPE Cans**
Recycling Percent	**Energy Savings** (Thousand GJ/86206.897 ton)	**Energy Savings** (Thousand GJ/63218.391 ton)
100%	**1602.586**	**1620.287**
80%	**1282.069**	**1296.230**
60%	**961.552**	**972.172**

Incineration (Waste-to-Energy)

Tin Cans ✗

HDPE Cans ✓

The techniques for burning refuse have been improved immeasurably over recent years from the crude fixed cell incinerators of the 1930s. Incineration without energy recovery is not an environmentally acceptable solution since the material resources are simply destroyed without any effective recovery.

Incineration with heat and power generation overcomes this weakness and may be the most effective method of disposal for our major conurbations in the future. However, such a plant is not economic below an annual input of 0.25

million tonnes. This quantity of waste represent the arising from a population of nearly one million people and only in our major centers of population does this concentration of development exist within an effective transportation distance of the chosen site.

As already mentioned, emission standards for flue gases are going to be very stringent in the European Community countries, and these will only be met by a high capital investment in flue gas scrubbing equipment. Incineration will continue to be the most expensive of all the techniques.

Plastics and Waste-to-Energy

Plastics for the most part are derived from petroleum and natural gas and have heating values measured in British thermal units (BTUs) competitive with coal and heating oil and superior to wood, paper, and other biomass fuels. Because of their high heating value, the residual plastics in MSW provide an excellent fuel for modern waste-to-energy plants. Residual plastics mean those plastics that remain in MSW after some plastic is diverted from MSW for environmentally and economically sound material recovery. Even in communities with extensive recycling, residual plastics at less than 10 percent by weight of MSW can provide over 20 percent of the fuel value for a local WTE plant.

A detailed European study has recently documented the ability of plastics to improve combustion in a modern WTE plant. The study also looked at the contribution of plastics to air emissions. This was done by intentionally adding plastics to the regular MSW feed to the plant and carefully monitoring the release of pollutants. Plastics were shown to have no negative effect on air pollution loads to the environment. The study included a specific examination of dioxin and furan emissions.

Table 4.5: Incineration of 1 kg of Packaging Material as waste

	Tin cans	HDPE Cans
Energy Generated (MJ)	-	51.83

Table 4.6: Energy generated during Incineration of Packaging Material as waste used for Packaging One Lakh Ton of 'Lube Oil'

Phase IV: Waste Management	Tin Cans	HDPE Cans
Incineration	**Energy Recovered**	**Energy Recovered** (Thousand GJ/63218.391 ton)
100%	**Not Done**	**3276.609**
80%		**2621.287**
60%		**1965.965**

Landfill

Tin Cans ✗

HDPE Cans ✗

Lube oil packaging waste generally does not go for landfilling and therefore this technique of waste disposal has no significant meaning in context with the packaging material used in commodities like 'Lub oil' packaging. Modern techniques for landfill require the cell to receive the waste, to be lined with a leachate barrier formed of puddled clay and high-density polyethylene. The technology is expensive but is not the main obstacle to the establishment of future landfill sites.

Crude tipping practices of the recent past have deserved a hostile reception from the local communities. A 'not in my back yard' (NIMBY) syndrome in addition to the environmental damage foreseen by local residents from increased vehicle usage results in the major obstacle to future creation of landfill sites. However, new sites will have to be created, because without them organic as well as inorganic waste will have no effective disposal outlet. Landfill disposal costs will, in many countries, probably double or treble in the future.

The concerns over waste

The old concern – the conservation of resources

In 1972, the best-selling book limits to growth was published. It argued that the usage rates of the earth's finite material and energy resources could not continue indefinitely. The sequel, beyond the limits told the same story, but with increased urgency; raw materials are being used at a faster rate than they are being replaced or alternatives are being found. The result of such reports was the development of the concept of Sustainable Development. Sustainability requires that the natural resources be efficiently managed, and where possible conserved, but not to the detriment of the individuals quality of life.

The original concerns of Meadows et. Al., about the imminent depletion of natural resources has proved to be incorrect. For each raw material, the proven reserves in 1989 were greater than proven reserves in 1970. This is because 'proven reserves' are defined as reserves that could be extracted with today's technology and price structures. Technology and innovation have resulted in most resources being more available, at a lower extraction cost today than 20 years ago. Consumption has changed in favour of less material-intensive products and services-'eco-efficiency'. Energy efficiency has improved with technological advances and the recycling of many raw materials have increased the efficiency of material used. These factors have led to slow use of material than many economies. The per capita use of basic materials such as steel, timber and copper has stabilized in most OECD countries – and even declined in some countries for some products. This is not to argue that resources can never be depleted to unacceptable levels but in most cases, the time period required for this to happen is extremely long, allowing time for the implementation of technological developments.

The new concerns – pollution and the deterioration of renewables

The depletion of non-renewables is now not the urgent problem but two other concerns have become critical with respect to the 'need of future generations'. These are:

- The generation of pollution and wastes that exceed the ability of the planet's natural sinks to absorb and convert them into harmless compounds and
- The increased deterioration of renewables such as water, soil, forests, fish stock and biodiversity.

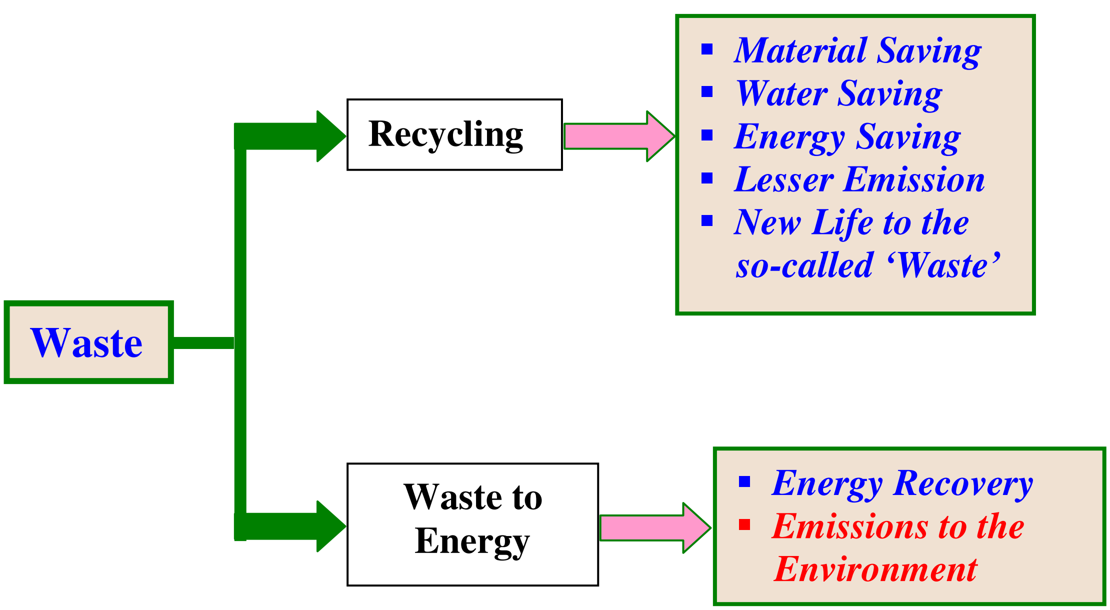
A Life Cycle Inventory Model for Integrated Waste Management:

The model's most obvious uses are waste management scenario optimization and comparisons. The actual data needs of the model are small, as wherever possible default data are provided. Although it must be emphasized that more data that can be supplied by the user to describe the waste management system under study, the more accurate the result will be. The model requires data on the number of inhabitant and household the study area and the amount of waste generated per person per year. It would tell waste characterization of the area under study. The goal of this model is to be able to predict the environmental burdens and economic cost of this specific waste management system. The scope of this model is to enable a Life Cycle Inventory of a specific waste management system to be carried out. The unit processes included within the model are waste generation, waste collection, sorting processes, biological treatment, thermal treatment, landfill and energy generation.

The calculations for life cycle inventory data were made using the IWM-2 model and then the values were averaged on per kg basis for different bulk packaging materials.

Table 4.7: Life Cycle Inventory table for Waste Management

	Reuse	Recycling	Incineration	Land filling
Tin cans	✗	✓	✗	✗
Plastic Bags	✗	✓	✓	✗



Conclusions

Detailed scenario of use of tin cans and plastic cans as packaging materials for 'Lube Oil' using life cycle analysis as the principal methodology has been covered in this study. Life cycle analysis using cradle to grave approach has been used to assess and compare the benefits for different 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.

The basis of this study has been considered as one million tonne of Lube Oil in keeping with the view of the consumption in order of magnitude.

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

1. It can be seen that production of tin cans requires more energy than plastic cans for packing equal amount of lube Oil. This is due to the higher weight of tin cans required to pack the same amount of lube oil. **The relative weight of only packaging material itself amounts to 86207 Mt for tin when compared with 63218 Mt of Plastic for packing one million tonne of Lube Oil.**

2. **Although energy consumption in the case of plastic in Phase I (production of raw material) is greater than that for the tin cans** due to high feedstock energy values of the polyethylene used to make plastic cans, **in the production of tin cans** (**Phase – II of the life cycle analysis) is found to be highly energy intensive and in this respect, plastic cans consume less energy.**

	Tin cans	**Plastic Film Bag**
Material Required (Mt)	**86207**	**63218**
Phases of Life Cycle Analysis	**Energy** (Thousand GJ)	**Energy** (Thousand GJ)
Phase I: **Production of Raw Material**	**3846.02**	**5052.87**
Phase II: **Production of Cans**	**3638.54**	**1472.99**
Total	**7484.55**	**6525.86**

3. Considering Phase – I and Phase – II together for packaging of one million tonne of Lube Oil the energy required to produce cans can be assessed as:

   i. **$Energy_{Tin\ cans}$ > $Energy_{HDPE\ cans}$ (~950 thousand GJ more for Tin cans)**

4. The pollution of water during the production of Plastic cans is negligible while it is very high in case tin cans.

5. **The release of chemicals into water is high for the production of tin cans as indicated by the high value of COD.** The COD and BOD values are found to be low in case of production of plastic cans.

6. **On the energy front during transportation there is considerable savings in the use of plastic cans for lube oil packaging** as plastic cans are lighter in weight 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.

7. **Reuse of tin cans and plastic cans is not the viable option** as this will lead to mixing of lube oil particles with the repacked material. Also being small in size it is not the common practice to reuse them.

8. **There is a considerable amount of energy savings in recycling of both tin cans and plastic cans of about ~1 x 10^6 GJ for 80% recycling compared to making the same product using virgin material.**

Phase IV: Waste Management	**Tin cans**	**Plastic cans**
Recycling Percent	**Energy Savings** (Thousand GJ/86207 ton)	**Energy Savings** (Thousand GJ/63218 ton)
100%	**1602.586**	**1620.287**
80%	**1282.069**	**1296.230**

9. **Incineration of plastic cans leads to considerable energy generation.** This is again due to very high calorific value of the HDPE used to manufacture plastic cans. The amount of energy generated is in the tune of 3277 thousand GJ for 100 % incineration. Recalculating the energy consumption in plastic cans, taking into account the energy generated during incineration, it can be said that plastic cans consume half the energy consumed by the tin cans.

Phase IV: Waste Management	**Tin cans**	**Plastic cans**
Incineration	**Energy Recovered**	**Energy Recovered** (thousand GJ/63218 ton)
100%	**Not Done**	**3276.61**
80%		**2621.29**

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