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Consultation on Downstream Petrochemical Industries in Developing Countries

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TECHNICAL REPORT:

NATIONAL STRATEGIES FOR THE DEVELOPMENT OF DOWNSTREAM PETROCHEMICAL INDUSTRIES IN THE DEVELOPING COUNTRIES*

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* The views expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has not been edited.

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1. INTRODUCTION & EXECUTIVE SUMMARY

1.1. Petrochemical products are not only desirable but also essential options in the pursuit to achieve a better quality of life. Products derived from petrochemical sources, viz., plastics, synthetic fibers, synthetic rubbers and various industrial chemicals are forming a part of the resource basket supplementing as well as complimenting various natural products like cotton, wool, paper, wood, metal etc.

1.2. These petrochemicals play an important role in the industrial economy of developing countries. Although in the world context, these petrochemicals have been in vogue for the last many decades and many of the products/markets have matured. They are still in the nascent/developing stage in most of the developing countries.

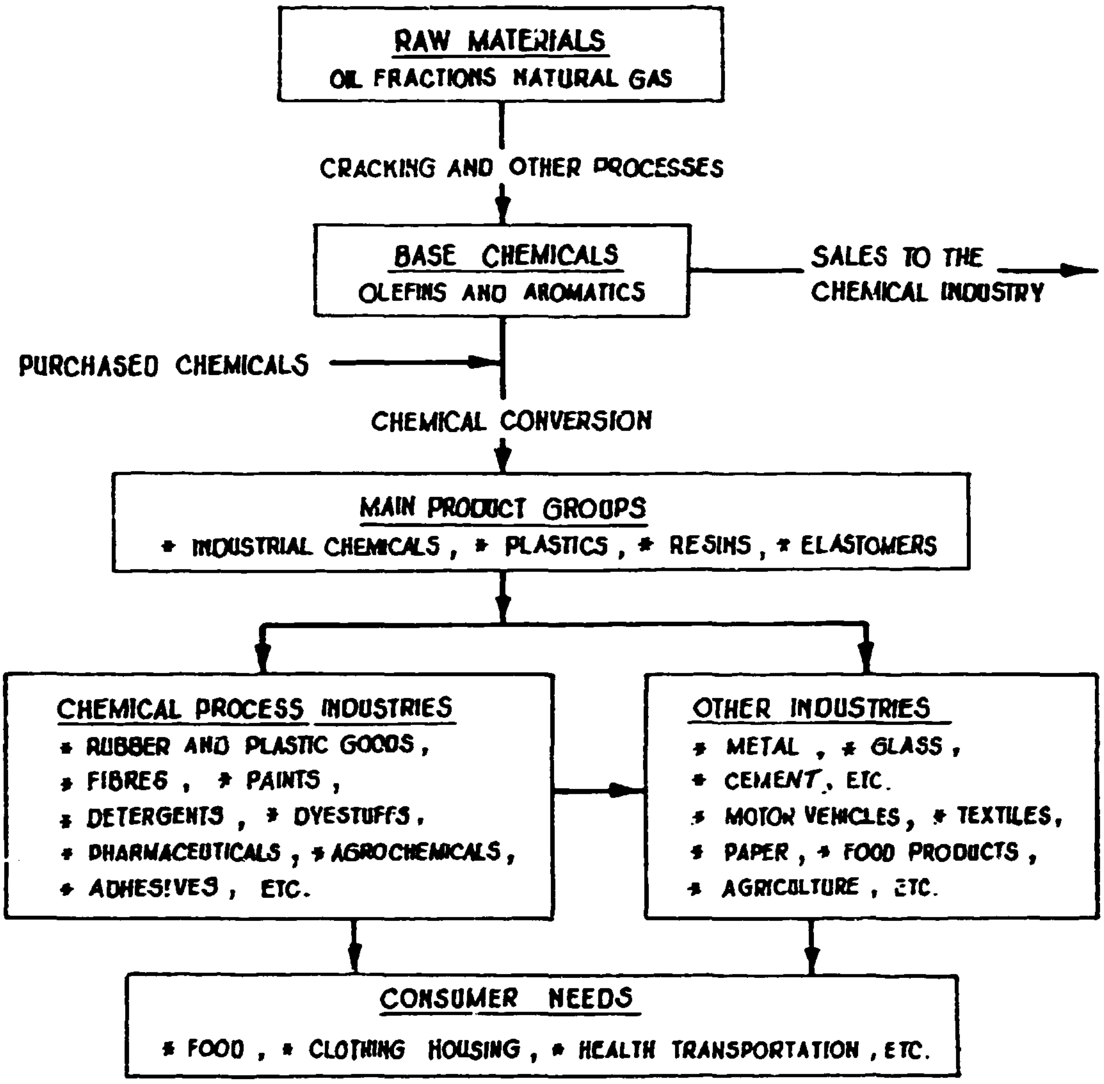
1.3. The petrochemical sector consists of six industries, viz., synthetic rubbers, synthetic fibers, organic petrochemicals, plastics, carbon black and surfactants. Further, following terms are defined to describe this field i.e. raw materials (feedstocks), primary and intermediate petrochemicals, petrochemicals end products and downstream industries.

1.4. Raw materials or feedstocks used for the manufacture of the basic petrochemicals include liquid (crude, distillate and NGL) and gaseous (natural gas, LPG) hydrocarbons as well as coal and biomass. Production, refining and processing of these materials for feedstock purposes is not included in petrochemistry. Primary or basic petrochemicals are the compounds manufactured from the raw materials (hydrocarbons and other) and include olefins, aromatics and syn gas. Olefins are the unsaturated hydrocarbons like ethylene, propylene, and butadiene. Aromatics are the unsaturated cyclic hydrocarbons which include benzene, toluene and xylenes. Syn gas is a mixture of hydrogen and carbon monoxide with or without nitrogen.

1.5. The integrated petrochemicals industry involves a whole range of technological processes (Fig.1.1F) and mostly originate from a few basic chemicals (Fig.1.2F).

1.6. Intermediates are derived from the basic petrochemicals. They are used for the manufacture of different end products or serving other industrial outlets These include such compounds as ethylene oxide, ethylene glycol, acetic acid, alkylbenzenes, terephthalic acid (PTA) and dimethylterephthalate (DMT), phthalic anhydride, methanol, monomers like vinyl chloride

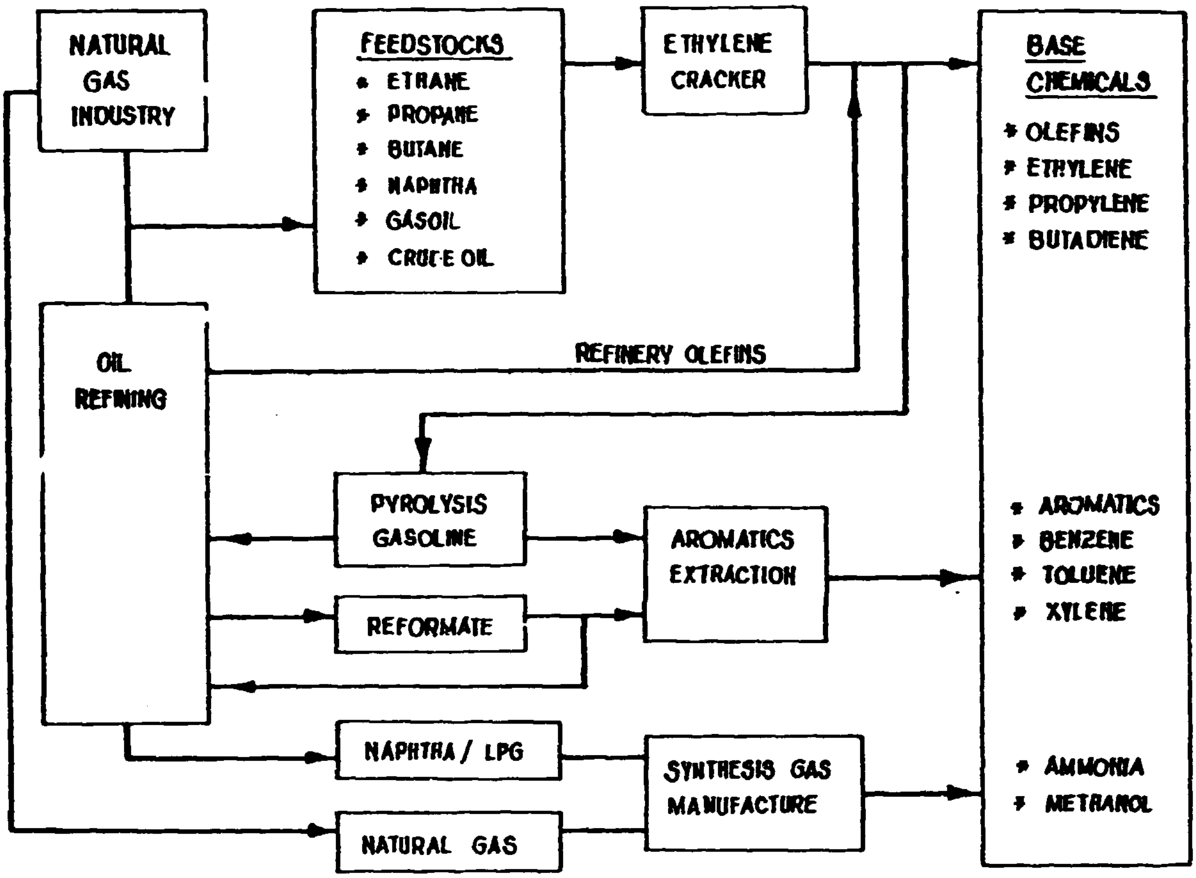
STRUCTURE OF THE PETROCHEMICAL INDUSTRY



THERE ARE THREE MAIN STAGES IN THE CHAIN BETWEEN RAW MATERIALS AND CONSUMERS. THE FIRST STAGE INVOLVES THE MANUFACTURE OF BASE CHEMICALS, USUALLY ON A VERY LARGE SCALE. THESE ARE CONVERTED INTO A RANGE OF PRODUCTS WHICH ARE SUBSEQUENTLY USED IN VARIOUS INDUSTRIES SUPPLYING CONSUMER GOODS. THE ACTIVITIES OF THE PETROCHEMICALS INDUSTRY INCLUDE THE MANUFACTURE OF BASE CHEMICALS, CONVERSION IN TO THE MAIN PRODUCT GROUPS AND TO SOME EXTENT PROCESSING OF FINISHED GOODS IN THE CHEMICAL INSUDTRY.

FIG. : 1 (1F)

MANUFACTURE OF BASE CHEMICALS



APART FROM SMALL QUANTITIES OF ETHYLENE, FROM ETHANOL, AND BY-PRODUCT BENZENE FROM COKE OVENS, ALL FEEDSTOCK FOR ORGANIC CHEMICALS IS DERIVED FROM OIL, GAS OR GAS LIQUIDS. THE NORMAL ROUTE FOR THE PRODUCTION OF OLEFINS IS THROUGH CRACKERS DESIGNED TO PROCESS SPECIFIC FEEDSTOCKS.

PROPYLENE AND BUTYLENE MAY ALSO BE AVAILABLE DIRECTLY FROM OIL REFINING PROCESSES OR CAN BE MANUFACTURED INDEPENDENTLY BY REMOVING HYDROGEN FROM PROPANE AND BUTANE. REFORMATE AND PYROLYSIS GASOLINE ARE THE MAIN FEEDSTOCKS FOR AROMATICS.

FIG. : 1 (2F)

(VCM), vinyl acetate (VAM), styrene and carbon black.

1.7. The range of petrochemical end products are truly wide and diverse. There are large varieties of plastics, both thermoplastics and thermosets. The major thermoplastics are LDPE, PVC, HDPE, PP, PS & ABS. The thermosets are PF, UF, MF, epoxy and unsaturated polyesters. Besides these, there are a large variety of engineering plastics and speciality polymers that have critical applications in areas requiring stringent performance criteria. The range of usage of plastics is also wide enough to encompass almost all facets of daily life as well as important sectors such as agriculture, transportation, communication, defence, aviation, space research and electronics.

1.8. The synthetic fibers from petrochemicals, viz., polyester, nylon, acrylic fiber have come to play an important role in meeting the growing clothing needs of the people. In many instances, they offer superior alternative to cotton or wool and the limited availability of these would invariably force to focus the attention on petrochemicals. Synthetic fibers have taken increasing share in the clothing needs of people all over the world.

1.9. The other important class of polymers from petrochemical sources are various elastomers such as SBR, BR, Butyl Rubber etc. They form essential components for tyre industry as well as for manufacture of various rubber goods for industrial and house-hold applications. In quite a few applications, besides complementing the usage of natural rubber, these synthetic products are necessary to achieve special end use performance characteristics.

1.10. Some of these products have touched the very core of national economies. The existing availability of natural fibers like cotton and wool is unlikely to show any significant increase. It is rather going down due to greater pressure on land for foodgrain production. Thus, meeting the clothing needs of populace has become a major challenge which synthetic fibers from petrochemicals can face effectively and efficiently. Similarly, greater usages of petrochemicals in agriculture would be necessary to increase productivity, improve storage and manage efficiently various inputs like water, nutrients, pesticides etc. In housing, transportation, communication and health care, various petrochemical products very often form essential part of our daily existence.

1.11 The growth of the petrochemical end products is slowly getting delinked with the growth of natural materials like cotton, natural rubber due to the established specific end use applications of both. The increase in the production rate of latter may not be promising.

1.12 The global production of the total major plastic materials is expected to be doubled (i.e. 105 million MTs) by 2000 AD; a speedy expansion in production capacity is expected of synthetic fiber mainly due to the polyester fibers; the growth rate of synthetic rubber will remain dependent on their demand in automobile sector. SBR & BR will continue to have major share of synthetic rubber area.

1.13 Although commodity plastics continue to dominate, performance plastics have registered a high demand growth rate in the industrially rich developing countries like Taiwan, Singapore, S. Korea and Hongkong. The countries like India and China have been consuming large variety of these materials but relatively in much smaller quantities. Some of the plastics like ABS, SAN, Acetals, PPS & thermoset are manufactured for captive consumption but their demand is largely met through imports.

1.14 The capacity expansion is mainly taking place in Asia Pacific region. The activities are more both in the countries who are rich in feedstocks (e.g. Indonesia, Thailand, Malaysia etc) as well as those having more demand than production to meet the requirement of huge population (e.g. India & China).

1.15 Petrochemical plants are mostly under private sector in developing countries. India is one of those countries, where the large industries including petrochemical sector continued to remain in public sector. However, to meet the huge local demand, expansion is taking place in private sector. The processing (conversion) industries of the major petrochemical end products are mainly in the private sector.

1.16 A large capacity expansion and its expected high growth rate till 2000 AD especially in feedstock rich countries has brought down the prices of the major building blocks (like ethylene & benzene) of petrochemical end products. This has increased the possibility of more activities of global export & import of these primary petrochemicals with a major shift.

1.17 Despite huge production mainly planned for exports, the local per capita consumption has been increasing fast in middle east countries (e.g. Saudi Arabia). This requires the creation of facilities for specialized training and building up infrastructure for processing and related areas to meet the local requirements.

1.18 Singapore, Malaysia, Thailand, Taiwan, Indonesia, Philippines, Hongkong and S. Korea will be producing more petrochemicals and grappling with over capacity; while petrochemical industry in India .ll will be undergoing processes of adjustment t' beralization policies.

1.19 Investments in first six-months of 1992 in China were nearly half of those during the entire 1979-91 period. This is mainly planned to produce petrochemicals for captive consumption as well as limited export.

1.20 On one side, when South American countries are passing through a stage of uncertainty, the East European nations including CIS countries may take time in recovery due to their local problems. Hence the growth in the petrochemical sector in these regions will remain moderate.

1.21 The global over capacity situation of both primary and secondary petrochemical products is developed mainly with the speedy expansion in the east. This has been a threat to western exporting countries, losing market especially in Asia.

1.22 Developing energy efficient and environment friendly technologies both for upstream and downstream petrochemical production is going to hold the key to success of the industry in future. In view of the exhaustible nature of natural resources which provide basic feed for petrochemical units, the longevity and profitability of the industry will be under continuous strain.

1.23 World over, growing economies have paid the price of growth by threatening environment. Issues in pollution present continuous challenges before the chemical industry in the nations and force them to continuously upgrade knowledge and technology for appropriate responsible care of the environment. It is certain that the growth of chemical industry (as expected to be high in East Asia) will be mainly dependent on the environmental needs.

1.24 The growth of processing industries of petrochemicals especially that of plastics will now be mainly dependent on the local demand and limited export of finished products. The employment potential will increase with the development in this area. It is likely that the fast growing demand of plastics in developing countries will provide more opportunities for self employment.

1.25 In order to avail the opportunity to import the low cost primary and secondary petrochemical products, some of the developing countries have to create additional facilities for their transportation and storage. On the other hand, the new exporting countries like Indonesia are mainly dependent on developed countries to establish the physical and institutional infrastructure for their exports. They, therefore, require to develop more skilled manpower for effective absorption of technology.

1.26 The linkages between petrochemical sector with other sectors of economy are required to be strengthened for effective and efficient utilization of the materials like plastics, fibers and rubbers. The new petrochemical rich countries in developing regions have to pay more attention in this direction.

1.27 The gains through interaction between petrochemical industries, research organizations and engineering institutions have not been fully realized since more dependence has always been felt to import the technology and not towards technology development. The petrochemical industries mainly concentrate on the absorption and assimilation of technology through training provided by licenser. Some requirements of these industries are met through local development of hardware. The tripartite interaction is required to be enriched for building strong technological base.

1.28 New and special grades of petrochemical products like polyester micro fiber, reinforcing grade of acrylic fibers, plastics for biomedical & space applications, high yield catalysts and their technologies will continue to remain with developed countries.

The concept to develop value added products has now picked up due to the heavy competition in the local and international market. Since this situation will continue in the coming years, development of speciality grades & quality improvement of the existing ones will get more attention.

1.29 The scientists and technologists have to direct their efforts towards fusion technologies for derived product ranges preferably with multiproduct sharing processes. Additionally, for better cooperation between developing countries, there is a need for strong data base.

In the coming years, the global competition is going to grow more in the petrochemical sector. The over capacity situation will continue due to low consumption, huge capacity being built up in developing countries and saturation in developed countries. With the growing demand largely in Asia Pacific region, the situation may somewhat ease out by the end of 2000 AD.

2. BRIEF REVIEW OF THE CURRENT STATUS AND FUTURE PROSPECTS OF THE DOWNSTREAM PETROCHEMICAL INDUSTRIES IN DEVELOPING COUNTRIES WITH SPECIAL EMPHASIS ON PLASTICS, FIBRES AND SYNTHETIC RUBBERS

2.1. Petrochemicals are regarded as the most value-added products converted from natural resources like hydrocarbons. While the primary usage of hydrocarbons satisfy our energy needs thus expanding it at its primary form; the manufacture of petrochemicals results in value added products that have utilities over a longer time-frame and help to satisfy some of the basic needs. In spite of this, use of hydrocarbons for petrochemicals forms only about 7-8 percent of the total hydrocarbon consumption.

2.2 There is, a direct saving of energy through the use of various petrochemical products. A comparison of the energy equivalent of a few basic raw materials like metal, glass, paper, wood and cotton indicate that comparable finished products made from petrochemical sources result in substantial energy savings. There are thus dual benefits derived from the use of hydrocarbon for petrochemicals.

2.3 Petrochemical products would be needed to meet the incremental needs of materials and also where superior characteristics/properties are required in many a demanding applications. In the present day competitive world, the developing countries have to strive for better and more efficient usage of their natural resources and opt for products which are functionally superior and economically competitive. The petrochemical industry with its wide range of a new breed of synthetic raw materials can satisfy the quest for more efficient end products for numerous applications.

2.4. Historically, petrochemical industries have been located near the market in advanced industrialized nations. The economies now favor their being located near the major source of natural gas.

2.5. The expansion of petrochemical sector in eighties has been due to the realization of the following factors :

- Huge demand & production gap in developing countries.
- Increasing demand in developed countries.
- The petroleum rich (oil/gas) countries realized that their natural resources can be converted to value added

products mainly for exports instead of crude oil for their revenue.

2.6. The necessity to fulfill basic human needs of growing population without severely depleting precious natural resources, provides a huge potential for demand led growth of these industries in the developing countries. This is evidenced by the current low per capita consumption.

2.7. The consumption of petrochemicals has been quite low in developing countries largely due to their low per capita GDP. It has, however, been experienced that in the developing countries having high per capita GDP and production capacities, the consumption increases at a faster rate. In Saudi Arabia for example, per capita consumption of thermoplastics has risen from 20 kgs to 60-80 kgs. in a short span of time (1). Similarly, the per capita consumption of fibres in S. Korea and Taiwan is much higher than other developing countries due to their high production capacities planned mainly for exports.

2.8. The scenario of production growth of the petrochemical products in the developing countries has changed in the last two decades. Countries like Saudi

Arabia, China, India, Mexico, Brazil and South Korea produce a large variety of petrochemical products. The expansion is continuing in the countries like India & China. The new entrants in this field are Malaysia, Thailand, Indonesia, Iran, Nigeria etc.

2.9. In Saudi Arabia only about 11% of their output is consumed in local market and the bulk of the petrochemicals are sold over seas (2).

A. AVAILABILITY OF FEEDSTOCK

2.10. In addition to pure gas reserves in Asia & Latin American countries, the production of oil leads to the production of huge amount of natural gases. In each one million barrels of oil production 500 million cubic feet of gas is released.

Total reserves of associated gas in Saudi Arabia alone are estimated to be in excess of 100 trillion cubic feet (3). The storage and processing of associated gas on a large scale began only in 1982.

2.11. In the past, the petrochemical industry has shown a relatively high rate of technological change. However proven technology has predominated in recent years.

Petrochemical plants are highly automated, continuous, often operating with catalytic promotion, and consequently requiring to be large to be economically viable. Petrochemical plants utilise natural gas, gas condensate (specifically ethane and liquefied petroleum gas (LPG), and oil products (specifically Naphtha) as both feedstock and energy source. Two-third of these hydrocarbons are used as feedstock to synthesise various compounds. The remainder of supplies needed energy including electricity. In US 70% of ethylene produced comes from condensate like propane, butane, & ethane obtained from natural gas. In Europe and Japan, on the other hand, naphtha refined from oil is used as feedstock to produce ethylene.

B. BUILDING BLOCKS FOR PETROCHEMICALS

2.12. The technology for the production of building blocks of petrochemicals has been mainly based on naphtha cracking. The availability of huge resources of natural gas/gas condensates has resulted in a shift from naphtha to gas cracker technology. This is found to be more cost effective and energy efficient.

2.13. Petrochemical plants are subject to the concept of minimum economic size because of being capital-intensive. The level of capacity determines the unit cost of petrochemicals which in turn points to the availability of markets of a size sufficient to absorb the petrochemical products. Therefore, the export oriented petrochemical plants of Saudi Arabia are relatively large.

2.14. Almost 60% of the world's basic chemicals manufacturing capacity is still located in the major consuming centres i.e. United States, Western Europe and Japan. This pattern, however, has been changing fast with major production capacities being installed mainly in developing countries.

2.15. Saudi Arabia has emerged as a major petrochemicals producer with 2.4 million MTs of ethylene capacity derived from large unutilised resource of associated gas. This will further grow by about 1.0 million MTs upto 1997. Iran & Iraq will also be the major player in Middle East.

2.16. Brazil, Mexico and Argentina have built up combined ethylene capacity of 2 million MTs to achieve self sufficiency.

2.17. In Asia Pacific a number of plants are in production, under construction or planning e.g. Thailand, Malaysia, India, China, Taiwan & Indonesia. The ethylene capacity in the region will increase by about 44% in the next five year.

2.18. Demand for petrochemicals is growing relatively slower compared to the past. The potential for rapid growth would be, however, concentrated in the developing countries and continued dispersion of manufacture of base chemicals could be expected. This will affect the future trading patterns for petrochemicals.

2.19. In the present scene of declining profitability from base chemical production and more competition from low cost feedstock areas, producers in the major consuming centres are required to improve their profitability.

C. PRESENT SCENARIO AND FUTURE TRENDS IN PETROCHEMICAL SECTOR

2.20. A drop in the demand as a consequence of the economic recession & over capacity situation, exist in petrochemical sector. Therefore, petrochemical plants are facing considerable underutilisation of their capacity; major cutbacks in employment levels; losses because of higher cost of product and lower prevailing prices. This elicited such responses as attempts at process improvements and energy savings to reduce production cost and rationalisation of their operations through capacity cuts, mergers, product specialisation and diversification.

2.21. Closure of old and marginal plants and temporary idling of others, reduced capacities has been a part of restructuring strategies of the major producers. Besides adopting new technologies such as low pressure, low temperature processing, more efficient catalysts, and new technologies/ routes to develop strong technology edge, there may be mergers, consolidation of operations, shift to high value added products and rationalisation moves. However, tighter environmental protection controls, rising trade barriers, increased engineering costs, reduced availability of finances and accelerated rates of technological obsolescence have complicated the effort for long-term planning to turn around the industry to reasonable profit levels.

2.22. Producers in the industrialised countries are concentrating on improving their competitive position by minimising their costs, developing newer and better products, using low cost technologies and shifting to specialities and tailor made customer services.

2.23. The growth potential in developing countries is tremendous primarily because their per capita consumption levels are still much lower. The growth patterns in these countries will be however, influenced by a large number of factors such as the level of their economic development, the structure of their economies, their per capita income, the diversity and the intensity of sectoral linkages, availability of technical and scientific infrastructure, availability of finances and government economic and monetary policies. The other factors would include the socio-economic needs of the country.

2.24. Domestic demands are far from saturation and hence future expansion will continue in developing countries. Market opportunities in the developing countries continue to be promising. The availability of low priced feedstock in many of them like Saudi Arabia, Iran, Mexico, Indonesia etc. would further give them an edge over the traditional producers particularly for the production of basic and intermediate products.

2.25. The major developing countries such as Brazil, India, China and Mexico are moving towards self sufficiency in several commodity petrochemicals. Over capacity and oversupply in the international market are therefore likely to continue.

2.26. The political and economic changes in the recent past particularly in Soviet Union and East European countries have opened new avenues for growth of downstream petrochemical products. There is only one million MTs capacity in the former Soviet Union. It is, therefore, understood that there will be a significant growth in demand of petrochemicals in this region. It is likely that the demand in whole East European countries will be met largely through imports.

2.27. The demand growth in the under developed countries having no share in petrochemical production (like a few CIS nations, Bangladesh, Pakistan, Sri Lanka, small Middle East countries etc.) may increase due to the easy availability and low cost in the international market.

D. PLASTICS

2.28. In the coming years, when developed countries will attempt for high value added speciality plastic materials,the growth of commodity plastic will continue mainly in developing regions.

2.29. The commodity plastics while maintaining their high demand will grow about 33% from 1990 to 1995 and is likely to touch a figure of 105 million MTs.

2.30. The per capita consumption of plastics in developing countries is far below (1kg to 3kg/head) than the world average (16kg/head) providing a huge potential for demand growth. The global over capacity situation therefore seems to be partly absorbed in these regions in the next few years. The lower export cost of the plastic materials in the feedstock rich regions has compelled the developed European and Japanese market to import from them. However, at present it has turned out to be a threat to the petrochemical industries of a few developing countries.

2.31. The change in the national policy in developing economies have resulted in liberal import of plastic materials in order to make their own industries more competitive and quality conscious.

2.32. There exists an imbalance in plastic conversion capacities; on one side countries like India have their conversion capacities more than their demand due to low per capita consumption whereas the middle east countries producing huge quantity of plastics have not yet developed adequate infrastructure even to meet their local demands of plastic products.

2.33. The technologies offered to developing countries are generally old and do not make them competitor in the international market. In order to overcome this situation vigorous indigenous R&D efforts will be required.

2.34. Engineering/ reinforced plastics are finding increasing applications in industrial sector. The major plastics are PC, PPO, ABS, FRP Epoxies etc. The growth rate of engineering plastics is expected to be around 8%.

Although many of the developing countries are not producing engineering plastics and depend mainly on imports, they largely produce a variety of additives required for improving the end use performance and better processibility.

E. FIBRE & FIBRE INTERMEDIATES

2.35. The growth rate of major natural fibre i.e. cotton is far below than synthetics. The production also varies since it depends on rain fall and various other natural factors.

2.36. Unlike the previous years, the cost of synthetic fibre is coming down faster. The decrease in cost, better properties and high durability are making the synthetic fibre more acceptable to people.

2.37. The increasing growth of synthetic fibre may not cause a threat to the natural fibre growers as synthetics is complementing the growing demand of fibres. However, in case of high cotton production; export possibilities have to be explored.

2.38. South Korea & Taiwan developed huge capacities in seventies for the production of synthetic fibre mainly for export, both as fibre and its finished products. A large capacity expansion is taking place in China, and ASEAN countries, to meet the growing domestic demand of basic human need of clothing.

2.39. The capacity growth of fibre & fibre intermediates have not kept pace with the economic growth in developing countries. This has resulted in price reduction, marginal profit/losses and under utilisation of their capacity. However, full capacity utilisation is expected by the turn of the century.

F. RUBBER

2.40. The total rubber (natural & synthetic) production is expected to grow @ 3.4% annually and exceed 18.8 million MTs by 1995. Synthetic rubber will continue to have its one third share of the total rubber production in the world. However, its growth will not affect the natural rubber market and on the contrary, supplement the growing demand of rubber in industrial and domestic sector.

2.41. The present world production capacity of all types of synthetic rubber is about 12.1 million MTs, of which USA accounts for 22.1%, CIS countries for 21.4% and Japan 12.8%. France, Germany, UK, Italy, Netherlands, Canada, Brazil & Rumania hold 28.3%. The balance of 15.4% production capacity is held by developing countries.

2.42. The developing countries may have problems if they go for the synthetic rubber business to compete with the developed countries in export markets. The mere possession of low cost oil or even of monomeric building blocks does not justify setting up of a new plant. Expansion of synthetic rubber production in developing countries may not satisfy the objective of maximising employment because of its high capital cost per unit labour.

2.43. With the economic and financial integration of European community markets, trade & export in a few developing countries may face stiffer competition from both East European countries as well as rapidly developing Asian countries like Singapore, S.Korea, Thailand, Malaysia, Taiwan, China.

2.44. Tyre industries consume rubber to the extent of 59% of the total production. 10% goes to mechanical goods such as belts, hoses and gaskets for industrial & general applications. Tyres & tyre products are expected to account for more than 61% of total new rubber consumption in 1995. Other applications, will account 20% for footwear, construction & as adhesives etc.

2.45. There is a need to create a stable base for rubber industry using R&D efforts to maximise operating flexibility, improving process effectiveness for achieving better raw materials & energy utilisation; minimising process waste & pollution and development of more efficient catalysts.

2.46. With the projected growth over the next decade it will be advisable to create an integrated planning policy at international level to forefeet the interest of developing countries and also take into account the widening technology gap created by computer controlled plant and machinery to meet international standard. A concerted effort is required between industry, academic institutions and other research centres to bridge the technological gap and improve the product quality and range. Industry need to be highly selective, if rapid progress is to be made in innovation, invention & exploitation of new technology.

3. APPLICATIONS AND POTENTIAL USAGES OF DOWNSTREAM PETROCHEMICAL PRODUCTS IN DEVELOPING COUNTRIES

The industrialisation in some of the developing countries is taking place at a faster rate. One of the major contributors in this growth is petrochemical industry. The demand of commodity materials and its production is growing speedily. This is unlike the developed countries, who are going for more of speciality materials.

The commodity materials fulfill the basic human need in the developing countries. The demand of such petrochemical products i.e. polymer is driven by the consumption in a few key end use segments. The performance of these segments is dependent on the growth pattern of the industries to which they are catering. Therefore, it can be said that there are certain core markets of polymers, the performance of which decide the growth in demand.

Plastics share is very high amongst the petrochemical products. Fig. 3.1F shows the global plastic consumption by market. The major application areas and potential usage of petrochemical products in developing countries is discussed in this chapter.

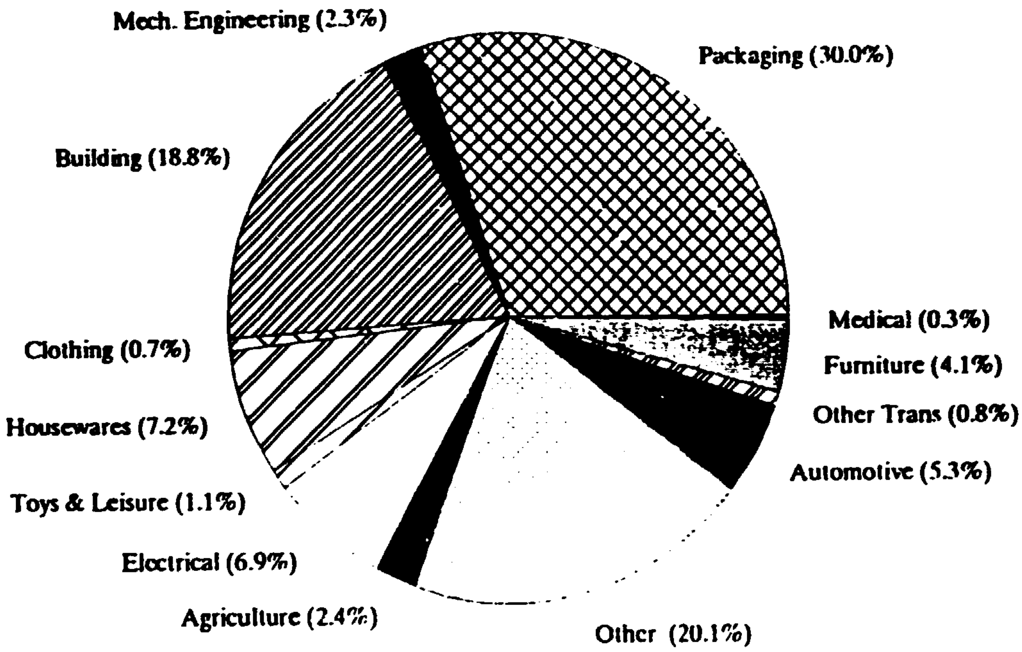


Fig. 3.1F: Plastics consumption by market
IPDA 1989

3.1 AGRICULTURE AND WATER MANAGEMENT:

The use of petrochemical products especially plastics and other chemicals for manufacturing of pesticides etc. have turned out to be a boon for increasing the food productivity, early harvesting, unseasonal crop and developing more land for crop cultivation.

Commodity plastics like PE, PP and PVC are largely used in this sector. The plastic products used are mainly extrudates as films, sheets and pipes. Some of the injection moulded products are also used in the assembly of irrigation systems etc. The use of these plastic products not only increase the food productivity but also help in economising the cost of production through controlled water supply in irrigation, restrict the evaporation of water and protect the seeds and seedlings.

The use of plastics in agriculture got a boost in developing countries in early eightees. The beginning was with the use of LDPE in this sector which attained a major share amongst all plastics with its use in canal lining, irrigation and water management, growth of fodder, milk packaging etc. The area under plasticulture in the world is shown in Table 3.1(1) and sectoral use of plastic in Table 3.1(2).

TABLE -3.1(1)

AREAS UNDER PLASTICULTURE WORLD STATISTICS

(Area in hectare)

COUNTRY	DRIP IRRIGATION	MULCHING	GREEN HOUSES
CHINA	15,00,000	28,70,000	1,82,000
USA	90,00,000	1,50,000	30,000
EGYPT	2,50,000	5,000	9,000
INDIA	55,000	1,000	25
SPAIN		1,00,000	45,000
JAPAN		1,33,000	1,07,000
EUROPE		1,00,000	1,15,000
HUNGARY			5,000
MOROCCO			4,400
CANADA			4,000
ISRAEL	ENTIRE AREA		2,000
AFRICAN CONTINENT			15,000

TABLE 3.1(2)

SECTORAL USE OF PLASTICS IN AGRICULTURE

USER SEGMENT	PRODUCT	PROCESS	LD/ LLDPE	HDPE	PVC
IRRIGATION	CANAL LINING FILMS	EXTRUSION	X		
FOODGRAIN STORAGE	CAP COVERS	"	X		
NURSERIES	NURSERY BAGS	"	X	X	
HIGH VALUE CULTIVATION	DRIP LATERALS	"	X		X
GREEN HOUSE	UV STABILIZED FILMS	"	X		
VEGETABLE CULTIVATION	LOW TUNNELS	"			X
GENERAL AGRICULTURE	MULCH FILMS BLACK & WHITE	"	X		
DIRECT COVERS	STANDARD LDPE FILMS	CO-EXTRUSION	X	X	
HORTICULTURE	BOXES, CASES TO TRANSPORT STOCK VEGETABLES AND FRUITS POTS & PROPAGATING BOXES	INJECTION MOLDED	X	X	

The World wide consumption of plastics film for agriculture and horticulture currently estimated to be in the range of one million MTs per annum. This remarkable figure has been achieved after many years of joint development efforts by the horticulturists and plastic industries. There is an increasing recognition for plasticulture in developing countries, specially South East Asia, China, India and some Latin American countries. Generally the growth pattern indicates spectacular development in some applications specially suited to the agronomic and climatic conditions of a particular country or zone.

In Western Europe for example, during the last five years the use of plastics has increased in the land area from 15,000 to 20,000 hectares. The share of polyolefin (LDPE, LLDPE, EVA) films for agricultural application is about 3,00,000 MTs. These estimates do not include films used for packaging harvested products, fertilizer bag, etc. The market is unevenly distributed in Europe with France, Spain and Italy alone consuming about 65% of agrifilms. The main applications are silage (40%), green houses (28%), mulch (17%), and low tunnels (7%). The other applications are direct covers, energy screen, pond liner and film for soil disinfection.

Germany is a highly developed industrialised country whose economy is strongly geared towards exports. Only 2% of its gross national product derives from agriculture. The country produces about 9.3 million MTs of plastics. About 0.372 million MTs is the share in agriculture and more than half of it goes for packaging purposes (fertilizer bags, pesticide cans, pots and containers for plants etc.). Nearly 70,000 MTs of LDPE, mainly in form of film is used for green houses, mulching, silage, covering of bulk goods like straw, hay, sugar-beets, lining of reservoirs, and other products include nets, meshes and mattings, pipes and tubes as well as pots and containers of various shapes. About 40,000 MTs of PVC is used in the form of films and pipes for coverings, linings and transportation of water and other liquid products. PP is used for non-wovens, mats and nets. HDPE is used for ducts (water transport, irrigation, soil heating) and all sorts of containers. Polystyrene (6,000 MTs) is mainly processed for plant-pots, trays and other devices. Expanded polystyrene is used as insulating material in greenhouses, livestock-buildings, cold storage, plant-pots and as soil conditioner in landscape-gardening.

Mulching has more popularity in U.S.A. States having the greatest concentration of mulched vegetables are Florida with 40,000 hectares, South Carolina with 5,060 hectares, North Carolina with 2,800 hectares, Georgia with 1640 hectares, and Louisiana with 760 hectares. In the Mid Atlantic area, Delaware, Maryland, and Virginia have a combined total of about 4,000 hectares of mulched vegetables. Tennessee, Texas, and Kansas have a total of 1300 hectares. In the northeast, the total area mulched is estimated to about 4,000 hectares.

Japan has been mainly cultivating vegetables (78%), flowers (10%) and fruits (11%) with the use of plastic products in horticulture over a land area of about 0.2 million hectares (Table 3.1(3)).

TABLE 3.1 (3)
USE OF PLASTICS FOR CULTIVATION OF AGROPRODUCTS AND LAND AREA COVERED IN JAPAN

(Area in hectare)

	Vegetables	Flowers	Fruits	Total
Plastics house	30,856	3,848	4,762	39,466
Rain Shelter	4,750	517	3,583	8,850
Tunnels	57,018	568	--	57,586
Mulching	120,332	--	--	120,332

In South East Asia particularly Malaysia, a rapid increase has taken place in the use of rain shelter for the cultivation of temperate climate vegetables. In India applications like canal lining, reservoir lining, cap covers for outdoor food grain storage and drip irrigation have been growing fast.

As regards China, in 1985, 23.4% of all plastics products have been used in agriculture field. The main products include plastics film, sprinkler and drip irrigation systems, pipes for water transportation, tubing for marsh gas, fishery facilities, farm machinery parts and accessories, etc. Because the cultivated land average value per capita in China is only about 0.1 hectare, plastics films have been widely used in the development of Chinese agriculture for vegetables, fruits, grain and industrial crops. In 1987, the land area covered for green house and mulching was about 70, 000 hectares and 2.3 million hectares respectively. In India, the use of plastics and its growth in agricultural sector has been modest as compared to China, W. Europe, Japan and Israel.

In Eastern Europe, Bulgaria had its consumption of plastics about 30,000 MTs in the agriculture sector till 1990. The major applications of plastics in this region are green house, mulching, irrigation, storage, cattle housing and packaging of agricultural goods.

3.1a IRRIGATION AND WATER MANAGEMENT:

Growing demand of water for industrial and domestic use has made it more scarce and expensive for agricultural purposes. Water suitable for human consumption and livestock is limited. Precipitation and ground water are the only sources of all fresh water and it varies from place to place, season to season and year to year. There is an urgent need to scientifically manage water resources to meet the future demands. The world water usage figure as estimated by F.A.O. (1977) suggest that its use for agriculture is expected to go down from 80 percent in 1967 to a projected 53 per cent by 2000 AD.

Agriculture being the backbone of all developing countries, irrigation plays an important role in maintaining high yield level and stability of production. Out of the total 172 million hectares of gross cultivated area, only 40 percent of it is irrigated (60-70 million hectares) in India and it is projected by National Commission on Agriculture (1976) that by 2025 A.D. it is possible to increase the area under cultivation to about 210 million hectares and maximum potential area under irrigation can be only 105-110 million hectare. However, by adoption of efficient irrigation management practices, this figure can go up.

In India, agriculture takes major share of water accounting to 85-90 per cent of the total water usage due to the conventional methods of flood watering being employed in this sector. However, this figure is likely to come down to about 75 percent or less in the next 30 to 40 years. Further, the quality of water available for agriculture is also getting inferior due to industrial pollution. Thus, with reduced availability of water for irrigation, efforts are being made to utilize the available resources more efficiently. Annual rainfall is the only source of fresh water supply and the quantum of surface flow has been estimated to be 144 million hectare mt. per annum in a study carried out in India. Table 3.1(4) shows the demand projection of water in India.

TABLE 3.1 (4)
PROJECTED DEMAND FOR WATER BY 2000 AD IN INDIA

(Fig. in Million hectare meters)

Type of Resource	Utilizable resource of water	Irrigation	Other uses	Total
Surface water (Major, medium and minor schemes)	66.6	45.6	3.44 to 9.8	49 to 55.4
Ground water	20.4	21.0	4.5 to 6.5	25.5 to 27.5

(i) CANAL LINING

The use of plastics in irrigation, and water management have proved to be a boon to increased water use efficiency, decreased water logging and soil salinity. Plastic films have been successfully used in irrigation as a lining material. Heavy duty HDPE film has been found most suitable for this application. Use of plastics film lining has offered several advantages: Seepage losses would be almost totally prevented, considerable cost saving due to reduction in section of brick or concrete lining, better strength recovery of masonry as well as concrete.

PVC, HDPE as well as LDPE pipes and tubings have continued to play an increasingly important role in Tubewell/well irrigation, and in adoption of sprinkler irrigation schemes. A research study on the "Economics of Sprinkler irrigation" indicated that the installation of Sprinklers on the farms not only improves the water use efficiency but also adds to the net irrigated area and has thus enhanced the cropping intensity on the farms.

Prudent application of advanced methods of irrigation, viz., drip and sprinkler irrigation has made possible the utilization of scarce water resources most beneficially in the desert, arid and semi arid regions. Intensive development efforts are necessary which would give direction for better utilization of plastics in agriculture in general and irrigation in particular.

(ii) DRIP IRRIGATION

Drip irrigation is described as regulated and slow application of irrigation water around the root zone of the crop, through a network of plastic pipes and emitters.

Though simple in concept, the wide spread use of drip irrigation is of recent origin. The concept had its beginning in Israel with the finding that better growth of the plant takes place near the leaking faucet and for the first time this system had its commercial use in late 60s for vegetables. The agriculture in Arava Valley (Israel), which is a desert area with brackish water, became progressive and profitable with the use of this new irrigation method, with much higher productivity. The concept spread to other areas with normal conditions. Presently, drip irrigation is a common practice in Israel agriculture.

Another important factor which really gave micro irrigation a fillip is the breakthrough in the field of material scene; when the petrochemical products like LDPE, LLDPE, HDPE, PP, PVC etc. were found to be most suitable in the modern drip irrigation components. The improvement in the process technology and the recent introduction of LLDPE which exhibits greatly improved strength and stress crack resistance, have resulted in producing tough, flexible and excellent quality drip lateral pipes. When suitable additives including antioxidants, stabilisers and carbon black are added to clear polyethylene, a durable and economical product for micro irrigation becomes a reality. The large scale commercial use of the system, understandably has been more extensively used in Israel, USA, Australia and the Middle East; which have traditionally suffered from shortages of irrigation water (Table 3.1(5)).

TABLE- 3.1(5)

DRIP IRRIGATION: AN INTERNATIONAL SCENARIO

Countries	Area (million hectare)
USA	9
Israel	Entire Area
Egypt	0.25
China	1.50

Drip irrigation had its beginning in the seventies, though its widespread adoption was only after mid-eighties. In the early years, the adoption level was very poor in developing countries like India due to lack of awareness, non availability of good system, the high initial investment, lack of financial assistance from the government as well as commercial banks. Early eighties saw the launching of sustained promotional campaigns. The future for drip irrigation is quite bright in all developing countries. This sector is predicted to grow at an annual average growth rate of 30% in the coming years.

(iii) SURFACE COVERED CULTIVATION (MULCHING)

Mulching is the practice of covering the soil around the plants to make conditions more favorable for growth and conserve the available moisture. Natural mulches such as straw and compost have been used for centuries. The advent of synthetic mulches have altered the methods and benefits of mulching. Paper mulches attracted much attention in the 1920s but were not adopted for commercial vegetable production due to paper failure and cost of material. The sixties and seventies saw the introduction and growth of plastics mulches.

Mulches can increase yield and improve product quality by conserving soil moisture, protecting soil structure and modifying soil temperature. Black mulches, being opaque, prevent weed growth, while reflective mulches repel certain insects. Over the years, mulches have gained acceptance for such crops as strawberries, tomatoes, muskmelons, cucumbers, squash, peppers, egg plant and watermelons. In Spain out of a total area of 1,46,175 Hectare under plasticulture 100,000 Hectare is under mulching mainly for strawberry, asparagus, melons and now cotton. About 0.2 million hectare is under mulch in Europe. U.S.A. has about 0.15 million hectare under mulches.

China has been the forerunner in the use of plastic mulches. The area under mulching has shown a stupendous growth during the last 10-12 years, from a mere 79 Hectare in 1979 to a massive 2.87 million Hectare in 1989. The major crops being covered are cotton, melon, corn, rice, vegetables and peanuts. LDPE film of 14 micron thickness are mainly used. Thinner film of LLDPE (8-10 microns) have also proved to be as effective as thicker LDPE film at a lower price and are becoming popular. The land area for mulching in various countries is shown in Table 3.1(6).

TABLE 3.1(6)

MULCHING : AN INTERNATIONAL SCENARIO

Country	Area (million hectare)
China	2.9
Rest of Asia	0.4
Western Europe	0.2
N.America	0.15

(iv) PROTECTED CULTIVATION (GREENHOUSE, TUNNELS)

Greenhouse cultivation is the method of growing crops under protected and controlled environment conditions. Use of glass houses is more or less restricted to a limited number of countries in North Western Europe. In contrast, plastic green houses have rapidly gained global importance. Greenhouse, by trapping of heat and carbon dioxide, aid in improved photosynthetic activity and thereby help in providing better crop with high yield. In extreme weather and off-season, by using appropriate control systems, greenhouses can help in successful and profitable cropping.

Polyethylene films with UV stabilisation are found to be the most suitable cladding material for greenhouses. Other glazing materials are fiberglass, EVA etc. Newer materials like acrylic sheets and engineering plastics like polycarbonate are now being tried but their technical promise is offset, at present due to high cost.

The adaptation of greenhouses are also directly linked to the agroclimatic and socio-economic conditions, prevalent in a location. Large areas are found in the Mediterranean region, China and Japan. The greenhouses in Spain along the Mediterranean coast have huge structures without much of control mechanisms. Nylon meshing is provided all around to provide ventilation during day time. About 28,000 Hectare are under greenhouse cultivation in Spain and about 17,000 Hectare under low tunnels. Western Europe has around 61,000 Hectare under greenhouses.

In Asia, especially China and Japan have made steady progress in cultivation through green houses. About 0.182 million Hectare is under greenhouse in Asia. In China, the area under greenhouse and tunnels have grown from 16,000 Hectare in 1978 to 0.112 million Hectare in 1988. Polyethylene film with a life span of about 2-3 years are commonly used. Cucumbers, tomatoes, garlic and Chinese Cabbage are the major crops. More recently, plastics greenhouses are being used for growing flowers, condiments, some fruits and interestingly for sheltering live stock. Greenhouses for production are not generally heated but are designed to make the best use of solar energy like lean-to-wall greenhouses.

In Japan, about 42,000 hectare land is under greenhouse, of which 77% is used for vegetables. Plastic film also finds an effective use there as rain shelters covering. Interestingly, PVC is being used extensively for plastic houses and tunnels in Japan. African and Middle East countries have also resorted to green houses and tunnels with about 20,000 - 25,000 hectares. The land area being used by developing and developed countries through green houses is given in Table 3.1 (7).

The potential advantage for plasticulture is now more widely recognised in the world and development taking place within the industries and research institutes is expected to lead an increasing demand for plastics. Environmental issues particularly rubbish disposal necessitate immediate consideration. Technological improvement in the material used for green houses, silage, land drainage and packaging of products are bound to have considerable impact.

TABLE 3.1(7)

PROTECTED CULTIVATION : AN INTERNATIONAL SCENARIO

	Countries	Area (hectares)
Greenhouses		
	Asia (Mainly China, Japan)	1,82,000
	Western Europe	61,000
	Africa/Near East	15,000
Tunnels		
	Europe	54,000
	Italy and Spain alone	27,000
	Egypt	8,800
	Japan	55,000

3.2. HOUSING AND SHELTER:

Amongst the three major petrochemical products, this sector largely consumes plastics. One of the largest consumer of plastics next only to packaging is housing & shelter (Fig.3.1F). The consumption in this sector ranges from 13 to 22% in developed countries (Table - 3.2(1)). About 20% of the total world production of plastic constitute only about 2% (by value) of total building materials. Some of the major areas of consumption of plastics in building and construction are pipes and fittings, conduits, resin bonded boards, insulation, panels and sidings, flooring, profile extrusions, glazing & sky - light, vapour barrier, plumbing, lighting fixtures decorative laminates, wall covering etc. (Fig. 3.2 (1F)). Extent of the use of different plastic products for building application is shown in Table - 3.2 (2) which gives a comparative idea of plastic products consumption in developed countries (USA) and developing countries (India). A large variety of plastic materials are available globally but only about a dozen are important from the building industry point of view. These are listed in Table - 3.2(3) alongwith standard abbreviation.

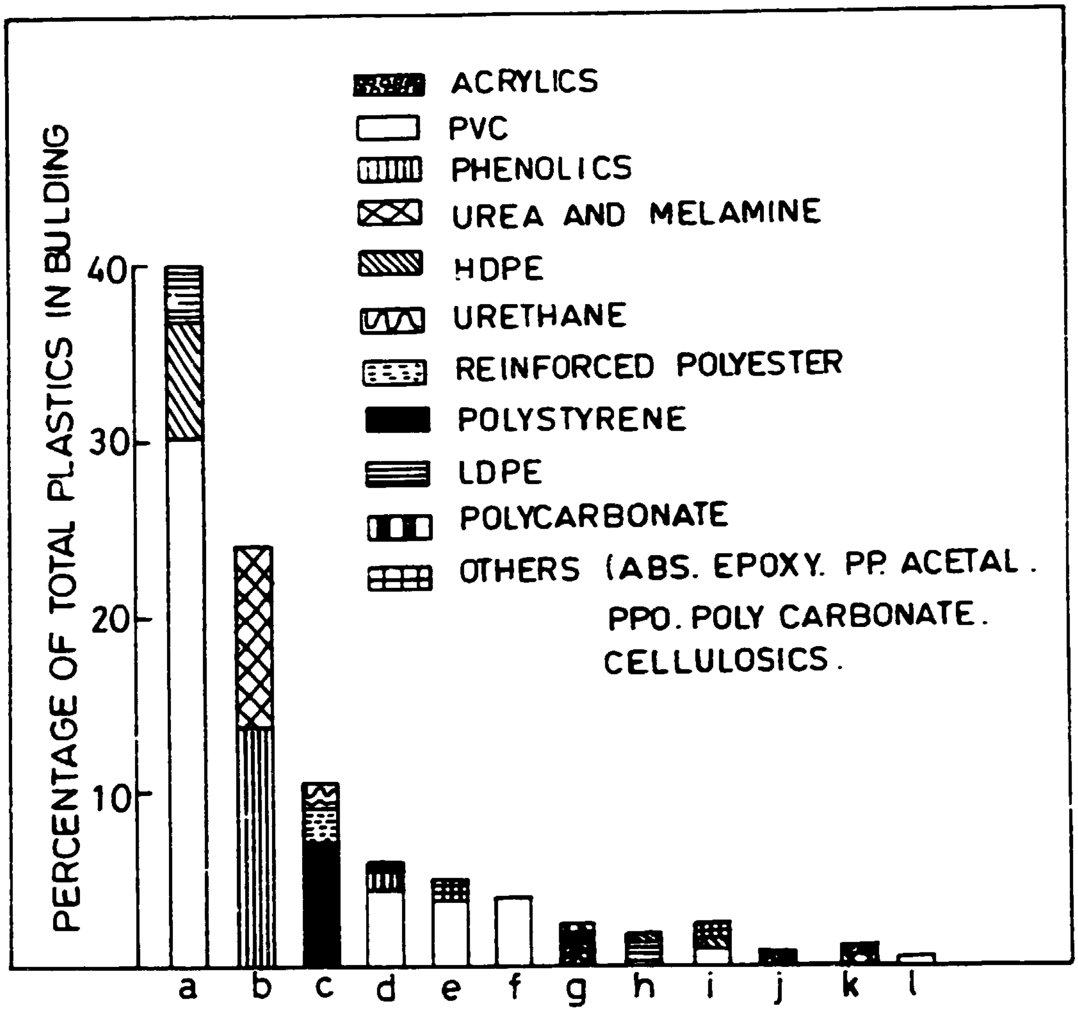


FIG.:3·2(1F)APPLICATION WISE DISTRIBUTION OF PLASTICS IN BUILDINGS.

a. PIPE FITTINGS CONDUCTS
b. RESIN BONDED WOOD
c. INSULATION
d. PANELS AND SIDING
e. FLOORING
f. PROFILE EXTRUSION
g. GLAZING AND SKYLIGHTS
h. VAPOUR BARRIERS
i PLUMBING
j LIGHTING FIXTURES
k DECORATIVE LAMINATES
l WALL COVERINGS

TABLE - 3.2(1)
CONSUMPTION OF PLASTICS IN BUILDING
(1985)

(Fig. in million MTs)

	Total consumption	Consumption in the Building sector	(%)
Western Europe	13.8	2.76	20
Japan	7.0	0.91	13
USA	18.4	3.92	21
Canada	1.2	0.26	22

Table - 3.2(2)
APPLICATION WISE CONSUMPTION OF PLASTICS IN BUILDING IN USA VIS-A-VIS INDIA

	Consumption(1983-84)			
	U.S.A.		INDIA	
	'000 MTs	%*	'000 MTs	%*
Pipe, fittings, conduits	1847	40	43	86.2
Resin bonded Boards	1028	25	-	-
Insulation	437	10	0.25	0.5
Panels & Siding	259	6	0.53	1.1
Flooring	197	5	3.0	6
Profile Extrusion	132	4	0.39	0.8
Glazing & Skylight	98	2.5	0.12	0.24
Vapour Barrier	90	2.0	0.03	0.06
Plumbing	87	2.0	0.64	1.3
Lighting Fixtures	45	1.0	0.76	1.5
Decorative Laminates	35	0.8	-	-
Wall Covering	26	0.5	0.18	0.36

* percent of total plastics used in building and construction

TABLE - 3.2(3)
MAIN PLASTICS FOR USAGE IN BUILDINGS

Name of Plastics	Abbreviation
Polyethylene	PE
Polyvinyl Chloride	PVC
Polypropylene	PP
Polystyrene	PS
Polymethyl Methacrylate	PMMA
PolyvinylAcetate	PVA
Melamine-Formaldehyde	MF
Urea-Formaldehyde	UF
Phenol-Formaldehyde	PF
Polyester	PE
Epoxy	EP
Polyurethane	PU
Acrylonitrile Butadiene Styrene	ABS
Glass Fibre Reinforced Polyester	GRP

The demonstrated potential of polymers in replacing conventional materials is the result of their outstanding properties listed below :

- High strength to weight Ratio
- Reduced energy consumption
- High corrosion resistance
- Ease of fabrication / Mass production.
- Ease of colouring, shapes and sizes
- Excellent electrical and thermal insulation
- Can be tailor made
- Ease of maintenance

Plastics are 2-3 times better than steel and aluminium and several times better than other building materials like brick and concrete in weight to strength ratio. Metals use 2.5 to 7 times more energy units on a volume basis. Further unit volume of plastics replaces

3-8 units metals by weight. The light weight property of polymers is a key factor in their cost competitiveness with alternative materials. Table - 3.2(4) shows the comparative properties of plastics with conventional material i.e. metal used for housing application.

The traditional building materials like wood, cement and steel are generally in short supply and the methods of construction for practically all the traditional building materials are based on manual labour and large amount of water for curing, taking a long time to set. The growth demand for housing all over the world has forced everyone to think about reducing the time for construction of building. This is possible only by prefabrication in factories and with materials suitable for mass production.

3.2.1 IMPORTANT APPLICATIONS OF PLASTICS IN HOUSING & SHELTER :

The overall applications of plastics in housing & shelter are listed in Table - 3.2(5). In developing countries, the use of plastics in housing & shelter was recognised much later than developed countries. The application wise consumption pattern of plastics is

TABLE 3.2(4)
COMPARISION OF PIPE PROPERTIES PLASTICS VERSUS METAL

Sr. No.	Characteristics	Plastics pipes LDPE	Plastics pipes HDPE	Plastics pipes PVC	Conventional pipes CI/GI	Conventional pipes AC
1.	Specific Gravity	0.91-0.93	0.94-0.96	1.35-1.45	7.2-7.8	2-2.8
2.	Tensile Strength Kg/cm^2	115-170	265-280	445-600	1400-4000	100-400
3.	Young's Modulus 10, Kg/cm	1.3-1.5	8.0-9.1	24-31	2100	-
4.	Thermal Conductivity L Cal/m hr. C	0.288	0.434	0.125	70	0.24
5.	Coeff. of Thermal Expansion - per C	16-18	12-16	5-6	1.0-1.2	-
6.	Flexibility	Highly flexible, pipe can be coiled	Less flexible than LDPE	Relatively rigid	Rigid	Rigid
7.	Available sizes (mm)	12 to 140	10 to 400	16 to 315	50 to 315CI 60 to 100 GI	50 to 315
8.	Common jointing methods	Insert type joints and Compression fittings.	Compression fittings, fusion welding threaded joints.	Solvent welded joints, welded joints threaded joints.	Threaded for GI Lead join and cement joint for CI	Cement joints
9.	Application	Irrigation, water distribution etc.	Water distribution etc.	Water distribution sewerage, Rain water pipes etc.	Water distribution CI for sewerage etc.	Water main, rain pipes, sewerage etc.
10.	Effect of low temp.	Good low temp. properties uneffected by large no. of freeze thaw cycles	Same as for LDPE low temp. with	Tendency to be come brittle, at low burst temp. possible handling problem, repeated freezing & thawing reduces working pressure.	Likely to burst at freezing temp.	Likely to burst at freezing temp.
11.	Dependence of working	Yes	Yes	Yes	Negligible	Negligible

TABLE- 3.2(5)
WORLD WIDE APPLICATIONS OF PLASTICS IN BUILDING

APPLICATION	MATERIAL
Excavation	
Land drain	HDPE/UPVC/PP/NYLON/FABRIC
Floor	
Damp courses and floor underlays	PE Film, Pitch, Polymer
Damp-proof membranes for solid concrete floors	Rubber/bitumen compound backed with PE film
Curing membranes	PE film
Thermal insulation	Polyurethane foam, Rigid PVC foam
Retaining Structures	
Low friction bearing pads for bridges and pipe lines	PTFE
Primary Elements and accessories	
Air supported structures	PE film or PVC coated fabric
Structural gaskets and water stops	Plasticised PVC - extruded, rigid PVC, foamed PVC & PU
Masonry Plugs	Nylon, PE or PP
Self-drilling screw fasteners for fixing sheet & panels	PE, PVC
Wall tiles	Urethane foam, Marble chips & PMMA

Table -3.2(5)-- continued

Table- 3.2(5)-- continued

Frame supported structures	PVC coated fabric
External Wall	
Curtain walling-infill panels	UF, Urethane rigid foam cored, UPVC foam
Walls for solar heat collection	Exolite-double skin acrylic sheet
Wall coping	UPVC
Shading device	GRP coated with Vinyl
Internal Walls Partitions	
Interior and exterior panels	Profiled or flat, translucent opaque or clear sheet, reinforced PVC, UPVC foam, PVC coated steel, UPVC, Urethane foam core.
Shaped interior Panels	PVC and acrylic
Interlocking translucent extrusions	UPVC
Acoustic sealing battens	Polyurethane foam
Building Panels	PVC, PVC & Steel concrete reinforced PUR foam, FRP sheet, PVC laminated with honey comb.
Panel joints	UPVC, Silicone sealants, PU sealants
Partitions	UPVC coated panels, Melinex/ UPVC coated, Laminated plastics
Thin wall parts	Foam

Table -3.2(5)-- continued

Table -3.2(5)-- continued

Floors	
Form Work	PP
Roofs	
Roof Sheet	Plasticised PVC coated steel, Plastics coated steel laminated to urethane foam, Painted aluminium laminated to isocynates, woven fibre glass laminated to thermoplastic polyester, Urethane foam laminated to various rigid water proof sheets.
Multipanel system	PUR & Steel
Mansard roofs	Reinforced plastics
Roofing underlay (Sarking)	PVC,PVC/rockwool, PE/foam, PE, EVA,Nylon mesh, Polyurethane foam board Phenolic foam.
Insulation & roof deck	Polyurethane foam board, Sprayed, Polyurethane rigid foam, UPVC, foam, Metallised film, Urethane
Combined facia/gutter units	UPVC
Eaves filler blocks	Flexible urethane foam, PE, PE foam, PVC foam
Dry Verge system	UPVC
Washers, caps and covers for fixing bolts	PE and PP
Net Support for thermal insulations Under roofs	PE and PP
Zoo-roofing	PC
Roof Membrane	PVC coated Polyester

Table -3.2(5)-- continued

Table -3.2(5)-- continued

Structural Beam	GRP
Snow guards	UV stabilised transparent PC
Reflecting ceiling panels	Chromepolyester laminated PVC

Accessories, Door & Window Fittings etc.

Hinges	Acetal/nylon (with spring action)
Integrally moulded hings	PP
Door furniture	Nylon, Acrylic, PP
Sliding door fittings	Nylon, UPVC
Window stays and fasteners	Acetal, Nylon
Draught excluders for doors/ windows	UPVC, UPVC/flexible PVC
Window and door sub-frames and cavity closures	UPVC, UPVC foam
Wall plugs for holding frames	PE
Hinged draught strip for doors/ windows	PP
Garage door roller bearings	Nylon
Door closer	Acetal
Automatic gate latch	Acetal and Nylon
Structural sealants	Foamed PVC & PV, Silicone building sealants
Window operator cover and handle	PS
Solar attenuation film	Polyester film, UV stabilised polyester coated with anti-reflecting substances

Table -3.2(5)-- continued

Table -3.2(5)-- continued

External Openings, Windows

Window frames	Plasticised PVC sheathed aluminium, Steel, UPVC patent glazing bars, plastics, coated steel
Glazing	Acrylic sheet.
Security glazings	Glass-PC laminated with urethane foam, window grilles
Bulls eye panels	Acrylic
Bullet-resisting laminate	PC fused with proprietary interlays
Double glazing systems	UPVC-extruded channels, Flexible PVC channel, Double skinned glazing-PVC Polyester film with nylon fixtures, PE foam.
Louvre Windows	Various plastics
Vertical blind louvres	PVC
Temporary glazing	PE film
Window sub-frame and damp proof fixing	UPVC

Internal Openings, Doors

Conventional doors	Cellular or solid cord doors with laminated plastics surfaces, UPVC clad with frame
Sliding doors	Acrylic panels
Decorative	Acrylic

Table -3.2(5)-- continued

Table -3.2(5)-- continued

Architrave	UPVC, foamed UPVC
Complete folding doors	Plasticised PVC with insulation, UPVC
Flexible doors	PVC
Roller doors and shutters	UPVC
Metal-PVC clad	PVC
Door sub-frame and damp-proof	UPVC, foamed UPVC
Balustrades	
Handrails	Acrylic, UPVC, PVC on steel
Handrails capping	Plasticised PVC extruded
Banister rails	Shrink on tubing - PVC
Ceiling Suspended	
Translucent for illumination	Modular type, UPVC foil, plastic PVC film
Opaque	UPVC foil, Polyurethane core
Decorative	UPVC, UPVC foam
Plastic frames	UPVC
Openings in roofs, rooflights	
Domelights	Acrylic, PVC, PVC wire laminate
Corrugated sheet	UPVC, UPVC wire-laminate
Double skinned roofing	Interlocking translucent UPVC extrusions
Tiles	PVC wire laminate
Barrel vault covers	Acrylic or UPVC

Table -3.2(5)-- continued

Table -3.2(5)-- continued

Patent glazing bars	UPVC
Skylights	PC, CAB
External Wall Finishes	
Architectural cladding panels	Acrylic, Vinyl, UPVC foam
Wall cladding or siding shaiplap	UPVC-extruded, UPVC foam, Rigid faced Aluminium or Steel/PVC faced
Protective coatings (spray or brush)	Solvent based vinyl, water based vinyl
Resin-bonded trowel finish	Polyurethane/aggregate
Internal Wall Finishes	
Wall lining for tunnels, vaults etc.	UPVC
Washable wall coverings	Vinyl - coated textile, Vinyl-coated paper, polyester film Metallised film/cotton laminate, laminate cald board.
Wall tiles and cladding	Vinyl, UPVC foam
Sprayed protective coatings	Solvent based vinyl
Large diameter and rectangular pipe for cladding of columns during concreting	UPVC
Acoustic tiles	Vinyl/ UPVC
Wall seals	PVC, Silicone building sealants, PU sealants
Insulated wall lining	Polyurethane foam, laminates, UPVC foam
Insulation panels	EPS/PP
Insulation	PUR, Polyisocynate foam

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Floor Finishes	
Tiles and continuous flooring	Vinyl, foamed PVC base with nylon flock surface, PP needle felt carpet tiles, PP carpet,tiles, PP carpet, Nylon/ Terylene tiles,
Seamless floor coverings	Vinyl, Vinyl coating, Polyurethane
Wood lacquer and concrete seal	Polyurethane resin
Skirting, including combined skirting/ electrical trunking	UPVC, formed UPVC, Plasticised PVC
Semi-sprung and impact sound insulation, insulated partition fixing	Plastics foam and wood/ fibre composites, PE foam
Dry screen	PE foam, Polyurethane foam
Carpet underlay	Foamed PVC
Monolithic floor finish	Urethane concrete
Treads and nosings	Plasticised PVC
Ceiling Finishes	
Ceiling tiles and roof lining	PVC plaster board laminate, PVC/Plaster board polyurethane foam, Vinyls
Coving (Electrical turnking)	UPVC
Roof Finishes	
Roofing sheet	PVC/Asbestos laminate, Bitumen Pitch Polymer

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Corrugated sheet steel	Plasticised PVC-coated, laminated to Urethane foam
Corrugated sheet-aluminium	Painted and laminated to Urethane foam
Corrugated sheet-plastics	UPVC wire laminate, UPVC
Washers, caps and covers for fixing bolts	PE and PVC
Breather vents	UPVC and GRP,PP,UPVC
Dry verge system and roof trim	UPVC Insulation Polyurethane, sprayed Polyurethane foam, PVC foam
Flashing	PVC
Mounting pads for roof paving slabs	PE
Protective coating (spray or Brush)	Vinyl-water based, PU
Prefabricated plumbing units	Polyurethane
Refused Disposal	
Ducting and chutes	UPVC
Refuse Bags	
Refuse holders	PE
Drainage	
Soil systems	HDPE,UPVC
Water systems	HDPE,PP and UPVC

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Transparent drain trap bases	TPX
Pipe clips, sealing rings,joint washers, ballon guards vent terminals etc.	Various
Underground drainage	HDPE,UPVC,PP,PP/Nylon fabric for sub-soil drainage
Fittings for Pitch/fibre and clay drain pipes	PP
Sewage works fittings and pipes	UPVC,UPVC,(fittings only), PE PP/ABS
Corrugated conduits	PVC, PE, PP & Nylon
Spiral would pipe	Nylon reinforced to PVC
Road gulley	PP
Drain expansion plugs	Nylon/acetal
Rodding equipments	PE
Gulley grids	PP
Rainwater Systems	UPVC,PP,HDPE
Roof and balcony outlet	UPVC and GRP<PP & PE
Window wall covers	Terite Butyrate
Combined facia/gutter units	UPVC
Effluent treatment plant-packing	UPVC
Moulded pipe plugs	Nylon, cellulose Acetal, PVC, CPVC, PP, LDPE
Hot and cold water	
Water mains pipes and fittings	UPVC,PE, PP

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Water service pipes	UPVC, PE, PP
Protection for underground pipe	PE Film
Cold water storage cisterns	PE,PP,UPVC
Liners for clod water storage cisterns	PE
Overflows	UPVC,PE,PP
Ball valves	Acetal or nylon
Valves	PP, Acetal Copolymer, reinforced nylon
Ball floats	PP,PE,PE foam
Silencer tubes	PE
Stock cocks or drain cocks	Acetal, Brass, Acrylic crosshead
Taps	Acetal with acrylic cross heads, brass with acrylic crossheads
Shower fitting; mixing valves roses and accessories	Acetal
Pipe clips	Various plastic material
Celling plates	PE
Pipe-thread sealing tape,	Unsintered PTFE
Gasketing cord (joining cord) for sealing threads and pipe flanges	
Insulated hot water storage tanks	Rigid urethane foam

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Pipe insulation	Rigid urethane foam PVC covered, dispensed Polyurethane foam, Pipesections
Plumbers' washers	PE
Pump	Thermoplastic polyester
Fuel gas compressed air, medical gases vacuum etc	
Pipe	PE,PP,UPVC, Plasticised PVC sheathed copper and steel.
Fittings and valves	UPVC, PE,PP
Equipment control	Acetal
Governor	Acetal
Handwheels & discs	PE, PP
Refrigeration	
Wall sections and foam filled wall panels	PVC faced
Wall lining Insulation	UPVC, PVC coated steel Polyurethane foam, PE foam
Cold Stores	Rigid urethane foam insulated structure PVC foam
Space heating	
Expansion tanks for hot water systems	PP
Pipe for slab heating	Polybutylene
Pipe for hot water system	Plasticised PVC insulated

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Celling heating systems	Elements of conducting plastic materials in sheet form, enclosed in insulating-sheathing of moisture, resistant polyester film.
Moulding for heating system	EPS
Insulated hot-air ducting	Rigid urethane foam coated metal work
Solar collector panels	PC glazed, Polymers, carbon-impregnated black PP sheets, ERC
Insulation	Polyisocynate foam laminated with PVC
Absorber	Black Polysulphone
Side Channels	Glass filled PC
Ventilation and air conditioning	
Ducting	Blow moulded PP or UPVC,PE
Extractor fans	Acetal, UPVC/PP
Louvred grills	UPVC/PP, Acrylic
Mesh for grills etc.	Expanded [illegible] perforated UPVC
Ventilators louvres & airbricks	UPVC,PP or [illegible]uminium
Flexible duct connectors	PVC
Pipes & ducts	Rigid Urethane foam insulation, PVA vibration damper.
Cover fan blade	Mica/PP

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Conduit systems including turning	UPVC, PP
Wiring conduits Table fan wings	Polybutylene Graft copolymer
Intricate moulding	PBT
Coating for plenum wire	Flouro polymer
Insulated cables	Polyethylene or Plasticised PVC
Cable trays	UPVC
Cable	Polyamide film & EVA copolymer
Switches plugs, sockets etc.	UF or acetal
Wiring insulation	Teflon or Polysulphones
Cable Clips	PP,PE, Nylon, UPVC
Wire jacketing	Polythene based PUR
Turret boxes	UPVC
Cable fastening	PP,PE, Nylon, PVC
Lamp socket	PET/PBT
Cord guard electrical ducting	Flexible vinyl
Lighting	
Light fittings	Acrylic and vinyl
Circulation Fixtures	
Acoustic telephone hoods	Acrylic
Signs, lettering etc.	Acrylic or UPVC

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Letter box plates	Nylon
Light-weight mirrors	Metallised polyester film
Trolley rail	UPVC
Curtain rail and fittings	Nylon and acetal, UPVC (rail only) PVC coated steel
Curtain pulleys	Nylon
Venetian blinds	UPVC
Venetian blind mechanisms	Nylon, Acetal, PP, PE
Roller shutters	UPVC
Roller sun blinds	Coated fabrics
Duck boards & safety mats	PVC
General room fixtures	
Working surfaces, bench tops and sides	Various materials
Fume cupboards	UPVC or PP
Cabinet panels	PUR foam
Book case	PUR foam
Shelf supports	Nylon, UPVC
Hinges and door furnitures	
Stadium seating	UPVC
Drawers	UPVC

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Culinary Fixtures	
Sink, sink units	Acrylic, Mineral reinforced Acrylic
Working surface	Various materials
Extractor fans	Acetal
Hoods	UPVC or PP
Kitchen tools	PP blended with foam
Kitchen mixture taps	Acetal/acrylic
Dish washer sight tube	Styrene methyl methacrylate copolymer
Sanitary Fixtures	
Bath (and panels)	Acrylic
Complete bathroom unit Wash basins (single or multiple toilet tables	Acrylic reinforced with Polyester fibre
Shower trays	Acrylic
Shower cabinets	Acrylic
Prefabricated cubicles for toilets showers and changing areas	Plastic laminates, UPVC
Fitting for WC cistern	PE, Acrylic, PP UF
Padded toilet seats	Plastic foams
Toilets siphon assemblies	PE,PP
Bathseats	PVC
WC Pan connectors	EVA, PP, PVC

Table 3.2(5)--- continued

Table 3.2(5)--- continued

WC Flush pipes and connectors	PVC
plugs and waste fittings for bath and basins	PE, PP
Cistern pulls	PE
Bathroom cabinets	
Bath tubs	PP, acrylic
Bathroom accessories (Towel Rails, Bath racks)	Acrylic
Waste basket	ABS
Piston drive, toilet refill valve	Acetal copolymer
Cleaning Fixtures	
Sinks for laboratory and dark room	PVC, PP, or PE
Furniture	
Chairs and stools	PVC, PP, PBT, GRP
Chairs, settees, tables etc.	Acrylic
Chairs seats	Nylon-coated,Nylon-6 yarn
Upholstery materials	Vinyl
pipe furnitures	PVC
Furniture padding	Recycled or virgin PET, Nylon polyurethane coated, polyether foam, PE foam
Table-leg hinge	Acetal

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Site Primary Elements	
Fence rails and posts	UPVC
Gates	UPVC
Fencing	Plasticised PVC-coated wire-mesh and chain link, PE mesh
Wall coping	UPVC
Rivets fencing assembly	PE, PP, Nylon
Road furniture	PE, UPVC
Grassland reinforcement and ground restraint	PP, PE, mesh or fabric
All-weather recreational surface	PU
Grate	FRP
Swimming pool sides	PS Structural foam
Structural Units: Plastics	
Non-load bearing walls	Various rigid foam lami-amtes
Section:Plastics	
Air fume and dust ducting	UPVC, PP, Plasticised PVC
Fence rails, wall coping	UPVC
Boxing in of soil pipes	UPVC
General extrusions as panel trim	UPVC, foamed UPVC
Skirting	Foamed PVC
Foam sealant strip	Foamed PVC or PU

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Tubes, Pipes : Plastics	
Metal pipe	PVC sheathed
Connectors and fittings for	
pitch fibre pipe	PP
pipe and fittings	PP, PE, UPVC
pipe accessories	Fluoropolymers
Wire mesh : Plastics	
Plastics mesh	PE, PP
Fencing	Plasticised PVC coated wire mesh and chain link,PE mesh
Spacers for reinforcement bars	PE, PP
Wires and ropes	PP
Quilts, Cellular: Plastics	
Foam	PE foam, UPVC, plasticised PVC polyurethane foam sheet block and pipe sections. Rigid urethane foam
In Situ Foam	UP, Sprayed rigid urethane foam
Infill panels, partitions, etc.	Various cores and surfaces
pipe insulation	Rigid urethane, PE foam
Foils, films: Plastics	
Foils, films	PE and PVC
Film, Tap adhesive	PE
Wood grain: Finished film	PVC
Water-Permeable membrane	PP Nylon fabric

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Overlap sheets: Metal and Plastics	
Corrugated sheet-metal	PVC coated, Laminated to urethane foam
Corrugated sheet-Plastics	UPVC
Rigid Sheets	
Coated plaster board	Plasticised PVC coated, Melamine coated
Plastics sheet	Acrylic,PP profile extruded board, UPVC or UPVC wire laminate
Laminates and panels for wall cladding, partitioning infill Paneling, insulation, flooring decoration, work tops.	FRP sheets, glass-reinforced polyester film. Honey comb plastics. RIM urethane.
Tiles: Plastics	
Wall and ceiling tiles	Vinyl
Flexible sheet: Plastics	
Flooring tiles and continuous flooring	Vinyl
Papers and fabrics: Plastics	
Internal wall finishes	UPVC, Vinyl-coated paper and textiles
Water permeable membrane	PP Nylon fabric

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Thin coating: Plastics	
Surface coating paints	Polyurethane lacquers
Fasteners: Plastics	
Masonry plugs	Nylon, PVC, PE or PP
Wall ties	PP
Architectural Iron mongery	Nylon and acetal
Rivets	Nylon, PP, PE, PVC
Resin grouted anchors & rock bolts	Polyester, phenolic
Screws, bolts etc.	PVC, PP
Washers for fixing bolts	Nylon
Design, physical planning	
Drafting film	Polyester film-based (may be supplied diazo sensitised)
Scribing film and peeling film	Polyester film-based
Drawing office instruments	Acrylic and PVC
Planning symbols	Acrylic
Protection	
Film for weather protection during construction of structures & stores; packaging; concrete mould lining; control of concrete curing; air or bubble houses; temporary glazing	PE, EVA & PVC
Safety helmets	PP

Table 3.2(5)--- continued

Table 3.2(5)--- continued

Tarpaulins	PVC coated, polyurethane (eyeleted)
Temporary shelters or storage	PVC sheet on metal frame, PE on frame
Film for protection from solar radiation	Polyester
Temporary works	
Concrete shuttering lining for producing decorative effects	Vinyl, PE foam
Lumn shuttering	Large-diameter UPVC pipe, Square or rectangular UPVC pipe
RM work, floors	PP
Temporary access roads	PP, Nylon fabric
Storage	
Bulk Containers, storage tanks	PE, PP and PVC
Vibration insulation	
Impact insulation flooring	PE foam, PVC foam, polyurethane foam
Sound insulation	
Acoustic sealing of panels	PVC foam & PVC chip foam, polyurethane foam
Thermal insulation	
Wiring conduits	Glass Fibre foam, Fibre Products, Asphaltic Product Gypsum wall boards.

shown in Table - 3.2(6) for India as an example for developing countries.

TABLE -3.2(6)
APPLICATION WISE CONSUMPTION PATTERN OF PLASTICS IN HOUSING AND SHELTER IN DEVELOPING COUNTRIES

	Component	Materials	Consumption pattern % share
1.	Wires and Cables	PVC	28.79
		LDPE	4.96
2.	Electrical Fittings	Phenolics/PP	0.670
3.	Toilet Seats	PP, HIPS	0.223
4.	Water Proofing	LDPE	0.074
5.	Roof Sheets	GRP	0.119
6.	Various Profiles like handrails, step nosing, expansion joints etc.	PVC	0.377
7.	Pipes & Conduits	PVC	49.64
8.	Sanitary appliances like:		
	a) Flushing Cistern	PP/HIPS	0.29
	b) Toilets Pots	PVC	0.347
	c) Plumbing Fixtures	PVC	0.248
9.	Overhead water tank	LPDE	0.745
10.	Floor Tiles & Skirting	PVC	2.929
11.	Wall Paper	PVC	0.178
12.	Partitions	PVC	0.943
13.	Thermoformed false Ceiling & Wall Panels	HIPS	0.034
14.	Heat insulating film	Polyester	0.049
15.	Sound and Heat Insulation	PS & PUR foam	0.173
16	Others		0.248

The major share i.e. 45 - 60% in this application is of PVC. This material is mainly used as pipes, fittings, conduits, floorings, wire & cable. Plastic pipes have their main application in water supply & drainage. The other applications are in replacement of copper fittings with PVC syphon for automatic urinal and complete replacement of chromium plated flushing system for urinals. The use of plastic overhead water storage tanks has largely replaced the conventional RCC, AC, G.I. tanks. These tanks are mainly consuming HDPE, LLDPE and GRP. GRP tanks are costly and are used in specific applications. Plastic tanks are light weight, leak proof, rust proof, hygienic, unbreakable,easy to install and maintenance free etc. Squatting pans and traps for hand pour flush latrines have been replacing ceramic in this application.

The water supply system in developing countries is inadequate and therefore an imbalance exists. In order to achieve the target of uniform supply of this essential commodity a large amount of pipe will be required. The requirement of plastic pipe will further get a boost through their extensive use in sanitary system, both in rural and urban areas.

There are various other application areas growing in the developing countries to meet the requirement of building material. This attempt is to fulfill the basic requirement of housing for human being. In India alone a short fall of 30.98 million houses existed in 1991 and this will grow to 35.90 million by 1996 as reported in a national daily "Indian Express", Baroda edition on May 23, 1993. A similar situation exist in other developing countries especially those having high population density like China etc.

Plastics have been finding its usage in providing cheaper houses. The popularity is increasing for use of composite panels having foamed PS/PU foam for doors & partitions, PVC extrusion profiles for windows, FRP and red mud PVC sheets for roofing, acrylic/polycarbonate moulding and profiles insulation, PVC tiles and sheets for flooring and skirting, wall paper and coverings & products made of PVC and thermosetting materials for electrical applications.

More care is needed for selection of right material / formulations, in order to achieve satisfactory performance, and high durability for plastic products for housing applications. This is mainly important because climatic conditions are different in different regions.

For the purpose of estimating demand for plastics in housing & shelter, the applications of plastics could be grouped in three categories depending on anticipated growth. The first group consists of applications which are exclusively in plastics. Here demand would be proportional to the growth of building industry. These applications are wires and fittings, electrical fittings and toilet seats. The second group of applications are those which are used as alternative building materials. The growth rate of such applications can be higher than that of building industry. These applications are water proofing, roofing sheets, pipes and conduits, sanitary appliances, overhead water storage tanks, floor tiles and skirting, wall papers and covering, foam for heat and sound insulation, polyester films etc. The third group of applications are those which are popular in developed countries but not in developing countries so far. These are for example, special profiles for windows and doors rolling shutters etc., drain waste vent system and opaque corrugated roof sheets.

The consumption pattern and demand projection of plastics in housing & shelter for developing countries have been calculated on the basis of average consumption pattern of plastics in developing countries (Table 3.2(7). As compared to the developed countries the CARG for developing countries will be almost double in the period of 1995 - 2000 AD.

TABLE - 3.2(7)
CONSUMPTION PATTERN OF PLASTICS FOR HOUSING IN DEVELOPING COUNTRIES

(Fig. in '000 MTs)

Region	1992-93	1995	2000	CARG, % 1995-2000
South & South East Asia	1448	2628	6535	20%
Africa & Middle East	476	777	1774	18%
CPE Europe	960	1742	4332	20%
Latin America	645	1134	2700	19%
Other developing countries	260	473	1170	20%

* Housing and shelter includes material for building construction, power transmission, telecommunication, & drinking water supply.

Source : Compiled from different sources.

3.3 CLOTHING AND FOOTWEAR

3.3.1. CLOTHING

The basic human need for clothing is met through fibre in the textile sector. The natural fibre continues to dominate in the textile sector; however its share has came down with the capturing of global market by synthetic fibre in early fifties. The petrosynthetic fibres, viz., polyester, Nylon, acrylic fibres etc. now play an important role in meeting the growing need of clothing. This is due to the fact that natural fibre like cotton, wool etc. is unlikely to show any significant growth in future. It would be a major challenge to meet the future needs of the clothing for growing world population. The synthetic fibre from petrochemicals can help in facing the emerging scenario effectively and efficiently; specially when synthetics offer superior alternatives to cotton and wool.

There are several large producers of cotton in this world. Even then this has not prevented them from producing the synthetic fibre/yarn to take care of local needs. The Table 3.3(1) gives the share of natural and synthetic fibre in major cotton producing countries.

TABLE 3.3(1)

SHARE OF NATURAL AND SYNTHETIC FIBRE IN MAJOR COTTON PRODUCING COUNTRIES.

(Fig. in '000 MTs)

Production	China	USA	CIS (Formerly USSR)	India
Cotton 1990/91	4470	3400	2834	2074
Synthetics 1990	1309	3430	914	433
Cellulosics 1990	203	229	561	217

By producing large quantities of synthetic fibre China has been able to achieve the following goals:

a) Free some land from cotton cultivation for other crops.

b) produce textiles for the export market, both cotton and synthetics, and

c) offer fabrics to their local population with superior looks, easy care and better durability.

A similar trend is being followed in other developing countries like India. The per capita consumption of synthetics is shown in Table 3.3(2) for a few developing countries in early eighties. There was a feeling that the increased consumption of synthetic fibres/yarns will adversely affect the livelihood of the weaker section of the society who depend on the cotton related economy. It is now recognised that modern technology has created a situation where the traditional methods of fabric manufacture have to be adopted to the new socio-economic conditions. Till the sixties, natural fibre was the only material for clothing in developing countries. With the growth of synthetic fibre, the share of cotton came down to about 70% in 1985. However, the trend indicates the dominance of natural fibre over synthetics where cotton continues to take the lead. The other non-synthetics like cellulosics, wool and silk will have marginal share.

The properties favouring the use of synthetic fibre in all types of climatic conditions has improved the acceptability in all the developing countries. Tables 3.3(3) and 3.3 (4) give a comparitive idea of the properties of natural and synthetic fibres.

Polyester feels like silk or wool, nylon more like cotton and acrylic like wool. The salient features of acrylic fibre are summed up below :

TABLE- 3.3(2)

COMPARISON OF CONSUMPTION OF SYNTHETICS IN DEVELOPING COUNTRIES

Country	Synthetics Production 1984 in 000 meters	Population in millions 1983	Consumption per Capita (kg)
China	701	1019	0.69
Indonesia	149	155	0.96
Phillipines	53	52	1.02
Thailand	89	49	1.81
Brazil	216	130	1.67
S. Korea	746	40	18.65
India	153	733	0.21
Mexico	285	75	3.80
Egypt	19	45.2	0.42
Pakistan	17.5	89	0.196

TABLE - 3.3(3)

FIBRE PROPERTY COMPARISON FOR TEXTILE USAGE

Properties	Nylon	Polyester	Cotton	Viscose	Silk
Durability (Cotton=1)	3.0	3.5	1.0	0.3	1.0
Moisture Absorption*	4.0%	0.4%	8.5%	14.0%	8.0%
Prints Brightness :-					
Initial	Very Bright	Very Bright	Not so Bright	Bright	Very Bright
Exposure to Sunlight	Fades	Does not fade	Fades heavily	Fades heavily	Fades slowly
Effect if Soap	Fades	Does not fade	Fades heavily	Fades heavily	Fades
Abrasion Resistance	Excellent	Very good	Poor	Very poor	Poor
Drape	Good	Very good	Average	Average	Good
Wrinkle Resistance	Good	Very good	Very poor	Poor	Very poor
Crease Recovery	Good	Excellent	Poor	Poor	Poor
Static Development*	Moderate	High	--	--	Little
Comfort/Feel*	Average	Poor	Excellent	Good	Very good

* Disadvantage is overcome by Texturising/Crimping and Application of finishes during fabric processing.

TABLE - 3.3(4)

COMPARATIVE PROPERTIES OF FIBRES

Cross Section	Cotton	Viscose	Nylon	Polyester
Tenacity	3.5	2.1	5.0	5.0
Elastic Modulus	55	65	24	100
Extension	7.3	21	20	20
Density	1.52	1.52	1.14	1.38
Moisture-Regain	8.5	11	4.2	0.4
Wet-Dry Ratio	110	50	90	100
Refractive Index	1.557	1.534	1.550	1.630
Imbibation of Water				
Relative Percentage	45	100	13	5
Friction Coefficient	0.22	0.43	0.47	0.58

- superb soft touch and silky appearence
- dye brilliancy
- warmth from high bulk yarn products incorporating shrinkable fibre
- low shrinkage or washing
- good crease recovery
- low pill formation
- long lasting pleats and folds

Owing to the easy dyeability and bulk characteristics synthetic fibre offers application possibilities in a wide range of woven and knitting textiles like dress materials, sarees, blended sui^ings, single and double knits.

Polyester fibre is largely used for blending with cotton commonly in the ratio of 60:40 and adequate processing facilities are available in developing countries to process the material as per their requirement. As regards acrylic fibre, the spinning does not pose any special difficulty in cotton system spinning. On the contrary, it is easier to process this fibre in the cotton system compared to the other synthetic fibres. In addition to the modified cotton system spinning using 64 mm long acrylic fibre also facilitates manufacture of bulky hand knitting & hoisiery yarns. The processing of these synthetic fibre on conventional mechines for cotton have also encouraged the processors to easily opt for this material.

The applications of synthetic fibre in clothing are enumerated below :

i) Nylon filament yarn (NFY) is mainly used for sarees and knit wear garments due to its lower density as compared to polyester filament yarn (PFY). It has higher moisture absorbance and has higher bulk in crimped yarns giving a better cover. Lower deniers, including monofilaments, can be produced easily which help in reducing the fabric weight per meter. NFY attracts lower processing cost.

(ii) The PFY is preferred in men's wear due to its much higher crease recovery and wrinkle resistance, better drape, longer retention of prints and colour, better abrasion and pilling resistance compared to both NFY and polyester staple fibre (PSF). The use of PFY in ladies wear like sarees has picked up at a faster pace since the development of crimping, twisting, texturising and wet processing technology has rendered a lot of manoeuvrability in design, patterns, fashion, etc. It has also increased the air permeability which overcomes the inherent defect of low moisture absorption.

(iii) In the case of PSF the major use is in shirting, dress materials and suitings, since it can be blended with cotton, wool and viscose to give a dull and smooth feel. This blending helps in increasing the moisture absorption. However, since the spinning of higher counts is both difficult and costly, its usage in sarees is negligible. The process of carbonising was developed to reduce the weight. Only where carbonising process is used, it has some applications in sarees.

(iv) Acrylics are poised to replace wool due to their superior properties. In the world, the main end use of Acrylic is in hosiery, knitwear, suitings etc. The non wear clothing areas of application are blankets, carpets, tapestry etc. However, due to cost factor in developing countries, use of Acrylic has remained restricted to only sweaters, pull overs etc. Acrylic lacks the properties to penetrate woven fabric market and therefore has restricted growth potential.

Some of the indicative factors for the high future demand of synthetic fibre for clothing in the developing countries are given below :

a) The quality consciousness has increased in the people of developing countries. Earlier the craze was more for imported synthetic garments but with their indigeneous availability, these are more in demand.

b) The increasing competition in the market has resulted in better and newer designs of textile products.

c) Some of the developing countries are exporting ready made garments fibre & yarn to developed countries and earn valuable foreign exchange.

d) Because of the over capacities of synthetic fibres in countries like Taiwan and South Korea, the cost competitiveness has increased. The lower cost will take the synthetic products to the lower income group people.

e) The labour is cheap in the developing country, hence the finished products will be more in demand.

f) The per capita consumption of synthetic fibre is very low which not only indicates that the consumption will increase in the coming years but it will largely substitute the natural fibre. The consumption trend of synthetic fibre and its share for clothing is shown in Table 3.3(5).

As an example the demand estimate for textiles and fibres in India is shown in Table 3.3(6). This gives an idea about the future requirement of clothing and the share of synthetics and cotton in this sector.

3.3.2. FOOTWEAR:

Footwear is one of the commodity items of all common man. Leather and the natural rubber were the

TABLE - 3.3(5)

THE CONSUMPTION TREND OF SYNTHETIC FIBRE & ITS SHARE IN CLOTHING IN DEVELOPING COUNTIRES

(Figure in '000 MTs)

	1984		1990		1995		2000	
	Total	Clothing	Total	Clothing	Total	Clothing	Total	Clothing
China	703.11	421.86	843.73	506.24	140.60	84.36	2812	1685
Indonesia	148.80	89.28	107.14	64.30	297.60	178.56	596	360
Philipines	52.04	31.22	62.45	37.50	104.08	62.40	208	125
Thailand	88.69	53.21	106.43	63.88	177.40	106.44	356	215
Brazil	172.01	103.20	206.41	123.84	344.00	206.40	690	415
South Korea	746.00	447.60	895.20	537.12	-	-	-	-
India	153.93	92.36	370.00	110.82	680.00	184.00	1080	370
Maxico	285.00	171.00	342.00	205.20	570.00	342.00	1140	684
Egypt	18.98	11.50	22.75	13.65	40.00	24.00	75	45
Pakistan	17.44	10.46	12.50	7.50	35.00	21.00	68	40

TABLE- 3.3(6)

DEMAND ESTIMATE FOR TEXTILES AND FIBRES IN INDIA

	1989-90	1994-95	1999-2000
Population in million	834	902	972
Total per capita demand (mts)	14.158	15.830	17.933
Total requirement of cotton cloth (mill mts.)	8340	9020	9720
Total requirement of non cotton cloth (mill mts.)	3468	5259	7710
Total cloth requirement for domestic consumption (mill mts.)	12160	14279	17430
Add for export of cotton cloth @15% (mill mts.)	1251	1353	1458
Total cotton cloth required (mill mts.)	10696	11793	12798
Possible fibre profile			
Viscose (mill kgs.)	150	150	150
Wool & Silk (mill kgs.)	20	25	30
Nylon (mill kgs.) (20%)	54	89	138
Acrylic (mill kgs.) (15%)	40	67	100
Polyester (mill kgs.) (65%)	176	289	445

materials used in footwear application before the entry of synthetic polymers. The entry of synthetic polymers have largely reduced the share of leather in this applications due to its superior end use performance. The availability of large quantities of natural rubber in countries like India and Malaysia has been quite favourable for the growth in this sector. Synthetic polymers have helped in improving the design and quality of footwear.

Rubbers are extensively used for the manufacturing of footwears. Even in leather footwear the soles are manufactured from rubber besides PVC. Canvas shoes are wholly manufactured from rubber. Natural rubber is mainly used in this sector though various general purpose synthetic rubbers like SBR, BR are also used for the manufacturing of soles alongwith NR. For the manufacturing of microcellular sheets, high styrene resin (SBR) is used extensively. Table 3.3(7) shows the consumption trend of rubber in footwear application. Though, there are a few organised manufacturers in this area like M/S. Bata etc, a large number of small and medium scale manufacturers are also producing more than 60% of the requirement of footwear. Hawai Chappals are mostly manufactured out of natural rubber. Synthetic polymer i.e. EVA has also gained popularity for this

TABLE 3.3 (7)
RUBBER CONSUMPTION AND ITS SHARE IN FOOTWEAR APPLICATION IN DEVELOPING COUNTRIES

(Fig. in '000 MTs/Year)

	1989	1990	1991	1995
China/Asia CPEC				
i) Synthetic Rubber	350	380	403	508
ii) Natural Rubber	590	630	668	843
iii) Total New Rubber	940	1010	1071	1351
iv) Non Tyre sector	329	354	375	475
v) Application in footwear out of total	103	354	375	475
vi) Average growth rate in footwear	<-------------	12%	------------>	
Eastern Europe				
i) Synthetic Rubber	3020	3060	3120	3400
ii) Natural Rubber	342	368	383	413
iii) Total New Rubber	3362	3428	3503	3813
iv) Non tyre sector	1176	1200	1225	1335
v) Application in foot wear out of total	370	377	385	419
vi) Average growth rate in footwear	<-------------	4.2%	------------>	

TABLE 3.3(8)
REGION-WISE PVC CONSUMPTION AND ITS SHARE IN FOOTWEAR APPLICATION IN DEVELOPING COUNTRIES.

(Fig. in '000 MTs)

	1990		1995	
	Consumption	Share in Footwear	Consumption	Share in Footwear
CPE Europe	2100	231	2371	355
Latin America	1261	140	1698	230
N.Africa & Middle East	610	55	1084	108
South Asia	144	15	189	21
South East Asia	1985	235	3113	345
Other Developing Countries	432	35	559	38

Does not include Centrally Planned Asia Economies.

type of chappals in developing countries. About 24% of EVA produced in India and Indonesia is consumed in the production of footwear. The use of EVA has also given popularity to sports shoes which have fancy appearance, a wide choice of design and more durability.

Soft PVC is one of the major thermoplastics for footwear industry. The reprocessability of PVC is the reason for reduction of consumption of virgin PVC. Currently PVC footwears have established markets with different price and buyer segment. Whereas virgin PVC sandals and monsoon wear are used by the middle and upper class of urban population; reprocessed PVC footwear is perhaps the only alternative available to the poor class. The consumption trend of PVC in this application is shown in Table 3.3(8).

In addition to the use of rubber and PVC in shoe sole making, polyurethane (PUR) has made its place in the footwear industry due to high flex resistance, abrasion resistance and thermal insulation properties. Out of the total urethane market world over, 5.2% share goes to footwear industry. Urethane market share is relatively small in the developing countries due to the high cost and their limited indigenous production. Only a few developing countries like India, S.Korea, Singapore & Taiwan produce polyurethane, whereas most of the demand is met through imports. However, there is a steady growth trend of this polymer in new footwear applications.

Till 1989, PUR chemicals consumption for footwear application, in the world market reached about 1,30,000 MTs - equivalent to 400 million pairs of soles. The ICI report on the world soling market in 1983 (as reported in Popular Plastics of February edition of 1988) is given below :

PVC	19%
Rubber	35%
Leather	15%
Polyurethane	5%
Other materials	6%
Unidentified	20%

The major footwear producers and exporters are S.Korea and Taiwan, accounting for over 40% of world footwear exports ; fast growing are China, India, Brazil, Mexico, Middle Eastern Countries and East Europe.

3.4 HEALTH CARE:

The use of polymers in health care has been very little as compared to other applications. About 0.3% of plastics and even smaller share of rubber are used in this sector. Application wise, a large variety of polymer products are used in this sector. These have not only substituted the conventional materials but also given a new turn to the medical science. Polymer applications in this sector include their use in intracorporal, paracorporeal, hospital & home care products, disposables and pharmaceuticals.Table 3.4 (1a-1d) covers the list of applications where polymers are used.

Speciality grades / formulations of biocompatible polymers having permissible limits of nontoxic additives are used for biomedical applications. It is also essential to sterilise polymeric products to be used for medical applications to obviate the possibility of induce' complication/rejection reactions. There are mainly two methods employed for the sterilization.

(i) Ethylene oxide (ETO) sterilization

(ii) Radiation sterilization.

Sterilization by γ-radiation is more commonly used. This essentially requires the material to be stable to these radiations. Hence selection of polymers also requires this factor to be considered. Table 3.4 (2) lists the polymers alongwith their applications, which are γ-radiation stable.

In developing countries the use of polymers in health care is much smaller than developed countries. Although the progress of medical science in developing countries is satisfactory especially in a few Asian and East European countries but the indigenous availability of products required in this area are very limited.

A large variety of hospital, home care products and disposables are being produced in developing countries consuming speciality grades of commodity plastics like PVC, PP & UHMHDPE. A few of these countries also produce and consume other materials like polyurethanes and polymer composites for artificial body parts. Since biocompatible, nontoxic grade of polymers have limited production, a large amounts of finished products and polymeric materials are imported from developed countries. Engineering plastics like polycarbonate, PPS, PPO etc. required in this sector are not produced in these countries. The machines / equipments and other requirements like moulds / dies are also imported in developing countries. A list of commonly produced plastic products in developing countries and the material used for them is given in

Table 3.4(3).

Other than plastics, elastomer like silicon rubber & natural rubber find medical applications due to their inert nature. Natural rubber is widely used to meet the demand of more contraceptives required for birth control in highly populated countries like India and China and now this device is more popular for the control of disease like 'AIDS' all over the world. Natural rubber is also used in the manufacturing of surgical gloves. Despite the increasing use in this sector the percentage share of rubber will continue to remain very low.

Looking towards the existing trend, it can be understood that developing countries will continue to produce bulk commodity plastics but not much of special grade of material/speciality polymer for medical application and hence it is likely that these countries will be largely depending on developed countries to meet their requirement of polymers and finished products to be used in this sector.

Although the actual figures of polymer consumption are not available for developing countries, the present trend indicates that the demand will continue to grow several folds in this sector in the coming years.

TABLE- 3.4 (1a)
REPLACEMENT OF BODY TISSUES

Body part	Norm of polymer consumption and polymer(s) used	Important functional	Conventional
1. Cardiac assist devices: sacs -they collect the blood from the heart & pump it to the aorta.	Polyurathane based polymers. Polyether based Biomer Norm: Half a gram per sac.	Blood compatability To prevent adhesions by the proteins and fats on its surface to avoid throumbus formation and subsequent vessel blockage or tissue damage. Smooth blood contacting surface. Mechanical characteristics: Strength & durability, long lasting flexibility, resistant to wear and fatigue	Chemically modified silicones
2. Heart valve replacements	Polyurethane and graphite substrate coated with pyrolitic carbon: Norm 20 gms. per valve	To prevent blood clot formation Machanical strength Blood compatibility	Stainless steel and silicone rubber. Chemically modified animal tissues. Pyrolytic carbon
3. Artificial blood vessels	PTFE or Dacron Norm: 50 gms per meter	Porosity leading to a stable, biological approximation of a natural lining to prevent blood clot formation. Flexibility & durability	N.A.
4. Body housing ventricle	Biomer with Dacron mesh sandwiched between layers Norm: 25 gm/housing each.	Biocompatibility Durability with minimum requirements.	N.A.

Table 3.4(1a) continued

Table 3.4(1a) continued

Body part	Norm of polymer consumption and polymer(s) used	Important functional	Conventional
5. Opening to vessels from heart	Polyurethane Norm: 10 gm per opening	Compatibility with blood & vessels Long lasting flexibility under constant stresses and strains.	N.A.
6. Ventricle base	Injection moulded polyurethane	Biocompatibility with heart & blood Durability	N.A.
7. Ventricle Diaphram	Four layers of Biomer with graphite in between Norm: 30 gms per diaphram.	Interness Flexibility Durability	N.A.
8. Ventricle assist devices	Textured material of polyurathane Norm: N.A.	Pseudointima	N.A.
9. Synthetic blood	Perifluoro carbon Norm: N.A.	To transport oxygen and nutrients	Fluosel
10. Prostheses	Carbon fibre reinforced polymers Polymer based composites. Norm:200 gm/ sq. mtr.	Strength Should not fructure & loosen Biocompatible at the implant site. Blood compatibility able to transfer stress from implant to nearby bones	Metals for both orthopedics and dentistry. (Titanium alloys made of chromium & cobalt) Bioactive ceramics, glasses & glass ceramics.

Table 3.4(1a) continued

TABLE 3.4 (1a) continued

Body part	Norm of polymer consumption and polymer(s) used	Important functional	Conventional
11.Tendon & Ligament repair	Kevlar Dacron PTFE Pyrolized carbon fibres Norm: N.A.	Biocompatibility Strength Should encourage new tissue growth Ease for a surgeon to handle	N.A.
12.Synthetic replacement to human skin	Porous Polymers derviced from bovine collagen fibres Silicon rubber Norm: N.A.	To resist infection to body and retain water in body Biodegradable	Polymeric substitute
13.Encapsulation of pancreatic islet of langerhans	Composite material consisting of amino acid polymer, & polysaccharide polymer derived from seaweed. Norm: N.A.	Strong encapsulation Should permit outflow of insulin and inflow of glucose	N.A.
14.Intraocular lens implant	PMMA Silicone rubber of hydrogel Norm: 250 mg per lens.	No negative reaction to eyes Should not get discoloured by UV light	N.A.
15.Casts	Polyurethane Norm: 200 gm/ sq. mtr.	Strength Low weight Resistant of wetting and breaking Should allow patient to move with greater freedom and to bathe more easily.	Plaster of Paris

Ta[illegible].4(1a)

Table 3.4(1a) continued

Body part	Norm of polymer consumption and polymer(s) used	Important functional	Conventional
16.Sutures	Glycolic acid polymers & copolymers Polypropylene Norm: N.A.	Should elicit minimal tissue reaction Enable physician to perform microsurgery	Cat-gut sutures
17.Leg Braces	Polyphenylene sulfide Graphite fibres. Norm:	High strength to weight ratio Ease of fabrication	Metal

TABLE - 3.4(1b)
REPLACEMENT OF BODY PARTS

Parts	Polymer/material	Functional requirements	Conventional material & remarks
1. Facial prostheses, ear implant, false teeth.	Silicone	Bone cells should naturally cling to the surface of titanium facilitating surgeons to implant permanent fixtures into patients remaining bones. Silicone protheses can then be clipped on & off as desired.	Developed by Nobel pharma the Sewdish Company. Success rate for operation is high.
2. Arms and Hand prostheses	Plastic Form & Metalwire	The artificial arms of future would be robotic; computer controlled devices capable of doing anything. Latest model of mechanical hands involve "myoelectric control in which impulses from remaining musceles into electric signals Motion Control in USA make a more robust model of elbow, which allows people to continue doing heavy work.	These prostheses are mainly cosmetic.
3. Hair.	Acrylic hair Silicone	Acrylic hairs are feared to be dangerous But tissue expansion in which the scalp is stretched by a silic one naloon under the skin the bald patch is removed and the expanded area of scalp which does have hair replaced it.	Natural hair trans-plant are not satisfactory

Table 3.4(1b) continued

Table 3.4 (1b) continued

Parts	Polymer/material	Functional requirements	Conventional material- & remarks
4. Larynx replacement	Silicone Bio-Singerprosthetic voice valve to be used in conjun-ction with plastic tracheostoma	Are as good as real larynx Trachrostoma is used to prevent accidential suffocation. However, it's life is about three months because of food intake.	
5. Male genital organ	Silicone implant	To help man suffering from impotence. Silicone implants range permanently erect & bendable	
6. Foot and Leg	Glass Fibre & resin Ultra Roelite leg is made up of carbon fibre with duralumin joints.	Should be light and stable Quantum foot looks and works like a real one.	Japanese have developed "myo-electric" and robatic legs, but they are heavy. JE Hanger launched a "Quantum Foot made of two sprung plates composed of 62 wafer-thin layers of glass fibres of glass fibre & resin
SKELETON KEY			
7. Bone	Composite of polyethylene reinforced with hydroxyapatite	They should be long lasting. The big advantage of polyethylene composite is that it encourages natural bones to grow towards it.	Titanium and cobalt chrome alloys but their draw backs are discomfort,infection and wear & tear

Table 3.4(1b) continued

Table 3.4(1b) continued

Parts	Polymer/material	Functional requirements	Conventional material-& remarks
			especially in the young and active. They wear loose after 18 months in the young, 8 to 10 years in elderly.
8.Elbow	Cobalt Chrome alloy fitting into a polyethylene cup.	There are about a dozen different elbows on the market, none of them entirely satisfactory. They tend to be prosthetic joints made. They usually wear out after ten years and are unsuitable for heavy work or sports. They do provide relief for elderly patients suffering from rheumatoid arthritis.	
9.Knee	Cobalt chrome alloy fitting to polyurethane liner on the tibial platean.	There are some 200 designs on the market, Current research focuses on more durable materials - and on the possibility of transplants. The world's first knee transplant was performed during 1987.	
10.Ligaments	Polyester/Teflon	This is the most favoured material today. Conventional materials - silk, kangaroo tail tendons, and carbon fibre.	
11.Artificial fingers joints, and knuckle.	Silastic silicone rubber	They are less than perfect: they tend to break, and do not provide full movement. US manufacturers produce these metacarpophalangeal and interphalangeal joints.	
12.Hip replacements	Polyethylene ceramics and alloys.	Artificial hip made of polyethylene, ceramics and alloys can improve the lives of arthritis sufferers dramatically. An injection moulded plastic hip initiates the machanics of a natural joint and is held in place by titanium filaments.	
13.Tendons	Polyester fibres with silicone rubber coating.	Tendons made of polyester fibres with silicone rubber coating are sometimes used to mend damaged fingers.	
14.Muscle	Polymer Prostheses	People who loose muscles through accidents or disease are often given polymer prostheses which help the remaining muscles to work normally without actually working themselves.	

Table 3.4(1b) continued

Table 3.4(1b) continued

Parts	Polymer/material	Functional requirements	Conventional material-& remarks
15.Mammarian glands	Silicone, polyurethane	The latest silicone implant used both for vanity and to compensate for lumpectomics include a "port" through which silicone fluid can be added or taken away.	

TABLE -3.4(1c)
OTHER INTRACORPOREAL PRODUCTS

Product	Materials characteristics	Functions/material and remarks	Competing material
1. Joints i.e. Hip replacements	Ultra high molecular weight polyethylene	Should not disintegrate under wear & tear of human body. Should last long for use during remaining life of the person. According to Royal National Orthopaedic Hospital, London the joints made with these material would last many years.	PTFE The material eventually disintegrated under the wear & tear of human body.
2. Reconstrution of larynx, trachea, urethra, esophagus, artificial skin, etc.	Thermoplastics polyester - Polyester fibre meshes	They are employed for reconstruction surgery Biocompetability and mechanical functional requirements.	--
3. Surgical Applns: - patching blood vessels - repairing ventricular outflow tracks, - sewing fings for artificial heart' valves etc.	Thermoplastic polyester	Biocompatibility Mechanical functional requirements.	--
4. Tissue fixation	Polyester reinforced Silicone.	As mesh backing for solid structure to permit tissue fixation.	

TABLE - 3.4(1d)
HOSPITAL, HOMECARE AND PARACORPOREAL PRODUCTS

Products	Material(s) used	Important properties of material & functional requirements of product	Conventional material and remarks.
1. Blow moulded vessels for medical and pharmaceutical use.	Low density polyethylene	LDPE is alternative to PP. LDPE used for vessels where sterilization temperature does not exceed 110 C.	Polypropylene
2. Flexible blood handling accessories :			
2.1 Collection/storage bags and tubings for IV and other uses.	PVC	Flexible, toughness, clarity and chemical resistance charactestics of the material. Should be resistant to sterilization induced discolouration.	--
2.2 IV drip chambers	PVC	Goodrick's recent gamma - resistant grade. The critical chamber seals should remain air tight under heavy flexible action. Flexible toughness, class VI USP designation and 65 shore hardness are the main characterstics	--

Table 3.4(1d) continued

Table 3.4(1d) continued

Products	Material(s) used	Important properties of material & functional requirements of product	Conventional material and remarks.
2.3 Moulded devices	PVC	Gamma stability To inject medication into IV solution lines. The compound permits solvent welding of the IV devices to flexible vinyl tubing.	--
2.4 Blood tubing & other medical equipment, pump tubings for cardiac surgery.	PVC PVC Urethane alloy	Softness & controlled stiffness Kink-free soft drops characteristics and elimination of static build up. Clarity & low friction sufrace. Resistance to extraction by common solvents.	--
3. Injection Moulded products : Petri Dish Inoculating loops Pipetting systems & syringes. Centrifuge tubes	PS & PP gamma resist.	PP is radiation sensitive, PS is better. It allows hotter moulding. Gamma resist PP products are designed to overcome embrittlement and discolouration problems.	--
IV containers and saline solution bottles	PP 13R15A	Moulding grade homopolymer of PP a 20 MF1 low flexural modulus grade.	PVC
4. Cryovials	PP Homopolymer	To stone sperms, blood and other biologicals at extremely low temp. (-135^{o}C & 196^{o}C). PP has non-wetting properties and suitability for precision mould to ensure full sample retrieval	--

Table 3.4(1d) continued

Table 3.4(1d) continued

Products	Material(s) used	Important properties of material & functional requirements of product	Conventional material and remarks.
5. Tissue Culture Flask	'Breathable' Polyolefin based polymer alloy.	Does not require to be open to the atmosphere. The alloy in Fenwal's blow moulded or formed flasks is highly gas permeable.	Moulding PS roller bottles.
6. Surgical trays	Polyarylsulfone	Must survive intact under sterilization without crazing & craking problems. Chemical resistance and transparency.	polysulfone polyetherimide polyethersufone
7. Microfilteration apparatus	Polysulfones	Rapid immunoassays and nucleic acid hybridization. Developed by Bio-Rad known as Bio-Dal. Sterilizability, transparency and close tolerance mobility. Suitability to work with toxic or otherwise hazardous biological reagents.	--
8. Body of a reusable tubex injector to hold disposible cartridge/needle unit.	Polysulfones	Sterilizability by steam It costs 25% as much as stainless steel, lighter.	Stainless steel Engg. resins
9. Moulded handles for an electrical scalpel	Polysulfones	Can withstand hot-air-sterilization temp. upto 180^0 C. Exhibiting dimensional stability & hydrolysis resistance.	--
10. Components of percussionator respirator	Polyethersulfone	To withstand temp. more than 204 C. Inertness to chemical attack.	--

Table 3.4(1d) continued

Table 3.4(1d) continued

Products	Material(s) used	Important properties of material & functional requirements of product	Conventional material and remarks.
11. Flaspack sterilization tray system.	Polyetherimide	Ultem provides greater resistance than sulfone based materials to stress crazing & cracking under repeated autoclave conditions at 130 C. Flashpack is a pressure activated container that flash sterilizes its contents: surgical instruments. Autoclavability, sterilizability, impact strength & chemical resistance.	Sulfones.
12. Health Care products. Lenses, pkg. trays, covers for food warmers, safety shield.	Polycarbonate	Although polycarbonate cannot match all the performance peaks of resins like sulfones, polyetherimide, PC offers cost/performance. Physical characteristics.	--
13. Cardiotomy reservoir	Polycarbonate	For a heart lung system used during surgery to collect blood and start filtering it before it is pumped to the systems' oxygenerator. Dimensional stability under negative pressure is important. Optical properties particularly eliminations of persistant black speck problems. Moldability and sterilization by ethylene oxide.	--

Table 3.4(1d) continued

Table 3.4 (1d) continued

Products	Material(s) used	Important properties of material & functional requirements of product	Conventional material and remarks.
14. Disposable arthoscopic cannula (surgical tube)	Polycarbonate (Gamma resistant)	The cannula protects soft tissue around knee joints from damage during surgery by functioning as a tough sleeve.	Conventional PC
15. Inj. Moulded latch mechanism	Polycarbonate	To present unexpected needle separation & consequent interruption of drug flow in IV systems.	--
16. Positive locking IV connection device; housing latch & inj.cap.	Polycarbonate	Optical clarity High strength & stiffness. Ability to tolerate flexing and repeated intentional connects and disconnects.	--
17. Very small inj. moulded transfer device (6 gms)	Polycarbonate	High productivity. Inertness. Optimum cost/performance	--
18. Add-A-Vial	Polycarbonate	This unit is inserted between sealed drug vial and IV container to mix the drug with diluent at the patients bedside. Easy flow characteristics of PC, and tough plysical properties.	--
19. Ortho Pack lator (100 gms) Other moulded products:	Polycarbonate	A medical device that uses electrical current generated by a 9-volt alkaline battery to promote healing of bone	--

Table 3.4(1d) continued

Table 3.4(1d) continued

Products	Material(s) used	Important properties of material & functional requirements of product	Conventional material and remarks.
mounting clip window caps elect. pads		fracture. The light weight high impact material resists current dissipation and has very good insulating properties, thus helping to ensure site constantly receives the specified electrical signal.	
20. Moving Parts such as IV spikes and stopcocks.	Thermoplastics polyester.	Excellent lubricity Chemical resistance Withstand EO & Gamma sterilization.	--
21. Components used in sophisticated medical eqpts. drip chamber cartridge Tubing set parts Male & Female connections Artorial and venous slide clamps	Thermoplastic Polyester Kodar PET G 6763 Copolyester	Close tolerance mouldability	
SEATTIE Foot Inner Spring	Urethene Foam acetal homo polymer	Strain energy absorption and timed thrust/life effect Foot is prosthetic device that replicates the recoil & spring of human muscle	--
22. Equipment components Opthalmic products Specially medical pkg.	Nylon 6 and Nylon 6/6 resins	These have been principal applications historically. They cannot be used as permanent implants as they loose strength and rejected by the body tissue.	--

Table 3.4(1d) continued

Table 3.4 (1d) continued

Products	Material(s) used	Important properties of material & functional requirements of product	Conventional material and remarks.
23. Transparent body of a drip counter	Special unnuoleated Nylon - 6	Ti..s is used to control blood transfusions. The part is moulded in a chilled mould Crystal growth is eliminated resulting in a highly amorphous part with good clarity. This induced transparency diminishes by increase in thickness.	--
	Nylon-12	This resins is relatively economical as compared to Nylons modified to retard crystalline growth which are used for thicker parts demanding cla-ity without manipulation of moulding conditions.	--
24. Holter Cardiac Monitor	Nylon/ABS	It weighs around 250 gms. including cassettee tape & batteries. It records synchronous movement of heart over 24 hour period helping to detect heart abnormalities. It is worn on the hip Conventional materials : Plastics & Metal	--
25. Soft Contact lense cases and side-by-side heaters	Polysulfone, Polysulfone alloys (second polymer is most probably thermo-plastic polyester)	For storage and disinfection of soft contact lenses The alloy is claimed to be better and less costly as compared to straight polysulfone.	--
26. Housing panels of blood analyser	Modified PPE Structured roam	Cost reduction and better appearance/esthetic qualities like round edges & varied texture.	--
27. Lab Eqpts. & disposable sur-gical instruments	Modified PPE resin	Withstand ethylene oxide and gamma radiation sterilization. Used for both moulded and extrusion products.	--

TABLE - 3.4(2)
SOME RADIATION STABLE POLYMERIC MATERIALS AND THEIR REPORTED USE.

Vinyl	Unplasticised PVC (rigid)	Anaesthetic airways, endotracheal tubes, tracheostomy tubes, M-tc-M double airways, mounts and adaptors containers.
	Plasticized PVC (flexible)	Tubings, catheters, cannulae, infant feeding tubings blood blood giving and taking sets, blood and plasma bags, aprons and other sheetings.
Olefins	Polyethylene-low density, high density	Implants, osscicles, artificial tear ducts, tubing, film especially bags for containing sterile articles, film laminates.
	Poly (methyl pentene):	Syringes, connectors, tubings, and
	ethylene/vinyl/ acetate	plungers
Styrene	Polystyrene	Hypodermic syringes, sponges and phials.
Polyamides	Nylons	Sutures, gauze filters, intravenous tubing, cannulae, ureteric and angiography catheters, connectors, adoptors, film for packing.
Flurocarbon polymers	Poly trifluro-ethylene, fluorinated ethylene/ propylene resins	Transfusion sets, chambers, filters, implants specialised cannuale, woven yarn/fabric for aortic valves and arterial
Polyester	Polyethylene terephthalate	Film and film laminates,
Epoxide resins		Electrical insulation such as for cardiac pacemakers.
Natural and Silicone rubbers		Tubings, implants, hydroacephalous valves, arteriovenous shunts.
Acetals	Polycarbonate	Oxygenators, syringe components
Thermo-setting materials	Phenol formaldehyde; Urea formaldehyde	Bottle caps & closures

TABLE - 3.4(3)
PLASTIC IN MEDICARE PRODUCTS BEING GENERALLY PRODUCED IN DEVELOPING COUNTRIES

	Plastic products	Approx. Wt. of plastics per piece (gms)	Plastic used
1	Crutch Tips/Shoes	70	PVC
2	Gripper	160	ABS
3	Wheel Film	220	ABS
4	Pulley Wheel	80	Nylon,66
5	Disposable Syringes	20	PP
6	Ampules	1.5	LDPE
7	PVC containers and tubings for IV solution	-	PVC (non toxic)
8	I.V. Sets	30	PVC
9	Blood Adm. Set	35	PVC
10	Blood Donor Set	16	PVC
11	Scalp Vein Sets	5	PVC
12	PVC Pouches for IV fluids	25	PVC
13	Eye droppers	1.5	LDPE
14	Cap for dropper	0.2	LDPE
15	Poly bag for dropper	0.2	LDPE
16	Spoon for taking medicines	2.5	PP
17	Reel for sutures	13.5	PP
18	Containers for ointments	75.0	PP
19	Spool	8.5	PP
20	Cups (10 ml.) for taking medicines	1.8	PP
21	Hearing aids	3.5	PP
		35.0	ABS
		12.5	Nylon

3.5. P A C K A G I N G

The packaging sector consumes largest share of plastics i.e. 30% in developed countries (Fig.3.1F) and 36.5% in developing countries. Commodity thermoplastics i.e. LD/LLDPE, HDPE, PP/PPCP, have their major share in this sector.

The packaging area will continue to dominate among the various end-use segment. A careful analysis of the end-use pattern shows that within the packaging sector, textiles and garment packaging, food packaging including milk are dominant. The demand of woven sacks is driven by the demand of fertilizer & cement industry and bulk commodities. Table-3.5 (1) shows the user segments and plastics used for their packaging.

By providing cheap packaging material, plastics have a role to play in reducing the effective cost of basic items of consumption such as food grains, edible oils, milk, sugar etc, to the consumer. Packaging in conventional materials such as jute, glass, wood and paper is not only expensive but will always be inadequate even to meet the exploding demand for bulk packaging alone. Other than lower cost, use of plastics in packaging is widely accepted due to the technical reasons i.e.(i) light weight hence, low energy required

TABLE - 3.5 (1)
PACKAGING PRODUCTS AND USED PATTERN OF PLASTICS

User Segment	Products	LD/LLDPE	HDPE	PP/PPCP	PVC	PS
FLEXIBLE TYPE						
Liquid Milk	Multilayer Film	X				
Processed Food	Multilayer film & composites	X	X	X		
Textile & Garments	Film	X	X	X	X	
Woven Sacks	Raffia Tapes		X	X		
Unit Packaging System	Film	X		X	X	X
Cereals Salts, Sugar Detergent	Film	X				
Carrier Shopping Bags	Mono/multilayer Film	X	X			
Industrial Products	Loose liner films	X	X			
	Shrink/stretch wrap film	X				
	Coated Raffia	X				
	Laminated products	X	X			
	Speciality films & sheets (Formed sheets, Bubble film, wavelock, Minigrip, laminated films).	X			X	
Consumer Products	General Purpose films & bags	X	X	X	X	
	Confectionery	X		X	X	
	BOPP film			X		
	Sutli/strapping			X		
RIGID TYPE						
Milk, fruits & vegetables	Crates		X	X		
Pharmaceutical & house hold	Lids, caps & closures	X		X		X
Bulk chemicals & oils	Blow moulded containers		X	X		
Solvents & thinners	Blow moulded containers	X	X	X	X	
Retail liquids	Blow moulded containers		X	X		X
Cosmetics	Containers		X		X	X

for handling, (ii) high permeability resistance to gas/moisture which helps in increasing the shelve life of packed product & (iii) easy and economical processing.

As a result of growth in production of basic items of consumption, the packaging needs for these items would be enormous by 2000 AD. There is a misconception that plastic packaging would displace the conventional packaging material such as jute, paper and wood. This belief is unfounded as the acreage under forests and jute is not keeping pace with the increasing need of packaging industry and productivity increase is unlikely to be adequate to meet the rising demand (Table-3.5 (2)).

TABLE - 3.5 (2)
DEMAND-SUPPLY GAP OF JUTE AND THEREBY REQUIREMENT OF PLASTICS IN INDIA

			1984-85	2000 AD
(i)	Total sacking requirements	Mn Nos.	1960	4500
(ii)	Total jute sacking available	Mn Nos.	1600	1900
(iii)	Demand Gap	Mn Nos.	360	2600
(iv)	Equivalent quantity of HDPE/PP required to meet supplementary demand	Tonnes	39000	286000

Mn - Millions.

The packaging sector mainly consists of four areas i.e. Industrial, consumer, processed food and pharmaceuticals. The developing countries like China and India are the large agro based economies requiring about 63-67% of plastics packaging share in non-industrial area (Table-3.5(3)). The compound annual growth rate in these Asian countries between 1984-85 to 1989-90 has been 8% and this is expected to be about 18-20% upto 1995 due to their faster economic growth. The other agrobased developing countries like Malaysia, Indonesia and Thailand, will show a similar growth trend in packaging sector. The countries like Taiwan, Singapore, and S.Korea have been expanding their textile and other industrial establishment much faster hence their consumption in packaging sector is more towards the industrial packaging. The demand of some of the packaging products in developing countries is met through imports from other countries. The exporters are India, Indonesia etc. for the products like woven sacks, bags etc. A mixed growth trend is expected in Latin American countries, whereas Middle East countries will require more material in packaging of consumer goods. The present trend and expected future growth of plastics in packaging in developing countries is shows in Table-3.5(4).

The packaging products are mainly divided into two types i.e. flexible and rigid. The consumption of flexible packaging is many times more than rigid by volume.

TABLE-3.5 (3)

PRESENT STATUS (CONSUMPTION) AND DEMAND PROJECTION OF PLASTICS IN PACKAGING FOR INDIA & CHINA

	1992-93						1995						2000 AD					
Packaging	LD/LLD	HDPE	PP	PVC	PS	Total	LL/LLD	HDPE	PP	PVC	PS	Total	LD/LLD	HDPE	PP	PVC	PS	Total
Industrial	142.8	329	73.5	23.5	30	598.8	71.3	415	120	27	35	668.3	336	816	178	48	80	1458
Consumer	238	43	336.8	8.8	-	626.6	285.6	52	390	10.2	-	737.8	560	110	790	18	-	1478
Processed food	272	58	84.2	5.8	-	430	326.4	53	85	6.8	-	471.2	640	134	200	12	-	986
Others	27.2	-	5	11.9	-	44.1	32.64	-	15	14.0	2	63.64	64	-	22	24	-	110
Total	680	430	499.5	50	30	1689.5	816	520	610	58	37	2041	1600	1060	1190	102	80	4032
CARG, %						<----------10.70%----------						><----------15%----------						>

* Compiled from different sources

TABLE - 3.5(4)
PRESENT TREND AND EXPECTED FUTURE GROWTH OF PLASTICS IN PACKAGING IN DEVELOPING COUNTRIES

(Fig. in '000 MTs)

Region	1992-93	1995	2000 AD	CARG, % 1995-2000
Asia/Pacific	4384	5700	10260	12.5%
Middle East	520	650	1250	14%
Eastern Europe	2352	2822	4860	11.5%
Latin America	1445	1806	3110	11.5%
Africa	490	612	1175	14%

* Compile from different sources.

** This includes polyethylene and polypropylene only.

The materials used in packaging and their use pattern in developing countries are as follows :

3.5.1. LD/LLDPE :

The demand of LD/LLDPE is primarily driven by the packaging sector. Among the various segments of packaging, food items including liquid milk and processed food packaging are the primary drivers of growth.

The liquid milk requires mainly flexible packaging. This depends on the amount of milk production brought under organised sector. The value added milk products consume a large quantity of flexible packaging materials. These are mainly used in the form of satchets, replacing cans and glass bottles. In India, during 1985-90, the relative share of satchets have grown from 49.8% to 74% and the share of cans and bottles have gone down by 24% as shown in Table-3.5(5).

TABLE - 3.5(5)

RELATIVE SHARE OF PACKAGING FOR MILK(%) IN INDIA.

	1985	1990
LD/LLDPE Sachets	49.8	74
Cans	18.5	6
Bottles	17.5	6
Bulk vending	14.2	14

In developing countries there has been a significant development in the packaging of processed food from mid of eighties. Sophisticated processing capacity have been established to meet the growing demand of the processed food industry. Multilayer films involving a good share of LDPE is preferred for this application.

A variety of industries use LDPE film in the formet rolls, liners, bags and extrusion water substrates for intermediate packaging. The output of these industries are intermediate to the industrial sector itself. The usage of LDPE in packing for bulk chemicals, drugs, machine tools, spares, engineering industrial components, plastic raw materials, automobile parts and appliances have been all grouped in this segment.

LDPE is also in growing demand for unit packaging of soaps & detergents. The consumption of LDPE in extrusion coating has largely grown from the last few years. This is required for coating on metal foils, woven sacks, jute bags, paper and cloth. The shelf life of essential commodities and processed food is improved by using these packaging products.

3.5.2. HIGH DENSITY POLYETHYLENE (HDPE):

The demand for the woven sacks is linked to the demand pattern of fertilizer, cement, sugar, salt and other bulk commodity packaging requirements. This has been mainly replacing/complimenting the jute and cloth bags in a few Asian countries. The largest producer of jute in the world is India. But the jute production has been more or less stagnant for nearly more than a decade (Table- 3.5(2)). The demand of synthetic sacks is mainly for the packaging of fertilizer and cement.

Fertilizer production is based on nitrogen, potassium and phosphatics. Packaging of fertilizer is mostly done in jute fabric laminated with LLDPE/HMHDPE film. Jute sacks are used for packaging of nitrogenous and other mixed fertilizers in jute producing countries. Woven sacks of HDPE are used for packaging of phosphatic fertilizers because of superior chemical resistance. Sacks made from PP/HDPE have many advantages over jute sacks - better stress and abrasion resistance, better moisture resistance etc. But they have the disadvantage of difficulty in stacking due to slippery surface. Among synthetic sacks, PP sacks can be stacked higher than HDPE due to better coefficient of friction.

In order to protect the jute industry Indian government reserves a certain areas for jute bags i.e.foodgrains, urea, sugar & cement. The government imports it and supplies to fertilizer plants for unit packaging and feeding the market.

Polymer consumption in fertilizer packaging is calculated assuming 80% of nitrogenous fertilizers to be urea which is necessarily packed in jute bags. The remaining 20% and the entire phosphatic are assumed to be packed in synthetic sacks.

Each synthetic bag consists of the outer sack and inner liner. The sack made of HDPE weights 110 gms whereas the linear made of LDPE weights 25 gms. Based on this the polymerwise breakup can be taken as 70:20:10 for HDPE:LDPE:PP.

Cement industry uses different packaging materials i.e. jute, multiwalled paper bags and synthetics. Jute dominates in India in cement packaging. Synthetic bags have several advantages over jute.

(i) They are stronger than jute
(ii) They are lighter and hence transportation and handling costs are lower.
(iii) Seepage from synthetic bags is very low (0.3%) compared to jute bags (5%).

Hence there is a strong preference of synthetic sacks. Amongst synthetic materials PP is preferred over HDPE. PP has lower density than HDPE hence higher yield. Secondly PP can withstand higher filling temperature i.e. upto 100°C as compared to 80°C for HDPE.

Production of cement, fertilizer and other consumer products will continue to increase in developing countries. Hence the growth rate of the packaging material will also be driven with the increasing demand of these items. The use of conventional packaging material will continue to decrease due to various advantage of synthetic material. This will give a boost to the demand growth of synthetic materials.

In the area of rigid packaging blow and injection moulded items are used for toiletries, vegetable oil, ghee, lube oils, pharmaceuticals and chemicals etc. However, LLDPE is capturing market in rigid packaging products in place of HDPE. The HMHDPE films and bags successfully removed paper from most of the consumer retail shops.

3.5.3 POLYPROPYLENE:

One of the major contributors for the growth of polypropylene in the market is packaging film especially the tubular quench (TQ) and biaxially oriented films (BOPP).

TQ PP film accounts for the largest volume sale of polypropylene. Textile over wrap and export garment packaging are the key sectors of use of TQ films. The second largest end use of TQ films is in the general purpose packaging sector.

The BOPP film represents one of the special applications of the polypropylene. This has captured significant markets from cellophane for cigarette wrapping, lamination, packaging of confectioneries, bakery products and other processed food items.

In rigid packaging PP/PPCP shares the market requirements of crates, blown bottles and containers for packaging & transportation of unit packs of perishables, pharmaceuticals, toiletries & chemicals. PP also shares the market of HDPE in woven sacks. In addition to this PP twines and strappings have been largely replacing jute and metal strip for unit packaging.

3.5.4. POLYVINYL CHLORIDE :

Rigid PVC film is used in the textile industry for overwrapping of garments. However, PP film has penetrated into this sector and resulted in a slower growth of rigid PVC films. However, twist wrapping of sweets and candy have been still retained by PVC. The calender foil market has been finding increasing use particularly in pharmaceutical and consumer products such as razor blades, toys etc.

Blown bottles of PVC have market for packaging of edible oils, fruit juices, mineral water and highly carbonated drinks.

3.5.5. POLYSTYRENE :

Thermoformed polystyrene containers are the major packaging products. The injection moulded containers for cosmetics and other similar applications have also gained importance.

3.6 INDUSTRIAL COMPONENTS AND ENGINEERING PRODUCTS.

The use of petrochemicals especially plastics and rubber in industrial components and engineering products has not only helped in modernisation of industries but also given birth to new products in the area of electronics, telecommunication and computers. Engineering plastics replaced metals mainly in three areas:

(i) Working parts in a form of compact thick sections , replacing die cast mouldings.

(ii) Large component housing replacing metal sheets.

(iii) Load bearing structures.

3.6.1 ENGINEERING/ SPECIALITY PLASTICS

The world wide share in consumption of engineering plastics in 1985 was only 2.1% of the total plastic material. The two largest consumer industries for engineering plastics were electrical/electronics and automobile. The share of major engineering plastics in developed countries during 1985 is shown in Table 3.6(1).

TABLE 3.6(1)

CONSUMPTION OF ENGINEERING PLASTICS IN DEVELOPED COUNTRIES-1985

(Fig. in '000 MTs)

Type	W.Europe	U.S.A.	Japan
PA (All types)	275	200	100
ABS	410	480	450
PC	90	140	50
POM	68	50	70

Amongst the developing countries like India the consumption pattern of engineering plastics was about 16000 MTs per annum (including PMMA). However, based on emerging demand trend, it is expected that in addition to ABS and Polyamides; Polycarbonates, Polyacetals, PET/PBT and PTFE will also be required in reasonably good quantities with the induction of advanced technologies from leading manufacturers of developed countries particularly in automobile, electronics and telecommunication sectors. The present global consumption of major engineering/performance polymers is given in the Table 3.6(2).

TABLE 3.6(2)
GLOBAL CONSUMPTION OF ENGINEERING PLASTICS

Products	Global Consumption (million MTs)
ABS	1.65
PMMA	0.85
PET	1.80
PA	0.80
POM	0.40
PPS	0.20
PBT	0.20
PF	0.30
UF/MF	0.15
PE	1.40
*EPOXY	0.96

* Consumption of epoxy for reinforced plastic applications are not available.

The sector wise consumption share of these materials is as follows:

(i) Automobile sector - 40%

(ii) Appliances - 25%

(ii) Telecom - 15%

(iv) Textile - 10%

(v) Other - 10%.

Different engineering polymers have got some specific features such as PMMA - optical clarity, polycarbonate - high impact strength, SAN - high chemical resistance and ABS - better blend of mechanical properties. In view of this, properties and applications of different performance plastics are discussed in the following sections.

3.6.1.1 ACRYLONITRILE, BUTADIENE, STYRENE (ABS)

Made from a continuous phase of styrene, Acrylonitrile (SAN) on to which a dispersed elastomeric phase of polybutadiene is grafted; ABS offers combination of toughness, rigidity and surface properties. These coupled with its excellent processibility make it the largest volume performance engineering polymer. The global consumption is estimated to be in the range of 1.65 million MTs and is growing at the rate of 4.5% per annum to reach the production levels of approximately 1.95 million MTs in 1995. The major application area of ABS are automotive, business machines, appliances, telecommunication and consumer electronics. In all these areas the product is used for interior non-load bearing panels and housing. It is also used in blends with PVC and polycarbonate.

3.6.1.2. POLYMETHYL METHACRYLATE (PMMA)

Commonly known as Acrylic, PMMA, made from Methylmethacrylate monomer; is distinguished by its excellent clarity and a good impact resistance under normal handling conditions. The product is easily depolymerised to its monomer and can again be polymerized, making it possible to obtain cast sheets from regenerated monomer with very little investment on plant and machinery. The current global consumption of virgin polymer is estimated to be 0.85 million MTs and is likely to reach one million MTs by 1995.

The major application of PMMA sheet is in the glow sign market followed by glazing market in the building industries, fabricated novelty products and for automotive applications in public transport system. The molding grades of resin are used for automobile, lenses, dials for instruments, and consumer electronic products.

3.6.1.3 POLYETHYLENE TEREPHTHALATE (PET)

Made from condensation polymerization of ethylene glycol with dimethyl terephthalate/ terephathalic acid is dominated by its usages in the textile industry as the most widely used synthetic fiber. Different grades depending on the degree of crystallinity, are also used for blown bottles, insulation films and to a limited extent for moulded appliances.

Nearly 1.8 million MTs PET was used globally for bottles and film applications in 1991. Of this 55% was used for production of bottles for beverages, drugs, cosmetics, and edible oils. The balance quantity was used in films for packaging, magnetic tapes, strapping etc. Polymers which have higher mechanical properties and better temperature resistance are primarily used in industrial applications requiring structural performance at elevated temperature. Besides this it retains its inherent plastic properties of being insulating medium to electrical and thermal energy.

3.6.1.4 POLYBUTYLENE TEREPHTHALATE (PBT):

Polybutylene Terephthalate (PBT), made from condensation reaction of 1,4 Butanediol with dimethylterephthalate, is predominantly used in moulding. Small quantities of PBT is also used in moulding applications, but its contribution to the total engineering plastic products is quite low. Thermoplastic Polyester is also used as an alloying material with Polycarbonate for automotive impact bearing applications.

Excluding the fibre, bottle and film applications, of PET, the consumption of PET and PBT for moulding is estimated to be 0.25 million MTs and is likely to reach 0.3 million MTs by 1995. Due to its crystalline nature it imparts good chemical resistance, superior electrical properties, excellent heat resistance and dimensional stability in the filled form. Thermoplastic polyester is widely used in electrical, electronics and domestic appliance applications.

3.6.1.5 POLYAMIDES (PA)

While there are a number of Polyamides commercially developed;the usage is dominated by two major types i.e. Polyamide 6 (produced from polymerization of caprolactam) and Polyamide 66 (produced from condensation reaction of hexamethylene diamine and adipic acid). The physical and mechanical properties are largely determined by the degree of crystallinity.

Though Polyamides were initially developed as a synthetic fibre material, over the years they have been used for film and moulding applications as well. Fibre applications even now constitute the primary usage. Being crystalline polymers, Polyamides offer very good solvent resistance and in the filled form mechanical properties are substantially improved. Due to relatively lower cost compared to other engineering thermoplastics, the global consumption is also highest and is currently estimated to be 0.8 million MTs which is likely to reach one million MTs by 1995.

The moulding markets account for 55% of the resin consumption and are broken up into automotive (11%), electrical (11%), engineering (14%), textile (7%), hardware items (3%), and miscellaneous applications (9%). The balance 20% is made-up of extruded rods, flats and film applications.

Bulk of the Polyamides used by the industry is in the transportation sector. This is followed by usages in the electrical, electronics, industrial machinery, appliances and consumer items. Significant volume of Polyamide is also used for monofilament and film applications.

3.6.1.6. POLYCARBONATE (PC)

Amongst the major engineering thermoplastics, PC is perhaps the fastest growing polymer in terms of its usages. The general purpose grade of PC is a linear polyester of carbonic acid in which the dihydric phenols are linked through carbonate groups. Addition of a small amount of polyhydric phenols can enhance flame retardancy, melt strength and other properties. The consumption at present is estimated to be in the range of 0.6 million MTs and is expected to reach one million MT by 1995. The material has its demand in safety shield and helmets, bio-medical area, electronics and a large variety of engineering products.

3.6.1.7. POLYACETALS (POM)

Polyoxymethylene (POM) commonly known as Polyacetal is available as a homopolymer made by polymerization of formaldehyde and as a copolymer from polymerization of trioxane with small amount of comonomer which randomly distributes the carbon-carbon bonds in the form of oxyethylene groups. The oxyethylene units in the polymer chain help to prevent thermal, oxidative and chemical attacks on the polymers.

The global presence in the polymer is dominated by DuPont manufacturing, homopolymer grades (Delrin) and Hoechst-Celanese manufacturing copolymer grades (Celcon). The present estimated consumption is approximately 0.35 million MTs which is likely to go up to 0.4 million MTs by 1995. The material has got its application in electrical, industrial, irrigation and engineering products.

3.6.1.8 MODIFIED POLYPHENYLENE OXIDE/ETHER(MPPO/MPPE)

Polyphenylene Oxide is made by oxidative coupling of substituted phenols with elimination of water molecule. In its pure form PPO is characterized by high heat resistance but poor thermal stability. To make it amenable to conventional thermoplastics processing techniques it is suitably alloyed with Polystyrene. This process of modification made it the first commercially successful alloy in the world.

Modified PPO market is dominated by GE Plastics, the originator of the alloy. The present global consumption is estimated to be 0.2 million MTs which is likely to reach 0.25 million MTs by 1995.

Due to its excellent electrical properties, good mechanical properties and flame retardancy, mPPO is widely used in business machine, telecommunications, electrical and electronic applications. It is used in the automotive field for heat resistant interior parts and as an alloy with Polyamide, for on-line paintable exterior body panel applications. Due to high hydrolytic stability, mPPO is also used for various fluid and environmental engineering applications. The present consumption is estimated to be 300 MTs which is likely to reach 3,500 MTs by 1995 and, 7,300 MTs by 2000 AD.

3.6.1.9 POLY TETRA FLOURO ETHYLENE (PTFE)

PTFE is widely used in industrial applications due to its excellent chemical resistance, heat resistance and good mechanical properties. The global estimated capacity is 44,000 MTs which is likely to go up to 55,000 MTs shortly. The self lubrication properties and high heat resistance is the reason for its acceptability in many industrial components.

3.6.1.10 POLY PHENYLENE SULFIDE (PPS)

PPS has very high temperature resistance and almost zero mould shrinkage coupled excellent mechanical properties and chemical resistance. It is being used in small quantities for critical applications in electrical, electronic, business machines and consumer novelty items etc. The current global consumption of PPS is estimated to be 15,000 MTs.

3.6.1.11 POLY SULFONE

Due to their high heat resistance and transparency polysulfones are also used in small quantities for medical applications requiring repeated sterilization and components for dairy equipments which need the property for visual inspection of internal content or flow of products. The global consumption is estimated to be 11,000 MTs; bulk of this goes for medical applications.

There are a large number of other low-volume, high-value thermoplastic resins that are used in industrial applications, requiring specific performance criteria. This includes polyetherimide, polyetheretherketone (PEEK), polyarylate, polyimide, poly-amide-imide and liquid crystal polymers.

3.6.2 THERMOPLASTIC ALLOYS & BLENDS:

Thermoplastic alloys and blends have high developmental cost associated with invention and commercialization of new polymers. With the substantial progress achieved in the field of comptibilizer technology, a wide range of alloys and blends are being commercialized to clinch market in specific application segments where a single polymer is either functionally deficient or economically unattractive. Use of engineering thermoplastics and speciality polymers in this area has made substantial progress.

The commercially successful list of alloys and blends include AL/PVC, ABS/PPO, PC/ABS, PC/PBT, PC/PE, PPO/PA, PPS/PTFE, ABS/Polysulfone, PBT/Polysulfone, polysulfone or polyethersulfone with PTFE etc. In most of these areas the compatabilizer technology is closely guarded resulting in few successful manufacturers able to offer these alloys.

3.6.3 THERMOSETS

Details of global consumption of thermosets collected from different industrial sources has been shown in Table 3.6 (2) and their main applications are shows in Table 3.6 (3)

TABLE 3.6(3)

APPLICATIONS OF THERMOSETS

	End Use Applications	Percentage
1.	Electrical accessories, plugs, switches etc.	29
2.	Electronic parts (connectors), switchgear and other related electrical components including telecommunication components	25
3.	Non-electrical domestic appliances e.g. Pressure cooker handles, Knobs etc.	10
4.	Electrical appliances-household end use applications	5
5.	Automobiles (e.g. Distributor Cap)	7
6.	Defence Applications	2
7.	Textiles-Garments Industry	5
8.	Novelty items (ashtray)	1
9.	Household items; Toilet seat	2
10.	Miscellaneous (Ind. trolley, Railway (signal relayst) Industrial parts.	14
		100

3.6.3.1 PHENOL FORMALDEHYDE (PF)

The consumption of PF had been growing at a very low pace over the past few years. The main reason could be low technological improvements both in the production as well as the processing areas. The growth rate expected to be 2.5% per annum during this decade to reach a level of 16,500 MTs during 1995 and 18,700 MTs in the year 2000 AD.

3.6.3.2 UREA FORMALDEHYDE (UF)/ MELAMINE FORMALDEHYDE (MF)

UF moulding powders are mostly used in the electrical industry (80%) and for production of buttons (15%). Small quantities are also used for manufacture of toilet seats and for novelty items. MF is mostly used for moulding of tablewares (95%) and a small quantity for electrical applications, as industrial laminates.

The current consumption of UF/MF is likely to grow at a more rapid pace compared to that of PF. The demand is estimated to reach 12,000 MTs by 1995 and 19,000 MTs by 2000 AD.

3.6.3.3 UNSATURATED POLYESTER

Unsaturated Polyesters are versatile thermosets offering a wide range of products and enormous varieties of application possibilities, made from a mixture of phthalic anhydride, maleic anhydride, propylene glycol, ethylene glycol and styrene monomer these are used primarily with reinforcing materials like glass, aramid and carbon fibre. The reinforced applications of unsaturated Polyester account for 80% of the total usages. Advances made in the areas of Sheet Moulding Compounds (SMC), Bulk Moulding Compounds (BMS) and Dough Moulding Compound (DMC) have enabled to overcome the processing draw back of the thermosetting resin at the same time availing of its property benefits.

The primary usages of reinforced unsaturated polyester is in the electrical and electronic industry. Automotive and transportation sectors also use substantial volume followed by industrial applications.

The major processes involved are hand laying up, compression moulding, SMC, DMC, filament winding, pultrusion, continuous impregnation, casting etc.

3.6.3.4 EPOXY RESIN

Widely made by condensation of epichlorohydrin with bisphenol-A, diphenyl propane; epoxy is primarily used for coating, bonding and to a very limited extent for specialized reinforced plastic applications. In the latter category, bulk of usages are in the electrical laminates for printed circuit breakers. The global consumption of epoxy in the reinforced application is estimated to be 3.36 million MTs.

The growth in consumption of engineering/ speciality plastics would entirely depend on the demand of the end user industries. The extent to which these plastics either in prime form or as compounds, alloys and blends proved to be cost/performance effective, alternative to the existing materials of construction. There is an ample scope in developing countries with the diversified applications of these plastics.

Engineering/speciality plastics are high cost, low volume materials. The consumption pattern of the major ones is given in Table 3.6 (4) for developing countries. Materials like ABS, Nylon, PPS, PMMA, PET, PBT, PTFE etc. are manufactured in the countries like India, China, Mexico, Argentina and S. Korea etc. The large consumers are Hongkong, Taiwan, S. Korea, India and

TABLE 3.6 (4)
CONSUMPTION PATTERN OF ENGINEERING PLASTICS
(%)

	Polyamides	Polycarbonates	Polyacetals	PET/PBT	ABS	PTFE
Transportation	4-5	4-5	10-15	8-15	12-15	-
Teletronics	18-20	25-30	40-45	25	25	-
Electrical	4-5	10-15	15-20	-	Neg.	10
General Engg.	45-50	15-20	15-20	12	15	75
Others	15-20	35-40	5	40	40-45	10
	(monofilaments/ bristles/ consumer)	(consumer/ domestic)	(consumer/ domestic)		(refrigerator/mixie housing)	
Misc.	5	5	5	5	4-5	5

materials, these countries largely depend on import. Capacities building is also planned for PC and polyacetals in developing countries.

Taiwan and Hongkong are large producers of consumer electronics, computers and telecommunication products mainly for their export. These countries have adequate infrastructural facilities for the processing of engineering and speciality plastics. They have also gained expertise in this area. The blends/alloys required for special end use applications are also produced and adequate facilities for their compounding have been created.

Some of the speciality materials and thermosets are used in defence, aerospace and other high tech applications. Countries like India and China have expertise in the application development of these materials. Their material requirement is partly fulfilled by local production. Fibres like PP fibre, acrylic have gained its market in automobile and industrial sectors. Indigenous rubber production partly takes care the requirement of industrial and engineering components like tyres, gaskets, seals, belts etc.

4.0 EXPERIENCE GAINED FROM THE DEVELOPMENT PATTERNS OF DOWNSTREAM PETROCHEMICAL INDUSTRIES IN INDUSTRIALISED COUNTRIES AS APPLICABLE TO THE CONDITIONS PREVALENT IN DEVELOPING COUNTRIES:

The development of downstream petrochemical products has surpassed the traditional materials not only in terms of economics but also in performance. These products are substituting as well as supplementing the natural materials which are mostly found in short supply and could not fulfill the basic human needs. The existence of certain products in electronics, electrical, telecommunication, transportation and business machines is only due to petrochemical products. The increase in the standard of living is largely due to the availability of these products as per demand in developed countries.

While discussing the experience from industrialised countries and their applicability in developing countries , some of the general features of the latter are necessary to be covered here.

In general, the overall situation is quite different in developing countries than the developed ones.

Hence, the experience gained from industrialised nations can be used in developing countries by taking into consideration their geographical situation, climatic conditions and local needs.

Huge population and its uncontrolled growth in certain developing regions is one of the major causes of concern. Today's planning, therefore, cannot hold good for tomorrow and an uncertainty prevails at all levels of bureaucratic and political sphere. The speedy economic growth in general is only possible by an effective control on population. This will provide better opportunities of education & development of people, and improving the standard of living, effective utilization of resources with the diversification of attention towards overall modernization.

Political scene is different in different developing countries. The decision changes with the change in power in democratic countries and policy decisions are delayed or modified for political gains which result in huge losses. The programmes therefore are modified and take either long time for implementation or dropped, at times. On the other side, stability is more in developed countries and the decision of national interest are efficiently implemented and they remain unchanged even with the change in political situation of the country.

Another drawback in the developing countries is the lack of managerial skill. This becomes one of the reasons of imperfection in planning, delay in decision making and implementation of programme at all stages. The developed countries on the other hand are strong in this aspect and therefore have succeeded in fast economic growth.

Some of the developing countries, although rich in their natural resources are unable to utilize them effectively due to various direct or indirect problems generally of short duration but of varied nature and arise in succession. This is mainly due to poor organisational structure and lack of problem solving skill in decision makers.

The technology development has mainly taken place in developed nations i.e. USA, Japan and Western Europe. They have succeeded in this attempt with joint efforts and strong interaction between institutions, industries and research establishments. As it stands true that necessity is the mother of invention, most of the developments in the petrochemical sector had taken place at the time of the world war II. Early realisation of need for synthetic material, high managerial skill, perfect planning and uninterrupted speedy implementation of science and technological programmes are a few facts for the success of developed countries. The growth in this area has therefore mainly taken place there . On the other hand, developing countries have always concentrated in fulfilling the basic human needs for their large population. This has compelled them to give more thrust on the agricultural sector without much of modernisation. The long term planning has helped the developed countries to effectively use and specify the usage area of their resources.

The demand of petrochemical products in developing countries grew at a faster rate in 80's, as a result of which huge capacity expansion plans were made. A number of new plants have already gone on stream and many are in offing. This expansion is not only for the captive consumption in these countries, but also to export a good amount of petrochemical products due to the availability of huge reserves of feedstock especially in Asia/Pacific region.

It is most likely that low cost of petrochemical products will not be the only reason to compete in the export market but the grown up over capacity demands more efforts for the development of value added products and activities for new application development for better marketability. In developed countries, group of experts constantly work to keep the demand of their material growing whereas developing countries opt for a technology for only the production of the materials but do not give a serious thought for their better reputation in the market. They also lack in their efforts for better market development.

The fast changing scene where the developed countries keep modernising and developing new technologies, developing countries are not able to keep pace and the technologies imported by them from developed countries become obsolete. The new technologies involve more automation and energy efficiency, lower cost of production, and are generally eco-friendly. In developing countries more concerted efforts are required for effective absorption and necessary modification of the technology to suit the local conditions. Contribution of scientists and technologists has to be more in this direction. It also requires a good technological data base and better information technology as in developed countries having huge production capacities for petrochemical products. Some of the developing countries having high production capacity for petrochemical products do not even have the facilities for research and development in this area. In their long term plan, they are therefore required to create these facilities to meet the challenges in future. Countries who have built up their capacities mainly for export may face problem with the development of new technologies in developed nations providing petrochemicals at lower cost. This makes it important to continuously update their technology through in-house research facilities as experienced in developed countries.

The education system in developing countries generally has less relevance to the needs of the economy. The training / education programmes are less practical oriented/job oriented. Experience gained from industrialised nations have to be utilized for modifying the education system so that more self employment opportunities are created. The job knowledge is necessary for the new entrants so that they keep interest in updating their knowledge especially in petrochemical sector. Countries like India and China have created facilities for the practical oriented training in this area to meet their local demand for manpower. Modernization of the existing facilities and setting up of institutions for such training will be required in the developing nations.

The aim of a social security system is to make sure that buying power is equitably distributed among the entire population so that every one in a country has money to buy goods and services that will keep the whole work force employed in manufacturing goods and providing services. It should also ensure that wages, incomes and prices are controlled so that the law of supply and demand is not allowed to depress wages in a surplus labour market or drive up prices in a country of chronic shortages. Most of the highly populated countries are economically backward. Buying power of most of them is not such that they can even afford the minimum required for daily life. It is therefore understood that the per capita demand growth of petrochemicals will remain low. Therefore the setting up of new petrochemical plants should be more need based and as per the expected growth rate. Simply going with the equation that "standard of living is linked with petrochemical products" does not hold good for a few developing countries. Such countries have to carefully look for the availability of natural resources meeting the requirement of human needs before planning for highly capital intensive new petrochemical plants.

The growing unemployment in developing countries does not favour automation; as a step to modernization which is more in industrially developed countries. A difficult situation arises when a compromise is to be made for control of production cost through automation and provide more opportunities for employment alongwith import liberalization. An experience of developed countries cannot be fully practiced in this situation of developing countries. However their experience can be used as guidelines in economising the production cost of petrochemical products and develop cost consciousness amongst producers.

The environmental problem due to more industrialization has been felt globally. The chemical industries are largely responsible for the pollution. It is also expected that the Asia/Pacific will be the growth centre for production of chemicals and petrochemicals in the coming years. Many of the industries are however suffering due to the environmental problem. It is there fore necessary that before the new technology selection for future expansion, a careful thought has to be given on this aspect.

The research activities in developed countries are mostly in groups where scientists and technologists make joint efforts not only to develop materials, catalysts or chemicals but also see that it is scaled up and a technology is developed for the production. In developing countries on the contrary, the efforts made are more on basic research for self gain in term of enhancing basic knowledge instead of applied work as a group activity. Hence the research activities are not targeted towards development of new materials or technology but more or less left as laboratory activity. The experience gained from developed countries is required to be used in developing countries in order to make the efforts of scientists more in the direction of applied research leading to scale up and production. The basic research will in no way be in line for fulfilling the local needs. The new research areas in which activities are going on in the developed countries are opted, but they are not aimed for development of technology/materials.

Petrochemicals as synthetic materials are stable to biological attack. They have long life and cause waste disposal problem. Developed countries have been consuming very large quantities of plastics, rubber, fibre and other petrochemical products but the pollution caused by them is a major concern. In developing countries the consumption of these materials will grow over a period of time and to help in protecting the environment they have to contribute in selection/ developing such products/technologies which can help in avoiding this nuisance.

Some of the developed countries have been discouraging the use of polymers like PVC and PS for certain applications like food packaging mainly due to environmental pollution. The developing countries on the contrary have not yet paid much attention to this problem. A careful thought is to be given to diversify the applications of such materials in other sectors leaving a place for other products which are more compatible to environment.

International agencies through their expertise have been providing the services for the economic growth of the developing countries. UNIDO has played a big role by helping all the developing and developed nations to bring them to a common platform by providing the expertise in technology selection, training and setting of new establishments of petrochemicals. It is also expected that their experience and expertise will further help in deciding the future course of action for the growth of downstream petrochemical products in developing countries.

The experience gained from industrialised countries has been largely useful as guideline to the developing countries for the growth of petrochemical industries since they differ from each other in terms of availability of natural resources and geographical location. However, in future, developing countries have to make a strong infrastructure for providing technical support to their local petrochemical industries through indigenous efforts of application development, strengthening of training facilities, more activities in research and development of applied nature and strengthening linkages between industries, R&D centres and academic institutions.

5.0 IDENTIFICATION OF MAJOR CONSTRAINTS TO AND OPPORTUNITIES FOR THE PROMOTION OF DOWNSTREAM PETROCHEMICAL INDUSTRIES IN DEVELOPING COUNTRIES

The reality of our existence on this earth is that all the nations have been clubbed under the heads dueveloped, developing and under-developed. Indian ethos give far broader out-look by saying that "entire world is one family".

Developing nations have many of their constraints in common originating from within the nation and/or sometimes imposed upon by dynamic forces of other nations. The net result is slow/checked national growth. One of the indicators of national growth is growth of social fabric of the citizen through science and technology (S&T). Therefore in all developing nations S&T needs to form a respected part of national planning leading to its implementation. Based on regional infrastructure, feedstock, energy and human resource skills, developing nations must make their own long term technology forecast that can be suitably adopted. This needs to take care futuristic technical environment. Petrochemical industry is more volatile with respect to life cycles of technologies of a product.

5.1. NEED FOR TECHNOLOGY CHANGES :

In the field of petrochemicals, it is the customer who dictates the specific product requirement in to-day's scenario.

Since these needs are changing rapidly, the new technologies evolved are of fusion in character rather more time and money consuming "break-through" type. Such needs arise primarily due to:

- Competition - for improved processes (productivity, efficiency)
- Financial Crunch - for low fixed and operating cost.
- Energy Crunch - Limited resources.
- Safer Routes/Chemicals - More safety awareness.
- Eco-friendly - New environmental restraints (Emission levels and Biodegradability)
- Standardization - Swing technology with respect to feedstocks and product grades.
- Obsolescence - Unit process/Unit operation changes with new concepts.

- Plant Compactness - Land scarcity.

Once the need for change is established, there is normally a constant debate between developing or acquiring such technologies. This is decided based on the knowledge of repetitive/non-repetitive or guarded technologies. To-day's technologies aim for optimum usage of hydrocarbons.

5.2. PETROCHEMICAL COMPLEX - MOTHER PLANT AND DOWN-STREAM UNITS :

Productwise, petrochemicals are characterised as primary building blocks, intermediates and end products. It is the techno-economic integration of the above that leads to the combination of units called "PETROCHEMICAL COMPLEX". These complexes can be :

- Aromatic Complex
- Olefins Complex

The mother plant of an aromatic complex called "Xylenes plant" is invariably fed with High Aromatic Naphtha (HAN). It gets reformed in p-xylene (beside ortho and meta xylenes) and benzene as building blocks.

P-xylene is used for the production of synthetic fibre intermediates like DMT and PTA which in-turn are used for making synthetic fibres like PSF, and PFY, O-xylene can be used for making phthalic anhydride; benzene is the main feedstock to produce an intermediate like caprolactum which is used to make NFY and nylon tyre cord, benzene is also used to manufacture styrene, phenol, LAB etc.

The mother plant of an olefins complex is called "Cracker", when it is fed with Low Aromatic Naphtha (LAN) the unit is called naphtha cracker. When it is fed with C_2/C_3 fraction of the natural gas, the unit is called gas cracker.

A complex based on naphtha beside ethylene and propylene gives other co-products like butadiene, benzene, C_5 & C_7. A gas cracker yields more ethylene, propylene building blocks with very limited co-products of C_4, C_5, C_6 carbon numbers. It has the advantage of low capital investment, low energy requirement and can be located away from refineries or gas fields.

A very large number of products can be made by putting downstream units from building blocks and co-products as stated above.

5.3. AGONY AND JOY OF PROMOTING DOWNSTREAM PETROCHEMICAL UNITS :

The conventional concept is to have mother unit along with downstream unit together. Due to rising prices and high capital cost to set-up mother units, invariably downstream units are conceived first based on distant sources of feedstocks. Mother unit setting-up is deferred. This is done to take advantage of low global prices of building blocks produced from world size large units. Thus complexities of setting-up downstream petrochemical complexes are unique for developing nations. The said downstream units are limited for intermediates or products. Figures 5.4(1) to 5.4 (6) give significant possible petrochemical products from various building blocks.

The agony and joy with respect to constraints & opportunities to promote downstream petrochemicals can be better dealt through following:

a) To face the reality of the situation, the nations have to develop human resource for work and on

PETROCHEMICALS FROM ETHYLENE

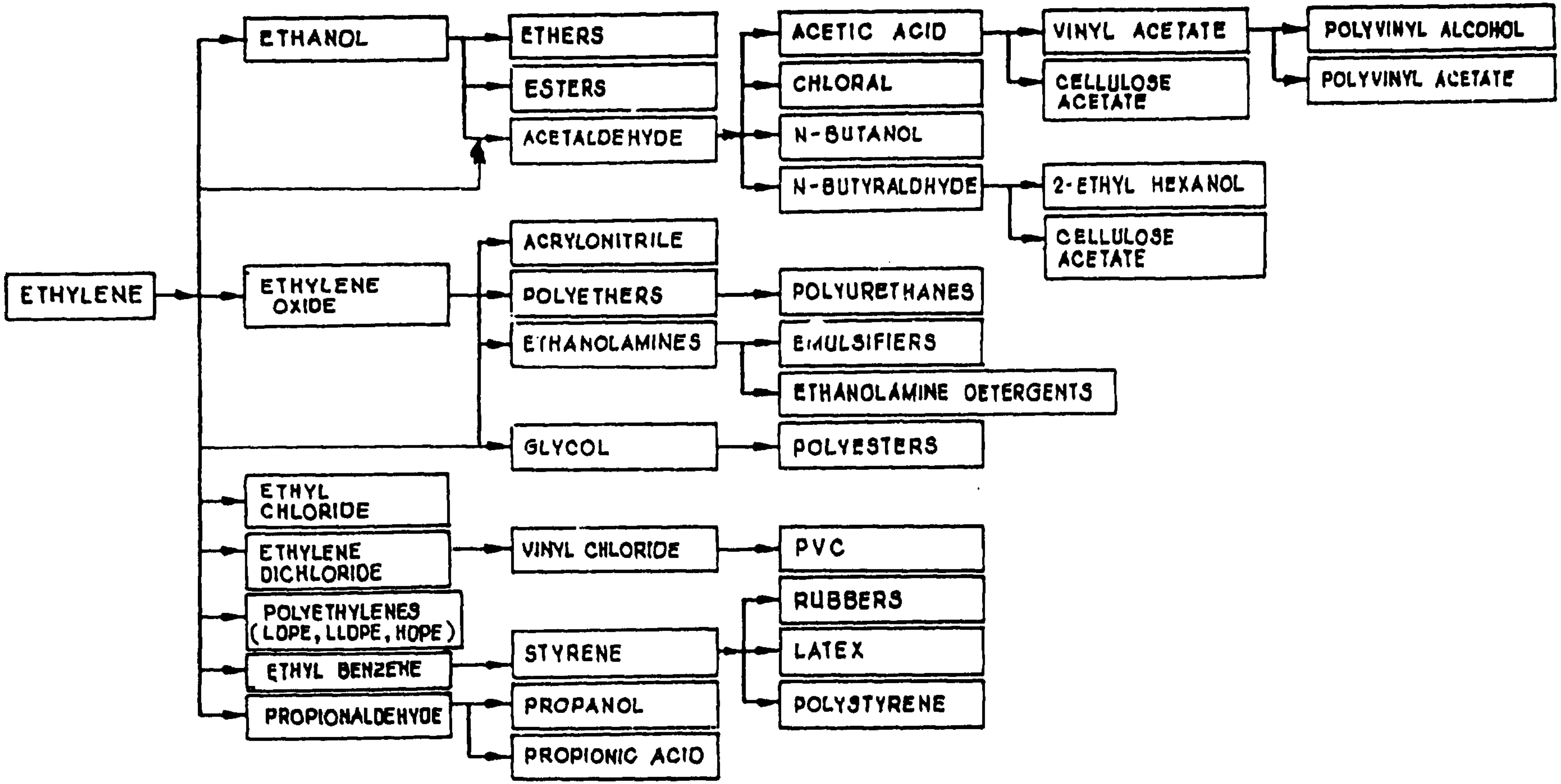


FIG. : 5·4 (1)

PETROCHEMICALS FROM PROPYLENE

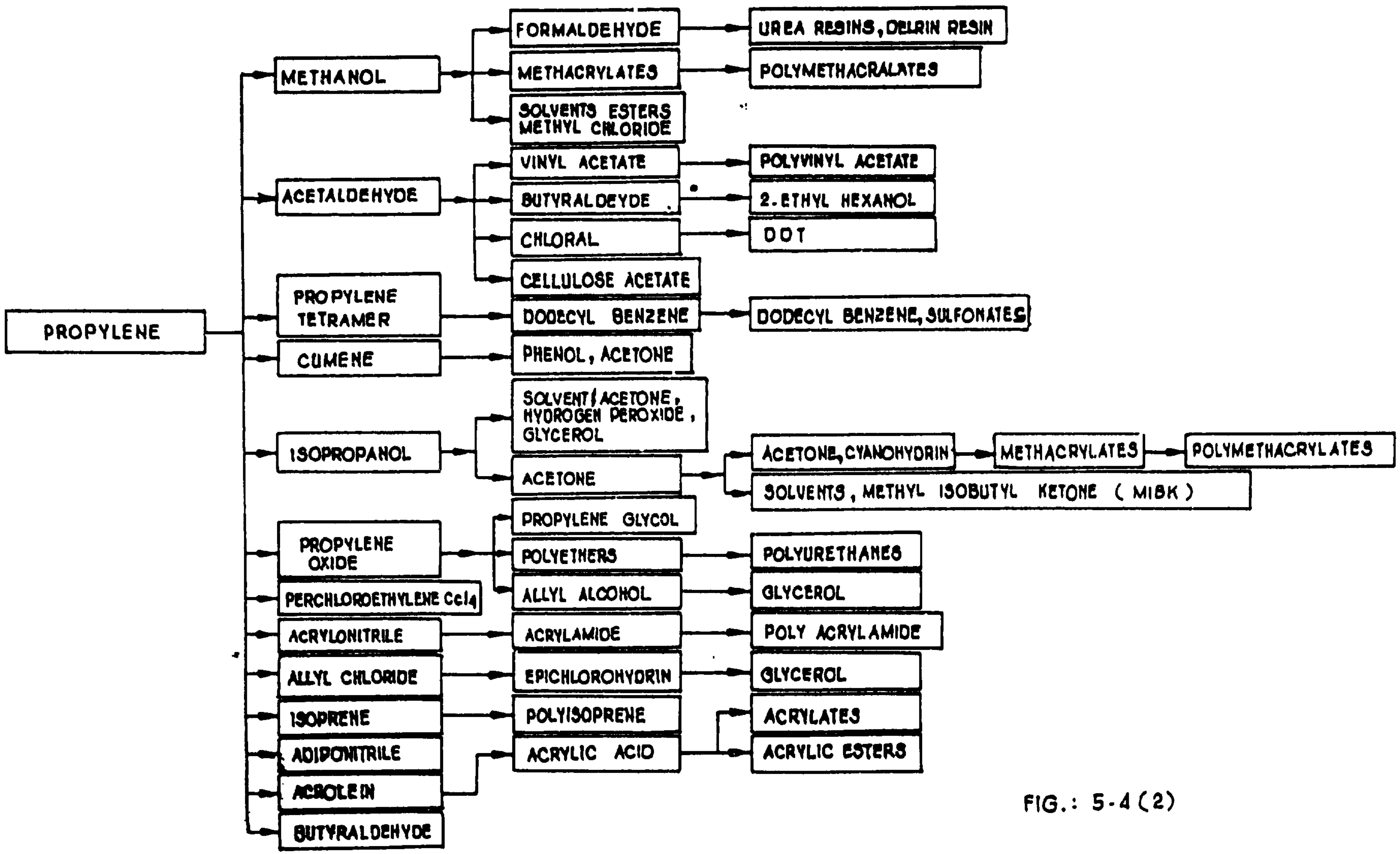


FIG.: 5-4 (2)

PETROCHEMICALS FROM BUTYLENES & BUTADIENE

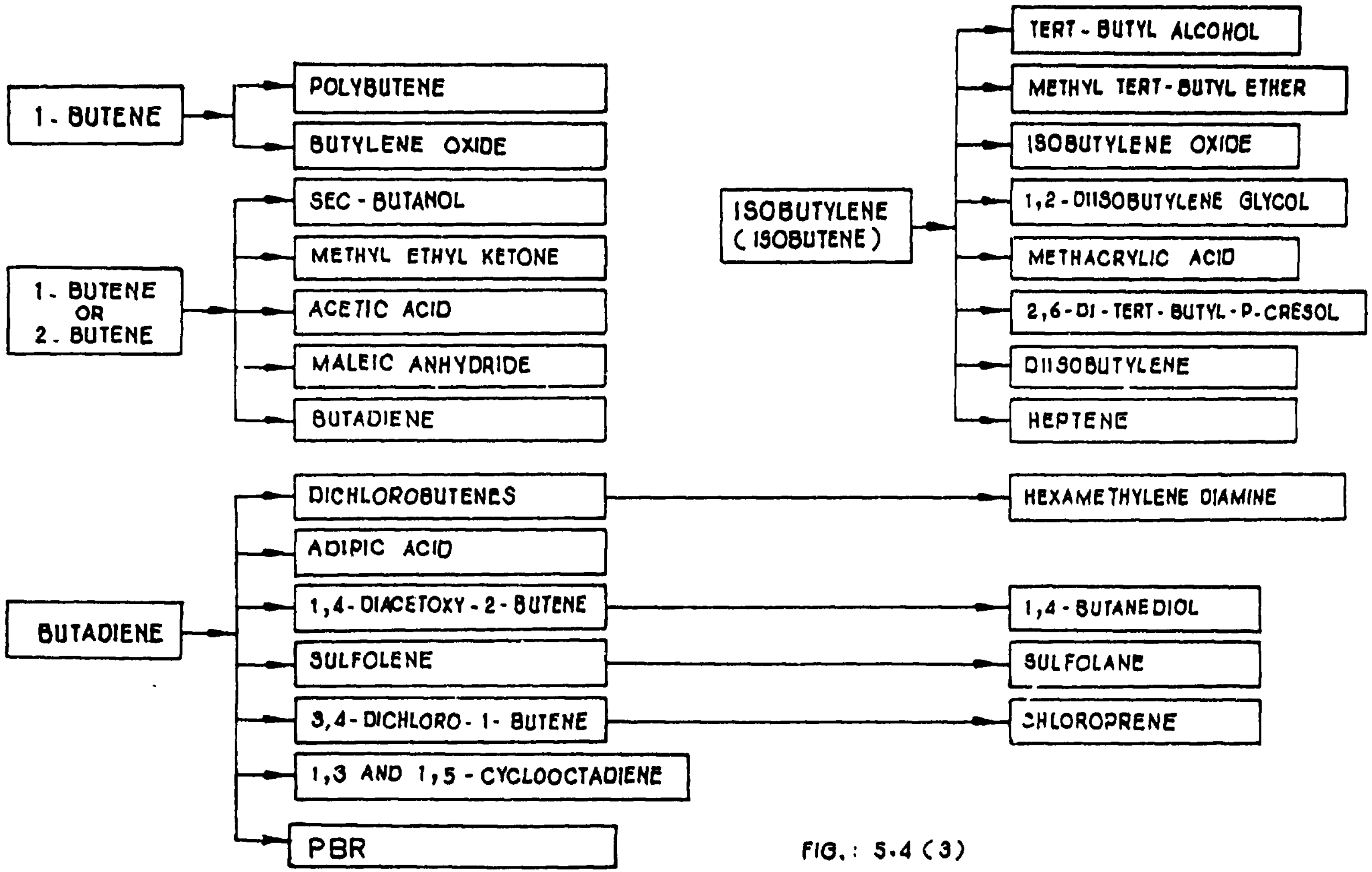


FIG.: 5.4 (3)

PETROCHEMICALS FROM BENZENE

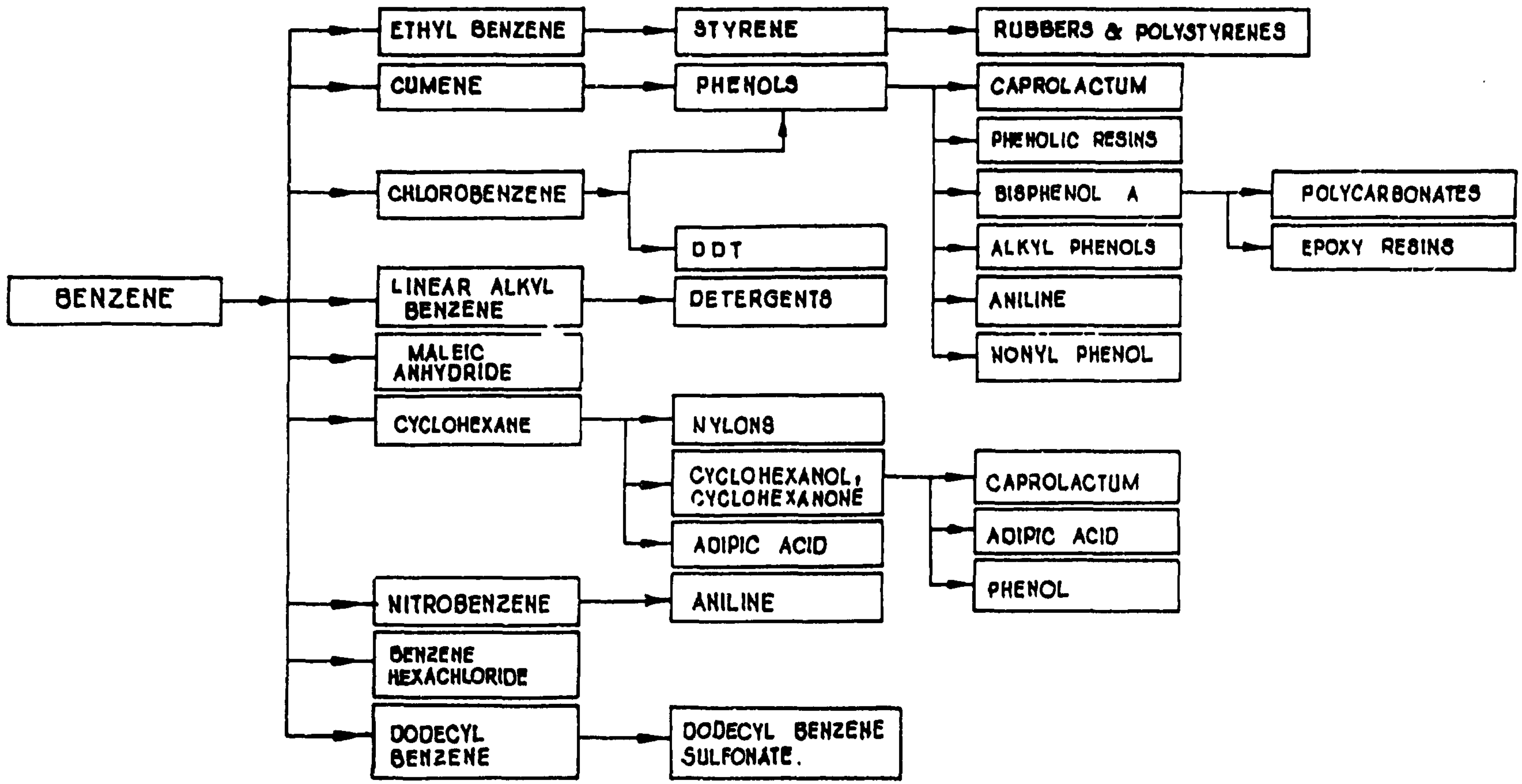


FIG.: 5-4(4)

PETROCHEMICALS FROM TOLUENE

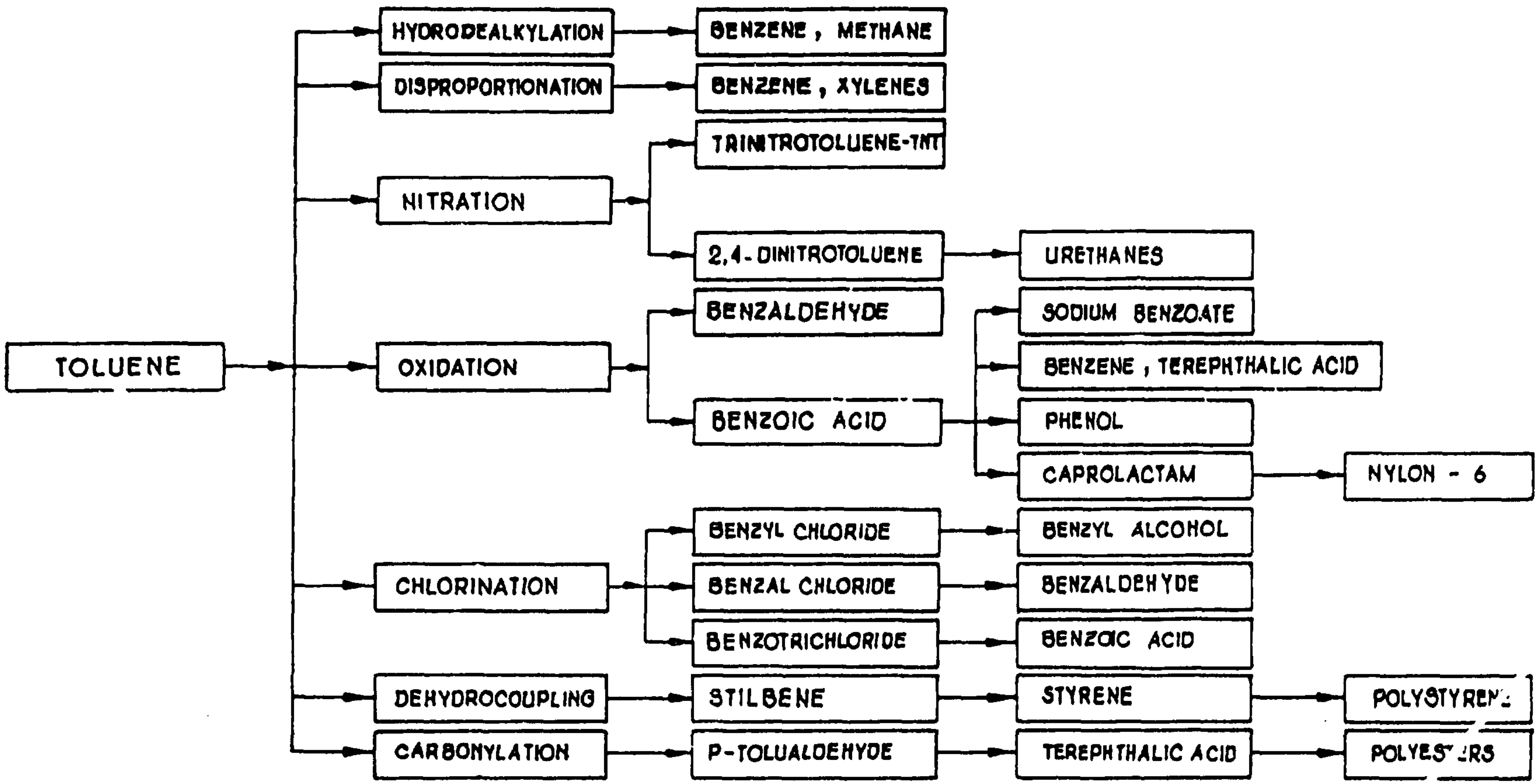


FIG. : 5-4 (5)

PETROCHEMICALS FROM XYLENES

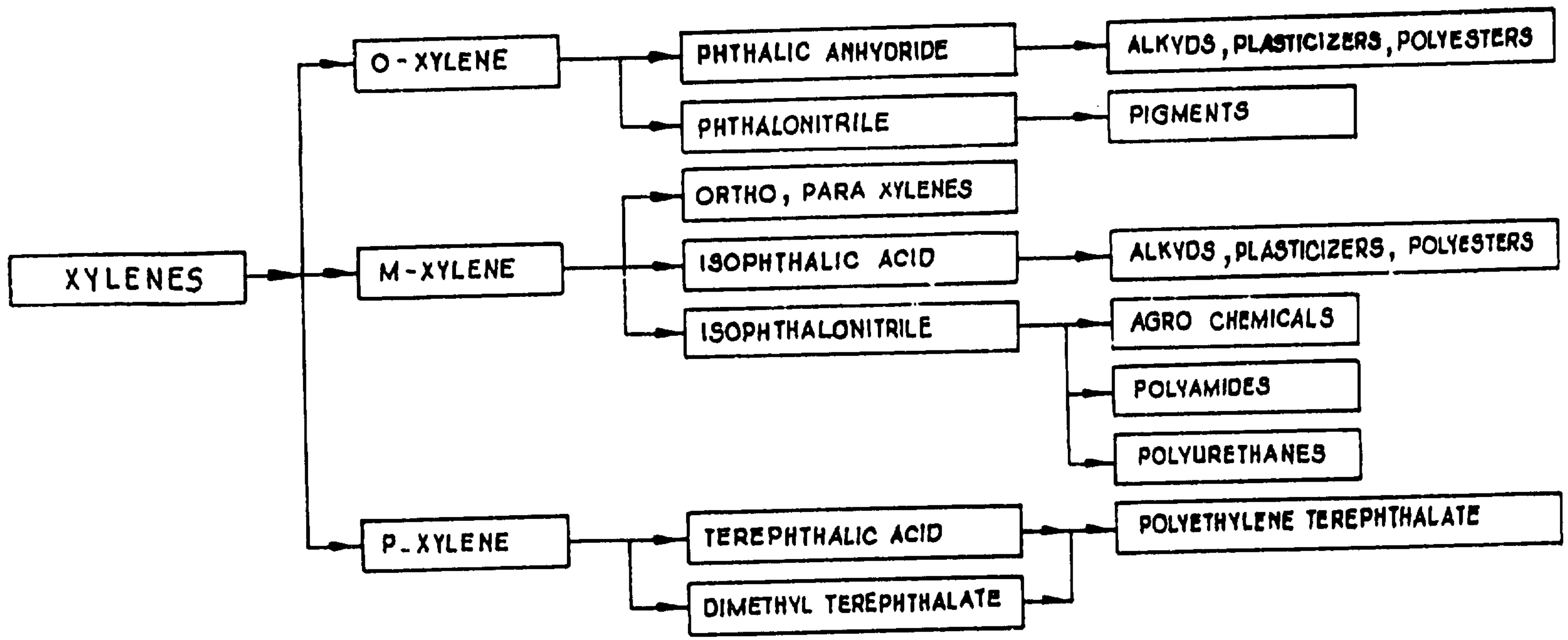


FIG. : 5·4 (6)

advisory panel. More thrust on applied research using fusion technologies approach is a must. One has to do market seeding prior to large dumping of the products from various downstream units. For this greater economic assistance can be provided from various developing nations itself rather than getting the same from developed nations at high cost and lavish terms.

b) Protected economy allows a nation to be within her domain, liberalization is the only way to come out and face the world.

c) Sometimes the Government Laws in terms of taxes and statutes are not conducive to the basic spirit of industrialisation.

d) Realise your own regional needs, possible value addition, present and future market potential to decide product mix rather than taking a leap for conventional mode.

e) Strategically, sometimes it is preferred to avoid stiff competition and go for non-existing product mix so that the country is master of the main market.

f) It is a better approach to establish port-terminals for taking price advantages of building blocks through international market and also establish relatively large size units close to the terminal to facilitate export.

g) Decide unit sizes (and MES) based on local conditions with respect to location, feedstock availability, financial position rather than guided by world size units.

h) Choose a technology that can be absorbed/adapted/assimilated with ease at the desired location and the available operating skilled staff. Occasionally technologies offered are for initial testing (imparted in the name of being latest at high cost) or when it loses its regional value at which it continues its existing operation.

i) Developing nations have to catch-up and incorporate the concept of inherent safety during plant design to minimise the risk. They also need to go for Hazop/Hazan type checks for critical areas for improved plant and personnel safety.

j) Port terminals help in easy exports, thereby avoiding large hydrocarbon movement by road/railways. They are not ever burdened and available for better public utility.

k) Today's customers are more product quality conscious. This needs additional efforts funding in and market intelligence.

l) Concern for improving present environment and betterment in future takes good amount of finances. Each individual unit has its primary effluent treatment facility rather than only one common centralised facility. Real value addition of feed streams is realised by promoting downstream units in petrochemicals.

Scientists and technologists have to direct their efforts towards fusion technologies for desired product ranges preferably with multiproduct swing processes. Human skills need to be developed along with industrialisation of a developing nation to design, erect, commission and smoothly operate the technologies. Industry needs encouragement from local Government. For better co-operation between developing countries, there is a need for strong data base and directory of experts in various fields for technical exchange.

6.0 ELEMENTS OF A SECTORAL STRATEGY FOR THE GROWTH OF DOWNSTREAM PETROCHEMICAL INDUSTRIES IN DEVELOPING COUNTRIES

6.1 FEEDSTOCK AVAILABILITY, MANUFACTURING CAPACITIES DEMAND CHARACTERISTICS AND GROWTH ASSESSMENT FOR DOWNSTREAM PETROCHEMICAL PRODUCTS.

6.1.1 SCENARIO OF WORLD CHEMICAL INDUSTRY :

The total market of the world chemical industry today is estimated at dollar 1.1 trillions. The world chemicals market is dominated by Western Europe & North America with 29% & 27.5% share respectively. Over the years, the overall share in the world's chemical business has been changing. The Asian chemical industry has been expanding generally in the field of commodity chemicals. The share of world's chemical production of US has dropped by over 20% whereas that of Japan has risen from 5.5% in 1960 to about 15% in 1990. It has been forecasted that Asia/Pacific's market share of the chemical sectors will be the world's largest by 2002 increasing from 26% to 35% with the value of industry production more then double, i.e. $ 604 billion (4).

The Asia Pacific region currently consumes 30% of the world chemicals and by the end of the decade it would be a potential market for 40% of the world chemicals. The expansion in Asia Pacific therefore present a severe threat of competition in the commodity market. The capacity additions announced in the Asia Pacific would have profound impact on the chemical industries of the industrialized nations. The export markets of both Western Europe and US are likely to be severely affected.

In terms of world chemical market by type, petrochemicals share is more than 400 billion US $ or nearly 40% of the total chemicals requirement.

The raw materials used in petrochemical production are classified according to their stage of transformation through various technical processes towards the final products as follows:

Basic raw materials : Petroleum and Natural Gas.

Basic intermediates : These include olefins, paraffins and aromatics - ethylene, propylene, butylene, methane and homologs, toluene, xylenes etc.

Secondary intermediates : These include basic intermediates that have been processed into: acetaldehyde, acetone, styrene, caprolatam, acetic anhydride, vinyl chloride, methanol, ammonia, glycol, polyisobutylene, and polyolefins.

Final or end use products : These include plastics, synthetic rubber, synthetic fibres, detergents, nitrogen fertilizers, automotive chemicals, resins and pesticides.

In the past, the petrochemical industry has shown a relatively high rate of technological change. However, proven technology has predominated in recent years. Petrochemical plants are highly automated, continuous often operating with catalytic promotion, and consequently requiring to be large to be economically viable. Petrochemical plants utilize natural gas, gas condensate (specifically ethane and liquified petroleum gas "LPG" and oil products "naphtha") as both feedstock and energy source. The two third of these hydrocarbons are used as feedstock to synthesize various compounds. The remainder supplies needed energy including electricity (5). In U.S. 70% of ethylene produced comes from condensates like propane, butane and ethane obtained from natural gas. In Europe and Japan, on the other hand naphtha refined from oil is used as feedstock to produce ethylene.

The outlets for petrochemicals are the highly developed chemical processing industries. Value adding conversions and transformations are required before petroleum based olefins, ammonia or aromatics reach the consumer as garments, fertilizers, plastic bags, rubber tyres etc.

6.1.2 GLOBAL VIEW OF PETROCHEMICAL INDUSTRY:

The global petrochemical industry went through a very interesting phase during the eighties. The industry saw :

- Recession
- Rationalisation
- Restructuring
- Resurgence
- Recovery
- Reinvestment

From the mid eighties, the world economy showed stronger growth. Demand for petrochemicals grew at a much faster pace than expected. In fact, growth of most of the commodity thermoplastics was at much faster pace than GDP of these nations. This was the period of resurgence and recovery. With demand outstripping supplies petrochemicals became scarce and prices spiraled. In fact the return on investment became so attractive that it started a fresh spate of investments Today the industry is facing over capacity and recession, the effect of which is more felt in developed countries. The developing countries are also not unaffected by this situation.

6.1.3 OUTLOOK FOR WORLD OIL:

The world crude oil supplies are sufficient to meet the demand of petrochemical sector in the foreseeable future. The current reserves are approximately 1 trillion barrels. With two third of this reserves in the middle east including 1/4 of this in Saudi Arabia, the world can expect continued influence of price and supply by the Saudis. Crude oil and refined products will remain a primary source of energy well into the 21st century.

Between 1973 & 1980, the real price of oil rose approximately ten fold. This increase led to the cost escalation of petrochemicals manifolds. Though long-term prices are upward, it is predicted that they would be at slower rate and with less volatile swings.

6.1.4 PETROCHEMICAL FEEDSTOCKS:

The major petrochemical feedstocks are naphtha, natural gas liquids (NGL) and gases. Olefins are derived from gas oil, propane/butane, ethane, refinery gases also. Today, worldover, 60% of olefins are derived from naphtha and 27% from ethane/refinery gases. 12% comes from propane/butane predominantly used in USA. Though naphtha is still the primary feedstock for petrochemicals, with shifting of capacity build up to natural gas rich countries the importance of gas as an alternate route is growing. Competitiveness of gas based petrochemical expansion however, primarily depend on the price of crude oil and the valuation of gas.

Natural gas resources worldwide is about equal to world's crude oil reserves. However, for petrochemical needs their use has been at a much slower pace than crude oil. Canada, Mexico, Middle East, Asia and N. Africa are belts where potential of growth of petrochemicals from gas is good. The gas production is a direct result of oil production to the extent of about 500 million cubic feet of gas for each million barrels of oil produced. Total reserves of associated gas are estimated to be in excess of 100 trillion cubic feet in Saudi Arabia alone (3).

6.1.5 BUILDING BLOCKS OF PETROCHEMICALS:

The building blocks for petrochemicals are ethylene, propylene & butadiene. Ethylene is the driving force behind petrochemical growth.

The present global ethylene capacity is about 70.90 million MTs. The total capacity is projected to increase to about 15.3% and 23.6% by 1995 and 1997 respectively as shown in Table 6.1(6). This capacity increase will be about 72.40% in Middle East, 69.24% in Asia Pacific, 40% in East/Central Europe and 15.4% in Latin America by 1997. In China alone, the projected ethylene capacity growth will be about 63% with the expansion of 5 existing plants and proposed 13 new plants. The capacity of ethylene based complexes in China will be about 5.9 million MTs/Year by the end of the decade (7). Amongst the Latin American countries, Brazil and Argentina are the countries who will contribute for ethylene capacity in the next 5-6 years. The projected growth in developed countries is only about 10.60% but they will continue to dominate in 1997 with their 40% market share. The beginning in the petrochemical sector in Africa is with ethylene capacity of 0.855 million MTs and this will increase by about 48% by 1997.

TABLE - 6.1(1)
GLOBAL ETHYLENE CAPACITY & ITS PROJECTION

(Fig. in '000 MTs)

	1992	1995	1997	Increase from 1992 to 1997
A. Developed countries				
i) USA & Canada	23435	25355	25355	1920
ii) West Europe	17910	19875	20230	2320
iii) Japan	6204	7004	7004	800
SUB TOTAL	47549	52234	52589	5040
B. Developing Countries				
1. Asia Pacific				
i) China	2255	3080	3680	1425
ii) South Korea	2715	3155	3155	400
iii) Taiwan	845	1065	1515	670
iv) India	570	1170	1420	850
v) Thailand	315	728	728	413
vi) Other Asia/ Pacific countries	1060	1650	2635	1615
SUB TOTAL	7760	10848	13133	5373
2. Middle East	3165	4537	5457	2292
3. East/Central Europe	7505	8380	10505	3000
4. Latin America	4091	4521	4721	630
5. Africa	855	1255	1265	410
TOTAL	70925	81775	87670	16745

With the shift in feed stock to gas, propylene as a coproduct would not be available in large quantities. In fact, the present propylene capacity would go upto 46.70 million MTs in 1995. Technology innovations are on the way to supplement propylene availability. Propane dehydrogenation is being tried out and once the process is commercially proven, it will free propylene from ethylene and could have an independent price base. The world's butadiene capacity with its steady growth will go upto 7.9 million MTs by 1995. The other feedstock styrene has attracted major investments and the world capacity would rise to about 20 million MTs by 1995. Amongst Asia/Pacific countries a major expansion of styrene is planned in Indonesia & Thailand in order to produce plastic materials and rubber to meet their demand (8,9).

On one side when the global petrochemical industry is heading towards large expansion especially in Asia Pacific, Middle east and central / east Europe, the present recession has been forcing to slash down the prices of petrochemical products. As a result of this some of the petrochemical industries in West Europe are either being closed down / reducing production or incurring losses. In Asia Pacific, South Korea is producing ethylene 20% above the domestic demand and its government has imposed ban on the present expansion plant (8).

This over capacity situation in the world is likely to prevail even in the next few years with capacity of ethylene, propylene and styrene being more than the demand by 16%, 17% and 8% respectively in 1995 (Table 6.1(2)).

TABLE - 6.1(2)
PROJECTED GLOBAL SUPPLY/DEMAND BALANCE OF SOME KEY PETROCHEMICALS - 1995

(Fig. in million MTs)

Product	Capacity	Demand	Imbalance	% Use
Ethylene	86.00	72.00	14.00	84
Propylene	46.70	39.00	7.70	83
Styrene	20.00	18.40	1.60	92

Source : Compiled at UNIDO Secretariat from various publications.

6.1.6 PETROCHEMICALS IN DEVELOPING COUNTRIES :

Looking at the world's statistics of some of the petrochemical products such as thermoplastics, rubbers & synthetic fibres, it can easily be seen that the developing countries, despite laying on rich reservoirs of hydrocarbon, raw materials & minerals, have negligible share of production of chemicals and petrochemicals. For example, Japan alone with no reservoirs of hydrocarbons, has 11% share of world production of these materials, while the total share of all developing countries is about 12%.

Developing countries have been mainly depending on imports from developed nations to meet their local demand of petrochemicals. The scenario is now changing and the oil/gas rich developing countries are speedily developing/expanding their inhouse petrochemical capacity which will not only be sufficient to meet their local demand but also make them competitior in export market.

Some of the growth features in petrochemical sector of developing regions are given below :

6.1.6.1 MIDDLE EAST, AFRICA & WESTERN ASIA:

The Gulf states have 2/3 of the world's oil/gas reserves. Gigantic downstream petrochemical units producing about 6.30 million MTs of petrochemical have been set up in Saudi Arabia alone. They are in a position to export huge quantities of petrochemicals to developed and other developing countries. Saudi Arabia and Iran are fast expanding and adding new petrochemical products in their production range. North African countries also plan to expand their capacities and will be in a position to export their products to the developed countries due to less local demand. The whole region will be a major exporter. Their own per capita consumption will however remain substantially lower than the developed countries for next several years. These countries have yet to expand their infrastructure for the conversion of petrochemical products into finished goods and make efforts for new application development for local consumption.

6.1.6.2 EAST, SOUTH EAST & SOUTH ASIA :

These regions have large consumers like India and big produces like Singapore, Korea and Taiwan and share about 30% primary as well as endproduct production and consumption of the developing countries.

India having identified large oil and gas reserves is in for good growth in petrochemical capacities which may not be sufficient to meet the domestic demand for the end products and hence imports in large quantities will continue in coming years. Pakistan with its gas reserves has yet to build up capacity for petrochemicals and it is expected to go on stream by 1995.

Indonesia with its large reserves has good prospects for petrochemical industries growth. Singapore and South Korea have set up refineries and petrochemical complexes based on imported crude and will be largely exporting their primary and finished petrochemical products to third world countries. Thailand and Malaysia, with their petro resources are having good prospects for petrochemical industry.

The demand for the petrochemical products may force the region to import olefins from oil rich countries but still they are likely to remain net importers of endproducts even though some countries like Indonesia may turn out to be net exporter.

6.1.6.3 LATIN AMERICA :

These countries have huge hydrocarbon reserves and also have substantial demand for petrochemicals. Mexico, Brazil, Venezuela and Argentina have registered a healthy growth of petrochemical industry and they are emerging as exporting countries with sound base for petrochemicals.

6.1.7 MAJOR PETROCHEMICAL END PRODUCTS :

The major petrochemical end products are plastics, synthetic fibre and synthetic rubber, having their share of 60%, 10% and 10% respectively the remaining 20% is of other products. The production capacity, capacity utilization, demand and consumption of these major petrochemical end products in the past, present and future have been discussed in the following section. The future growth has been estimated by using the technique of trend transplantation.

TREND TRANSPLANTATION :

The technique of transplantation is one way of forecasting future apparent consumption of various petrochemicals based on their growth trends. The main hypothesis behind this approach is that the growth of petrochemical is basically derived by the growth of user industry sectors of the economy. Since petrochemicals find applications in almost all the industrial and household sectors, the growth of petrochemical industry is a barometer of overall industrial progress. The life cycle of overall economy progress of countries has been assumed to be similar which is probably a valid proposition in general. In order to forecast future growth trend of petrochemical products, past apparent consumption and population data have been used as the base material. Mathematically the model can be explained as under:

$$Cij = Ij * Pi\ (j-1)$$

Cij = Apparent consumption forecast for petrochemical product 'i' for the year j.

Ij = Country/region's population in the year 'j'.

Pi(j-1) = Per capita consumption petrochemical product 'i' in given country/region for the year (j-1).

6.1.7.1 PLASTICS:

Plastics are the dominant and most versatile group of downstream petrochemical industries and as such are characterized by ever increasing substitution of traditional materials and penetration into new fields of application. Commodity plastics embrace polyvinyl chloride (PVC), polyethylene (low density polyethylene, linear low density polyethylene, high density polyethylene, ultra high molecular weight polyethylene, polypropylene (PP) and polystyrene as main constituents in all economic sectors. Their versatile use includes pipe and fittings, tubings, siding and window profiles, wire and cable covering, bottles, films and sheetings, blow moulded food containers, auto fuel tanks, injection moulded thin walled bottles, industrial pallets, crates and cases, bullet proof vest, fire-retardant safety clothing for industry, food trays, refrigerator liners, luggage, video cassette covers, business machine housings, automotive duct work and panels, household appliances, electronic equipments, trims, stadium seats, power tools, business machine and appliance housings.

Some of the main factors contributing to the progressive demand for plastics and to their emerging potential for substitution of traditional materials are the following :

(i) Conservation of natural resources like forest, land, and water, while avoiding pollution associated with extraction of metals;

(ii) lighter products to save energy;

(iii)durability and recyclability;

(iv) easier-to-form products to save machine and man-power hours;

(v) easier-to-handle products to save manpower and costs;

(vi) more competitive products on the basis of cost and performance;

(vii) more corrosion resistant, better-quality products to save maintenance and capital cost;

(viii) improved materials with respect to thermal, mechanical, electrical and physical properties to withstand severe operating conditions;

(ix) new systems and technologies to cater to innovative engineering applications;

(x) cost-effective systems in sectors like agriculture, water distribution, etc.; and,

(xi) new and better products to improve living conditions and satisfy aesthetic demands.

The needs explain, to a large extent, the dramatic growth of commodity plastics, often surpassing GDP growth rates, despite heavy restructuring in the up-stream petrochemicals and the overcapacity situations reflecting an established cyclic phenomenon for the industry.

The increase in the standard of living in the developed regions was largely due to the availability of downstream petrochemical products. In the year 1989, the highest consumer of plastics in terms of kg/head was Belgium, where people consumed on average 144 kg. of plastics. They were closely followed by Germany (131 kg/head), the US (108 kg/head), Austria (102 kg/head) and Switzerland (93 kg/head) (10). Similar trend of high per capita consumption of some commodity plastics is reported in developed countries for the year 1991 (Table 6.1(3)) (11).

TABLE - 6.1(3)
REGIONAL PER CAPITA CONSUMPTION OF THERMOPLASTICS, 1991

(Fig. in Kgs.)

	LDPE	LLDPE	HDPE	PP	Total
North America	9.00	6.80	11.60	9.00	36.40
West Europe	11.70	3.10	8.10	10.10	33.00
South America	2.56	0.28	1.40	1.36	5.60
East Europe	3.20	1.00	1.40	1.10	6.70
Africa	1.00	0.20	0.60	0.50	2.30
Asia - Pacific	1.20	0.50	1.20	1.64	4.54

Source : Paper presented on Polyolefins by Mr. Gary K. Adams at CMAI seminar on Petrochemicals, held in Houston USA on March 25-26, 1992.

The consumption in developing countries is far below than even the present world average of about 16 kg/head. In India, it is just about 1 kg. and this is expected to reach 2.5 kgs. by the turn of the century. China's present consumption is 3 kg/head and despite will reach to 6 kg by 2000 AD.

In 1940, world plastics production was estimated to be in the region of one million MTs. In 1990 it stood at over 100 million MTs (10) (this figure most likely includes both commodity and engineering plastics). The capacity of commodity plastics alone will grow to about 33% from 1990 to 1995 and is likely to touch a figure of 105 million MTs. (Table 6.1(4)).

TABLE -6.1(4)
WORLD POLYMER CAPACITIES

(Million MTs)

Polymer	1985	1990	1995
LDPE	13.86	15.689	17.812
LLDPE / HDPE	12.74	21.271	28.587
PP	8.69	11.451	21.527
PVC	15.71	20.925	24.815
PS	8.14	10.000	12.702
TOTAL	59.14	79.336	105.443

The global polymer industry performed exceedingly well during late eighties. Strong demand growth and excellent margins turned even the least profitable petrochemical company into profit. The world consumption of plastics is given in Table 6.1(5). The region-wise consumption of major commodity plastics is shown in Tables 6.1(6) and 6.1(7). According to the conservative estimates, by the year 2000 the plastic industry will be at least 50% larger than the present size (12). Annual average growth rate of major polyolefins is shown in Table 6.1 (8). Factors like better fabricating equipment, better lot-to-lot uniformity, new speciality grade and products, technological innovations, use of reactor granules instead of pellets for reducing costly manufacturing step in making polymer will contribute to the growth of the industry. The Asia - Pacific, Latin America, Middle East, Africa, CIS countries and East European regions will be growth areas for commodity plastics.

6.1.7.1a POLYETHYLENE:

The global capacity of LDPE is currently 7 million MTs. This capacity is going to see a substantial rise in the next 5 years. The capacity expansion programmes

TABLE -6.1(5)

GLOBAL POLYMER CONSUMPTION

(Fig. in '000 MTs)

Product	1980	1985	1990	1995	CGR%
PVC	11300	13160	15180	18300	3.8
LDPE / LLDPE	11250	14460	17410	23300	6
PS	5310	6380	7860	10100	5
HDPE	5130	7630	9960	12600	4.8
PP	4910	7590	10130	15600	9
ETP	670	1160	1650	2320	7
ABS	1160	1610	2010	2500	3.9
TOTAL	39730	51990	64200	84720	5.6

TABLE 6.1 (6)

WORLD CONSUMPTION PATTERN OF LDPE, HDPE AND PP

(Fig. in '000 MTs/year)

Region	LDPE			HDPE			PP		
	1988	1995	2000	1988	1995	2000	1988	1995	2000
A - Developed Countries									
North America	5071	6231	7274	3679	5291	6278	2705	4515	-
Western Europe	5080	5900	7352	2600	3500	3004	3000	5000	-
Japan	1353	1600	1867	760	905	1144	1450	2150	-
B - Developing Countries									
Africa	347	420		210	260		125	225	-
Middle East	397	520	1741	140	220	488	185	325	-
Asia / Pacific	2510	4187	2855@	1571	2479	2103@	1910#	3040#	-
Latin America	983	1380	3199	505	910	1572	520	1160	-
Eastern Europe	1968	2401	3648*	856	1363	2300*	740	1240	2400*
Other Developing countries	-	-	695	-	-	428	-	-	-

Source : Report of the Committee for Perspective Planning of Petrochemical Industry (1988 - 2000 AD) Government of India. Report of Sub - Group on Polymers, Vol.4, July 1986, page 229,230.

@ - Far East & Oceania only.

- South Asia & South East Asia only.

* - CPE Europe only.

TABLE 6.1 (7)
WORLD CONSUMPTION PATTERN OF PVC AND PS

(Fig. in '000 MTs/year)

	PVC 1990	PVC 1995	PVC 2000	PS 1990	PS 1995	PS 2000
A - Developed Countries	10180	12034	14209	6534	8199	10236
North America	3942	4879	5975	3568	4655	5980
Western Europe	4815	5482	6245	2158	2480	2849
Japan	1423	1673	1989	808	1064	1407
B - Developing Countries	6532	9014	12607	2516	3821	5380
Africa & Middle East	610#	1084	1516	180#	482	716
Asia *	2129	3302	4833	838	1308	1964
Latin America	1261	1698	2501	635	919	1291
CPE Europe	2100	2371	3049	748	962	1218
Other developing countries.	432	559	708	115	150	191

Source : Report of the committee for perspective planning of Petrochemical Industry (1986-2000 AD) Government of India. Report of Sub - Group on Polymers, Vol.4 July 1988, page 229, 2301.

1 - Does not include Centrally Planned Asian Economics.
- Figures include only N. Africa & Middle East.
* - South Asia & South East Asia.

TABLE - 5.1(8)

WORLD's ANNUAL AVERAGE GROWTH RATE OF POLYOLEFINS

1988 - 1995

Region	LDPE	HDPE	PP
North America	3.26	6.26	7.6
Latin America	5.77	11.45	12.1
Western Europe	2.30	4.94	7.6
Eastern Europe	3.14	8.46	7.7
Middle East	4.42	8.16	8.4
Japan	2.60	2.72	5.8
Asia / Pacific	9.54	8.25	6.0*
Africa	3.00	3.40	8.8
Total Average	3.97	5.68	7.5

* - Far East/Oceania.

of LDPE and HDPE in different regions can be seen from the tables 6.1(9) and 6.1(10).

TABLE - 6.1(9)
REGIONWISE LDPE CAPACITY BUILD-UP
(Fig. in 'ooo MTs)

Region	1985	1995
North America	3466	4275
Western Europe	4091	5878
Japan	571	1425
Eastern Europe	1802	2137
Latin America	971	1425
Asia Pacific	1109	1960
Mid East	416	534
Africa	139	178
TOTAL -	13865	17812

TABLE 6.1(10)
REGIONWISE CAPACITY OF HDPE IN THE WORLD
(Fig. in '000 MTs)

Region	1988	1995
North America	3730	5066
Latin America	497	932
Western Europe	2380	2790
Eastern Europe	940	2305
Middle East	--	--
Japan	903	964
Asia / Pacific	1309	2924
Africa	100	265
TOTAL -	9859	15246

The world Polyethylene consumption growth peaked in 1987 at 9% and then slowed down subsequently. The

Pacific Rim and Latin America showed the strongest growth of PE. Much of the growth in the Pacific Rim was directly attributable to the emergence of China as a major consumer of Polyethylene in this regions ((Table 6.1 (11)) (13).

TABLE 6.1(11)
CAPACITY AND MARKET DEMAND OF MAIN PLASTICS IN CHINA
(Fig. in '000 MTs)

Item	Capacity	Market demand
LDPE	557	850
HDPE	470	450
PP	662	720
PS	128.3	229.5
PVC	900	720

In order to meet its own requirement, China is expanding its production capacity of polyethylene (LDPE, HDPE & LLDPE) by about 440,000 MTs. It will reach to about 1,567,000 MTs by 2000 AD (14). Capacity expansion is under way to meet the local demand in India. During the next 5 years Pacific Rim is likely to continue leading the world in Polyethylene consumption.

Amongst ASEAN countries, polyethylene producers have been mainly Indonesia, Thailand, Malaysia, Singapore (Fig.6.1.1F). Indonesia's first polyethylene plant of 200,000 MTs capacity has been commissioned recently (7). Since there is no gas/naphtha cracker, Indonesia will procure ethylene for other countries like Japan/

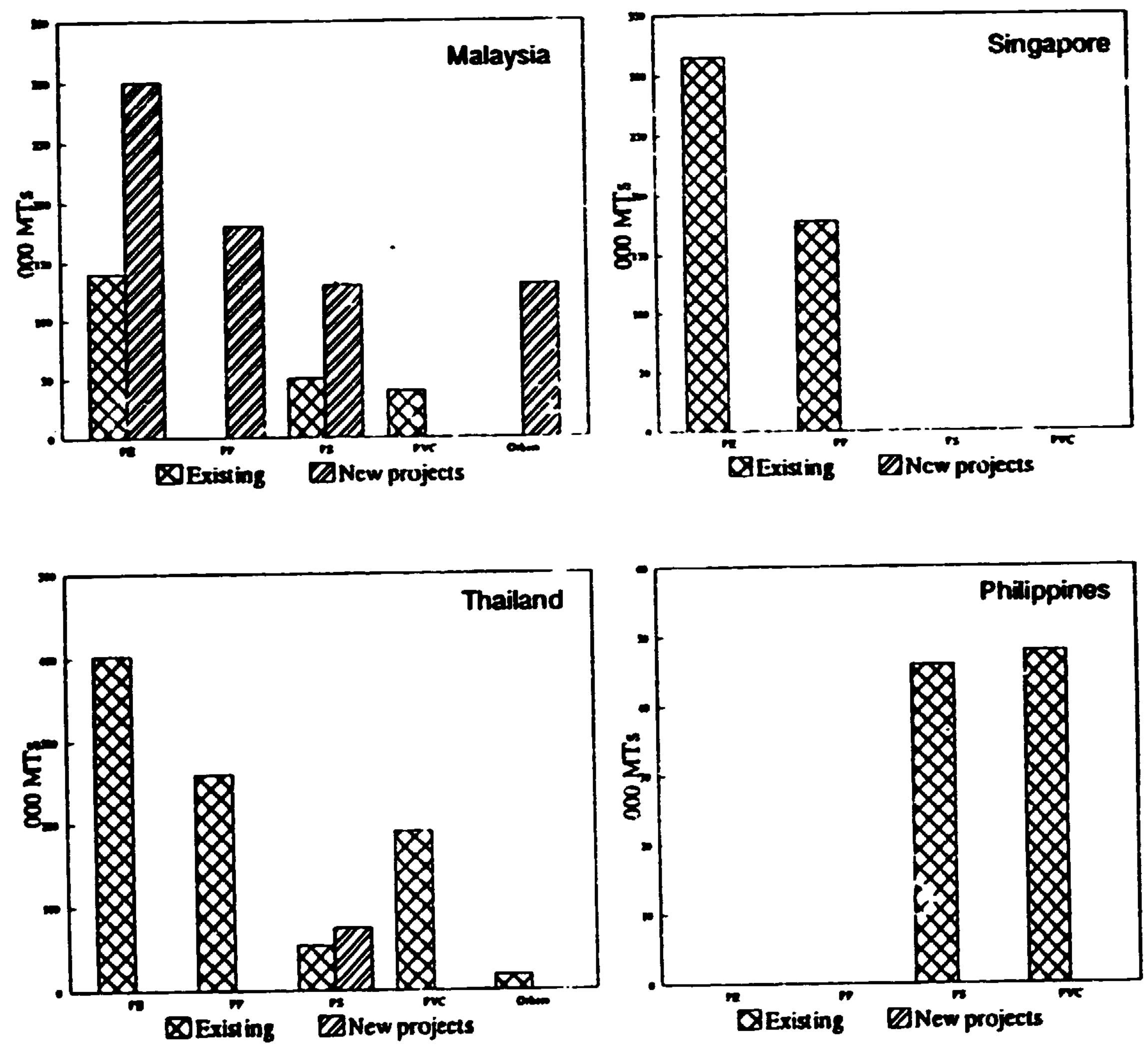


Fig. 6.1.1F: Existing production capacities and new projects in various countries

S. Korea. Capacity expansion of polyethylene is under way in Malaysia and with the addition of 300,000 MTs, its production capacity will increase by more than 3 times. The demand of thermoplastics in ASEAN countries is shown in Fig.6.1.2F. The demand, production and import of Indonesia as an emerging player is also shown in Fig. 6.1.3F-5F (15).

Amongst the middle east countries, Iran, Iraq and Saudi Arabia are expanding the capacities in a big way. Iran was not producing polyethylene so far but its demand has been about 400,000 MTs which will not even be met through their indigenous production in the coming years (Fig.6.1.6F) (18). The demand is also increasing at a faster pace in Saudi Arabia.

The expansion plans in Latin American countries indicate that their production capacities will be more than domestic requirement and hence they will be exporting their excess material to North America & West Europe. Out of the total consumption of low density polyethylene, over 63% is consumed for film and sheet applications. This trend is likely to continue and the film and sheet market will contribute to the growth of LDPE. Wire & Cable is another sector which will contribute significantly to the growth of the market.

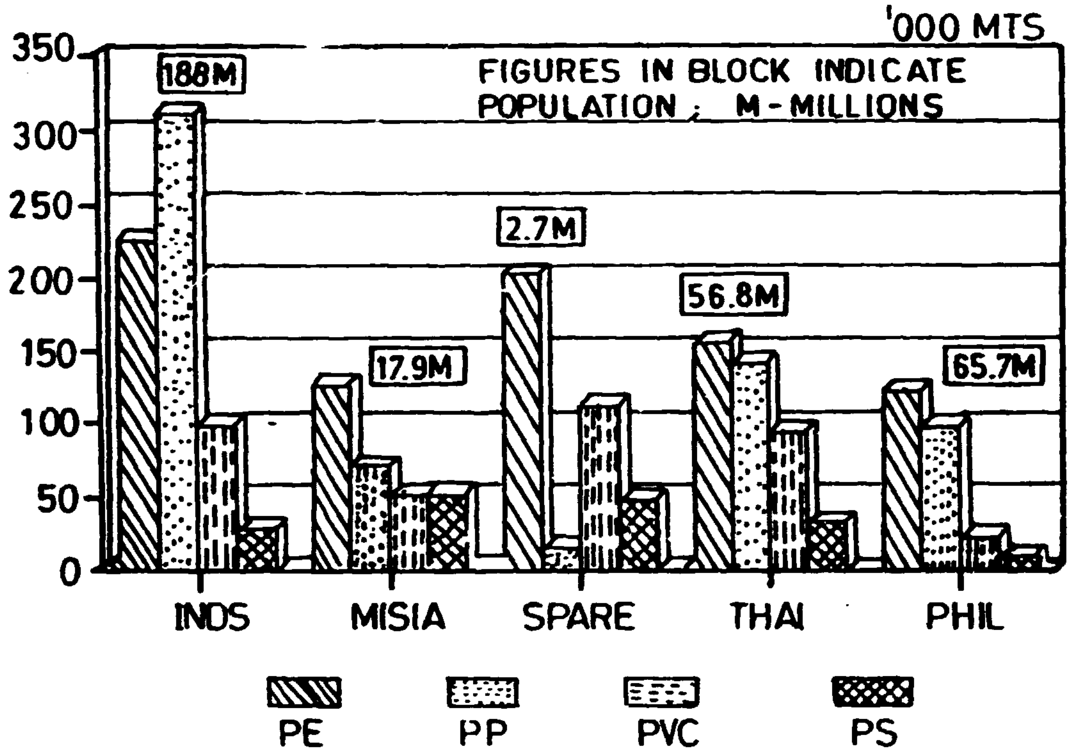


FIG.: 6·1 (2F) ESTIMATED DEMAND OF PLASTICS FOR ASEAN COUNTRIES (1990).

SOURCE : SUARA PEMBARUAN, KAMIS, 5 FEBRUARI 1993. (INDONESIA)

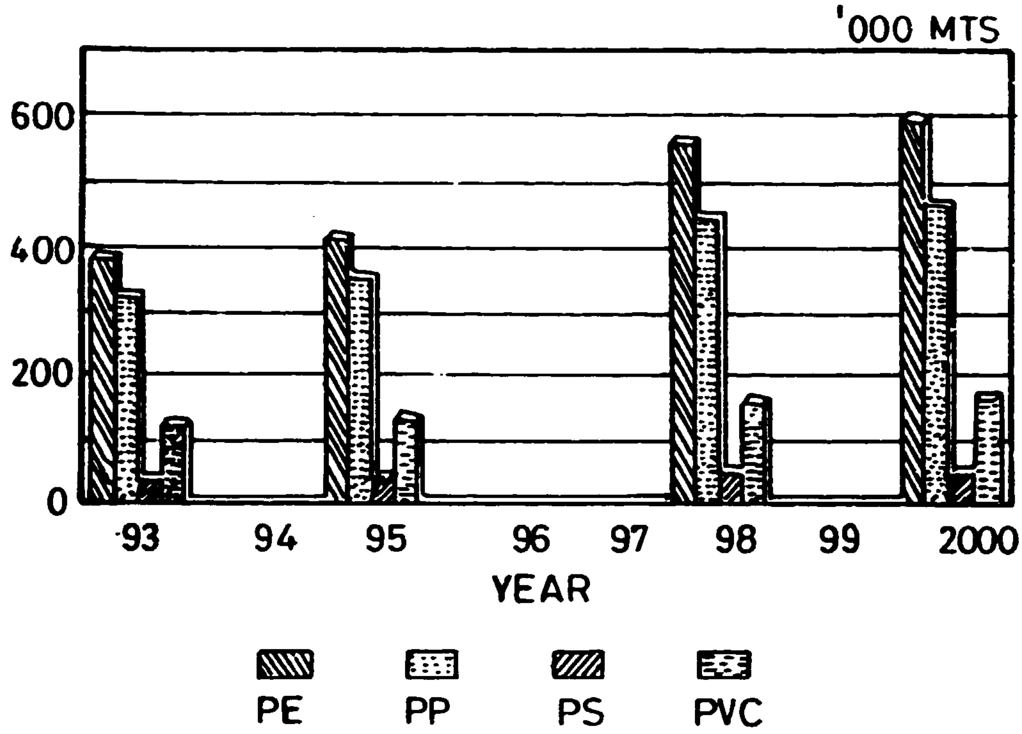


FIG.: 6·1 (3F) PROJECTED DEMAND OF PLASTICS IN INDONESIA.

SOURCE : MINISTRY OF INDUSTRY, INDONESIA

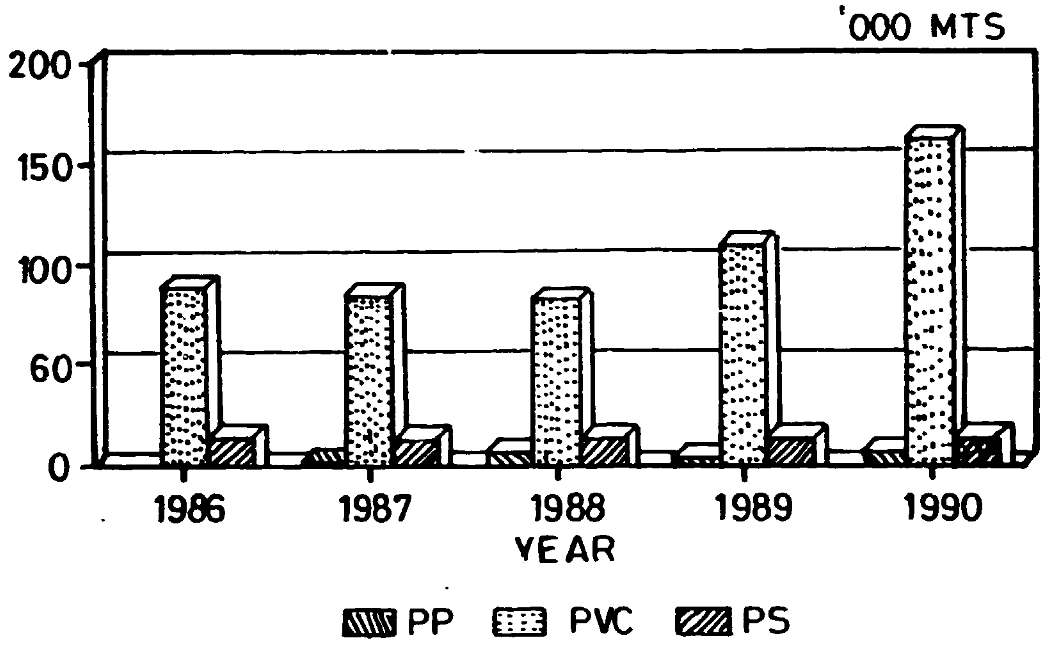


FIG.: 6·1(4F) PRODUCTION OF PLASTICS IN INDONESIA (1986 - 1990).

SOURCE : DEPARTMENT OF INDUSTRY, INDONESIA

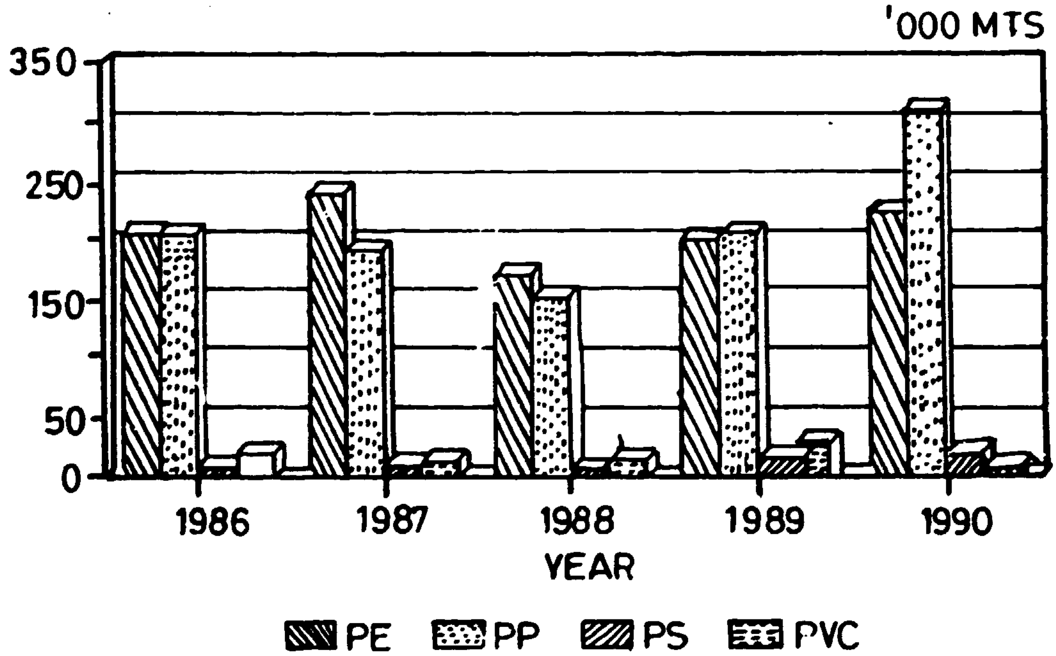


FIG.: 6·1(5F) IMPORTS OF PLASTICS TO INDONESIA (1986-1990).

SOURCE : CENTRAL BUREAU OF STATISTICS, INDONESIA

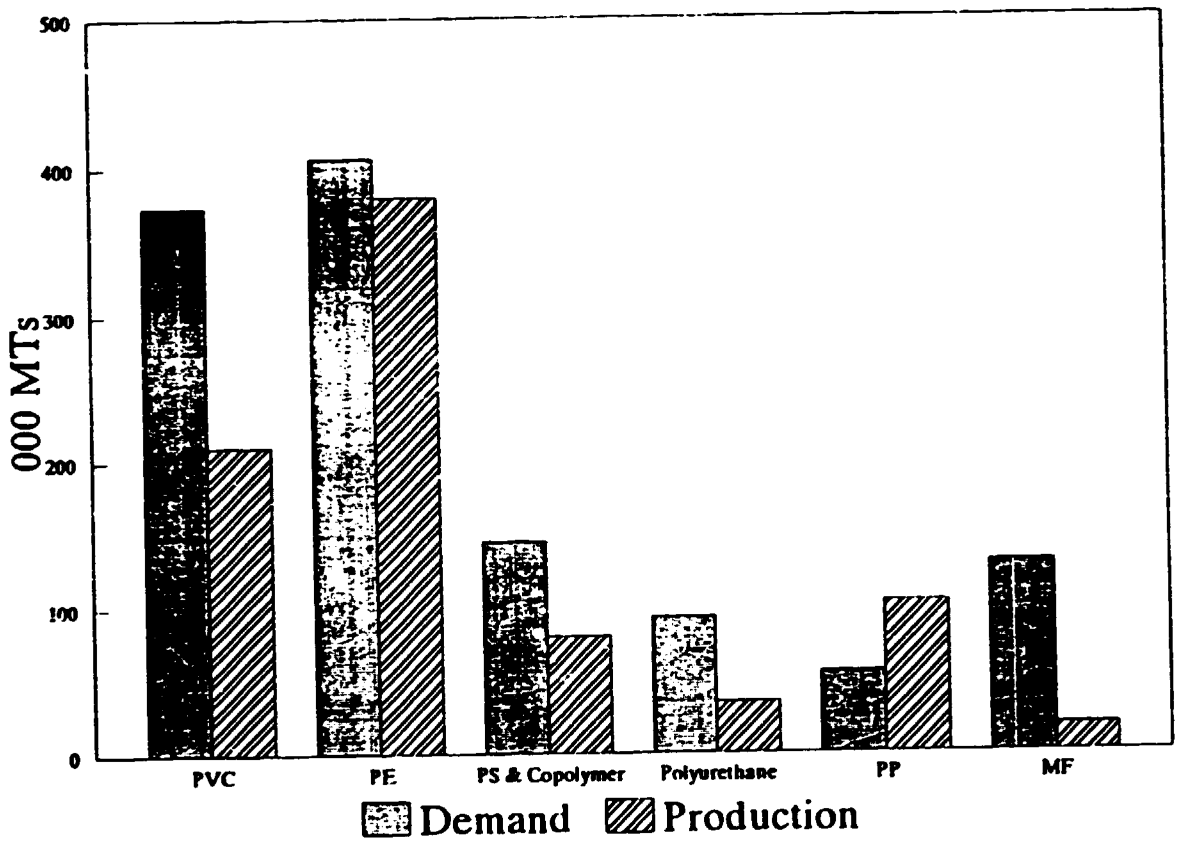


Fig. 6.1.6F: Expected demand and production of plastics in Iran by 1995

6.1.7.1.b POLYPROPYLENE

Polypropylene has been a star performer amongst all polymers. The growth rate of polypropylene has been phenomenal and as a result, the world polypropylene capacity expansion is projected to grow at a CARG of 13.4% over the next few years. In Western Europe alone 16 new plants have been planned by 1995 totaling about 7 million MTs and raising the capacity from 3.2 million MTs to well over 5 million MTs in 1995. However, capacity expansion is not limited to industrialised country. Many newly industrialised countries particularly in the Pacific Rim have also announced large capacity expansions. The regionwise break-up of capacity for the 1985-95 period can be seen from the table 6.1(12) :

TABLE 6.1(12)
REGIONWISE PPHP CAPACITY BUILD-UP
(fig. in '000 MTs)

	1985	1995
North America	2900	5300
Western Europe	2700	6200
Japan	1150	2300
Eastern Europe	625	1075
Latin America	175	1292
Far East & Oceania	1050	4500
Mid East/Africa	90	1000
TOTAL -	8090	21527

The polypropylene technology have gone though repeated upgradations and now very efficient catalysts produce new products with wide range of performance properties. These new polymers can serve the lower end of the engineering polymer markets. This possibility of new market has made petrochemical companies to invest in polypropylene business. While in the developed nations, polypropylene end use patterns are shifting; the rest of the world continues to use the resin in film, fibre and moulding applications. The greatest potential for polypropylene appears to be in the large consumer non durable and automotive markets. With the growing demand in Pacific Rim countries, the world PP production shift is taking place towards the newly industrialised countries.

6.1.7.1.c POLYSTYRENE:

Polystyrene like all other polymers has enjoyed good growth rate worldwide primarily due to better economic performance of most developed and developing regions. Between 1983 to 1990, the world polystyrene consumption grew @ 6% (plus) per year.

The polystyrene growth is dependent on growth of the packaging and appliances sector. With two large consuming regions - US & Western Europe showing depressed demands, the polystyrene growth in the next few years is likely to be moderate. The world production capacity of polystyrene in 1990 was 10.5 million MTs and is expected to reach 12.5 million MTs i.e. over 20% of 1990 in a six year period. The regionwise break up of capacities is given in the table 6.1(13).

TABLE 6.1(13)
REGIONWISE POLYSTYRENE CAPACITY BUILD-UP
(Fig. in '000 MTs)

	1985	1995
North America	2606	3048
Western Europe	2525	3176
Japan	1059	1778
Eastern Europe	733	1016
Latin America	489	635
Far East & Oceania	734	2922
Others	--	127
TOTAL -	8146	12702

The world demand of polystyrene was 8.5 million MTs in 1990 and is expected to reach more than 11.4 million MTs by 1996 representing a compound growth rate of 5% per year. Amongst developing countries China's requirement for PS is double than the production capacities (Table 6.1(11)).

Amongst ASEAN countries, almost all the countries take care of their local demand through indigenous production except Singapore. The capacity expansion is on way in Malaysia by 3.6 times (Fig. 6.1.1F (15)). Thailand will be adding the capacity of 75,000 MTs by 1995 with its indigenously available feedstock (15).

This has been attracting Japanese moulders of appliances & electronic products and they are moving to Thailand to use their easily available cheaper PS. Indonesia's styrenics complex producing PS, HIPS and other products will be on stream by 1994 (16). This will make them self sufficient in polystyrene.

Although, the growth of polystyrene has primarily been affected due to waste disposal problem because fast food service products are one of its largest outlets. In US, on environmental considerations, the consumption of polystyrene products may be affected. In Taiwan environmental protection administration has ruled that all manufacturers, importers and retailers of polystyrene containers will be responsible for collecting and recycling their products. Despite certain growth constraints, it has recently been reported that polystyrene is faring the best of all the commodity polymers and the prospects look even better for the next few years (18a).

6.1.7.1.d Polyvinyl Chloride (PVC):

The global capacity of PVC stands at 21 million MTs. This is expected to rise to 25 million MTs by 1995. The regionwise PVC capacity build-up during 1985-95 can be seen from the table 6.1(14) :

TABLE 6.1(14)
REGIONWISE PVC CAPACITY BUILD-UP

(fig. in '000 MTs)

Region	1985	1995
North America	3770	5707
Western Europe	5185	6204
Japan	1728	2233
Eastern Europe	2356	2578
Latin America	678	1985
Mid East/Africa	315	994
Far East/Oceania	1728	4315
TOTAL -	15710	24815

The global PVC consumption grew at a healthy rate during the late eighties. Much of this growth was through the housing markets. Both in US and other developed economies, its share in housing grew substantially. The pipe market has been the major consumer. Other end uses like siding and accessories, wall coverings, floorings, window profiles did especially well. Hospital and health care products also showed good growth rate in developing countries. PVC film has been growing steadily over the years. The world demand for PVC is forecasted to grow around 3.8% average upto 1995. The region with the higher growth rate would be the Pacific Rim and slow growth rate in US & Western Europe. The leading end-use segments will continue to be housing, packaging and medical applications. The net trade balance would be more in favour of Latin America and Asia pacific countries.

6.1.7.2 FIBRE INTERMEDIATES & FIBRE:

6.1.7.2.a FIBRE INTERMEDIATES :

(i) Para xylene:

World para xylene capacity reached almost 9.6 million MTs in 1991-92 and will reach 12.3 million MTs by 2000 AD under current plan (Table 6.1(15)). The Far East is the major contributor alongwith Japan. The other capacity will be installed in the regions/locations like Middle East, China, India and a few other developing Asian countries.

Due to the present excess capacity, the utilization is expected to be as low as 73% during 1991-92 which may go up slowly to 82% by 2000 AD. Thus it appears that there will be a very competitive scenario for para xylene during 1992 - 2000 AD (19). The demand will continue to grow much faster in Asian countries and hence the consumption in this region is expected to remain higher than rest of the world.

The present capacity share in developing countries is about 38.92% (about 4 million MTs). This will reach to about 56.76% (5.67 million MTs) by 1997. The CARG in will be about 9% from 1991 to 1997. The total increase in the capacity from 1991 to 1997 in developed countries will be about 4.85%.

TABLE-6.1(15)
GROWTH TREND OF PARA XYLENE PRODUCTION CAPACITY IN DEVELOPED AND DEVELOPING COUNTRIES

(Fig. in '000 MTs)

	Region	1991	1993	1997
A.	**Developed**			
	N. America	2965	2805	2805
	W. Europe	1360	1315	1475
	Japan	1965	2190	2315
	A. Total	6290	6310	6595
B.	**Developing**			
	L. America	450	450	735
	E. Europe	785	785	785
	M/East Africa	225	265	319
	S/SE Asia	449	719	1699
	E. Asia	1438	1803	2138
	Total	3347	4022	5676
	CARG, %		9.0	
	Total (A + B)	9637	10332	12271
	Capacity Utilization (%)	75.6	78.3	79.3

The major contributors for this capacity growth in developing countries are given below.

Latin America
- Mexico

M. East/Africa
- Iran
- Iraq

S/SE Asia
- India
- Indonesia
- Singapore
- Thailand

E.Asia
- China
- South Korea
- Taiwan

There is likely to be no further growth in E. European countries till 2000 AD.

(ii) DMT/PTA :

The polyester industry is utilizing more and more PTA as compared to DMT and the share of PTA which is around 65% at present will go upto around 70% by 1995. World DMT and PTA consumption is projected to grow at an average annual rate of 1.8% and > 6.2% respectively over the period 1991-97.

The present world capacity of DMT is likely to remain static with a little expansion in Brazil, India, Iran, Mexico offsetting a decline in other areas. The estimated capacity during 2000 AD will be around 4.9 million MTs (Table 6.1.(16)). Due to stagnation in DMT capacity, the capacity utilization will remain at a healthy level of 90% plus up to 2000 AD.

The present capacity share of DMT in developing countries is about 42.5% and with a little increase by 1997 it will reach to about 44.11% (2.14 million MTs). The CARG from 1991 to 1997 in these countries will be <2% as compared to a negative trend (i.e. - 2.16%) in developed countries.

TABLE - 6.1(16)
GROWTH TREND OF DMT PRODUCTION CAPACITY IN DEVELOPED AND DEVELOPING COUNTRIES
(Fig. in '000 MTs)

Region	1991	1993	1997
A. Developed			
N. America	1410	1350	1350
W. Europe	995	995	995
Japan	365	365	365
A. Total	2770	2710	2710
B. Developing			
L. America	528	620	695
E. Europe	689	689	749
M. East/Africa	120	180	180
S/SE Asia	143	153	153
E. Asia	365	365	365
B. Total	1845	2007	2142
CARG, %		<2	
Total - (A + B)	4620	4722	4857
Capacity utilization (%)	86.2	87.8	91.3

The world PTA capacity was around 8.75 million MTs with a capacity utilization of 82% (Table 6.1(17)). However, with the growth of the polyester industry, the capacity utilization is expected to go up to 94% by 2000 AD with a production capacity of about 11.2 million MTs.

TABLE - 6.1(17)
GROWTH TREND OF PTA PRODUCTION CAPACITY IN DEVELOPED AND DEVELOPING COUNTRIES.
(Fig. in '000 MTs)

Region	1991	1993	1997
A. Developed			
N. America	2240	2310	2310
W. Europe	1152	1162	1212
Japan	1440	1440	1440
A - Total	4832	4912	4962
B. Developing			
L. America	455	545	575
E. Europe	--	--	--
M. East/Africa	70	70	70
S/SE. Asia	355	425	1675
E. Asia	1440	1440	1440
B - Total	3921	4891	6996
CARG. %		>10	
Total - (A+B)	8753	9803	11958
Capacity utilization (%)	82.0	83.1	86.3

In developing countries the capacity expansion in the period of 1991 to 1997 will increase upto 78.4% i.e. from 3.9 million MTs to about 7 million MTs with CARG of > 10%. The major contributors in developing nations for this capacity increase are listed below.

<u>L.America</u>
- Brazil
- Mexico

<u>S/SE Asia</u>
- India
- Indonesia
- Thailand

<u>E. Asia</u>
- China
- S. Korea
- Taiwan

Developing Asian countries will continue to dominate in the production of PTA. The growth in China alone will be doubled from the present of 0.74 million MTs to 1.31 million MTs by 1997. The present capacity growth trend will lead to the dominance of developing countries over developed countries by 1997 with their world share of 58.5%. The contributors for capacity growth of PTA may increase after 1995 with the expansion/new installations in middle East, S/SE Asia, E.Europe & Africa, which are under consideration.

(iii) MONOETHYLENE GLYCOL (MEG):

Compared to other intermediates of polyester fibre, the capacity expansion of MEG has taken place both in developed and developing countries upto about 16% and 38% respectively in the period of 1989 to 1993. The average growth rate in developing countries in this period has been about 7.5% (Table-6.1(18)). This growth will be about 10.8% and 15.5% in the period of 1993 to 1996 in developed and developing countries respectively. However, the share of developing countries will remain much lower than developed countries. USA alone is likely to maintain its share above 40% of the total world capacity. Amongst developing countries the major share holders are Saudi Arabia, China, South Korea, Taiwan, India, Mexico and Brazil. In the period of 1993 to 1996 the capacity expansion/new installation will continue to take place in Brazil, Iran, Saudi Arabia, Nigeria, India, Indonesia and China.

TABLE - 6.1(18)
GROWTH TREND OF MEG PRODUCTION CAPACITY IN DEVELOPED AND DEVELOPING COUNTRIES.

(Fig. in '000 MTs)

Region	1989	1991	1993	1996
A. Developed				
N. America	3415	3300	3715	4360
W. Europe	995	1125	1350	1350
Japan	707	782	874	874
A - Total	5117	5207	5939	6584
B.Developing				
L. America	437	497	587	617
E. Europe	633	628	628	628
M.East/Africa	693	770	775	1200
S/SE Asia	175	208	455	495
E. Asia	603	881	1073	1123
B - Total	2541	2984	3518	4063
CARG, %	7.5		4.5	
Total - (A + B)	7658	8191	9457	10647

The capacity utilization upto 1995 will remain around 80% in the world. The growing capacities in developing countries will keep pace with the growth of local polyester industry. The production in Saudi Arabia will share the export market with USA with its production of 0.52 million MTs (20). However, import in Asian countries will fluctuate with their capacity utilization and its cost variation in the market.

(IV) ACRYLONITRILE (ACN):

ACN consumption for acrylic fibre is about 60% of its total production (Table- 6.1(19)). The other major usage are for the production of ABS/SAN and adiponitrile. Thus the growth of ACN is mainly dependent upon the growth of acrylic fibre. In the next couple of year the growth of acrylic fibre will be negligible with the estimated production of 2.2 million MTs in 1991 to 2.4 million MTs by 2000 AD. Therefore, it is expected that capacity increase in case of ACN will be marginal during 1991 - 2000 period. The estimated capacity of ACN during 1993 is 4.26 million MTs which is expected to grow marginally upto 1995 and about 5 million MTs by 2000 AD with the capacity utilization of about 90% throughout the decade. Table - 6.1.(20) given the scenario of expansion of ACN worldwide up 1995 (21). Amongst developing countries/regions the capacity expansion is expected in China, CIS countries and M.East/Africa.

TABLE- 6.1(19)
ACRYLONITRILE - WORLDWIDE

(Fig. in '000 MTS)

	1993	1994	1995
Capacity to produce	4269	4286	4286
Production	3933	4069	4115
Production capacity utilization - %	92.1	94.7	96.0
Consumption in Acrylic Fibre	2299	2347	2366
Others	1634	1712	1759
Total...	3933	4059	4125

TABLE - 6.1(20)
GROWTH TREND OF ACRYLONITRILE PRODUCTION CAPACITY IN DEVELOPED AND DEVELOPING COUNTRIES

(Fig. in '000 MTs)

Region	1993	1994	1995
A. Developed			
N. America	1338	1338	1338
W. Europe	1075	1075	1075
Japan	608	608	608
A - Total	3021	3021	3021
B. Developing			
L. America	266	266	266
E. Europe	377	377	377
M.East/Africa	80	92	92
S/SE. Asia - India	30	30	30
East Asia	495	500	500
B - Total	1248	1265	1265
World capacity	4269	4286	4286
Capacity utilization - %	92.1	94.7	96.0

(v) **CAPROLACTAM:**

About 80% of caprolactam is consumed in the production of nylon fibre and balance goes for resin. The demand of textile yarn is gradually decreasing in industrialised countries while resin are shcwing some growth.

Amongst developing countries the major growth of caprolactam between 1990 to 1996 is with the capacity increase in Asian countries. The CARG in developing countries is about 7% in this period (Table 6.1(21)). However, there is no further growth is expected by the turn of the century due to the saturation in the market.

The global capacity utilization continues to be around 90%. This is with the production of nylon fibre to about 2.3 million MTs in 1991 which is expected to grow marginally upto about 2.7 million MTs by 1996.

TABLE 6.1 (21)
GROWTH TREND OF CAPROLACTAM PRODUCTION CAPACITY IN DEVELOPED AND DEVELOPING COUNTRIES.

(Fig. in '000 MTs)

Region	1990	1993	1996
A. Developed			
N. America	622	650	684
W. Europe	776	871	871
Japan	510	562	562
A - Total	1908	2083	2117
B. Developing			
L. America	157	159	159
E. Europe	881	821	829
M. East / Africa	25	25	25
S / SE Asia	22	112	192
E. Asia	510	562	562
B - Total	1293	1375	1723
CARG, %		7	
Total - (A + B)	3201	3458	3840
World Production	3015	3125	3445
Capacity utilization - %	94.2	90.2	89.7

6.1.7.2 b SYNTHETIC FIBRE :

After plastics, synthetic fibres are the most important petrochemical products. Their main application is in textile sector and fulfills the basic human need for clothing. Apart from use in textile, synthetic fibres are finding increased application in the car industry for safety belts, upholstery, tyre card and carpets. They provide greater reliability due to their more durable nature. Other applications of synthetic fibre include carpet backing, filler in the industrial conveyer belt as well as truck tarpaulins.

As the major share goes for clothing, developing countries are producing mostly the grades suitable for the production of cloths. It was observed that most of the developing countries have reached a production level of 1 kg per capita of synthetic, while in India it was about 0.3 kg per capita. Even a country like China has achieved the synthetic production of 0.69 kg per capita in 1984. Indonesia and Brazil had achieved a figure of 0.96 and 1.67 kg per capita respectively (21).

Synthetic fibre is continuously increasing its share of total fibre consumption. In 1991, it accounted for 39.5% of the global fibre consumption. Amongst natural fibres, cotton is dominant and maintains higher share than synthetic fibre. However, the increasing demand of clothing is being met through synthetic fibre since the growth rate of cotton and other natural fibre like silk and wool is relatively much lower. The production of cotton also depends on the rainfall in the region, therefore, the supply varies every year.

The world share & production of synthetic fibres in 1991 is shown in Fig.(6.1(7F)) and Fig.(6.1(8F)) respectively (22). The world production of textile fibre/yarn from 1981 to 1990 shows an increasing growth of non cellulosic fibre at the rate of about 4% whereas natural fibre shows a growth rate of about 2% (Table -6.2(22)). However, the latter is maintaining its share of about 53% of the total fibre. The cellulosic fibre had a negative trend and its production decreased from 3.2 million MTs to 2.84 million MTs from 1981 to 1990. One of the major reason has been the environmental pollution problem in its production.

The most commonly used synthetic fibres are polyester, acrylic and polyamide. A few of their features are given below.

Polyester Fibre

- Silk/Wool like feel
- Fully used for clothing & can be blended with natural fibre like cotton, wool & viscose.

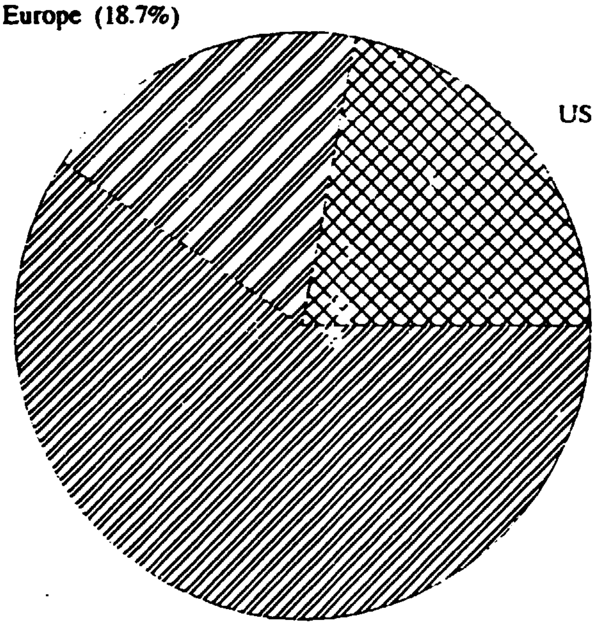


Fig. 6.1.7.F: Global share of synthetic fibre production
Ref: Chemical Week April 8, 1992, p.52

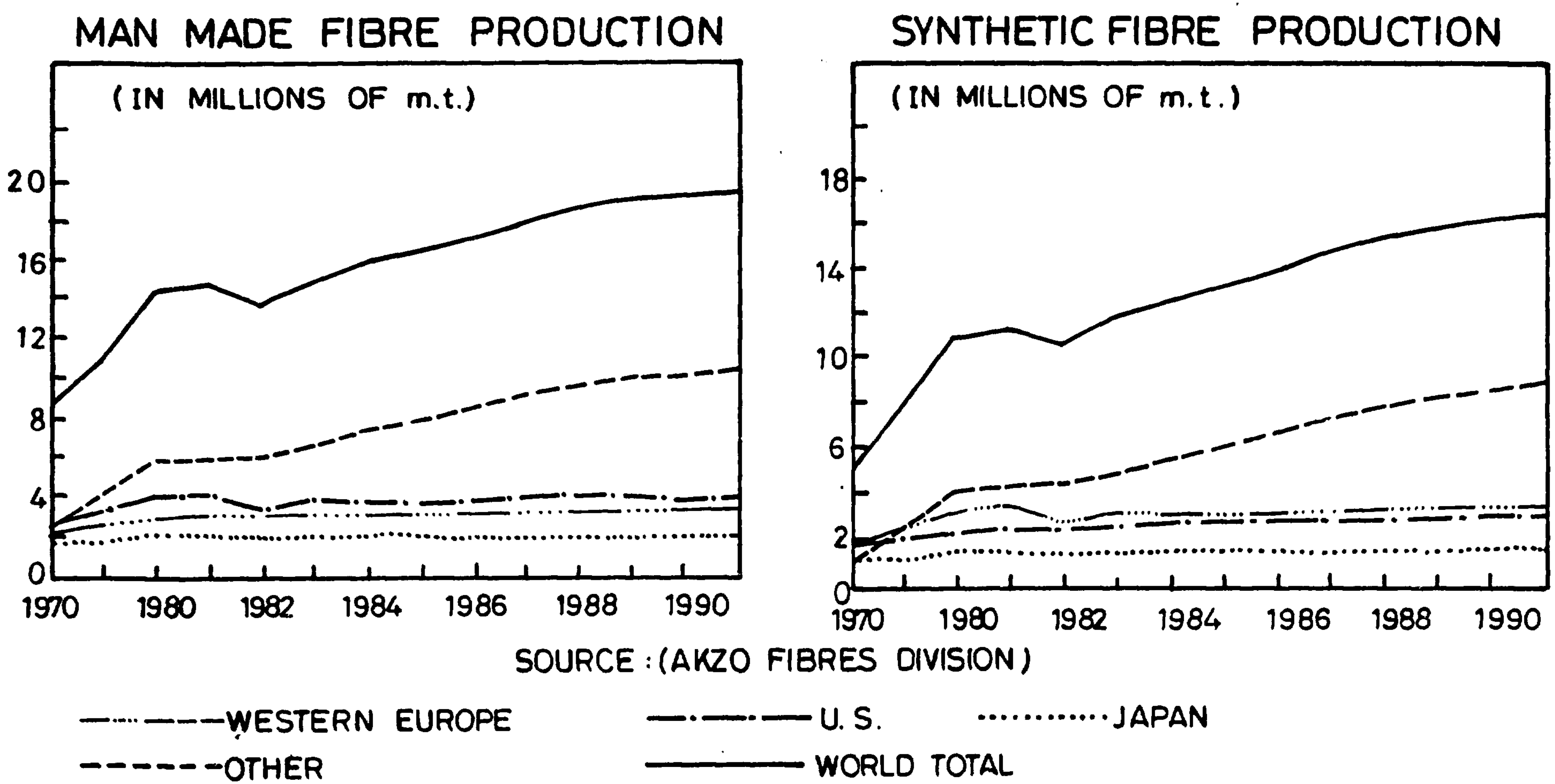


FIG. 6.1. 8.(F). GLOBAL FIBRE PRODUCTION

SOURCE : CHEMICAL WEEK APRIL 8, 1992, PAGE 49.

TABLE -6.1(22)
WORLD PRODUCTION OF TEXTILE FIRRES/YARN

(QTY. IN '000 MTs)

TYPE OF FIBRE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
A. Man-Made Fibres										
CELLULOSIC FIBRES										
Yarn + Monofilaments	1104	1023	1040	1029	924	924	910	948	925	901
Staple + Tow	2100	1922	1989	2065	2007	1935	1941	1939	1952	1945
SUB TOTAL	3204	2945	3029	3094	2931	2859	2851	2887	2877	2846
NON-CELLULOSIC FIBRES										
(Synthetic Fibres)										
Acrylic + Modacrylic	2090	2058	2221	2298	2381	2446	2525	2440	2352	2326
Nylon + Armid	3139	2854	3196	3354	3442	3497	3630	3789	3806	3765
Polyester Filament Yarn	2221	2131	2318	2493	2763	2858	3104	3486	3705	3910
Polyester Staple Fibre	3244	2974	3217	3560	3739	4000	4341	4568	4785	4711
Others	133	130	127	144	164	140	144	138	151	157
SUB TOTAL	10827	10147	10836	11506	12489	12941	13744	14363	14799	15634
TOTAL	14301	13092	13865	14600	15420	15800	16595	17250	17676	18480
B. Natural Fibres										
Raw Cotton	15296	14639	14217	19060	16565	18280	18243	18484	18733	18714
Raw Wool	1626	1629	1641	1682	1722	1790	1785	1883	1887	1964
Raw Silk	57	55	55	55	59	63	63	64	66	66
TOTAL	16979	16323	15913	20797	18346	20133	20141	20431	20686	20744
GRAND TOTAL	31010	29415	29778	35397	33766	35933	36736	37681	38362	39224

SOURCE : TEXTILE ORGANON (JUNE-1991)

Acrylic Fibre

- Gives more wool like finish.
- About 65% share goes for clothing,
  25% for sports & summer garments.
  10% for furnishing, carpets, building
  construction etc.

Nylon Fibre

- More cotton like feel.
- 25% share goes for clothing i.e.
  especially ladies wear.
- Industrial application includes furnishing,
  felt, tyre, etc.

The production capacity of synthetic fibre is fast growing in Southern and South East Asian countries. This region has undergone intensive capacity expansion. Taiwan and South Korea now have larger polyester fibre capacities than all the Western Europe; each producing about 1.2 million MTs per year of polyester staple fibre and filament (23). Indonesia also increased capacity by 64,000 MTs per year in 1991. Despite this increase Indonesia continues to import all kinds of fibres and export a good amount of finished textile products, using its weaving capacity of 5,628 million meters (15). Table-6.1 (23) shows the production growth of synthetic fibre in China. At present, the fibre in China is mainly used for garments' production. The percentage share of fibre for garments, industries and decoration is 60%, 25% and 15% respectively (13). The terylene (polyester) holds a leading position in fibre production. Its output accounts for 60% or more of the total output of synthetic fibres. This is depending on dress demand of 1.2 billion of Chinese people. However, the present proportion of polyester filament to staple is 45 : 50, which will be adjusted according to market demand.

TABLE - 6.1(23)
ASSORTMENT OF FIBRES AND THEIR OUTPUT IN CHINA
(Fig. in '000 MTs)

	1980	1990	2000
Synthetic fibres	314.1	1432	2150
Terylene	118.3	1042	1600
Staple	115.6	622	850
Filament	2.7	420	750
Polyamide fibre	31.7	112	280
Filament	22.3	102	260
Acrylonitrile fibre	58.0	122	400
Vinylon	96.7	55	50
Polypropylene fibre	3.3	75	150
Other fibres	6.1	26	30

Amongst synthetic fibre, polyester has its major share with the highest production growth rate of 5.2% from 1981 to 1990. The capacities and capacity utilization of polyester fibre (staple & filament) in developed and developing countries is shown in Tables 6.1 (24), 6.1 (25) and 6.1 (26). This shows that capacity growth rate in developing countries is much higher (i.e. >5%) in developing countries than the developed countries. The world share of 61% in 1987 is likely to increase upto 74% by 2000 AD (Table - 6.1(24)). The capacity utilization which has been ranging from 86 to 89% will also reach 100% with the economic growth by the turn of the century. There has been an overall increase in the capacity and production in developing countries. Africa, Middle East, Asia & Far East are fast growing. This will not only meet local requirement but also make a few of them competitor in the export market. Polyester staple fibre will continue to have there capacity share 1.3 to 1.5 times more than filament yarn. It will also hold its large share in the blend of natural fibre like cotton in developing countries. (Tables - 6.1 (25) and 6.1(26)).

The latest technological advancement of polyester fibre is the development of micro filament yarn. This is technically called micro filament yarn of 0.5 dpf. and provide a much higher degree of comfort and duplicating the look of silk. (19)

On one side, when polyester maintain its highest share of about 50%, polyamide and acrylics account for only 24% and 15% respectively. The growth of acrylic fibre is expected to be about 2.5% by the year 2000 (24). Table 6.1(27) shows that the global capacity will increase only by about 6.7% from 1992 to 1997. Acrylic

TABLE - 6.1(24)
POLYESTER FIBRE CAPACITY & PRODUCTION IN DEVELOPED AND DEVELOPING COUNTRIES.

Region	1987	1990	1993	1995	2000	Growth-%
	Polyester Fibre capacity (Fig. in '000 MTs)					
A. Developed						
N. America	1477	1610	1745	1745	1745	1.3
Western Europe	1041	1078	1266	1266	1266	1.5
Japan	813	802	802	802	802	(0.1)
Total - A	3331	3490	3813	3813	3813	-
B. Developing						
Latin America	556	621	735	735	735	2.2
Eastern Europe	868	904	931	1106	1312	3.2
Africa/Middle East	305	341	425	632	632	5.8
Asia / Far East	3565	4934	6662	7009	8151	6.6
Total - B	5294	6800	8729	9306	10830	>5.0
TOTAL - (A + B)	8625	10290	12542	13119	14643	4.2
	Polyester Fibre production (Fig. in '000 MTs)					
A. Developed						
N. America	1709	1566	1746	1796	1856	6.0
Western Europe	877	972	1062	1104	1136	2.0
Japan	606	680	710	730	800	2.2
Total - A	3192	3218	3518	3620	3792	-
B. Developing						
Latin America	429	463	578	647	720	4.1
Eastern Europe	736	739	807	921	1193	3.8
Africa/Middle East	281	309	376	442	614	6.2
Asia / Far East	3013	4118	5569	6615	8895	8.7
Total - B	4459	5729	7330	8635	11422	>6.0
TOTAL - (A + B)	7651	8847	10848	12255	15214	5.4
Capacity utilisation,%	89	86	86	93	100	

TABLE - 6.1(25)
POLYESTER STAPLE CAPACITY AND PRODUCTION
IN DEVELOPED AND DEVELOPING COUNTRIES.

Region	1987	1990	1993	1995	2000	Growth-%
Polyester Staple Production Capacity (Fig. in '000 MTs)						
A. Developed						
N. America	1191	1236	1306	1306	1306	7.0
Western Europe	560	596	708	708	708	1.8
Japan	359	351	351	351	351	(0.2)
Total - A	2110	2183	2365	2365	2365	-
B. Developing						
Latin America	249	292	391	391	391	3.5
Eastern Europe	586	586	596	761	916	3.5
Africa/Middle East	147	152	194	229	395	7.9
Asia / Far East	2105	2801	3848	4084	4922	6.8
Total - B	3087	3831	5029	5465	6624	-
TOTAL - (A + B)	5197	6014	7394	7830	8989	4.3
Polyester Staple Production (Fig. in '000 MTs)						
A. Developed						
N. America	1153	1045	1175	1215	1250	6.0
Western Europe	451	521	566	586	611	2.4
Japan	283	310	325	335	350	1.6
Total - A	1887	1876	2066	2136	2211	
B. Developing						
Latin America	196	229	304	350	386	5.4
Eastern Europe	473	454	507	612	857	4.7
Africa/Middle East	130	135	170	204	327	7.4
Asia/Far East	1723	2252	3100	3740	5205	8.9
Total - B	2522	3070	4081	4906	6775	
TOTAL - (A + B)	4409	4946	6147	7042	8986	5.6
Capacity utilization, %	85	82	83	90	100	

TABLE-6.1 (26)

POLYESTER FILAMENT CAPACITY AND PRODUCTION IN DEVELOPED AND DEVELOPING COUNTRIES

	1987	1990	1993	1995	2000	Growth%
	Polyester Filament Production Capacity (Fig. in '000 MTs)					
Developed						
N.America	286	374	439	439	439	3.4
W. Europe	481	482	558	558	558	1.1
Japan	454	451	451	451	451	-
a) Total	1221	1307	1448	1448	1448	-
Developing						
Latin America	307	329	344	344	344	0.9
Eastern Europe	282	318	335	345	396	2.6
Africa/ Middle East	158	189	207	227	237	3.2
Asia/Far East	1460	2133	2814	2925	3229	6.3
b) Total	2207	2969	3700	3841	4206	<6
Total (a+b)	3428	4276	5148	5289	5654	3.9
	Polyester Filament Production (Fig. in '000 MTs)					
Developed						
N. America	556	521	571	581	606	0.7
W. Europe	426	451	496	518	525	1.6
Japan	323	370	385	395	450	2.6
a) Total	1305	1342	1452	1494	1581	
Developing						
Latin America	233	234	274	297	334	2.8
Eastern Europe	263	285	300	309	336	1.9
Africa/ Middle East	151	174	206	238	287	5.1
Asia/Far East	1290	1866	2469	2875	3690	8.4
b) Total	1937	2559	3249	3719	4647	
Total (a+b)	3242	3901	4701	5273	6228	5.2
	Capacity Utilization (%)					
	95	91	91	99	100	-

TABLE 6.1(27)
WORLD PRODUCTION CAPACITY OF FIBRE & FIBRE INTERMEDIATES PRODUCTS

(Fig. in 000 MTs)

Production	Estimated Production			Capacity to Production	
	1989	1990	1991	1992	1997
1. PX	6792	6943	7287	9927	12326
2. PTA	6080	6726	7180	9613	11708
3. DMT	4076	4022	3983	4787	4857
4. MEG	5861	6153	6230	8911	10860
5. ACN	3617	3648	3655	4202	4589
6. PFY	3705	3901	4163	4965	5435
7. AF	2352	2208	2175	2995	3195

fibre has also not got much attention in developing countries as it is clear from the list of new projects (Table 6.1 (28)). Amongst Latin American countries Mexico is expanding its Acrylic fibre capacity. Taiwan, Thailand, S.Korea, India, Indonesia and China share their capacities of acrylic fibre in Far East/South East Asia. Special grades of acrylic fibre for housing and construction has continued to be a product of import in developing countries and export of developed countries like Japan.

TABLE -6.1(28)
STATUS OF NEW PROJECTS - INTERNATIONAL

Name of the company	Country	Product	Capacity (MTA)	Start up schedule
Pertamina	Indonesia	PX	3,70,000	Q-1, 1995
Slovnaft State Enterprises	Czechoslovakia	PX	1,20,000	1994
Kuwait Petro	Kuwait	PX	4,00,000	1992
Kuwait Petro	Kuwait	EG	1,65,000	1994
Eastern Petro	S. Arabia	EG	63,000 (Exp.)	1993
Prala	Venezuela	EO/EG	86,000	mid-1992
National Petro	Iran	EG	3,00,000	1994
Union carbide/Mitsui	Canada	EG	3,00,000	1994
Arak Petro Corp.	Iran	EG	1,05,000	1993
Sharq	S. Arabia	EO/EG	7,20,000 (Exp.)	Q3-1993
Monomers Colombo	Venezuela	PTA	1,30,000	1992
Amoco Indoprakasa	Indonesia	PTA	2,50,000	Q1-1994
Mitsubishi	Indonesia	PTA	2,50,000	1992
Mitsui Petrochemicals	Indonesia	PTA	2,50,000	Q1-1992
Mitsui Petrochemicals	Sumatra	PTA	2,50,000	1993
Tuntex Thailand	Thailand	PTA	3,50,000	mid-1994
State Corporation	USSR	Corpo.	88,000	1992
Tong Young Nylon	S. Korea	Corpo.	1,20,000	1992-93
Namhae Chemical Corp.	Korea	Corpo.	1,40,000	1994
Formica Plastics	Taiwan	ACN	70,000	1993
Saratov	USSR	ACN	75,000	1992
Petkim	Turkey	ACN	15,000	1992
Sasol Industries	S. Africa	AF	36,000	mid-1993
Soficar West	France	Carbon-Fibre	700 (Exp.)	June 1992
Sunkyong Industries	S. Korea	PE-chips	2,20,000 (Exp.)	Q3-1992
Sunkyong Keris	Indonesia	PSF	23,100	Q2-1993
Allied-Signal	France	PSF	19,000	Q4-1993
Eastman/Texmaco	Ireland/Indonesia	PSF	1,80,000	mid-1992
Hoechst Tejin Fibres	Japan	PFY	-	Q4-1993

Despite the continued requirement for garments, upholstery, decoration & rubber reinforcement, the growth rate of nylon fibre has been much lower compared to other fibres.

Polypropylene fibre has picked up market in developed countries with its major applications like upholstery, carpets etc. This fibre has also been penetrating the market in developing regions like India, China and other Asian countries. However, its demand is largely meet through the import of fibre grade polypropylene from developed countries.

Specially fibres like Carbon fibre, Kevalar & Aramide have their applications in defence aerospace and other industrial sector. The total requirement of these reinforcing fibres is met through import in developing countries. Only a small production capacity of carbon fibre exist in India and China. The production cost with small capacity plants in these countries is much higher, which prohibits their marketability.

6.1.7.3 SYNTHETIC RUBBER:

Synthetic rubber is a strategic petrochemical product of considerable significance in the world economy and has maintained growth rate of about 6-7 % during the last decade. It will continue to grow in future with the industrial and agricultural growth. The world's transport industry more or less depend upon the rubber industry.

Natural rubber is mainly produced in the tropical areas of the world. This is unable to meet the raw material demand for manufacturing industries. As a result, synthetic rubber has been developed which accounts for about 67% of the total rubber at present.

6.1.7.3.1 BUILDING BLOCKS FOR RUBBER:

Main building blocks for the production of synthetic rubber are butadiene & styrene. Butadiene occupies a special place among synthetic rubber monomers.

6.1.7.3.1a BUTADIENE:

The bulk of butadiene is produced either by catalytic dehydrogenation of n-butane or high temperature cracking of petroleum distillates. The consumption of butadiene in developed and the developing country is given in Table 6.1(29).

TABLE - 6.1(29).
WORLD CONSUMPTION PATTERN OF BUTADIENE
(Fig.in '000 MTs)

	1990	1995	2000
A. Developed Countries			
North America	3550	4495	5685
Western Europe	1616	1912	2252
Japan	1207	1706	2365
TOTAL	6373	8113	10302
B. Developing Countries			
CPE Europe	136	164	196
Latin America	430	579	775
N. Africa & Middle East	0	0	0
Other developing countries	90	110	134
South East Asia	278	431	658
South Asia	53	73	97
TOTAL	988	1359	1860
Share of developed countries, %	87	86	85
Share of developing countries, %	13	14	15

The consumption in the developed countries has already reached to a saturation stage. The share of developing countries is expected to increase by 20% from 14% till the end of century. There is a full utilisation of the production capacity and hence the expansion in developing countries is going to be more than in developed countries.

6.1.7.3.1b STYRENE:

Styrene is the second major monomer being used in production of rubber. Currently there are more than 80 units in the world engaged in the manufacture of styrene. Styrene capacity is increasing steadily. Many new plants especially in North America are coming up. Table 6.1(30) gives world plant capacities for styrene monomer. USA has 30% of the total installed capacity followed by West Europe, Japan and S. Korea.

TABLE - 6.1 (30).
WORLD CAPACITIES FOR STYRENE

(Fig. in '000 MTs)

Year	Capacities	
	World	U.S.A.
1980	11635	4000
1985	12622	3782
1990	17000	4800
1995	20000	-

The expected global consumption of styrene during 1990; 1995 and 2000 AD in given in Table 6.1(31). The demand of styrene is estimated to be lower than production capacity in 1995 (Table 6.1(2)). End usage of styrene includes in the manufactures of polystyrene, ABS, SAN, & SBR besides being used in polyester resins as a cross linking agent. Styrene is also used in textile as a binder and in a number of other chemical products.

TABLE - 6.1(31)
EXPECTED STYRENE CONSUMPTION IN THE WORLD

(Fig. in '000 MTs)

	1990	1995	2000
A. Developed Countries			
North America	5918	7708	9894
Western Europe	3643	4281	5012
Japan	2287	3276	4581
TOTAL	11848	15265	19487
B. Developing Countries			
European CPE	1084	1384	1742
Latin America	907	1318	1835
N.Africa & Middle East	0	0	0
South East Asia	768	1248	1920
Other developing countries	201	263	335
TOTAL	2997	4359	5889
WORLD TOTAL	14845	19524	25396

6.1.7.3.2 WORLD RUBBER PRODUCTION AND CONSUMPTION:

The world's rubber production is expected to grow @ 3.4% per annum and will exceed to about 18.8 million MTs by 1995. The production of natural and synthetic rubber is projected to rise up to 6.7 million MTs and 12.1 million MTs respectively according to a study of world markets for "tyre and rubber" by leading edge reports. World's consumption figures of natural and synthetic rubber in tyre & non tyre sectors and their percentage compound growth rate upto 1995 is given in Table 6.1 (32).

TABLE - 6.1 (32)
WORLD RUBBER CONSUMPTION SECTORWISE:
(Fig. in '000 MTs)

	1986	1989	1995	CARG, % 1986-89	CARG, % 1989-95
1. Rubber consumption	13,678.3	15,633.3	18,673.0	4.55	3.01
2. Natural	4,434.1	5,353.4	6,716.5	6.48	3.85
Tyre	3,183.2	3,860.6	5,015.7	6.64	4.46
Non-Tyre	1,250.9	1,492.8	1,700.8	6.07	2.20
3. Synthetic	9,244.2	10,297.9	11,956.0	3.60	2.55
Tyre	3,970.7	4,370.0	4,757.3	3.25	1.43
Non-Tyre	5,273.5	5,909.9	7,198.7	3.87	3.34

From the above table it is clear that in 1989, share of natural and synthetic rubber consumption in tyre & non tyre sector was about 34.2% and 65.8% respectively. The average compound growth rate of the latter was 4.5%. World rubber consumption is expected to grow 3% annually and reach more than 8.6 million MTs by 1995.

Developing countries will continue to have high growth rate. However, the developed countries alongwith Japan will continue to account for more than 71% of total world tyre consumption. The consumption of rubber in developed and developing country is given in Table 6.1 (33).

In 1990 synthetic rubber consumption was merely 0.4% and it further declined by 7% as compared to 1990 due to slump in the automobile and construction sectors. Due to the economic and political changes in Eastern Europe and USSR, the synthetic rubber is expected to grow at @ 1.5% per year reaching to 9.1 million MTs in 1995 & subsequently 9.9 million MTs in 1996 (according to the analysis of the international institute of synthetic rubber producers). Among all other rubbers, styrene butadiene rubber is the most widely used synthetic rubber.

TABLE - 6.1 (33)
WORLD RUBBER CONSUMPTION COUNTRYWISE
(Fig. in '000 MTs)

	1986	1989	1995	CARG, % 1986-89	1989-95
A.DEVELOPED COUNTRIES					
1. United States	2,762.6	3004.8	3420.0	2.84	2.18
2. Canada	276.2	276.0	285.0	(0.02)	0.54
3. West Germany	640.7	668.6	-	1.43	-
4. Germany	-	-	1023.0	-	-
5. France	273.7	568.2	690.0	6.25	3.29
6. Italy	418.0	444.0	493.0	2.03	1.76
7. Other EC	268.3	296.5	340.5	3.39	3.31
8. West Europe	227.6	226.8	254.0	0.12	1.91
9. United Kingdom	325.0	372.5	429.0	4.65	2.38
10.Japan	1,445.0	1760.0	2175.0	6.71	3.59
B.DEVELOPING COUNTRIES					
1. Brazil	360.2	408.7	480.0	4.30	2.72
2. Mexico	170.0	179.0	209.0	1.73	2.62
3. Latin America	231.0	253.0	291.0	3.08	2.36
4. Spain	266.0	286.0	325.0	2.45	2.15
5. U.S.S.R.	2,335.0	2604.0	3098.0	3.70	2.94
6. Africa (Mideast)	377.0	428.0	510.0	4.32	2.96
7. China	710.0	925.0	1190.0	9.22	4.29
8. India	321.1	423.2	545.0	9.64	4.31
9. South Korea	349.0	530.0	710.0	4.94	4.99
10.Other Asia	695.0	846.0	1065.0	6.77	3.91
11.Oceania	94.9	117.0	144.0	7.23	3.52

Other synthetic rubbers are polybutadiene with about 17% market share ; Ethylene-propylene, Butyl, Nitrile, Polyisoprene, & Polychloroprene rubbers have about 29% share in the market.

Non Tyre uses of synthetic rubber particularly polybutadiene fall in two categories one which goes to modify plastics such as polystyrene and acrylonitrile butadiene styrene (ABS) to give improved impact resistance. A small amount goes to various kinds of mechanical goods; some of which are used in the automotive industry. These mechanical goods are hoses, gaskets, seals and wire coatings. The low expected demand of rubber in mechanical goods may not have any effect on the growing consumption. Consumption pattern of different types of rubber is shown in the Table 6.1(34).

Market share of various synthetic rubber will change to a limited extent : The role of synthetic rubber is well illustrated by looking at rubber consumption in the U.S.A. They produce a total of about 2 million MTs of synthetic rubber per annum out of which about 2/3rd accounts for two principal rubbers i.e. SBR and BR. Centrally planned economies will have consumption of 2.9 million MTs of synthetic rubber by 1995.

TABLE - 6.1(34)
WORLD PRODUCTION OF DIFFERENT RUBBER
(Fig. in '000 MTs)

	1986	1988	1990	1995
Synthetic, %	67.2	67.0	66.5	64.5
SBR Solid	2,477	2,417.0	2,440	2,649
SBR Latex	254	264.4	271	294
Carboxylated SBR Latex	1,332	1,139	1,150.0	1,198
Polybutadiene	1,136	1,176.0	1,172	1,324
Ethylene-Propylene	558	589.4	603	721
Polychloroprene	249	248.4	248	260
Nitrile solid/latex	250	244.2	249	290
Other synthetic (include butyl & isoprene rubbers in addition to others)	967	984.4	997	1,132
Total synthetic	7,060	7,073.8	7,178	8,002
Natural Rubber	4,169	4,216	4,301	4,902
Total New Rubber	11,229	11,290	11,479	12,904
Synthetics, %	62.9	62.7	62.5	62.0

Source : Chemical Business April 5-19, 1991, p-15.
Except CPEC and East Europe.

Excluding CPE countries and Eastern Europe, global consumption of polybutadiene is expected to grow more than 1.3 million MTs by 1995. Relatively low growth pattern for PBR & SBR will be caused by the little increase in tyre production and continuing shift of truck and bus tyres towards the radial ply design.

Tyre and tyre products are expected to account for more than 61% of total new rubber consumption in 1995.

About 51% of all synthetic rubber produced will go into tyres & tyre products. Replacement demand is expected to average 2.5% annual growth upto 1995. The replacement market will benefit from the expanding base of world motor. Vehicle registration and longer lasting tyres will decrease the demand for replacement tyre.

Natural rubber also holds a significant share of the total rubber market. The radialisation of automobile tyres, is no longer a primary course for change. Competitive demand position is the main reason for continued growth of natural rubber in tyre sector with synthetic rubber. The major synthetic rubber produced throughout the world is styrene butadiene rubber (SBR). Other major general purpose rubbers like polybutadiene shows lesser growth rate while the market for speciality rubbers is expanding. Thermoplastic elastomers are growing at a rate which outstrips the percentage growth rate of all other synthetic rubber. More and more of general purpose synthetic rubber producers are commencing market penetration for speciality thermoplastic elastomers. Thermoplastic elastomers consumption is expected to rise from 6,83,000 MTs to 8,58,000 MTs in 1994 with an average annual growth rate of 7% in the world market. However, the yearly growth of total new rubber is at the rate of 2.1% world wide.

An examination of natural rubber versus synthetic rubber consumption in developing country like India and that of the developed countries reveals that the ratio of NR/SR consumption in India & China is 80/20 whereas it is 30/70 in the developed countries. This ratio of consumption holds good for both the sectors of consumption such as Tyre and Non Tyre as evident from the Table 6.1 (35).

TABLE - 6.1(35)
RUBBER CONSUMPTION TYRE AND NON TYRE SECTOR

(Natural rubber versus synthetic rubber)
Percentage

Country	Tyre		Non Tyre	
	NR	SR	NR	SR
U.S.A.	30	70	13	87
U.K.	42	58	23	77
France	43	57	20	80
Germany	65	35	17	83
Italy	41	59	23	77
Japan	39	61	21	79
Canada	29	71	16	84
Brazil	30	70	16	84
India	78	22	82	18
China	65	35	80	20

Source IISRP

Developing countries like India & China have indeed a very low per capita consumption compared to the developed economies. This is due to the low per capita GDP and slow growth in automobile sector. The per capita consumption is not likely to rise to the level of those countries whose population growth is at a lower level than the countries like India & China in the near future .

The present over capacity situation and speedy expansion of production capacity of synthetic rubber in developing countries for their captive consumption may face stiff competition in export market and if import is liberalised local rubber manufacturers may face under utilization problem due to lower import cost in certain cases. Today, rubber industry is also passing through a difficult phase due to global recession in automobile sector.

6.2 INTEGRATION OF DOWNSTREAM PETROCHEMICAL INDUSTRIES WITH OTHER SECTORS OF NATIONAL ECONOMY TO CAPITALIZE ON SYNERGETIC EFFECTS

The basic human need of materials is largely met through natural products like cotton, wool, silk, jute, wood, leather, latex etc. These products have always been in short supply and even in future their growth rate will not be able to keep pace with the increasing demand in highly populated countries. The demand supply gap of materials can only be met through synthetic products. The emergence of petrochemical industry has now made it possible to fulfill the increasing human needs. The effective utilisation of valuable petrochemical products can only be possible through its linkage with core sector of national economy.

The downstream petrochemical products are be broadly classified into :

6.2.1a. PLASTICS:

6.2.1b. SYNTHETIC FIBRE & FIBRE INTERMEDIATES

6.2.1c. RUBBERS (ELASTOMERS)

6.2.1d. CHEMICAL & CHEMICAL INTERMEDIATES

The core sector of national economy considered for studying the synergetic effects are :

6.2.2a. Agriculture and Food Processing;

6.2.2b. Irrigation and Water Management;

6.2.2c. Housing and Shelter;

6.2.2d. Clothing;

6.2.2e. Medical and Health care;

6.2.2f. Industrial components and Engineering Products;

6.2.2g. Transportation;

6.2.2h. Telecommunication;

6.2.2i. Solvents and Chemicals

6.2.1a <u>Plastics</u> :

The major plastic materials are Low Density Polyethylene/Linear Low Density Polyethylene (LDPE/LLDPE), High Density Polyethylene (HDPE), Polypropylene Homopolymer (PPHP), Polypropylene Copolymer (PPCP), Poly vinyl chloride (PVC), Polystyrene (PS), Acrylonitrile Butadiene Styrene (ABS), Polyethylene Terephthalate (PET), Polyphenylene Oxide (PPO), and Polycarbonate. The major Synthetic Fibre and Fibre Intermediates are :

6.2.1b(i) <u>Fibres</u> : Nylon, Polyester, Acrylic

6.2.1b(ii) <u>Fibre Intermediates</u> : Para xylene, Caprolactam, ACN, DMT, PTA, MEG.

6.2.1c <u>Rubbers</u> : Synthetic rubbers like polybutadiene, polybutylene, SBR, and nitrile rubber are the petrochemical products. Other synthetic rubbers are silicon rubber, chloroprene, polyisoprene, etc. The natural rubber has its share in various applications even as a bland with synthetic rubbers. The recent entry of thermoplastic elastomers have opened up new areas of applications.

6.2.1d <u>Chemicals & Chemical Intermediates</u>

The major chemicals and chemical intermediates are: Ethylene Oxide (EO), Linear Alkyl Benzene (LAB), Xylenes and other solvents.

The growth in petrochemical industry has been proved to be an indicator of overall growth in the developing countries, since it fulfills the basic human needs of clothing, housing and food. This impact has been very well experienced in developed nations.

Some of the gains due to the synergistic effect are given below :

i) Overall industrial growth due to the expansion of conversion industries (to produce finished goods) and ancillary units (for manufacturing of moulds/dies, industrial components, additives etc).

ii) Employment generation.

iii) Increase in productivity of food & clothing.

iv) Increase in the standard of living of the people.

v) In addition to the basic needs, people get better means for communication, energy transfer, transportation and housing etc.

vi) Energy conservation

vii) Pollution control

In order to avail the gains from the synergetic effect of downstream petrochemical industries with other sectors, planning and growth monitoring is constantly needed.

The growth of petrochemical industries is now mainly concentrated in the Asian region which will take care of the demand supply gap of the products in the region. The per capital consumption will also increase with the availability of more material by 2000 AD. Although a number of end use applications have been developed over the years, more efforts will be needed in this area in order to capitalise on synergetic effects while integration with other sectors of national economy.

Developing countries rich in natural gas/oil have gone in for speedy expansion in petrochemical sector mainly for export. In such cases local consumption is also increasing speedily but the lack of integration with other sectors may not give required impact for overall growth of these countries. The integration in some areas will be possible with the management control, equity participation in units in end use sector by the downstream petrochemical units. Some of the sectors covered are discussed in the following section.

6.2.2a. AGRICULTURE AND FOOD PROCESSING:

With the availability of plastics such as LDPE, LLDPE and PVC, a great thrust has been given on their applications in agriculture and water management. The direct use of these synthetic materials has been only 2.4% in this sector (3.1F). The packaging of raw and processed food is generally taken in packaging sector. Countries like U.S.A, Israel have made extensive use of plastic products for increasing the productivity of food. Some of the major applications are :

i) wide width agrifilm for canal lining and for cap covers used for storage of food products

ii) green houses

iii) mulching,

iv) drip and

v) sprinkler irrigation system etc.

Water management has been an area of great concern in various developing nations. In India, a National Committee of Plastics in Agriculture was formed to provide direction and guidance for integrated development. The committee comprised of experts from the Ministry of Agriculture, Department of Chemicals and Petrochemicals, representatives of plastic manufacturers, processors , the manufactures of irrigation and sprinkler system, research institutes, Planning Commission and other allied agencies. The major objective of this committee was to create an awareness amongst various departments of the Government including irrigation department, amongst farmers, agricultural research institutes, financial institutions and others about the concept of use of plastics in various applications in agriculture and water management where hitherto the conventional methods were being adopted which were not only expensive on a long term basis but were also less efficient in terms of use of water. With the continued efforts of this national committee supported by IPCL and other agencies, enthusiasm was generated amongst the irrigation department, farmers, system manufacturers and others.

The easy availability of PVC has also led to better irrigation systems using PVC pipes; particularly important are the manufacture of specially designed pipes (well screens) for filtration and desalination.

Various solvents like xylenes have also given thrust to pesticide sector which forms an important input into agriculture. Here the manufacturers of solvents have effectively integrated their efforts with pesticide manufacturers in the initial period to enable developing suitable solvents for effective formulations.

Despite the efforts made in a few developing countries, large unused land is available which can be used for cultivation of crops with the integrated efforts to meet the requirement of increasing population especially in Asia / Pacific region. This shows that there is large scope for increasing the productivity of food by the use of plastics and other petrochemical products. Efforts are required to be made in organised manner by developing countries.

FOOD PROCESSING

Virtually a revolution took place in the processed food industry because of availability of wide variety of polymers, a judicious selection and combination of which could be used for different types of multilayer packaging, providing suitable barrier properties required by different type of processed food. This also led to the thrust in export of processed food.

6.2.2b HOUSING AND SHELTER

Housing sector is the second largest consumer of plastics. The application of the petrochemical products are plenty as can be seen from Table 3.2(5).

The plastics like PVC and LDPE have played a very important role in the housing and shelter. Certain important applications in the housing sector are those of PVC extruded profiles and corrugated sheets for roofing and PVC floor tiles. The other applications in the housing sector have been the use of PVC pipes for drainage and water system, fixtures & conduits for underground or concealed wiring. Articles made from acrylic sheet are for bathrooms including light weight bath tubs.

Wide width black coloured low density polyethylene sheets provide ready application for roofing as shelter to flood affected area. PVC cables are providing a thrust in the electrification in general and rural in particular. Polystyrene and polyurethane have wide acceptability in the application for thermal insulation.

PVC red mud roofing and PVC coated mud houses are the other applications which found usage in rural sector of the economy. Because of close synergy between plastics and the housing sector it is supplementing the need for low cost housing. In India, the plastic manufacturers, National Building Construction Corporation (NBCC) and other allied agencies have provided an integrated approach to use of plastics in construction. There is large scope for support to this sector by providing the technology of low cost housing using plastic materials to meet the requirement of millions of people in rural and urban areas in developing countries.

6.2.2c. CLOTHING

Developing countries generally with large population have more requirement for food and clothing, whereas land for cultivation is limited and the agricultural yields are generally lower. Considerable land can be spared for agricultural products like foodgrains, edible oils, seeds etc. For the requirement of fibre in textile, clothing cotton can be supplemented by synthetic fibres like polyester & nylon and also the demand for wool by acrylic fibre. The development of synthetic fibres have not only supplemented the availability of cloth but due to the high durability it has reduced the expenditure on clothing, its maintenance and upkeep besides improving the appearance and feel of the fabric. Availability of nylon and polyester filament have given a boost to powerloom industry which is labour intensive and there are a large number of self employed weavers.

6.2.2d. MEDICAL AND HEALTH CARE

Availability of various types of plastics, elastomers and chemicals have revolutionised the medical and health care sector of the economy. These downstream petrochemicals have been very well integrated with industry developing various applications such as disposable syringes, IV bottles, blood bottles, blood bags, artificial heart valves, artificial limbs, catheters, suture, contact lenses requiring a large variety of commodity, engineering and speciality plastics and rubbers. These provide a convenient, better, safe and sterilized medium for medical and health care at affordable cost. These items are available in the disposable packaging and pre-sterilized using advanced methods (employing ethylene oxide sterilization or gamma radiation). For some of the items polymers like PTFE and silicon are used since they are biocompatible materials.

Extensive use of plastics and synthetic rubber is being made in this sector by developed countries (Table 3.4(1)). The developing countries are able to produce only hospital, home care and paracorporeal products using commodity plastics for local consumption. The demand of these finished products has been growing fast replacing conventional materials like glass and ceramics. The paracorporeal products require a large variety of plastics and rubber which are not produced in developing countries and hence for their production developing countries have to mainly depend on developed countries to meet demand of speciality plastic materials.

6.2.2e. INDUSTRIAL COMPONENTS AND ENGINEERING PRODUCTS

The birth of a few industrial/engineering products was not possible without petrochemicals. Some of these products are consumer electronics, business machines, electrical & automobile components. Various commodity and engineering plastics have their share in this sector. However, their consumption in quantitative terms is relatively lower than other sectors. Some of the major consumer areas are refrigerators, electronics, automobile, textile engineering components, audio-visual products, computer and communication equipments. These products are not considered to be consumer goods but rated as luxurious items in developing countries, since the per capita GDP in these countries is very low. The demand growth of such products is not very high. However, a large variety of sophisticated equipments/products are manufactured in developing countries like Taiwan, Singapore & South Korea & India mainly for export under buy-back mechanism. These countries have gained good expertise to process the engineering and specially formulated plastics and rubber. They will remain dependent on developed countries to meet their raw material requirement.

The consumption of engineering plastics is largely dependable on production of high value added industrial/engineering products and vis-a-vis. This is the reason of strong synergistic effect of engineering plastics with this sector of national economy which provide all benefits associated with the standard of living of the people of developing countries.

6.2.2f. TRANSPORTATION

Plastic industry has found a great synergy in the transportation sector particularly automobiles like passenger cars, motorcycles and cycles. With the increasing cost of fuel, the emphasis has been to develop fuel efficient vehicles and one factor in achieving fuel efficiency has been to reduce the weight of the automobile. In this direction plastic moulders, the automobile manufacturers, ancillary product and tool makers integrated their efforts in developing plastic components, replacing heavier metallic components by plastic. Apart from reducing the weight of the component, they also provided opportunity for having better finish and polish besides being resistant to corrosion due to weathering etc. In India, Maruti cars for example, has replaced large percentage of components by plastics. Similarly Hero Honda, Kinetic Honda and Bajaj have also introduced large number of plastic components thus achieving economy in fuel consumption.

Bicycle industry particularly the racing cycles for exports and domestic use have also taken advantage of light weight of plastic and substituted some parts such as seat, paddle, handle covers etc. and it is providing important thrust for export.

In the transportation of chemicals like ethylene, ethylene oxide etc. specialised road tankers have been developed with emphasis on safety and security. Bulk method of transportation using pneumatic loading and unloading system have also been developed. In the aviation sector use of performance plastic and carbon fibre is becoming increasingly invogue due to high strength and low weight of these plastics.

The tyre industry largely utilizes the synthetic rubber and depending on the requirements, blends with natural rubber are also largely used in this application. The demand of two wheelers will continue to grow in developing countries as compared to four wheelers and hence need of petrochemical products due to the growth of former will increase rapidly.

6.2.2g. TELECOMMUNICATION

With the availability of various plastics like LDPE, LLDPE, PVC and specialised wire and cable compounds, the telecommunication sector had a big boost with revolution in information technology. Some of the major applications are as under :

i) Telephone instrument.

ii) Junction box

iii) Cable, fax and other such machines.

Some of the applications demand engineering plastics which are not produced in developing countries that is optic fibre cable and junction boxes require the material like nylon 11, polyester (reinforced) etc. Such products are not manufactured in developing countries and their material demand is met through import.

6.2.2h. SOLVENTS AND CHEMICALS

The easy availability of chemicals like ethylene oxide have given a boost to dye-intermediates sector like vinyl sulphone which is an important area for export market. Besides various surface active agents used in oil industry as pour point depressant, surfactants for health care products. Similarly ethylene glycol is used in coolants for automobiles. Availability of acrylonitrile and byproduct HCN have given a boost to acrylates.

Abundance of Carbon Black Feedstock (CBFS) has led to setting up of units to manufacture carbon black largely used in rubber and tyre industry and in plastic industry as filler and UV stabiliser. Availability of solvent as byproduct from petrochemical industry has led to setting up of fractionation and distillation units in the decentralized small scale sector which manufacture tailor made solvents for paints and pesticide industry.

Linear Alkyl Benzene has led to a mushroom growth of detergent manufacturers. The efforts of LAB manufacturers in the initial period were integrated with detergent manufacturers developing various formulations. Some of the large detergent manufacturers may plan in terms of backward integration for manufacture of normal paraffins. Likewise certain refineries are thinking in terms of manufacturing normal paraffins from kerosene for manufacturing LAB. With easy availability paints manufacturers have carried backward integration for manufacture of phthalic anhydride. The energies and efforts are also being channelised in the field of development of catalysts, additives and antioxidants, UV stabiliser and spin finish for textile industry to take advantage of synergy between downstream petrochemical industry and its end usages.

6.3.A TECHNOLOGY TRANSFER AND LOCAL ABSORPTION OF IMPORTED PROCESS TECHNOLOGIES

Petrochemical industry is not only affected by energy crunches and advances in the same technology, but the effect of new technologies is all-pervading. All emerging technologies are primarily "Fusion Technologies" in nature rather than total "Break-through Technologies". Technological evolution is desired to catch-up with the race for :

- use of non-toxic materials
- low energy usages
- high efficiency processes to create economically new products with superior applications.
- ecologically friendly & better waste-management

Fusion technologies are demand-led, i.e. customer compels evolution of desired products. Break-through technologies are evolved from internal requirements to lower the cost or increase production efficiency. Either of these can be for commodity or speciality products. The later one being high-tech are basically knowledge base industries and therefore need high level of human skill which is rare in developing countries.

In most of the developing countries very little research (applied or fundamental) is being carried out. Due to various constraints, they need to divert available resources for more applied work. This is true for academic institutions, national laboratories and industrial R&Ds. This research then needs transformation to commercialization.

Technologies are related to the production of petrochemical building blocks (xylenes, ethylene, propylene, butadiene, benzene) from mother plants and product manufacture (elastomers, plastics, fibres, chemicals) from down-stream units. Every time developing nations debate which technology to import and which one to develop. The technologies can be with

- Repetitive need
- One time need
- Guarded/costly (High-tech)

It is desired to develop repeatedly required technologies which do not require long time or high skill for development. One time technology needs should be imported only. Development of technologies for third category is based on specific need of a developing country.

Subsequent details will cover technology transfer, its prerequisites, some practical tips, imported technology absorption, chemical plant and processing equipments of capital goods nature.

6.3A.1 TECHNOLOGY (T):

Technology is a major base for the growth and success of a country and needs better understanding. It is not only limited to the art of making a product. In its real sense it means and include :

- Process
- Know-how
- Patents
- Knowledge/capability for commercial improvements

Companies license out those technologies mostly which relate to products, that a licenser no longer intend to produce, do not intend to spend capital for new facility or where it loses potential in a geographical area. New technologies for commodity products are invariably not parted or parted at high cost. Technologies relating to high tech/strategic areas are mostly not parted with.

It is, therefore, important for a "licensee" to know which technology to buy, with what conditions of sale and the expected after sale services from "licenser". In the game of successful plant commissioning, the role of two other players viz. "Detail engineering contractor" and "Equipment suppliers" is also vital.

6.3A.2 TECHNOLOGY SELECTION (TS):

Today world needs petrochemical processes which are technically efficient, safe, environment friendly and economically attractive. Technologies are rapidly changing and the fear of obsolescence is increasing. Selection of best technology is often done under a number of constraints like

- limited study, budget and time
- incomplete information
- need to keep final selection confidential

The first step under above constraints is to identify "available technologies for licensing". Best approach for a licensee is to make an in-house team, who should collect information from published and electronic sources. Technology selection team should keep in mind the product market grades/quantity requirement and plant location. With the knowledge of feedstock, minimum economic size of unit, market and locational infrastructural support, one can visualize target plant capacity, technology choice and level of sophistication requirement. This is important for a developing nation.

The technology and licenser selection are based on

- technology features
- technology transfer/cooperation experience
- product grades/marketability
- process economies
- commercial features and experience

A model of technology selection chart is as per Fig.6.3(1F). It is desirable to visit plants operating with technology which is under final selection to assess their real commercial performance.

6.3A.3 TECHNOLOGY LICENSING (T.L):

Once process is selected, next step is to secure the license agreement. This is a contract between "Licenser & Licensee". Process license involves transfer of know-how and patent rights. It often includes reference to equipments which are of proprietary nature.

PROCESS SELECTION PROCEDURE

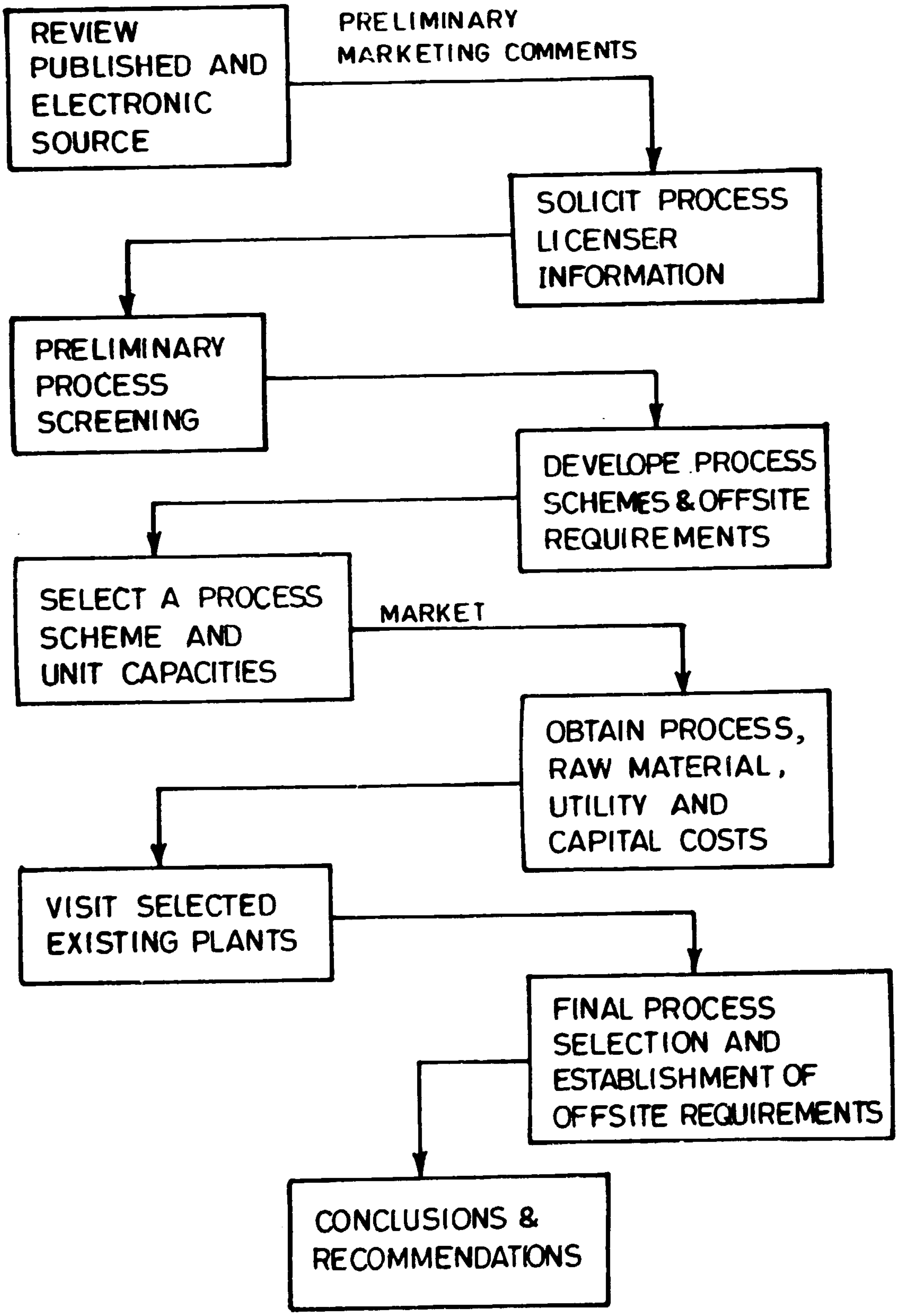


FIG. : 6·3(1F)

Normally number of separate agreements for part of process licensing efforts are being made. They cover initial confidentiality or secrecy agreement (CA) and the actual license agreement (LA) covering patents and know-how transfer rights, engineering services, training, catalyst supply, technical support during start-up, commissioning, market development and technical exchange.

C.A. is signed during final process selection, when licensee narrows down the list of potential licensers to one or two. It remains in effect till it is replaced by confidentiality (secrecy) clause in L.A. "Grant back" is plugged in L.A. for exchange of future commercial improvements upto a fixed period.

In order to effectively tie-up licenser, L.A. should be subjected to thorough scrutiny. Licenser needs to provide all information which an experienced detailed engineering contractor needs for designing rather than facing fresh requirement of generating basic information from other party. Occasionally improvements are not timely disclosed and charged later.

6.3A.4 TECHNOLOGY TRANSFER (TT):

Upon entering into contract with "licenser", proposed "Design Basis" document is prepared by "detail engineering contractor" in consultation with "Licensee". This is then frozen between above three during Design Conference.

Under the process license agreement, T.T. normally involves:

-Process specifications (Basic engineering) book
- Operating and laboratory manuals
- Technical manuals
- Raw material & additive
- Process control
- Product details and applications
- Fire/safety and waste disposal
- Expatriate assistance during design
- Erection and operation
- Operator training
- Market seeding/development assistance

Till recently, all this formed one time activity from licenser side. We share our experience briefly to provide tips of caution for a developing nation.

- Technology transfer details for ISBL is only provided by licenser. All OSBL details are developed by detail engineering contractor with meager help from licenser/licensee.

- All basic engineering information and suggested detail engineering information for critical areas should come from licenser.

- Licenser's interest is to maximize package units, which reduces engineering work from their side. At best they need to provide complete operating linkages between all units including package items.

- Normally licenser gives narrow range of process and operating parameters only. To better adapt the technology, it is desired to know the process/operating behaviour beyond the operating narrow range, through their R&D work or from actual operating information.

- Manuals as stated are heart of know-how. The tendency is to make chemical specifications stringent which makes indigenisation difficult for licensee and easy escape of process guarantee for licenser.

- Regarding expatriate assistance, the terms dictated by licenser are invariably too costly. Licensee has to get be¬t assistance for optimum time usage.

- L.A. normally includes operator's training for short-time at reasonable cost with a clause for additional training at higher cost. The training at first instant itself should be such that trained staff can take charge with full confidence and can deal with emergencies independently. Like operation, laboratory, maintenance and marketing exhaustive staff training is also essential.

- Market seeding/development efforts ensure smooth entry of product to be manufactured in the market. Licenser may help to seed the new product in applications he is familiar with. However, geographical area, socio-economic background and available infrastructure dominate locational market development. For this formation of an in-house team is the best way to steer.

It has been our experience that the success of technology transfer/technology co-operation largely depends on operating, maintenance services, skilled human resources and the harmony. This is possible when an efficient leadership is provided. Beside this, locational infra-structure requirement is a must.

A new concept of technology transfer (TT) is now mooted. "Business council of Sustainable Development", an international body of businessmen for promoting eco-friendly industrial development, supports the concept of "Technology Co-operation (T.C.)".

T.C. encompasses T.T. with respect to constant manpower development and upgradation of technology. T.C. includes process and design concepts of pollution prevention/control and waste management. For technology assimilations extended R&D co-operation in selected technology areas is a must. It is a worth while concept to provide primary waste water treatment facility within I.S.B.L. even when a unit forms a part of an integrated complex rather treating in central waste water facility only.

Licensers are also under pressure to transfer technologies to safe hands only due to disasters in chemical industries all over the world. This gives them an opportunity for accepting a licensee only with requisite background.

6.3A.5 ABSORPTION OF IMPORTED TECHNOLOGIES:

Absorption of an imported technology involves Licensee's capability to absorb, the suitability of technology for new environment and how smooth technology transfer has been effected by licenser. The part of detail engineering contractor and equipment suppliers is also equally important.

The three terminologies, normally in use are :

- Absorption
- Adaptation
- Assimilation

Absorption is only the first stage of knowledge of the technology. As explained under T.T., licenser gives operating process control and maintenance manuals.

TECHNOLOGY ADAPTATION :

When a licensee understands process control parameters even beyond the narrow ranges as provided for operation/control by licenser, we mean that the technology has been adapted by licensee.

TECHNOLOGY ASSIMILATION:

When a licensee understands the intricacies of entire technology through applied research and engineering and is in a position to make substantial commercial improvements independently, it is considered that licensee has been in a position to assimilate the technology. Thus it include design expertise also.

In a step towards technology absorption, developing nations have to develop their human resources at various levels so that a receiver can catch the signals and filter out the right once. This requires constant orientation in the desired area in the field of theory and on the job practice.

Well planned and executed initial system flush/checks (static & dynamic), pre-operational, precommissioning and commissioning activities help in faster technology absorption be made available from institutions.

Technology absorption will be easier if plant interruptions are least which calls for stable external supplies like utilities and feedstocks. Availability of pilot plants give better in sight of technologies. Very high automation, occasionally proves detrimental to technology absorption.

6.3.B CAPITAL GOODS REQUIREMENTS:

CHEMICAL PLANTS AND PROCESSING EQUIPMENTS:

The two terms invariably used with process plants are unit processes and unit operations. It is these "unit operations" which call for hardware of static or rotary type. Besides equipments for ISBL, they are also needed for OSBL and utilities.

Equipment manufacturer requires design, fabrication, inspection test facilities and proper material availability. Developing countries continue to import special critical, large size or sophisticated equipments. This is due to limited skill or rarely needed frequency of such items.

In each area, there are only handful of such specialised/proprietary equipment suppliers. For various petrochemical manufacturing or processing units, such equipments for specialised services can be as stated:

- Glass lined vessels, reactors, blowers, pumps, com pressors, pneumatic conveyors
- Mixers, separators (centrifuges, sieves with rotary

values)

- Process heaters, heat exchangers
- Process driers
- Extruders, balers, Bagging/wrapping machines
- Flare stack system
- Refrigeration, high efficiency boiler packages

ELECTRICAL:

- Large synchronous motors
- Plant communication systems in hazardous areas
- Flame proof phones, lifts, refrigerators

INSTRUMENTAL:

- Computer based process control
- Control valves
- Safety valves, breather valves, emergency vents, rupture discs
- On-line analysers
- Robotics

The steps need to be taken by developing countries include standardisation of capital goods, hardwares. This will assist developing countries to venture for manufacturing at least some of these items. One such attempt is to maximise use of swing technologies or technologies with identical process. Manufacture of LLDPE, HDPE, by swing process is a classic case. M/s. Mitsui has developed new technology for LLDPE, LDPE, HDPE in single production facility.

New process called "Super Polyethylene" combines a unique catalyst with high polymer designing techniques to ensure continuous production of polyethylenes having different densities, molecular structures and compositions. Minimisation of duty on import components for actual users of such items meant manufacture of these selective items under licensing arrangement in the country itself.

- Since provenness of major items is of significance (due to large investment at stake), manufacture of only proven models need to be attempted first.
- In overall balance, some equipments continue to be imported due to prohibitive cost of one time manufacture over a long time.
- Encourage and motivate domestic industry.

In fact product processing machines get least priority in developing countries. This leads to low availability of specific sector finished goods even if raw polymer products are available. With more and more availability of petrochemical products, there needs to be commensurate growth of processing machines for better and automatic processing/printing of petrochemicals.

In the above context, it is foremost for developing nations to direct their antenna and catch various signals from their nation and the world for:

- Technology data bank with their merits as existing.
- Coming up fusion and break-through technologies
- Technology forecast scenario
- Maintain register of experts with details of specialisation.
- Link research to applied field for better technology adaptations/assimilations.
- Develop human skills at various levels
- Petrochemicals product (supply/demand) data base.
- Impetus to this in national level and industrial corporate levels.
- Exchange programme between developing nations.

These are applicable for all technologies related to petrochemicals including building blocks, elastomer, plastics, fibre and chemicals.

6.4. HUMAN RESOURCE REQUIREMENTS

Population and poverty are integrally linked in developing economies. Petrochemicals have come to be regarded as symbol of economic development. It also helps in generating employment. There is a misconception that petrochemical industry is capital intensive and not labour intensive. The job generated will not be commensurate with the investment being made. If we take the petrochemical industries in totality (the mother plant, downstream petrochemical plants and the processing units) then this perception is not correct. The mother cracker and the downstream petrochemical plants are capital intensive and do not require large number of manpower. However, the products coming from these are not directly marketable. These are to be processed by the downstream petrochemical processing industry which are highly labour intensive. In addition to this, the employment opportunity also develop with the growth of ancillary industries, manufacturing hardware, machinery etc. for down stream petrochemical industries and their processing units. Table-6.4 (1) shows the relationship of manpower utilization in a typical mother cracker, downstream petrochemical plants and in the processing industries.

TABLE-6.4(1)
RELATIONSHIP OF MANPOWER UTILISATION IN MOTHER CRACKER, DOWNSTREAM PETROCHEMICAL PLANTS AND PROCESSING INDUSTRY

Mother Cracker	For 1000 Tonnes	2 Persons
Downstream Petrochemical Plant	For 1000 Tonnes	3 Persons
Processing Industries	For 1000 Tonnes	100 Persons

Technology being the most predominant factor in the industry, it requires sufficient training effort to develop the required skill-base. This will basically be in two areas. Firstly, manpower required for the Cracker units and the intermediate petrochemicals manufacturing units that are projected to be set up in future. Manpower in this area will require higher educational background and greater skills. Secondly the manpower will be required for downstream processing industries for the domestic or export market. Besides these two directly concerned areas for petrochemicals, manpower requirement also exists in related sector dealing with the transportation and storage.

6.4.2. MANPOWER REQUIREMENT FOR CRACKERS AND INTERMEDIATE PETROCHEMICAL MANUFACTURING INDUSTRIES :

Taking into account the future investments in the petrochemical sector, an assessment has been made for the manpower needs in petrochemical industries. The estimation of manpower has been made on the basis of planned investment till 1995 AD. For estimating manpower requirement, the manning standard of a typical unit in a developing country has been used. The manpower requirement has again been broken down into managerial, supervisory and non-supervisory categories. In the technical cadre, the estimation again has been divided into various technical streams.

On the basis of a typical petrochemical complex with the latest technology in a developing country and the investment projection, manpower requirement in petrochemical industry is as per Tables - 6.4 (2) and 6.4 (3).

TABLE-6.4(2)
COUNTRY PROFILE-
MAJOR PETROCHEMICALS INDUSTRIES COMING UP
(upto 1995)

Name of the country	Approx. investment (in Million US $)
Algeria	250
Argentina	1000
Bangladesh	200
Bahrain	200
Brazil	2400
Bulgaria	200
China	8000
Taiwan	4000
Colombia	60
Czechoslovakia	200
Hungary	100
India	3000
Indonesia	6000
Iran	3500
Libya	600
Malaysia	4000
Mexico	3000
Nigeria	3500
Philippines	600
South Africa	17
Thailand	2800
Trinidad	1000
Turkey	300
CIS	6000
Venezuela	2500
Vietnam	800
Yugoslavia	100
Total :	54327

TABLE 6.4 (3)

BASIS OF MANPOWER ASSESSMENT

A. INVESTMENT (Mn.US $)	MANAGERIAL			SUPERVISORY			NON-SUPERVISORY			GRAND TOTAL
	Tech.	Non-tech.	Total	Tech.	Non-tech.	Total	Tech.	Non-tech.	Total	
I. > 1000	70	30	100	325	75	400	1200	300	1500	2000
II. 750-1000	55	25	80	260	60	320	960	240	1200	1600
III. 500-750	42	18	60	195	45	240	720	180	900	1200
V. < 250	11	04	15	48	12	60	180	45	225	300

B. <u>TYPICAL COMPOSITION (%)</u>

	Supervisory	Non-supervisory
Chemical	20	30
Mechanical	35	25
Electrical	15	14
Instrumentation	15	17
Other (Quality Assurance, (Fire & Safety, Metallurgy, etc.)	15	14

There has been an imbalance in growth of petrochemical industries and availability of manpower in a few developing countries. The countries like Saudi Arabia, Iran, Thailand, Malaysia, Indonesia etc., despite inadequate facilities for education and training have built up large capacities for petrochemicals and down stream products. They mainly depend on other countries to meet their skilled manpower requirements. In order to meet the local requirements of finished petrochemical products, it is necessary for them to develop their local facilities to produce a skilled manpower. Manpower requirement for synthetic fibre manufacturing units are estimated on the basis of standardised sizes (Table-6.4 (4)).

TABLE 6.4 (4)
MANPOWER REQUIREMENT FOR SYNTHETIC FIBRE MANUFACTURING UNITS

Plant	Capacity (TPA)	Total Number of employees (direct)
PSF	30000	515
PFY	15000	580
NFY	12000	480
AF	12000	520

6.4.3. MANPOWER REQUIREMENT IN PROCESS INDUSTRY :

The manpower requirement for the process industry will be of three categories viz. managerial, supervisory and skilled. These can be further sub-divided into areas of polymer, fibre and other petrochemicals. Basically, the manpower assessment in these areas will be (based on the investment) made on the following basis:

(a) Manpower required for synthetic fibre manufacturing unit are estimated on the basis of standard sizes.

(b) Requirement of skilled manpower for conversion industry is assumed at 10 technical personnel for every 100 MTs per annum of polymer processed.

(c) Additional employment include replacement for staff erosion through retirement etc.

6.4.4. TRAINING FACILITIES :

(A) FOR CRACKERS AND INTERMEDIATE PETROCHEMICAL MANUFACTURING INDUSTRIES :

Universities, engineering institutes and polytechnics generally have established courses for training of different categories of personnel required by petrochemical industry. These may be classified as courses in polymer chemistry, polymer technology, plastic technology, plastic engineering, textile engineering/ technology, fibre chemistry, rubber technology, technicians depending on the emphasis on any specific area of specialisation. Most of the institutes impart training at post-graduate or diploma level and are typically of one to four years' duration. The nature of training includes theoretical lectures, laboratory practicals, project work, dissertation and a very limited practical training in related area. Countries like India and China have got institutional infrastructure for such education and training. The output from these institutes may have fairly good background knowledge about petrochemical industry. However, their knowledge base often is on outdated technologies as there is very poor interaction between universities and petrochemical industries. There is an imperative need for the petrochemical industries in such cases to interact closely with universities to ensure that the curriculum of training is updated constantly to meet the need of the industry. Petrochemical companies should endow a few seats for a professor in chemical engineering department in atleast one of the universities. They should also invest in upgrading the infrastructure facilities in the universities & polytechnics. Each major petrochemical unit should identify at least one university and one/two polytechnics as the affiliate university/ polytechnics.

The output from most of the universities and technical institutes have theoretical knowledge and they cannot be inducted into the industry directly. They need further practical and on the job training. For this countries have limited scope and have to depend upon licensers training facilities which becomes very expensive.

(B) FOR PROCESS INDUSTRIES :

As regards processing industries, the methodology to be adopted for training of manpower at various levels is given below :

(i) Polymers :

There is generally a dearth of skilled operation in the plastic industry. Although it appears that very large number of training institutes will be required to be set up to meet the estimated demand of supervisory and skilled manpower of the process industry during the coming year, experience in several countries has shown that the industry itself is also capable of creating reasonable number of trained manpower by imparting "on the job" training. For instance, during 1985-86 nearly 17,000 people in the supervisory cadre and 30,000 skilled operators were employed in the industry in a given country whereas there existed hardly any facility for training such manpower in the country. This was possible primarily because bulk of the processing equipments were of the conventional type manufacturing established products. With the shift towards more sophisticated plants for the manufacture of both conventional as well as new products, this type of "on the job" training both in terms of quality and number was not adequate. More and more well structured institutional training facilities were required to handle complicated plants and machineries for the manufacture of superior quality of existing as well as newer products.

(ii) SYNTHETIC FIBRE :

The synthetic fibre industry is highly capital intensive and the employment opportunities are generated indirectly in the intermediate petrochemical manufacturing units/trades. Clusters of such downstream processing units like texturising, twisting, dyeing and decentralised weaving not only create dispersal of industries but also provide local employment thereby discouraging migration of skilled labour towards crowded metropolis.

(iii) PETROCHEMICALS OTHER THAN POLYMERS, SYNTHETIC FIBRES INCLUDING INTERMEDIATES

In all these products manufacturing, technology is being continuously upgraded with better and improved conversion and separation techniques, and reduced energy consumption. There is also increasing sophistication in instrumentation and process control. It will be fair to expect most of the new units to go in for microprocessor based DCS systems. The net effect of all such technology and process improvements will be reduction in manpower. Even today, the existing units manufacturing these products do not have high employment intensity. In the future, employment per tonne of output will be even less.

6.4.5. TRAINING FACILITIES IN RELATED AREAS :

Large number of personnel will be employed in related areas like transportation and storage. Their training need can be met by existing training facilities for such category of people employed in other areas of industries. However, since petrochemical industry deals with hazardous and inflammable materials, there is a need to give training to such persons in safety aspects of handling petrochemical products.

6.4.6. GENERAL APPROACH :

(a) Petrochemical industry should interact closely with universities and technical training institutes to ensure that the curriculum of training is updated constantly to meet the need of the industry.

(b) Petrochemical companies should endow one seat of a professor in chemical engineering department in at least one of the universities.

(c) Petrochemical industries should invest in upgrading the infrastructure facilities in the universities/ technical institutes.

(d) Each major petrochemical unit should identify at least one university and two polytechnics as its affiliated university/polytechnic.

(e) There may be a need to introduce courses in process control, electronic instrumentation and corrosion & inspection in the existing universities and technical institutes.

(f) There may be a need to set up a Safety Institute

6.5 PHYSICAL AND INSTITUTIONAL INFRASTRUCTURE

The physical and institutional infrastructure plays an important role for development of down stream petrochemical industry. It is imperative that the infrastructural needs such as transport, communication, ware housing, distribution network, well developed rail and road network, port terminals etc. are essential to ensure sustainability over the long term. Understanding the systematic linkages of these vital forces is crucial in formulating infrastructural strategy.

6.5.1 TRANSPORTATION

Unlike other products, need for transportation of petrochemicals is of different nature. This involves handling of highly inflammable, hazardous & toxic gases, liquids and solids.

Transportation scenario for the future in developing countries will depend on income growth, supply of petroleum products, environmental protection norms and the growing political demand for equity. Transportation like most other sectors is considered to be mainly technology dependent. India as one of the producers and major users of petrochemical products looks for better planning of the transportation of all variety of goods including petrochemicals to different destinations. A National Transport Policy Committee in India submitted its report in 1980 projecting that the freight of consumer goods more than double and the mechanised road transport would increase from 77 billion ton kilometers in 1977-78 to 1982 billion ton kilometers in the year 2000. It is generally observed that water and air transport are relatively less prevalent when compared to the surface transport.

India has a high ratio of public vs private transport. According to a detailed study it would be desirable for major portion of goods traffic to be shifted to rail. For the transportation of solid products by road, trucks of increased capacities with a provision to protect the material during the rainy season are essential. The transportation of hazardous monomers and chemicals require special arrangements like refrigeration, nitrogen blanketing etc. and these will add considerably to the transportation cost. Products like rubbers and fibres are normally packed in bales and these are then crated. Facilities like fork lift etc. should be available for loading and unloading. Information on production schedules, inventory/stock levels, dispatch planning etc facilitate logistics of transportation. The availability or port terminal facilities, either own or hired near the production site is a major infrastructural facility, facilitating bulk exports.

The new major exporters of petrochemicals products like Saudi Arabia, Indonesia have to depend on the transport technology available in developed countries, but to suit the same to the local conditions, they require indigenous developmental efforts. Various other new entrants in petrochemical sector require careful planning for the transport of their raw material and product to meet the local requirements as well as export. Other countries who are expanding their capacities will further need to strengthen this area for efficient marketing of their products.

6.5.2 COMMUNICATION

Improvement in communication system is a healthy sign for growth in trade and business, since it improves the overall working efficiency. Over the years and especially in the last decade developing countries have developed a fairly extensive communication infrastructure. The telecommunication infrastructure has been rapidly expanded and modernised in recent years. A very large number of places are now interconnected through subscriber trunk dialing and even international subscriber dialing for telephone communications. Further these lines can now be used for data communications too, providing access to data bases and linking up computers. Satellite communication, indigenously produces small rural exchanges and the Multi-Access Radio Relay (MARR) systems are taking high quality telecommunication into rural areas also. Much of this growth in communications has been made possible and catalyzed by advent of INSAT system and domestic satellite communication. In the context of the development of downstream technologies the communication system becomes important in view of the crucial role of information and education it provides on processes and products.

The effectiveness of the communication media depends on the clarity of objectives and mapping out a coherent and appropriate strategy. Feedback from the customers, information on technical and aesthetic quality of the products are all important factors. Information about the methods, sources for physical supplies and for further details are to be effectively communicated. The communication strategy would need to include a mix of local and wider programmes.

The dissemination or transfer of information has for long been considered a prime goal of marketing strategy. One of the most important and obviously most difficult tasks in effective communication is creating change-changing beliefs and attitudes of people towards acceptance of new products. The role of stimulating and catalyzing an analysis of the situation of the new information provided, is best done through interpersonal communication.

An important but little used role of the communication media is to act as a feedback channel. Feedback programmes can be used to keep manufacturers informed on quality and applications of goods. They can also be used to put pressure on the supply system. The need for horizontal communication between different groups of people is particularly high for tasks related to market development.

Enhanced volume of movement of products demands effective communication among transporters, distributors etc. The communication media should be effectively used to cater information on production schedules, inventory/stock levels, dispatch planning etc. Facilities for rapid communication between head office and regional centres on material receipt status through road/rail, feedback on warehouse space, dispatch plan, product classification and movement priorities will aid the market development of new products.

6.5.3 STORAGE

The creation of optimum storage facilities both at manufacturing site and distribution centres is needed to meet customer's demands in time. Solid products are stored in warehouses with stacking facilities. Forklift facilities are essential for the distribution of these products. For storing liquid products, storage tanks of right material of construction should be made available at distribution centres. It may be required to provide these tanks with glass lining nitrogen blanketing or water sprinkling facility to take care of the special storage needs of the liquid products. In certain cases special certification of tanks is required. It is necessary to obtain insurances of the material while it is in transit. All warehouses should be properly ventilated with emergency exit etc. They should also have all modern communication facilities and suitable persons to man and maintain proper records. The construction of warehouses outside the battery limit at production units facilitate quick transportation of materials and safety.

6.5.4. DISTRIBUTION NETWORK

Materials are normally sold either through consignment stockists or through distributors. It is advisable to have at least a distributor/consignment stockist within a radius of 50-100 kms, thereby assuring easy and timely availability of materials to consumers. Further to ensure timely availability of materials to distributors/stockists it is preferable to have feeder warehouses in addition to warehouses at head quarters and regional centres. For the ease of handling distributors and stockists, they should be made to interact with the relevant regional offices. It is essential that the delivery of short weight to distributors should be recorded immediately as it becomes very difficult to handle such complaints later. There should be periodic interaction by the region with the distributors and also among the distributors within the region so that problems/constraints can be sorted out. It is the responsibility of the regional manager to ensure that timely and right quantity of material are supplied to various customers by distributors falling within the range. Here again communication media plays a vital role for the success of a vast distribution network which is essential for the growth of downstream technologies.

The fast expanding petrochemical industry will need strong link with material outlet point in order to minimise the investment on storage of huge quantities of products. This require an efficient distribution system both at national and international level. More input is therefore required for effective and efficient distribution of material. Highly trained and qualified manpower will therefore be required to meet this challenge. Developing countries have to make sincere efforts in this area by integrating them with their plans in petrochemical sector.

In addition to this, indigenous facilities are to be created for training to develop managerial, marketing/business skills since the demand of such manpower is bound to grow with the growth in petrochemical sector. Developing countries especially higher growth centres like Asia/Pacific has to encourage processing industries to meet the local demand of finished products and this will also require financial support with the creation of new financial institutions.

6.6 ENVIRONMENTAL AND SAFETY ASPECTS OF DOWNSTREAM PETROCHEMICAL INDUSTRIES

The petrochemical industry encompasses a wide spectrum of synthetic products produced through diverse production processes. This industry is currently undergoing the most prominent and long lasting changes due to the environmental regulations and laws. These changes are largely as a result of the increase in understanding on the importance of clean environment, availability of sensitive analytical methods and increasing public awareness.

Environmental and safety aspects of the down stream petrochemicals have great bearing to developing countries which constitute about half of the human settlement. Having recognised the significance of petrochemicals in the core socio-economic sectors, countries like Algeria, India, Brazil, Mexico, S.Korea, Venezuela, Iran, Iraq etc. have acquired capabilities for the production of many petrochemicals.

A large fraction of chemicals added each year in the inventory of chemical substances are derived from petrochemicals. Some of these possess carcinogenic, mutagenic, and teratogenic effects. The survey conducted by Process Research Inc., for the generation of hazardous wastes in petrochemical production processes showed presence of many chemicals which are classified as the priority pollutants by the US-EPA. Thus, Petrochemical industries are characterized as high polluters and hazards prone. The environmental management in petrochemical industries involve activities right from the planning stage to the ultimate disposal and involves many socio-economical and political issues.

6.6.1 PLANNING FOR ENVIRONMENTAL MANAGEMENT

It is now very well recognized that, if proper care is taken at the planning stage many environmental and safety related problems can be avoided. This is particularly true in the developing countries where the rapid industrialization is causing simultaneous and almost irreversible damage to the environment. After realizing this fact many developing countries have evolved strategies most appropriate at the local/regional/national levels and the regulations have been clamped. The important aspects for environmental management during planning stage include; 1) Selection of clean technology, 2) Location of plant, 3) Environmental impact assessment and 4) Risk assessment.

6.6.2 PETROCHEMICAL WASTE MANAGEMENT

Downstream petrochemical industries generate many pollutants in gaseous, liquid and solid states varying characteristics. Liquid wastes may contain floating, suspended or dissolved organic and inorganic pollutants. Air pollutants in this industry include oxides of nitrogen and sulphur, carbon monoxide, hydrocarbons and mercaptans. The solid residues are often flammable, corrosive, toxic and reactive. A list of the major pollutants is given in Table 6.6 (1).

TABLE-6.6(1).
MAJOR POLLUTANTS FROM AN INTEGRATED PETROCHEMICAL COMPLEX

Oil, Hydrocarbons, Sulphides, Organic cyanides, Acrylic acid, Polymer organics, Sulphates, Acrolein, Acrylonitrile, Sulphuric acid, Acetic acid, Hydroquinone, Phenols, Ethanol, Phenothizine, Fluorides, Kerosene, Chloroethanol, Chloral compounds, Ethylene dichloride, Solvents like Toluene, Xylenes, Butanol, Heptane, Benzene, Rubber crumb, Mono and poly glycol, Organic acids, Formaldehyde, Methyl benzoate.

Over a period of time petrochemical industries have learned many hard lessons. It is now very well established that for the sustainable development following hierarchy is assuming a top priority in petrochemical waste management.

1) Source reduction,
2) Waste recycling,
3) treatment and
4) disposal.

The treatment of petrochemical waste water is illustrated in flow sheet diagram (Fig. 6.6(1F)).

6.6.3 ISSUES RELATED TO ENVIRONMENTAL MANAGEMENT

Basically following issues are related to the environmental management in petrochemical industries.

1) Compliance of the regulatory standards
2) Occupational health
3) Ecological effects and
4) Hazards due to accidental release of toxic substances.

The purpose of legislation and environmental regulations is to protect people in their work place and in the environment from hazards to health or safety from products either consumed internally or released

FLOW SHEET DIAGRAM FOR THE TREATMENT OF PETROCHEMICAL WASTE WATER

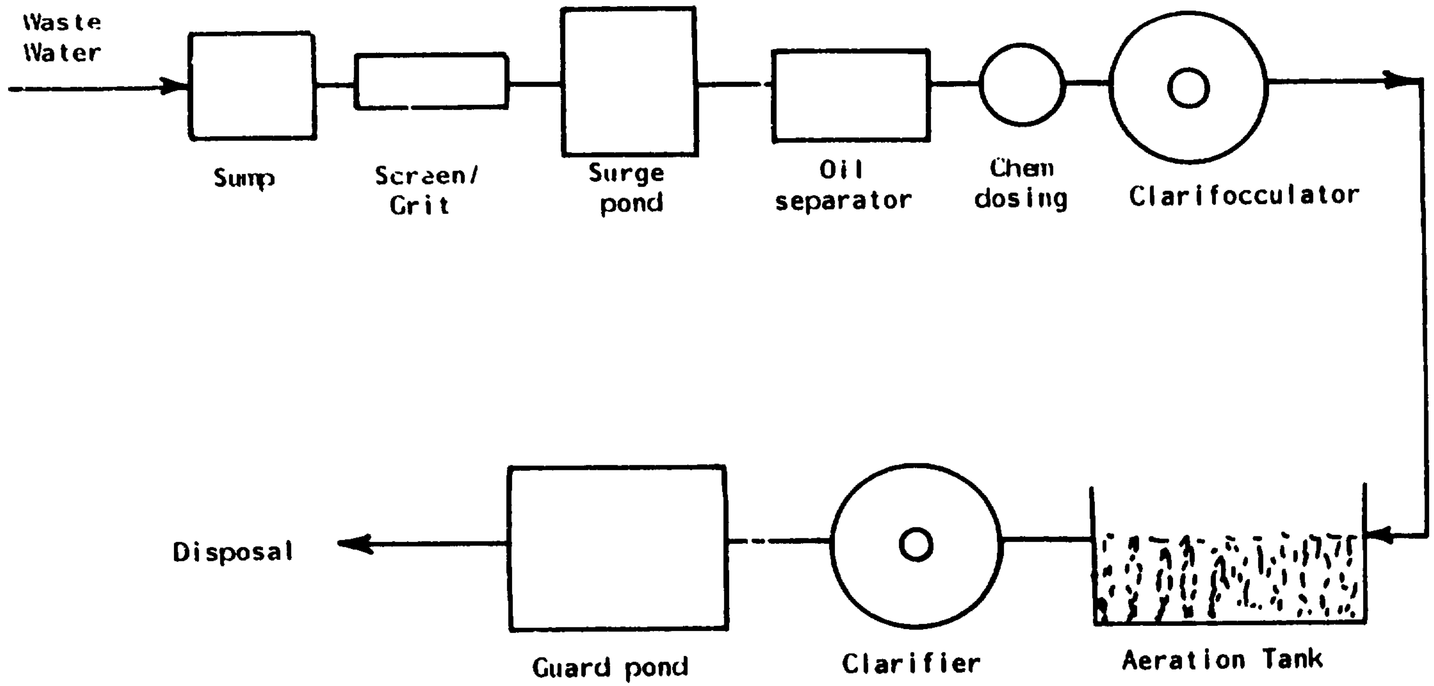


FIG. : 6.6 (1F)

into the environment. Several countries have enacted environmental & safety laws that have impact on the design & operation of petrochemical industries. In India, the Government has laid down the standards for wastes through the environmental protection act (EPA)-1986. The central pollution control board (CPCB) has also set up the Minimum Allowable National Standards (MINAS) for petrochemical industries.

Occupational health activities are directed towards the prevention of diseases and to maintain worker's health at the optimum level for maximum productivity. During manufacturing, workers are exposed to various chemicals. The effective management of the occupational environment requires continuous monitoring of work place environment, engineering controls at the high exposure zones and generation & dissemination of relevant data on the subject.

To maintain the ecological balance between different ecosystems following are essential. a) Environmental impact assessment for new projects, b) Assessment of waste management systems, c) Development of environmentally compatible technologies or waste recycling methods, d) Ecology as a part of social responsibility in corporate planning and e) Environmental awareness in the local population. Assessment of hazards is one of the important part in hazard management. Commonly used techniques for hazard assessment are a) Fault tree analysis, b) Event tree analysis, c) Failure mode & effect analysis and d) Random number simulation.

6.6.4 SAFETY ASPECTS

With the increase in economic size of petrochemical plants and technological complexities to deal with highly toxic, reactive and hazardous chemicals, safety has to be looked as an integral part of planning and design. Loss prevention or safety is emerging as a series of procedures in identification and evaluation of process hazards, provision of mitigating measures and protective devices, concern for fugitive emissions and above all awareness and training of personnel.

At present, there are no specific legislations applicable for safety in petrochemical industries alone in most of the developing countries. The executing agency like ministry of Environment brings legislation on various aspects of hazardous substance handling in most countries. According to ILO Regional Office for Asia and Pacific, legislation on chemical safety is at present in an evolutionary phase in most countries and varies from one state to another with in a given country. However, the common feature is a multiplicity of statutes and their implementing agencies. In many developing countries various policy measures have promoted the development of small scale industries. As a result a large proportion of chemical processing is carried out in small scale operations, which are not equipped to handle the environmental and safety aspects.

Thus, the major components of a comprehensive environmental and safety programme for petrochemical units include, a system of classification, packaging and labeling of chemicals (to be supplemented by chemical safety data sheets (CSDS) furnished by the supplier), choice of safe technology, site selection for installations, control & monitoring of exposure to chemicals in work environment, treatment of occupational diseases, safe transportation of hazardous chemicals within and outside the industrial complex and treatment and safe disposal of chemical wastes. It is also now very well recognized that legislation alone will not ensure environmentally safe plant operations.The development of successful safety and environmental management programmes is closely linked with the commitment of these industries to move progressively towards the "Self Regulation".

7.0 RECOMMENDATIONS TO POLICY MAKERS AND THE INDUSTRY

1) A drop in demand as a consequence of economic recession, decline in profitability and global overcapacity situation exist today in the petrochemical sector. The overcapacity of primary and secondary petrochemical products is the result of speedy expansion in the west, new units in developing countries, a race for earning through export and to meet the local demand. It is therefore, necessary that investment in this sector for expansion should be done in a more planned way for at least next 8 to 10 years.

2) A wide variation in the production cost has made the market more competitive and hence the selection of technology/ product should be based on the following criteria.

a) Energy efficient processes.
b) Speciality grades/products.
c) Single or multiproduct/multigrade process.
d) Environmental consideration.

3) Survival of petrochemical industries in developing countries requires more regional cooperation through striking a balance of production and demand and should launch joint ventures.

4) In the long term planning, the investment for expansion should be made while keeping in view (i) the availability of other products for similar applications in order to effectively use and take maximum advantage of petrochemicals. (ii) the demand growth of these synthetic products. (iii) growth of GDP. This is also required in the case of prospective exporting countries for their target importers.

5) In order to avail the opportunity of liberalization in export/import and cost competition, it is required that due attention should be paid to create infrastructural facilities of handling, transport, storage etc. for solids, liquid and gaseous petrochemicals and their related products which are generally very reactive, toxic and inflammable.

6) In developing countries per capita consumption of petrochemicals is likely to increase at a faster rate. The effective utilization of these valuable products is possible by

- creating facilities for training to develop manpower required by downstream and conversion industries.
- making efforts for application development as per local needs.

- developing facilities for conversion of petrochemicals into finished products.

This will not only be helpful to meet the local demand of finished products but also increase the employment potential and opportunities for self employment with the growth of ancillary industries.

7) Industries should have strong interaction with academic and research institutions and the curriculum of the educational/ training programmes should be amended according to the specific industrial need of manpower. It should thus be directed towards developing stronger managerial and technical skill in the prospective planners and technologists. This will also require constant upgradation of the training facilities.

8) The plans for expansion and further investment in this sector should be based on the benefits which are possible to be derived through the synergetic effects with other sectors of national economy since petrochemical products largely serve various important economic sectors related to basic human needs e.g.agriculture, water management, housing, clothing, health care etc. A strong data base is therefore necessary to meet this objective.

9) The R&D efforts should be directed towards

- absorption, assimilation and upgradation of the imported technology.
- make the technology more and more environment friendly.
- effective utilization of co-products.
- development of speciality and value added products.

The political and economic conditions are different in different countries, hence the above mentioned recommendations can be taken as guidelines for the growth of downstream petrochemical industries.

Appendix 1.

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24. European Chemical News; Mar. 11, page 22, 1991.

Appendix 2.

LIST OF ABBREVIATIONS

ABS	-	Acrylonitrile butadiene styrene
ACN	-	Acrylonitrile
ASEAN	-	Association of South East Asian Nations.
BR	-	Butadiene rubber
CA	-	Confidentiality
CARG	-	Compound annual growth rate
CPE	-	Centrally planned economies
DMT	-	Dimethyl terephthalate
E.Asia	-	East Asia
EEC	-	European Economic Community
E. Europe	-	East Europe
EVA	-	Ethylene vinyl acetate
HAN	-	High aromatic naphtha
HDPE	-	High density polyethylene
Inds.	-	Indonesia
IPCL	-	Indian Petrochemical Corporation Limited
ISBL	-	Inside battery limits
LA	-	License agreement
LAB	-	Linear alkylbenzene
LAN	-	Low aromatic naphtha
L. America	-	Latin America
LDPE	-	Low density polyethylene
LLDPE	-	Linear low density polyethylene
MEG	-	Monoethylene glycol
MF	-	Melamine formaldehyde
MISIA	-	Malaysia
M. East	-	Middle East
NR	-	Natural rubber
NFY	-	Nylon filamnet yarn
OSBL	-	Outside battery limits
PA	-	Polyamide
PBT	-	Polybutylene terephthalate
PC	-	Polycarbonate
PET	-	Polyethylene terephthalate
PE	-	Polyethylene
PF	-	Phenol formaldehyde
PFY	-	Polyester filament yarn
Phil	-	Phillipines
PMMA	-	Polymethyl methacrylate
POM	-	Polyoxymethylene (Polyacetal)
PP	-	Polypropylene
PPHP	-	Polypropylene homopolymer
PPO	-	Polyphenylene oxide
PPS	-	Polyphenylene sulfide
PS	-	Polystyrene
PTA	-	Purified terephthalic acid
PTFE	-	Polytetrafluoroethylene
PUR	-	Polyurethane
PVC	-	Polyvinyl chloride
R&D	-	Research and development
SAN	-	Styrene acrylonitrile copolymer

SBR	-	Styrene butadiene rubber
Spare	-	Singapore
S/SE Asia	-	South/South East Asia
S&T	-	Science and technolgy
T	-	Technology
TC	-	Technology cooperation
Thai	-	Thailand
TL	-	Technology licensing
TS	-	Technology selection
TT	-	Technology transfer
UF	-	Urea formaldehyde