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FIRST WORLD-WIDE STUDY ON THE PETROCHEMICAL INDUSTRY: 1975–2000

PREPARED BY THE

SECTORAL STUDIES SECTION

INTERNATIONAL CENTRE FOR INDUSTRIAL STUDIES

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LIST OF ABBREVIATIONS

ABS	= Acrylonitrile butadiene styrene resins
CEFIC	= European Council of Chemical Manufactures' Federation
CMEA	= Council for Mutual Economic Assistance
DDB	= Dodecyl benzene
DMT	= Dimethyl therephtalate
EEC	= European Economic Community
EFTA	= European Free Trade Association
GDP	= Gross Domestic Product
HDPE	= High Density Polyethylene
LDPE	= Low Density Polyethylene
LNG	= Liquid natural gas
LPG	= Liquified petroleum gases
MVA	= Manufacturing Value Added
O-xylene	= Orthoxylene
PBR	= Polybutadiene rubber
PP	= Polypropylene
PS	= Polystyrene
PVC	= Polyvinyl chloride
P-xylene	= Paraxylene
SBR	= Styrene butadiene rubber
Syndets	= Synthetic detergents
TOE	= Tons of Oil equivalent
TPA	= Therephtalic acid
VCM	= Vynil chloride monomer

1. INTRODUCTION

1.1 OBJECTIVES AND SCOPE OF THE STUDY

The Lima Declaration and Plan of Action on industrial development and co-operation was adopted at the Second General Conference of UNIDO in March 1975, and was endorsed by the General Assembly at its seventh special session. In the Lima Declaration the role of industry was reasserted as a dynamic instrument of growth to attain a rapid socio-economic development of developing countries. It called for an increase in the share of the developing countries to at least 25 per cent of total world industrial production by the year 2000. It declared that developing countries should devote particular attention to the development of basic industries such as petrochemicals, thereby consolidating their industrial structure and obtaining a larger share of world trade. The Lima mandate poses two practical problems: one, to explore the participation of each industrial sector in achieving the 25 per cent of total world industrial production; and two, to appraise the magnitude of the resources needed for its attainment.

This report relates to the study of both problems in the petrochemical sector. It addresses itself to the first problem by analyzing the world situation of the petrochemical industry, its structure and its evolution from the past up to the year 2000. Concerning the possible share of the developing countries in the total world petrochemical production by the year 2000, three alternatives are analyzed. ranging from the continuation of the present conflicting situation up to the degree of co-operation required to achieve the Lima target and self-sufficiency.

Concerning the second problem, a world petrochemical model was developed that is able to simulate long-range situations. The three alternatives mentioned above were processed and duly quantified in order to measure the resources needed by each of them. The consequences and co-operative effort required in each case are also presented so that both developed and developing countries may become aware of the implications and serious commitments that might be made in implementing any of these alternatives.

One of the main problems in carrying out this study concerns the data-gathering and the reliability of the information obtained. So far there is no world-wide authoritative set of data since no comprehensive statistical reporting system exists. Often basic data such as production, exports, imports and consumption are not internationlly comparable for all countries. The descriptive techniques and product definitions used for production or trade vary substantially since each of these systems was developed for a different purpose. Furthermore, classification criteria, degree of disaggregation, standards of valuation and techniques for data collection vary for these systems in each country.

Even developed countries face difficulties despite their long-standing sophisticated statistical reporting systems. For instance, the US is just completing the task of developing comparable statistical systems for exports, imports and domestic production. In Western Europe there is no harmonized statistical reporting system on a total European basis mainly concerning production and consumption data. Therefore the sheer magnitude of a comprehensive world-wide data gathering task is compounded by the need to have internationally comparable figures that are reliable enough to be acceptable by governments and industry. In view of the above we could not use any time/extrapolation methods to forecast to the year 2000 as is customary in industry. We had to develop more sophisticated forecasting approaches able to quantify long-term trends and to incorporate qualitative appraisals.

The three alternatives presented in the world petrochemical model are only some among many others possible and the petrochemical model was constructed to simulate the techno-economic relationships of the petrochemical industry to be used in the first consultation meeting on petrochemicals in order to get a feedback from the participants. We are aware that a model is an abstraction that only partially simulates reality although it gives useful techno-economic predictions. Current on-going work would give a closer approach to reality by using futures research techniques based on scenarios. These scenarios are built on the physical structure of the industry; on the specific aims, programmes and intentions of the actors (organizations active in the world petrochemical industry), and on the opportunities and constraints existing or becoming existent through the actions of the actors.

The appraisal of the three alternatives shown and of the formulation of other hypotheses would be the themes for scenarios. Once the appropriate feedback from the participants is received, ICIS would be in a position to prepare the corresponding scenarios. The study presented in this report is of the policy type and is addressed to policy-makers and decision-makers whose decisions and actions will shape the future development of this industry. Its scope is limited to the four main large-tonnage end-product petrochemical families: plastics, fibers, elastomers and detergents, along with their corresponding intermediate and basic products. The figures given were gathered from various primary and secondary sources by our technical consultants BEICIP (Bureau d'Etudes Industrielles et de Coopération de l'Institut Français du Pétrole) screened for reliability and statistically harmonized, unless otherwise referenced. The study was carried out in association with the International Labour Organization (ILO) which contributed in the manpower and training chapters.

1.2 Typology

The aims of the typology of the study are twofold: one, to ensure inter-sectoral comparability, and two, to highlight the particular characteristics of the petrochemical sector. To this end a simplified version of the major area and region geographical classification of the United Nations, Department of Economic and Social Affairs, Population Studies, was adopted. The regions considered are the following:

		Corresponding UN regions
(a)	Western Europe	Northern, Southern and Western Europe excluding Yugoslavia
(b)	Eastern Europe	Eastern Europe and the USSR including Yugoslavia
(c)	North America	North America
(d)	Latin America	Caribbean, Middle America, Temperate, and Tropical South America
(e)	North Africa	Northern Africa
(f)	East Africa	Eastern Africa
(g)	West Africa	Western Africa
(h)	South Africa	Southern Africa
(i)	Central Africa	Middle Africa
(j)	Middle East	Western South Asia
(k)	South Asia	Eastern and Middle South Asia
(l)	East Asia	East Asia excluding China and Japan
(m)	China	
(n)	Japan	
(o)	Pacific area	Oceania, Melanesia, Micronesia and Polynesia

In some cases the names of some regions are changed to the names by which they are more commonly known, such as the Middle East region. Although the regions are left in their geographical composition a further distinction between developed and developing countries is made. The developed countries include the regions (a), (b), (c), (h), (n) and (o). The developing countries comprise the regions (d), (e), (f), (g), (i), (j), (k), (l) and (m).

II. GLOBAL ASSESSMENT OF THE PETROCHEMICAL INDUSTRY: PAST AND PRESENT SITUATION

2.1 GENERAL CHARACTERISTICS OF THE PETROCHEMICAL INDUSTRY

The main characteristic of this industry is its production complexity that allows it a multiple choice of alternative products, processes and raw materials. On this basis it developed a competitive edge over natural and artificial products that, in the traditional markets for natural products, resulted in the rapid rate of substitution of petrochemicals for natural products. This product subsitution has accounted for the high growth rate of demand for petrochemicals. At the same time the continuous improvement in product performance has allowed the industrial end users of petrochemicals a higher flexibility and versatility in their particular applications than may have been expected from the natural products.

2.1.1 Markets

(i) One of the salient facts about the petrochemical industry is its rapid growth. World production rose from a few hundred tons in 1920 to 3.5 million tons in 1950 to about 70 million tons in 1976, and has averaged over 14 per cent a year during the past 25 years.

(ii) Its markets are composed of a limited number of users in several industrial sectors since petrochemical products usually need to be further processed before they are sold to final consumers.

(iii) The petrochemical industry sells mainly performance chemicals to the secondary processing industries. This requires the extension of technical services to these industries to develop polymer grades better adapted to the user's needs, to solve the user's technical problems in using the polymers, to collaborate with equipment manufacturers for the processing industry, to develop new machinery that better exploits the properties of the polymers, etc.

(iv) The abundance of modestly priced raw materials and sophisticated technologies gave petrochemicals a cost edge over other natural products for replacing them in their traditional markets. The need to meet the soaring demand of the processing industries led to the explosive growth rate of the last two decades since traditional products could not compete either quantitatively or economically with petrochemicals. Furthermore, petrochemicals have properties often superior to those of natural products.

(v) The characteristic growth pattern of demand for petrochemicals usually follows an S-shaped curve and reflects the extent of both product substitution and technology substitution with the passage of time. Typically, synthetic petrochemicals initially start slow followed very soon by a rapid growth during the substitution phase, and then tails off once the substitution phase is completed to continue growing in step with the overall growth of the economic activity. For example, thermoplastics are still in the super-growth substitution phase while elastomers and syndets are in the tailed-off normal phase.

Nevertheless with the soaring costs of raw materials, energy and capital investment, petrochemicals can no longer be considered as cheap substitutes for natural products but as materials on their own merits.

(vi) Petrochemicals are quite sensitive to price changes for they have to remain competitive with natural products to continue growing. For example, natural rubber has regained competitiveness in relation to elastomers and is putting up a strong fight back. The proportion of elastomers in the total rubber market is being checked at the peak proportion of 1973. Moreover, the slackening of demand growth rate for plastics is starting some skirmishing between competing plastics themselves for various processing applications. For example, the inroads made by HDPE into LDPE film markets, PP into ABS, PS and LDPE applications, PVC into ABS pipe markets, etc. This interplastics substitution comes about because the processing industries buy adequate performance at minimum cost after considering the whole production and distribution system and not on polymer price alone. For instance an HDPE film needs only half the thickness of an LDPE film to provide the same strength, hence the higher costs of HDPE are easily offset on a unitary basis.

Currently the petrochemical industry is mainly concentrated in a limited number of large-volume end product families whose end uses and technology are known well enough to permit their production by a broad range of companies in any region of the world. The intermediate and basic petrochemicals are technically integrated into the production of petrochemical end products and they usually have no alternative markets of their own.

2.1.2 Technology and investment

(i) The petrochemical industry involves the application of complex technologies both for the chemical processes and for the many technical alternatives offered concerning products, processes and raw materials. For instance, several basic products are required to produce some intermediates such as styrene or DMT. One intermediate can be used to produce several end products the uses of which can be very different, such as styrene to produce the elastomer SBR and the plastic PS. The same intermediates can be derived from different basic products, such as caprolactam can be produced from benzene or toluene. The same end product can be obtained in different ways, like polyester fibres can be produced from terephtalic acid or from DMT and ethylene oxide. The latter method offers an outlet for ethylene which the first method does not.
Furthermore, the basic products olefins and aromatics, may be produced in various ways. Production of benzene may be linked to that of ethylene if it is extracted from pyrolysis gasoline. Benzene may be extracted independently if a method involving catalytic reforming of naphtha and extraction from the reformate is chosen, or the two may be combined as one extraction unit may be fed both by a reformate and a pyrolises gasoline.

(ii) The organic chemical industry was the first research intensive industry characterized by a fast flow of new products and technologies that have been instrumental in changing societal patterns all over the world. Since the late 40's the organic chemical industry shifted from coal-based to petroleum-based thus becoming the modern petrochemical industry. The innovation effort persisted up to the 70's where we are now noticing a slowing down in technological advance due to sluggish demand, economic uncertainties and inflationary cost structures. Nevertheless, the industry is pressed to innovate continuously in order to keep productinn coste competitive, fending off the mounting effects of inflation, the ever-increasing salary demands, and price increases of feedstocks and other inputs.

(iii) All large tonnage petrochemicals are derived from eight basic building blocks: ethylene, propylene, butadiene, benzene, toluene, xylenes, ammonia and methanol. These in turn can be produced from various raw materials such as petroleum distillates, LPG, ethane, natural gas, coal, shale oil, bio mass. Each process except ethane and natural gas, involves a number of co-products that have to be upgraded from their fuel value into a chemical value.

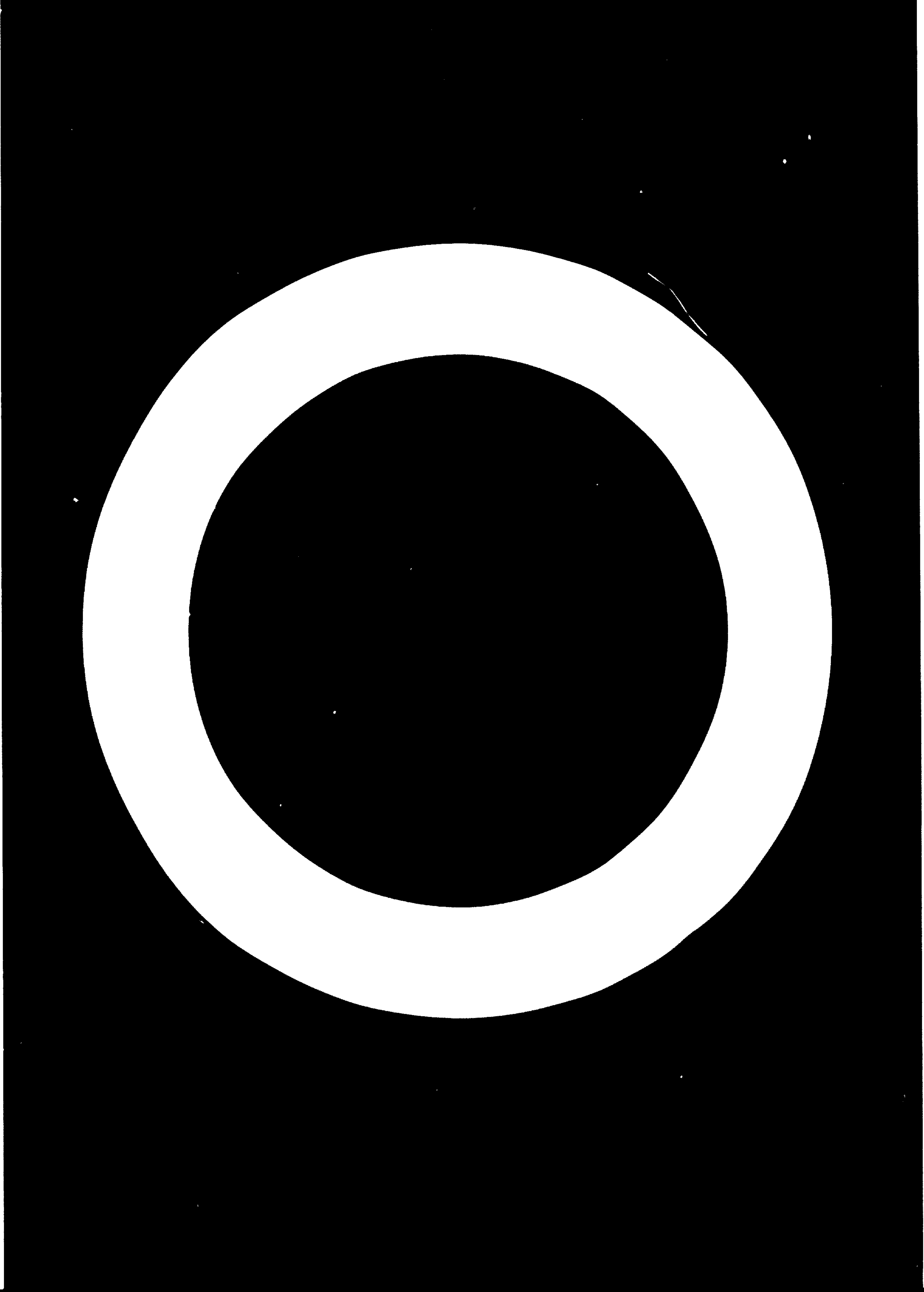
Considering the limited petroleum reserves and the steady growth in demand for oil products, the petrochemical industry is facing a growing competition from other energy users in the supply of its main raw material naphtha. Therefore the industry is currently speeding up research towards alternative feedstocks that use the heavy end of the oil barrel economically.

(iv) The cracking of naphtha as feedstock produced a number of co-products and involved costly purification and separation processes. This situation led to pressures for getting a chemical value out of co-products through new markets and/or uses, and to the development of integrated petrochemical complexes; it also spurred a maximum scaling-up of plant sizes to reduce the investment per ton of installed capacity and minimize production costs. These characteristics are currently the dominant features of modern complexes throughout the world. The industry is subject to restrictions of economy of scale although to a lesser degree since 1973.

At present the industry is going through a period of rapidly increasing unitary investment cost due to very large plant and construction cost increases, new environmental regulation and the need to conserve productive throughput factors. For example, a recent survey carried out by the Chemical Industries Association of the United Kingdom shows that plant and construction costs in the UK have gone from a cost index 100 in 1970 to 275 in 1977 and is expected to reach 396 by 1980. Therefore to build a plant in 1980 in the UK is likely to cost four times as much as a similar plant built in 1970, without counting additional equipment for pollution abatement and energy conservation.

(v) The industry operates large scale plants particularly in the case of the basic products. Considering the very substantial investments committed in the plants, there is a need to have efficient and continuous operations at high capacity rates and an effective maintenance of large complexes. It requires the keeping of a relatively small but qualified work force and its continuous up-grading through properly designed training programmes.

(vi) Because of the nature of raw materials, processes and products, petrochemical plants have potential health and environmental hazards. In the developed countries a number of its products have mandatory strict toxicity and pollution standards and some like VCM are recognised human chemical carcinogens.



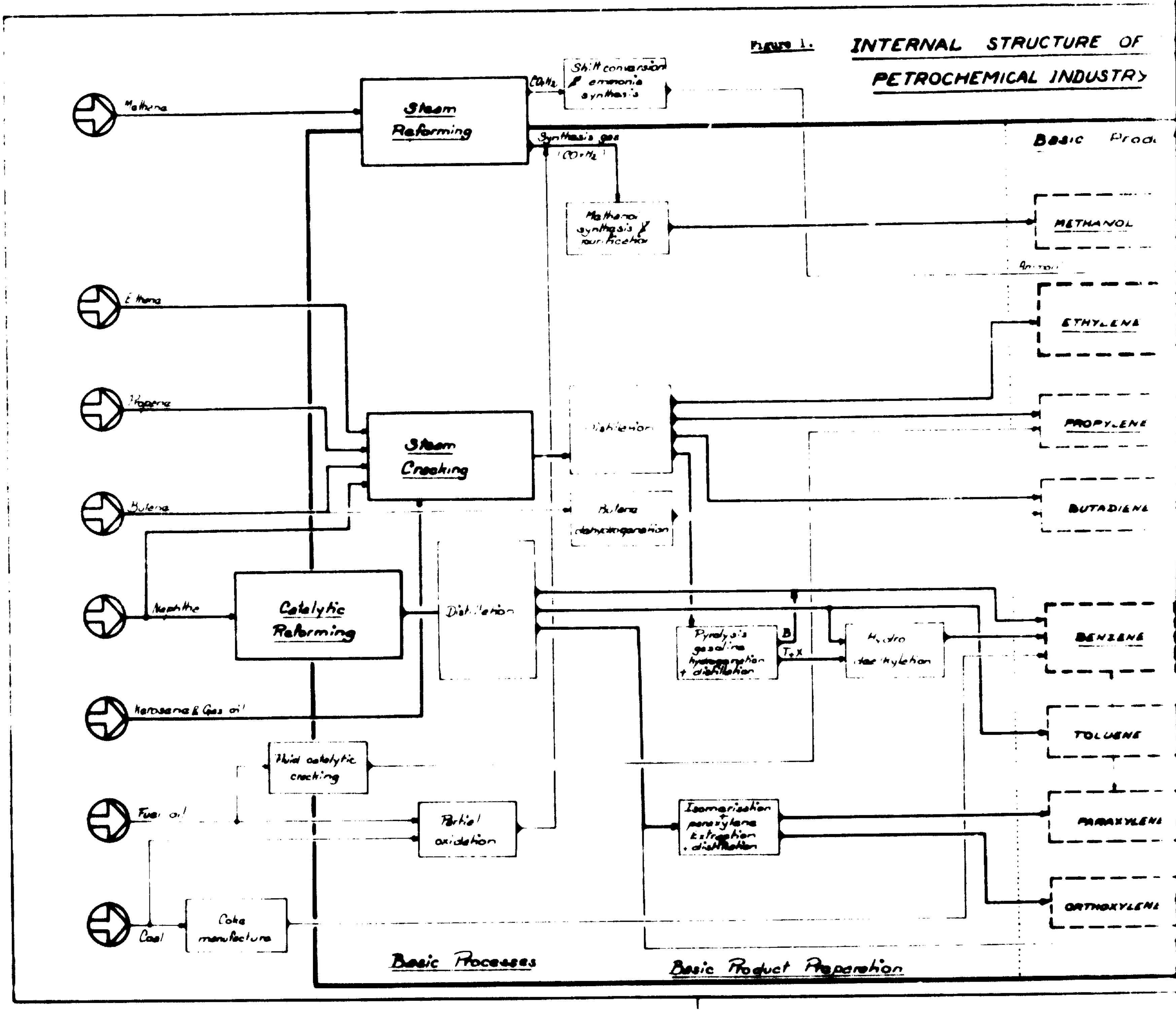
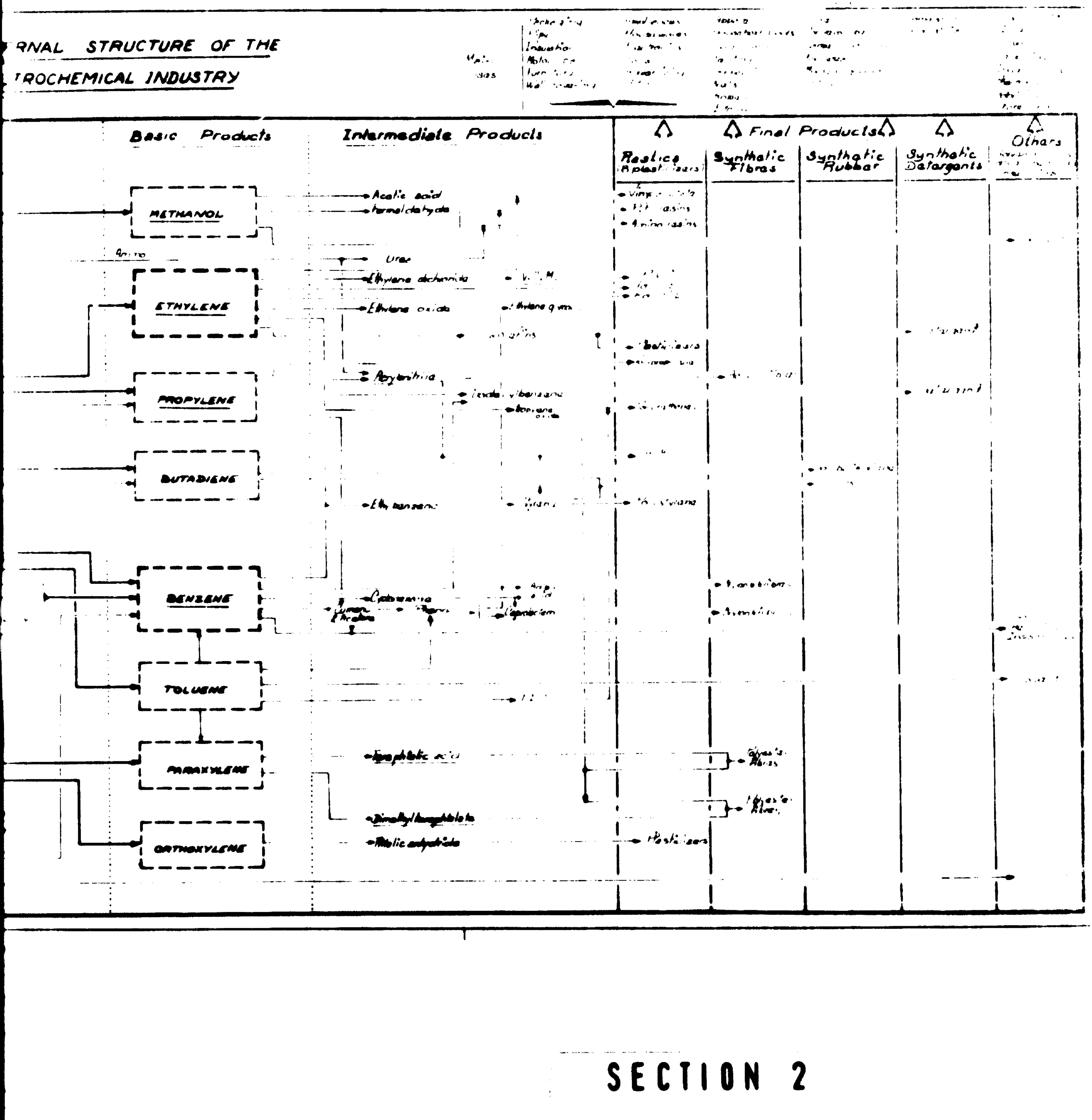
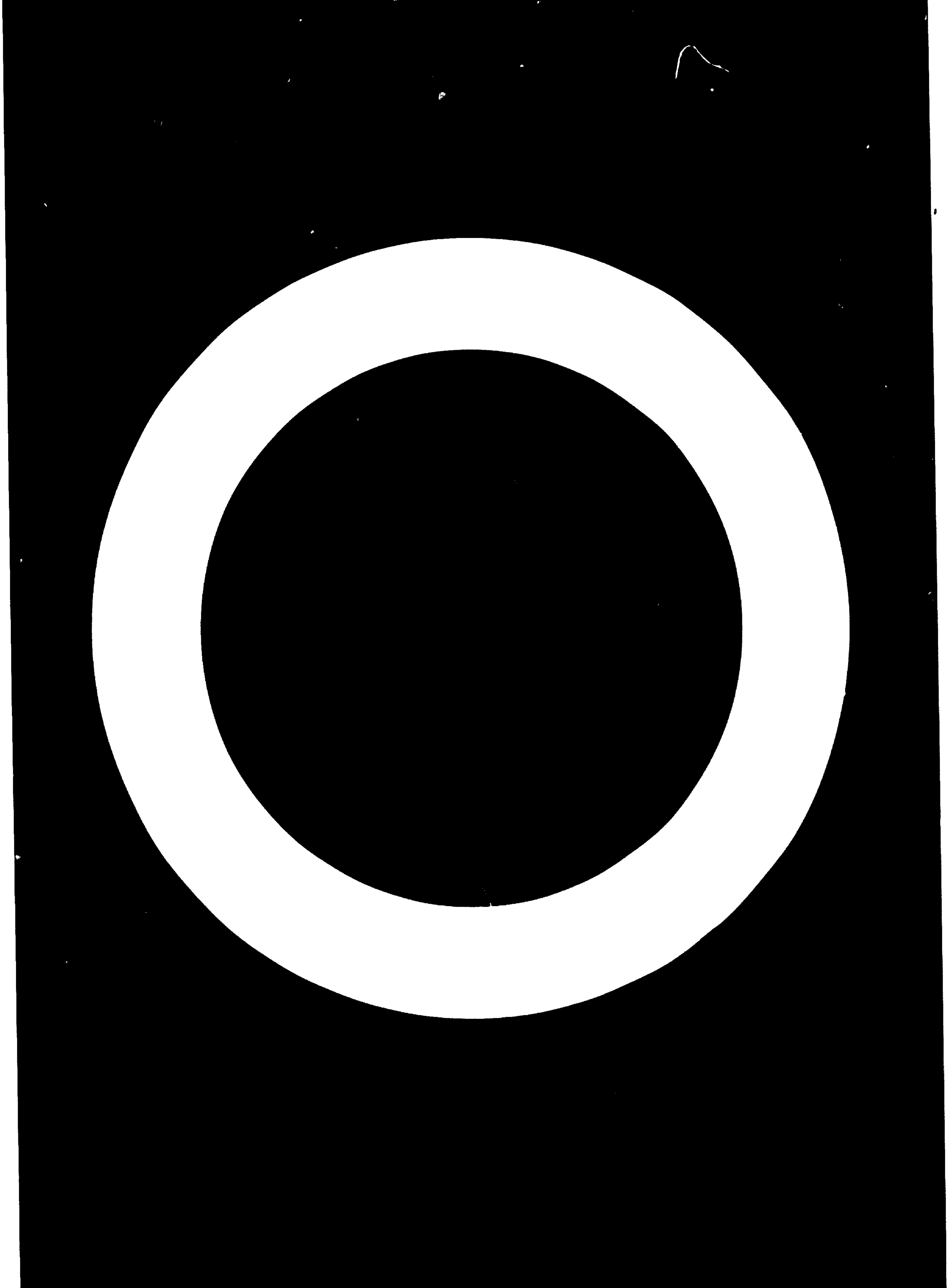


Figure 1.
INTERNAL STRUCTURE OF PETROCHEMICAL INDUSTRY
Methane
Ethane
Propane
Butane
Naphtha
Kerosene & Gas oil
Fuel oil
Coal
Steam Reforming
Steam Cracking
Catalytic Reforming
Fluid catalytic cracking
Partial oxidation
Coke manufacture
Shift conversion & ammonia synthesis
Synthesis gas
Methanol synthesis & purification
Distillation
Butene dehydrogenation
Pyrolysis gasoline hydrogenation + distillation
Hydro dealkylation
Isomerisation paraxylene extraction + distillation
B
T+X
METHANOL
ETHYLENE
PROPYLENE
BUTADIENE
BENZENE
TOLUENE
PARAXYLENE
ORTHOXYLENE
Basic Processes
Basic Product Preparation

SECTION 1


RNAL STRUCTURE OF THE
TROCHEMICAL INDUSTRY
Basic Products
Intermediate Products
Final Products
Plastics
Synthetic Fibres
Synthetic Rubber
Synthetic Detergents
Others
METHANOL
ETHYLENE
PROPYLENE
BUTADIENE
BENZENE
TOLUENE
PARAXYLENE
ORTHOXYLENE
Acetic acid
Formaldehyde
Urea
Ethylene dichloride
Ethylene oxide
Ethylene glycol
Acrylonitrile
Ethylbenzene
Terephthalic acid
Phtalic anhydride
Plastisizers

SECTION 2



Modern plants are designed to meet these standards under the most unfavourable operating conditions. As most processes operate at high temperatures and/or pressures and deal with catalytically activated inflamable toxic or corrosive materials, the products and effluents produced may bring harmful effects to human, animal and plant life and may adversely affect the quality of the environment. Damage may occur through continuous affluent discharges, leakages or accidents. The prevention of damage depends initially upon satisfactory plant design, reliable quality equipment, and proper pollution control measures and antipollution equipment. A qualified, alert and reliable maintenance system is required as well as safety protection and operation procedures. A permanent training and rehearsal programme is important to minimize any potential damage.

2.1.3 Internal structure of the petrochemical industry

The internal structure of this industry is presented in figure 1.

2.2 WORLD PRODUCTION OF PETROCHEMICALS

2.2.1 Factors affecting the production of petrochemical products

There are many different types of factors affecting the establishment and development of the petrochemical industry which may be grouped as geographical, economic, social, political, financial, technological and environmental. The analysis of the most important of these factors along with their trends gives a better insight into the industry.

(a) Existence and development of a market

The first condition for the setting up of this industry is the existence of an effective and potential demand. Concerning end petrochemicals, its products are very competitive with other natural and artificial products both as industrial materials and as finished goods. It can produce synthetic materials custom made to meet specific performance requirements.

Regarding basic and intermediate petrochemicals, it can competitively produce most of the organic chemical products that were traditionally manufactured from raw materials other than petroleum and natural gas such as coal, molasses etc, e.g. acetylene from calcium carbide, benzene derived from coal. The rapid development of this industry is due to its ability to supply at competitive prices products with stable specifications but whose properties are often superior to those of natural products, thus effectively substituting them to a large degree in their traditional markets.

The availability of petrochemicals led to a few new uses but in the main, market growth concentrated on existing applications.

The increasing availability of petrochemicals had a double effect on natural products. One, not only did prices fall but the frequent price fluctuations of natural products were reduced. Two, there was a marked improvement in the quality and productivity of natural products such as natural rubber, cotton, wool. These natural products, having regained competitiveness, have since recently been able to fight back the petrochemicals' penetration in their markets, for example, an increased proportion of cotton in polyester cotton fabrics from 65/35 to 50/50.

(b) Availability of petroleum raw materials

In order to set up a petrochemical industry there must be petroleum raw materials available, either in the form of gas or petroleum fractions obtained through refining. It must be emphasized at this point that the development and concentration of the petrochemical industry in such areas as North America, Japan and Europe were largely due to the existence of suitably priced raw materials: ethane and LPG associated with natural gas in the United States, and naphtha until recently in excess of the requirements of the petroleum products market, in Europe and Japan. In the past, a local supply of crude oil was not a major factor in the development of the industry, and, with the exception of the United States where the petrochemical industry is based on gas, most of the countries where this industry is well developed are not themselves producers of crude oil. The existence of gas or of a refining industry which can supply gas oil or naphtha is much more important. The proportion of raw materials used in petrochemistry, out of the total crude oil and gas produced, although constantly growing, is still small. It was less than 1 per cent in 1950 and is now somewhere between 4.5 and 5 per cent.

The availability of raw materials should be linked with the existence of a refining industry discussed here below. It affects the basic petrochemical production.

(c) Existence of a refining industry

The existence of a large-scale refining industry is an important factor for this industry. On the one hand, it is an indispensable source of feedstocks, for instance, in order to produce 300,000 MT/year of ethylene, more than 2 million tons of naphtha are required, and this amount, unless imported, requires a refinery of at least 5 to 6 million tons/year. On the other hand, the refining industry enables the valorisation of a large quantity of basic petrochemical co-products. For example, the production of 1 ton of ethylene by the steam cracking of naphtha yields about 0.2 tons of LPG and 0.65 tons of gasoline which can only be fully valorized by blending them with refinery products.

The refining and petrochemical industry rely on technologies which are in some respects fairly similar. The presence of personnel experienced in the operation and maintenance of a refinery is of great benefit to a starting petrochemical industry particularly concerning basic products.

(d) <u>Availability of manpower</u>

The technology used in this industry is complex and involves state-of-the-art developments in several fields such as chemistry, metallurgy, mechanics and electronics. Therefore the operating and maintenance work force is made up mainly of skilled personnel. In view of the large sums invested and the adverse effects of unscheduled plant stoppages on profits, it is advisable that the operation and maintenance of complexes be entrusted to very experienced personnel. The problems of training engineers, foremen, operators, maintenance specialists and chemists are a decisive factor,for training involves considerable expenditures.

The personnel requirements of this industry, particularly for the production of basics, are relatively small in proportion to output and investment. A fair-sized 1 billion dollar complex, under 1974 conditions, comprising 400,000 ton/year of ethylene, 580,000 ton/year of thermoplastics, 40,000 ton/year of PBR, 40,000 ton/year of acrylonitrile and over 400,000 ton/year of petroleum products, requires for operation, maintenance and general services, a staff of 2,050, 30 percent of which may be classified as unskilled workers.

Personnel requirements per ton produced are larger for end products than for basic products. For example, a plant producing 400,000 tons/year of ethylene and over 1 million tons of other basic petrochemicals and petroleum products requires about the same operational manpower as a 220,000 ton/year LDPE plant. A PVC plant operates with twice as much personnel as required by the corresponding VCM plant of similar capacity.

Synthetic fibers constitute a special case, for a large staff is required for production, the majority of which is unskilled personnel engaged in handling activities.

(e) <u>Means of financing investment</u>

The petrochemical industry is a capital-intensive industry requiring very considerable investments. For instance, the current cost of a complex centered around a 400,000 ton/year ethylene plant amounts to over 1 billion dollars under European conditions. Access to means of financing this high order of investment has been, and will increasingly be a major element governing the development and setting up of this industry.

In the past, the investment needs were largely financed from internal resources generated by petrochemical companies partly resulting from favourably priced raw materials. The advantageous cost structure of the industry favoured a lowering of prices that led to deep penetrations into the markets for natural products. The resulting large increase in volume of production contributed to an accelerated capital accumulation rate, mainly in developed countries that facilitated the financing of new plants. This accumulated capital also enabled a great deal of money to be devoted to research, and this outlay, stimulated by competition between companies, proved to be worthwhile for it extended the retained funds without stifling market developments.

(f) Developing a technology - the importance of research

The spectacular development of the petrochemical industry, due to the increasingly competitive nature of the products marketed, was made possible only through the continuous perfecting and improvement of a technology, thanks to particularly large sums being set aside for research. Between 1960 and 1970 the budget devoted by the leading chemical companies to the perfecting of existing techniques and the development of new processes was equivalent to 2 to 4 per cent of their turnover in the US and Europe. Companies engaged in production were not the only ones to undertake such research. Engineering companies and companies specialising in the development of processes were also very active in this field with a view to being able to offer more and more competitive techniques to their ever-growing clientele. This constant, sustained effort accounts on one hand for the relative complexity of the petrochemical industry, mentioned earlier, and on the other hand for the upheavals which take place within the industry whenever a new technique is perfected, as well as its capacity for adaptation to changing economic situations. Examples include the changeover from acetylene to ethyline as the main basic block, the progressive replacement in the US of producing butadiene from butane by extracting it from the C-4 cuts from the steam cracking, the use of heavier feedstocks, etc.

One of the most important fields of research concerned the continual improvement of the quality of end products, e.g. the mechanical properties of synthetic rubber and plastics; the solidity, homogeneity and great receptivity of synthetic fibres to dye stuffs; the degree of biodegradability of detergents. The two main lines of research, lowering of production costs and improving the quality of products led to the expansion of the market for petrochemical products, a major factor in the growth of the industry.

As far as any company or country is concerned, the development of a technology is not a prerequisite for the setting up of a chemical industry since a new producer can have access to a production technology once the necessary licenses have been acquired. The initial Japanese and, to a lesser extent, Western European petrochemical industry have been based on imported US technology.

It should be noticed that the research undertaken, stimulated by inter-company competition sometimes on a world-wide scale, has been very profitable. Each major change in the choice of production techniques that carries a considerable initial risk, has resulted in a marked reduction in cost and/or a significant improvement in the quality of the products. Research has also been indispensable to the design and implementation of ever larger plants with its concomitant positive effects on the profitability of the industry.

(g) Existence of a processing industry

The end petrochemical products are not sold directly to final consumers. They find their outlets in other processing industries such as plastics, textiles, tires, detergents. Without these processing industries there is no effective domestic market for petrochemicals even if there is a considerable demand for petrochemical based goods such as plastic pipes, films, fabrics, tires, syndets. These industries are very different in nature from the petrochemical industry. They do not require very substantial investments, employ a very large work force, and their threshold of economic size is much lower than in the petrochemical industry. Their production capacities match market growth fairly closely on account of their comparatively smaller plant sizes.

In most countries the processing industries precede the petrochemical production. They often receive technical assistance from petrochemical producers in terms of after sales service, product promotion, technical aid to better exploit the properties of petrochemical products, and constant improvements in the quality of end petrochemicals.

2.2.2 Development of the petrochemical industry

2.2.2.1 Evolution of the petrochemical industry

From the nineteenth century to about 1936, a coal-based organic chemical industry developed rapidly in France, Germany, United Kingdom and United States. By around 1920 the first few hundred tons of petroleum-based petrochemicals were produced for the automotive industry in the form of paints, anti-freeze and various additives. Later on, plastics, elastomers, synthetic fibres and syndets came to the market, but their combined feedstock requirements were small. The basic organic chemicals were made from coal by-products, acetylene from calcium carbide and molasses. The Second World War became a powerful stimulus for developing this industry in the United States since it rapidly expanded to meet a demand far in excess of what the traditional coal and agriculture sources could supply in quantitative and qualitative terms. Most of the present large tonnage petrochemicals were already invented by the end of the war. Among the countries with an important chemical industry only the United States was at that time a petroleum producer, hence there was no incentive to use oil as feedstock. The demand during the war for gasoline and synthetic products substituting for scarce natural products, the oil availability from new Middle East sources, and the huge post-war investments in refineries in Europe of United States oil multinationals, effectively removed the last objections of the European chemical industry for shifting from coal to petroleum.

Consequently in the late 1940s the main feedstock changed to petroleum-based routes assisted by a large simultaneous expansion of oil refineries in Europe and Japan. The changeover was made for economic reasons and easiness of operation and was innovatively based on naphtha, then modestly priced and in surplus supply. This new oil-based industry grew very fast during 1950-70 at about 2.5 times tne GDP growth in the same period. This rapid development was brought about by a soaring demand for polymer materials coupled with the inability of traditional materials to compete either quantitatively or economically with them. This led to the rapid substitution of petrochemicals in the traditional markets of natural products.

The cracking of naphtha increased the production cost of olefins and produced a range of co-products. This situation led to efforts for up-grading the worth of the co-products from their value as fuel, the development of integrated complexes and the maximum increase in plant sizes commensurate with the technical risk and the reduction of investment cost per ton of product. In this rather ebullient era, the economic risks by sluggish demand, plant break-downs etc. were more easily accepted. The evolution of large ethylene plants was inevitable if Europe and Japan were to beoome cost competitive with the United States production based on the simpler feedstocks ethane and LPG1/. These efforts brought about large technical advances in process chemistry and engineering.

1/ A.W. Taylor, "The petrochemical industry: some perspective views", Chemistry and Industry, 1 January 1977.

Currently, the production of olefins and particularly of ethylene, is the major operation of this industry, and has become its bellwether indicator for the development of the petrochemical industry. In the 1950s large naphtha-based ethylene plants produced 50,000 MT/y. At the end of the 1960s the large ethylene plants were producing 500,000 MT/y in one single train. Currently a growing number of experts thinks that maximum economies of scale have leveled off at about 600,000-650,000 MT/y [2].

Four main factors accounted for the super growth of the world petrochemical industry during the fast growing period of 1950-70:

(a) An explosive market growth due to the fast substitution of petrochemicals in the markets of natural products. The new materials had properties often superior to those of natural products.

(b) Naphtha, the basic feedstock, was a commodity whose prices were falling, even in monetary terms, the more so in terms of real purchasing value [3].

(c) The development of economies of scale in the petrochemical plants that led to the large-scale modern petrochemical complexes. This was facilitated by the adaptation of large-scale oil refinery technology, plant scale-up that decreased investment costs per ton of product, and by the spreading of overheads and semivariable costs. This trend, more visible during the 1960s, led to the provision of capacity ahead of demand in order to reap the benefits from large-scale operations, with the result that either in a down-turn in demand or in anticipation of full plant capacity utilization benefits, prices were lowered to unrewarding levels [4].

(d) The very fast technical developments in processes and engineering that gave petrochemicals a cost edge over natural products. Among the more important technical developments are the following [5]:

- more active, robust and selective catalysts;
- metallurgical developments of new materials able to withstand extreme temperatures, high pressures and corrosive environments;
- development of large and reliable centrifugal compressors;

2/ "Are bigger plants better? No small debate", News features, Chemical Engineering, 22 May 1978.

3/ "Structural changes and their effect in the organic chemical industry: some perspective views", N. Champion, Chemistry and Industry, 7 Jan.1978.

4/ op. cit. in 1/

5/ op. cit. in 1/

- advances in chemical analysis methods;
- new separation methods for products of higher and consistent purity;
- advances in instrumentation and control mechanisms and systems.

The success of this industry has been reflected in its very high growth rate that enabled large investments, sustained innovation efforts, and the ability to finance its own activities.

In the early 1970s there were signs that the four factors which had favoured this industry in the previous two decades were starting to decline in their effects. The emergence of new producers in developing countries highlighted the overcapacity build-up in the developed countries when the faster substitution phase of most petrochemicals but plastics was tailing off; the feedstock costs stopped going down and started to move up instead thus increasing the weight of variable costs over fixed costs; the benefits of plant economies of scale are peaking off at least for the foreseeable futures and the laws of diminishing returns began to apply to technical innovation developments due, in part, to "non-productive" research such as on pollution abatement and toxicology.

The sudden quadrupling of oil prices in 1973 brought the brewing crisis into the open. Despite all this, in the first half of 1974 the peak of the world-wide boom in petrochemicals was reached. After that, the important and promising petrochemical business developments that had been built up with the developing countries, virtually collapsed 6/.

In the developed countries price increases and shortages towards mid 1974 led to changes in buying habits, savings on materials and substitution for better cost-performance materials. For the same reasons their exports to the developing countries did not continue to grow. Moreover, stock control policy became a prime factor at all levels of the processing industries.

During 1975 a realistic adjustment to the changed world market situation took place. Because of product surpluses and differences in production costs in the various regions, petrochemicals were subject to price pressures from the market at times when production costs increased due to lower plant capacity utilization rates. The positive market recovery that started at the end of 1975 continued in certain areas into 1976. However, late in that year it became apparent that the recovery was to be short-lived. By September 1977 the world market receded strongly back to the bottom levels of late 1974. In July 1978 some positive signs of market recovery in the more depressed areas of Western Europe and Japan have started appearing.

6/ R. von der Heyde, "The organic chemical industry and its development: a commercial viewpoint", Chemistry and Industry, 7 January 1978.

To sum up, four factors can be pointed out as the main reasons for the current structural recession in this industry 7/:

(i) A stronger trend towards materials savings for technical and commercial reasons. This means that the pre 1973 product use structure is outdated therefore the expected increases in production and consumption cannot be realized. The evolving new end-use structure is not complete yet. Hence the more depressed petrochemical industries, that of Japan and Western Europe, are now consolidating and rationalizing the receding, stagnant and very low growth areas of their petrochemical industries.

(ii) A temporary lack of real innovations having short-term effects on production and sales.

(iii) The emergence of important new producers in Eastern Europe and in the developing countries that is creating overcapacity problems in the developed countries.

(iv) The overcoming of planning pitfalls that stem from the 1960s such as 8/:

- optimistic acceptance of exponential market growth predictions that led to overcapacity;
- double counting of export markets as this industry became more international in its trade;
- the disbelief in the likely growth of demand for certain products where a technical change of route was predicted, thus leading to undercapacity;
- the delays in plant completion and the unexpected low performance of some major plants incorporating insufficiently developed technical advances.

The growth of world production of the petrochemical industry is given below for the main families of end products and main basics, since the intermediate products are linked to the other two by technical factors and they have few markets of their own.

2.2.2.1 - 1. Main end products of the petrochemical industry

Table 1 shows the growth of the four main end products. Plastics account for more than half of the petrochemical products under consideration, in terms of tonnage and, even so, the production of plastics is still expanding rapidly, on account of the large potential demand.

As far as the other end products, such as synthetic fibres, rubber and detergents which came on the market more recently, are concerned, the substantial rise in production in the last twenty to thirty years can be

7/ op. cit. in 6/
8/ op. cit. in 1/

attributed mainly to their having rapidly supplanted those products which were already on the market, i.e., cellulose fibres, natural rubber and soap.

Generally speaking, the substitution of synthetic products is not complete, but considering the extent to which they have already penetrated the market, production of the three groups of products mentioned, namely synthetic fibres, rubber and detergents, can be expected to slow down in the near future.

Table 1. World production of the main end petrochemicals (millions of tons)

	1950	1960	1970	1974	1975
Plastics	1.5	7.0	30.2	44.6	38.5
Synthetic fibres	0.1	0.7	5.1	7.5	7.5
Synthetic rubbers	0.7	2.0	5.9	7.7	7.4
Detergents	0.7	3.5	9.0	11.0	10.8
Total	3.0	13.2	50.2	70.8	64.2

2.2.2.1 - 2. Main basic products of the petrochemical industry

The main petrochemical base products are olefins (ethylene, propylene, butadiene), aromatics (essentially benzene and xylenes) and methanol.

Two basic processes predominate, namely:

- steam cracking, which is the main source of olefins but which can also be used to produce aromatics;

- catalytic reforming which, independently from its use in refining, produces aromatics for the petrochemical industry.

In addition to these, steam reforming should be mentioned; it is used essentially for the synthesis of ammonia, but also for the synthesis of methanol.

The basic hydrocarbons resulting from these processes, i.e. ethylene, propylene, butadiene, benzene, xylenes and methanol, are the key products of the petrochemical industry. The paths leading from these basic products to the end products are numerous and complex but the main ones can be traced: ethylene and propylene serve as basic products for the most important plastics; aromatics for the basis for the synthesis of non-cellulosic fibres; butadiene is involved in the production of the principal synthetic rubbers. Methanol is used essentially for the production of formol, one of the constituents of adhesives. Table 2 shows the relative importance of the basic petrochemicals. World consumption of ethylene amounts to roughly double that of propylene or benzene.

Table 2. World production of the main basic petrochemicals
(thousands of tons)

	1965	1970	1976
Ethylene			
United States	4 600	7 700	9 900
Western Europe	2 000	5 950	9 600
Japan	900	3 050	3 800
Others	500	1 800	2 700 (1)
Total	8 000	18 500	26 000
Propylene			
United States	2 400	3 900	4 400
Western Europe	1 100	3 280	5 100
Japan	700	1 850	2 600
Others	200	500	1 600 (1)
Total	4 400	9 530	13 700
Butadiene			
United States	1 100	1 400	1 500
Western Europe	400	880	1 400
Japan	100	450	590
Others	300	400	1 400 (1)
Total	1 900	3 130	4 890
Benzene			
United States	2 700	3 900	4 500
Western Europe	1 450	2 750	4 100
Japan	380	1 570	1 900
Others	250	600	2 800 (1)
Total	4 780	8 820	13 300
P.xylene			
United States			1 500
Western Europe			750
Japan			550
Others			300
Total			3 100

2.2.2.2 Share in world production of petrochemicals, by main products and regions

Up to the end of the 1940s the United States was still virtually the only country with a significantly developed petrochemical industry thanks to its oil refining industry that developed the basic catalytic cracking and high pressure high temperature technologies that were later adapted to produce basic petrochemicals. By the mid 1950s the United States had about 87 per cent of the total world petrochemical production. This percentage has steadily diminished during the past twenty years to the current one third of world production.

From 1960 onwards Japan and Europe expanded their production more rapidly than the United States, with the result that Europe became the main world petrochemical producing region since 1971/72.

The share of the developing countries in world petrochemical production is still only marginal for all products but synthetic fibers. Their first venture into the petrochemical industry was the manufacture of synthetic fibres in view of the relatively small plant sizes for economic production and the larger share represented by labour in total production costs. In the other petrochemical areas, the production of developing countries prior to 1965 was almost non existent except for a few low-capacity plants mainly in Latin America. Even today there are about thirteen developing countries with an established basic petrochemical industry. Among the more important producers in developing countries are Algeria, Brazil, India, Republic of Korea, Mexico and Venezuela.

2.2.2.2 - 1. Share in world production of plastics

During 1950-1970 world production of plastics was nearly doubling every five years but between 1970 and 1974 its increase was little more than 50 per cent. Plastics production dropped during 1975 to recover the production levels of 1974 in 1976. This production increase has also shown a widening geographical spread as reflected in Table 3.

Table 3. Regional share of world plastics production (percentage)

	1960	1965	1970	1974
United States	50	39	30	32
Western Europe	32	39	41	43
Eastern Europe	9	10	10	10
Japan	9	11	16	14
Others a/	-	1	3	1
Total	100	100	100	100

a/ At this stage it is difficult to further disaggregate for lack of statistics.

Source: Calculated on the basis of ECE-CHEM/GE.1/R.3/Add.3, 5 Apr.1977

The share of the developing countries in plastics production is minimal. The three largest individual producers, the United States, Japan and the Federal Republic of Germany, account for over half of the total world plastics production.

From the total world plastics production, thermoplastics accounts for about two thirds. In 1975, the percentage of thermoplastics to total plastics production in the three largest producing countries were as follows: Japan 79 per cent, United States 74 per cent and the Federal Republic of Germany 66 per cent.

2.2.2.2 - 2. Share in world production of synthetic fibres

During the 1960s world production of synthetic fibres grew faster than that of plastics and rubber because early in the 1960s this field was practically in its infancy. Currently it is the more troublesome area of the petrochemical industry.

The production of man-made fibres in the total fibre output accounted for 22 per cent in 1960, 40 per cent in 1970 and 44 per cent in 1975.

Within the man-made fibres, synthetic fibres have been gaining impressively over cellulosic fibres. In 1970 synthetic fibres accounted for 56 per cent of total man-made fibres output, and in 1975 the figure was 71.5 per cent. At the same time, the cellolosic fibres physical output was diminishing. This production increase has shown a widening geographical spread with the emergence of developing countries as an important world producer, as given in table 4.

Table 4. **Regional share of world production of synthetic fibres**
(percentage)

	1960	1965	1970	1975
United States	46	40	33	33
Western Europe	31	30	31	26
Eastern Europe	5	7	7	11
Japan	18	19	21	14
Others	-	4	8	16
Total	100	100	100	100

Source: Calculated on the basis of ECE-CHEM/GE.1/R.3/Add.6, 16 May 1977

The largest world producers of synthetic fibres are the United States, Japan and the Federal Republic of Germany that together account for over 50 per cent of world production.

In 1975 the percentage of synthetic fibres to total man-made production in the three largest producing countries were as follows: the United States 84 per cent, Federal Republic of Germany 82 per cent and Japan 73 per cent. As for developing countries, two regions, Latin America and East Asia, account for over 80 per cent of the total synthetic fibres production of developing countries.

2.2.2.2 - 3. Share in world production of synthetic rubber

During the 1960s synthetic rubber production grew at 6.75 per cent annually. This growth diminished to 2 per cent annually during 1971-75. During the same period the share of synthetic rubber went up to around 70 per cent of total rubber consumption, but in some cases such as in the United States, it went up to 78 per cent. Since 1972 natural rubber is making a strong comeback and has recaptured a few percentage points. The world production has shown a widening geographic spread as given in table 5.

Table 5. Regional share of world production of synthetic rubber
(percentage)

	1960	1965	1970	1973	1975
United States	63	49	37	34	31
Western Europe	12	19	23	24	23
Eastern Europe	17	20	21	23	27
Japan	1	4	12	12	11
Other developed countries	7	7	4	4	4
Other developing countries	-	1	3	3	4
Total	100	100	100	100	100

Source: Calculated on the basis of ECE-CHEM/GE.1/R.3/Add.15, 3 June 1977

The 7.72 million tons produced in 1973 give the peak point after which a drop followed mainly in the United States, Western Europe and Japan. World production is estimated to have recovered the 1973 level by 1977. The largest world producers of synthetic rubber are the United States, USSR and Japan, accounting together for around 60 per cent of world production. As a difference to plastics and synthetic fibres, the main producers of synthetic rubber are oil multinationals and tire manufacturers in market economy countries. As for developing countries, Argentina, Brazil, Mexico and India account for about 90 per cent of the synthetic rubber production of developing countries.

2.2.2.2 - 4. Share in world production of intermediates and basic petrochemicals

These products have a rather rigid stoichiometric relation to the main large tonnage end product families shown above, and their production evolution has followed, in general, the growth pattern of plastics and synthetic fibres that together account for about two thirds of world petrochemical production. The regional share in world basics production is given in table 6.

Table 6. Regional share of basic petrochemicals
(percentage)

	Ethylene			Benzene		
	1965	1970	1976	1965	1970	1976
United States	58	42	38	56	44	[illegible]
Western Europe	25	32	37	30	31	31
Japan	11	16	15	8	18	14
Others	6	10	10	6	7	21
Total	100	100	100	100	100	100

There are very few developing countries that have a sizeable basic petrochemical industry in operation. Among them are Brazil, India, Republic of Korea, Mexico and Venezuela.

2.2.2.3 Regional production capacity

The main factors governing the existence and development of a petrochemical industry and analyzed in section 2.2.1 have been present together in the developed countries, hence their development and concentration in those countries. In fact, in 1977 Europe, Japan and the United States accounted for 92 per cent of world ethylene capacity, 97 per cent of benzene and 93 per cent of world butadiene capacity. Those regions also predominate in intermediates and end products capacities, with over 90 per cent of world capacity in plastics, elastomers and intermediates, and 84 per cent in synthetic fibres.

Although few developing countries have a sizeable basic petrochemical industry in operation, a number of them have important new projects in view, some of which are already under construction. Taking into consideration the plants scheduled to start operating before 1980, the share of the developing countries in world petrochemical production capacity will grow substantially.

For instance, the ethylene capacity of developing countries would increase about 2.8 times, from 2.6 million tons in 1977 to 7.3 million tons in 1980, while the developed countries would increase capacity in less than 40 per cent, from 36 million to 49.9 million tons. The current production capacities as of mid-1977 by regions, are given in annexes 1 (a) through (c). More detailed information on production capacities by product and country are given in appendix A.

2.2.3 Feedstock supply and energy requirements

2.2.3.1 Current situation by main regions

The petrochemical industry, by virtue of its structure, is subject to fairly narrow restrictions concerning the raw materials it can use economically. Petrochemical products are derived essentially from eight major intermediate products: ethylene, propylene, butadiene, benzene, xylenes, toluene, methanol and ammonia. These are the basic building blocks from which a large number of organic synthetic derivatives can most cheaply be prepared.

The more complex intermediates are rarely used, even though they are closer to the end product which is to be obtained. In fact, the preparation of these intermediates involves the production of other products both physically and chemically very close and which are extremely difficult to separate. It is therefore more economical to synthesize ethylbenzene from benzene and ethylene rather than to extract it from the aromatic cut produced by steam cracking.

Currently all these eight basic products are produced almost exclusively from natural and associate gas, and oil refinery cuts mainly naphtha. The only important exception is benzene, that is also produced as a by-product of metallurgical coke.

This situation of the petrochemical industry has remained without any structural change despite the very steep rise in feedstock costs due to the quadrupling of oil prices. The world petrochemical industry consumption of raw materials and fuel, by region, is given in table 7.

Table 7. World petrochemical consumption of hydrocarbons (percentage)

	1973	1976
North America	35	33
Western Europe	34	32
Eastern Europe	11	15
Japan	17	16
Others	3	4
Total	100	100

(a) North America

The lowest cost of gas in the United States favoured its penetration in all fields but transport. In the petrochemical industry methanol is always produced from natural gas feedstocks and ethylene production developed as follows:

	From gas (ethane or LPG)	From naphtha or gas oil
1971	84 %	16 %
1976	77 %	23 %

In 1971 ethane was still largely predominant, accounting for 51 per cent of all ethylene produced, followed by propane (33 per cent), naphtha and gas oil. As a result the propylene produced (by steam cracking) was not sufficient to satisfy the demand, the deficit being made up by propylene obtained as a by-product from FCC (fluid catalytic cracking). The amount of butadiene produced was also insufficient, and the additional demand had to be met by means of imports and butane dehydrogenetion.

The quantity of benzene produced by steam cracking was equivalent to only 10 per cent of the demand. Catalytic reforming of naphtha feedstocks was therefore used to provide a further 80 per cent in conjunction with toluene hydrodealkylation, and the remaining 10 per cent was obtained as a coke by-product. Catalytic reforming produced xylenes in far greater quantities than required by the petrochemical industry. The surplus was used as a solvent or in gasoline mixtures.

The decline in the part played by ethane and propane as raw materials for ethylene production is due to the rapid exhaustion of American gas reserves resulting from excessive use of this fuel.

In 1976 the North American petrochemical industry used roughly 6 per cent of the total hydrocarbon consumption (oil and gas) in the form of raw materials and fuels.

(b) Western Europe

The situation of Western Europe is the converse of that of the United States. The latter, being motor fuel consumers, have for some time now been obliged to upgrade heavy fractions to light fractions in order to make up the naphtha deficit. Western Europe, on the other hand, has for a long time had a surplus of naphtha since gasoline consumption is relatively lower compared to fuel oil requirements for industry and gas oil requirements for heating, transport and industry.

The surplus naphtha fraction, together with a limited supply of natural gas in some regions, has led to naphtha being used for the production of methanol (17 per cent for 1973 production) and ammonia (33 per cent of 1973 production).

In 1973, 93 per cent of ethylene was produced from naphtha, and the rest from gas oil and LPG equally. As a result, the amount of propylene produced was more than adequate, and there was a surplus of butadiene, some of which was therefore exported to the United States.

As for benzene, in 1973 it was produced 14 per cent from coal, 32 per cent from steam cracking gasoline, 25 per cent from catalytic reforming and 29 per cent from toluene hydrodealkylation, the toluene being obtained half from steam cracking and half from catalytic reforming. The catalytic reforming used for benzene production was more than adequate for xylene requirements. In 1976 the petrochemical industry (including ammonia) used approximately 12 per cent of total hydrocarbon consumption (gas and oil) as raw materials and fuels.

(c) Japan

Japan is in a similar position to Western Europe, but has always been, and still is, lacking in both gas and oil. Methanol is, however, mainly produced from natural gas feedstocks. Ethylene on the other hand, was produced in 1976 exclusively from naphtha. This resulted in a more than adequate supply of propylene and butadiene.

However, as was the case in Western Europe, catalytic reforming of naphtha had to be used to a great extent in order to meet xylenes requirements and to make up the benzene deficit. In 1976 the petrochemical industry (including ammonia) used about 15 per cent of the total hydrocarbon consumption (oil and gas) as raw materials and fuel.

(d) Eastern Europe

Full information is not always available on these countries, but it can be said that:methanol (and ammonia) are produced mainly from natural gas; there are few steam crackers in Eastern Europe based on naphtha, while these countries have a deficit for gas oil; benzene, which in 1973 was produced in greater quantities than ethylene, is rarely obtained from steam cracking but more usually as a coke by-product, the complement being made up by catalytic reforming.

Although propylene produced by steam cracking should easily be sufficient to meet the demand, there seems to have been a large butadiene deficit. This was not likely made up through butane dehydrogenation.

In 1976, the petrochemical industry (including ammonia) used roughly 6 per cent of total hydrocarbon consumption (oil and gas) in the form of raw materials and fuels.

(e) Others

In 1976 the petrochemical industry was still in its infancy in almost all the rest of the world. 75 per cent of hydrocarbon consumption was devoted to the production of ammonia for use in agriculture.

Options in the choice of raw materials are sometimes contrastive: for example, ethylene is produced from naphtha in Brazil, and also in the Republic of Korea. In Mexico, on the other hand, where there are large reserves of gas, ethane is used as a raw material. Other basic petrochemicals are as yet produced in very limited quantities only. In 1976 the petrochemical industry (including ammonia) accounted for little more than 2 per cent of total hydrocarbon consumption (oil and gas).

2.2.3.2 Production of basic petrochemicals

There is a distinction between methanol (and ammonia) on one hand, which are produced independently, and olefins and aromatics on the other hand, which are often produced in conjunction.

Methanol

Methanol is synthesized from a $CO + 2H_2$ mixture. This gas is the most reduced form of hydrocarbon, since whatever their original chemical formulation, all hydrocarbons (and even coal) can be transformed to give carbon monoxide and hydrogen. The preparation of ammonia, which also involves this synthesis gas as an intermediate step, will therefore be subject to the same requirements as far as raw materials are concerned. Completely desulphurated light hydrocarbon feedstocks (C_1 to C_9) are required for the steam reforming route. So the heaviest feedstock which can be used will be naphtha.

Another route which is beginning to be used and which is likely to develop is partial oxydation. This method, much more costly in terms of investments, involves the processing of low quality, inexpensive feedstocks which thus compensate for the penalisation as far as investments and yields are concerned. Residual refinery fuel oils or coal could therefore be used for the production of methanol.

Olefins

Theoretically, all hydrocarbon feedstocks, with the exception of methane, can be used for the production of olefins. Paraffinic feedstocks, however, are the best suited. Olefins are produced in steam cracking plants. Paraffins and branched aromatics are split to give unsaturated hydrocarbons. The aromatic nuclei are scarcely affected. Thus the olefin yield is greater with light feedstocks but decreases as the feedstock becomes heavier, as can be seen from table 8. It will also be seen from this table that large quantities of BTX (benzene, toluene, xylenes) can be obtained from steam cracking. For naphtha, gas oil and higher, the choice of feedstock has little bearing on the BTX yield.

The use of heavier and heavier feedstocks will lead to ever-greater quantities of low-valorization by-products, ranging in fact from 18.6 per cent with an ethane feedstock to 45.8 per cent for atmospheric gas oil and even to 51 per cent for vacuum gas oil. Olefins can also be obtained as a by-product in FCC (fluid catalytic cracking) plants. Yields of ethylene and propylene are low, 0.7 and 1.7 per cent respectively, but in practice, only propylene is recovered.

Finally those countries such as the United States which do not manage to satisfy their butadiene requirements by means of the production from steam cracking plants, resort to butane dehydrogenation.

<u>Aromatics</u>

Steam cracking plants cannot satisfy the total BTX requirements, even in those countries where the raw material is limited to naphtha and gas oil (Western Europe and Japan). In addition, xylenes produced by steam cracking cannot be used for the production of orthoxylene and paraxylene since they contain 60 per cent ethylbenzene.

The catalytic reforming process is used to produce additional BTX. The feedstock for such plants, unlike that for steam cracking, should be as naphtenic as possible. The aromatic yields from steam cracking and catalytic reforming plants are more or less as indicated below, depending on the feedstock.

	Steam cracking gas oil	Catalytic reforming of Middle East crude
	(percentage)	
Benzene	6	6
Toluene	3	20
Xylenes	2	20

It can be seen that the BTX are not obtained in equal quantities and there is, in fact, a large surplus of toluene and a small surplus of xylenes over the demand. For this reason hydrodealkylation is used, allowing benzene to be derived from toluene, and possibly xylenes.

Finally, there is still another source of benzene, this being the preparation of blast furnace coke, from which benzene is obtained as a by-product. This source,which in the past accounts for almost 15 per cent of the benzene produced in Europe, is no longer expanding and can thus be expected to show a relative decline. Benzene and naphthalene are the last petrochemical products to be extracted in sizeable quantities from coal.

Table 8. Steam cracker yields - Basis : feed = 100

FEEDSTOCK	ETHANE	PROPANE	LIGHT NAPHTHA	FULL RANGE NAPHTHA			ATM. GAS OIL
				HIGH SEVERITY	MEDIUM SEVERITY	LOW SEVERITY	
Products :							
Ethylene	80.0	45.0	36.2	31.4	29.7	28.2	25.7
Propylene	1.4	14.5	16.7	11.9	14.1	15.4	13.3
Butadiene	0.0	2.7	4.3	4.3	4.5	4.7	4.2
BTX	0.0	3.4	8.8	14.3	12.3	10.5	11.0
Sub-total	81.4	65.6	66.0	61.9	60.6	58.8	54.2
C_4's	4.8 (1)	2.0 (2)	4.2 (2)	3.9 (2)	5.3 (2)	6.8 (2)	4.5 (2)
Gasoline	0.2	4.2 (3)	6.5 (3)	11.1 (3)	14.4 (3)	17.4 (3)	9.6 (3)
Sub-total	5.0	6.2	10.7	15.0	19.7	24.2	14.1
Fuel gas	13.6	28.2	20.0 (4)	17.6 (4)	16.0 (4)	14.5 (4)	11.7 (4)
Fuel oil	0.0	0.0	3.3	5.5	3.7	2.5	20.0
Sub-total	13.6	28.2	23.3	23.1	19.7	17.0	31.7
TOTAL FEED	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Olefins yields	81.4	62.2	57.2	47.6	48.3	48.3	43.2

(1) *C4 cut*
(2) *Without butadiene*
(3) *Without BTX*
(4) *Including Hydrogen*

2.2.3.3 Actual feedstocks options

There is a limited choice of raw materials for methanol, benzene, xylenes, propylene and butadiene, the last two being tied to ethylene production. Only the production of ethylene offers quite a degree of flexibility, since a range from ethane to gas oil can be used. Feedstocks used in steam cracking fall into six categories, including three major ones: ETHANE, liquefied petroleum gas, FULL RANGE NAPHTHA, kerosene, ATMOSPHERIC GAS OIL and vacuum gas oil.

The steam cracking of ethane yields no butadiene and very little propylene. The steam cracking of gas oil yields propylene and butadiene, but with no flexibility. Only the steam cracking of naphtha allows the proportions of ethylene/propylene to be adjusted though within fairly narrow limits, 2.6 for high severity steam cracking and 1.8 for low severity steam cracking. On account of these limits there is usually an excess of propylene over the demand, even in the United States where propylene obtained as a by-product of FCC (fluid catalytic cracking) compensates for the low steam cracker propylene production.

The United States phenomenon is due to the importance of ethane as a raw material. Another result is a deficit of butadiene, this being made up through butane (or butylene) dehydrogenation and also by imports from Western Europe. The lack of flexibility in butadiene production in the latter region in fact leads to a permanent surplus of butadiene due to the importance of naphtha as a raw material for ethylene. The availability of the various qualities of hydrocarbon required for the basic petrochemicals will therefore have to be examined.

(a) Petroleum fraction availability

The crude fractions most in demand for the production of basic petrochemicals (naphthas) are unfortunately present only in limited quantities in crude oil. In order to assess the availability on a regional and worldwide scale, the following will be taken as an "average" crude:

	Share by weight (percentage)	Availability 1976 (millions of tons)
LPG and pentane	5	142
Light fraction (naphtha)*	13	371
Middle fraction (kerosene and gas oil)	35	997
Heavy fraction (fuel oil)	47	1340
Total	100	2850

* Corresponding to the C6-160° C naphtha "heart cut". A larger cut C6-175°C suitable as steam-cracker feedstock represents 15.5 per cent on crude.

This structure does not match world energy requirements, particularly in the case of the United States. Part of the heavy fraction is therefore cracked to yield a light fraction.

In 1976 approximately 230 million tons of heavy fraction was changed into 167 million tons of light and middle fraction by FCC, and approximately 40 million tons of heavy fraction was changed into 35 million tons of light fraction and middle fraction by hydrocracking. Only the latter method produces a feedstock which can be used in petrochemistry, and only for the manufacture of BTX. As aromatics are also very much in demand for gasolines, only one or two large, combined energy/petrochemical refineries in the United States can use ex-hydrocracking naphtha to produce BTX. At present, therefore, the flexibility presented by world refining capacity for the supply of petrochemical feedstocks is fairly limited:

	(percentage)
LPG	1.5 to 2.2
Pentane	3.5
Light fraction	13.0 to 14.2 (extension to 16.7)
Middle fraction	35 or less (32.5)

(b) Gas availability

There are two distinct sources of natural gas: (i) gas found in natural gas fields and (ii) gas associated with oil production.

(i) The first is usually rich in methane, contains a greater or lesser quantity of inert gases and often only a small proportion of higher hydrocarbons. The extraction of the higher hydrocarbons for olefin production is usually uneconomical. These gases are therefore mainly suited to energy needs and, as far as petrochemistry is concerned, to the production of methanol and ammonia. There are some natural gases, however, from which higher hydrocarbons can be economically recovered. One example is Hassi R'mel gas (Algeria) which has the following composition: Methane 79.6, inert gases 5.3 and other hydrocarbons 15.1 per cent respectively. The operation is facilitated by the fact that this gas is sold for export in the form of liquefied gas. The various steps in liquefaction make recovery very economical but it is, however, limited, because sufficient higher hydrocarbons have to be left in the gas for it to have a commercial calorific value (1000 BTU/SCF).

(ii) The gas associated with oil production, however, offers more interesting prospects in terms of raw materials for the petrochemical industry. These associated gases produced at an average rate of 800 SCF/BBl of oil, i.e. 166 m^3/ton of oil, often contain a good proportion of ethane, propane, butane and sometimes natural gasoline. Some examples are given in table 9 and from these the potential availability of NGL (natural gas liquids) associated with crude oil production can be assessed. Up till the oil price increase, extraction of NGL was carried on in the United States in particular, as can be seen from table 10. The main reason for this was the structure of energy prices in the United States, where gas was two or three times cheaper for the same calorific value, than oil. It was therefore economical to extract the maximum possible quantity of liquid products. The ethane fraction was entirely used as a feedstock for steam cracking, a further 10 per cent of the requirements of the latter being supplied by ethane produced in refineries. Part of the propane fraction was also used as a feedstock for steam cracking, but as the amount of ex-refinery propane available was roughly equivalent, there was a large excess of propane over the requirements of the petrochemical industry.

The incentive to recover NGL spread all over the world following the oil price increase at the end of 1973. This phenomenon was particularly pronounced among the oil producers of the Middle East. The cost of liquefaction plants and fleets of methane tankers, made necessary by the great distances from gas-consuming areas, led to Middle East gas having a valorization three or four times lower than oil. Emphasis is now placed, therefore, on extracting the maximum of liquid products from associated gas. Associated gases are usually collected and sent to a NGL plant where propane, butane and natural gasoline are extracted. Ethane is extracted only if it is to be used as a feedstock for steam cracking.

The gas producing countries have all launched or already set up large gas-collection programmes. Saudi Arabia will naturally, in view of the magnitude of the country's oil production and the richness of the associated gases, supply the greatest quantities of LPG since 15.3 million tons should be produced in 1985. By that time other producing countries should be in a position to supply large quantities of LPG, e.g. Iran 7.5 million tons; Abu Dhabi 4.5 million; Iraq 3 million; Kuwait 3 million and Qatar 1 million. Production of LPG in the Middle East will therefore rise from 5 million tons in 1974 to 35 million tons by 1985. Other areas will also emerge as producers of LPG from associated gas: the North Sea 6 million; North Africa 4 million (partly from natural gas). Quantities such as these will result in an export surplus of more than 20 million tons towards 1985. This surplus could present opportunities for the petrochemical industry.

Table 9. Typical composition of associated natural gases
(mol. percent)

	Venezuela	Saudi Arabia	Nigeria	Iran	No.Sea Ekofisk	Kuwait	Abu Dhabi	Libyan Arab Jamahiriya
Nitrogen	0.4	0.3	0.1	-	0.5	-	0.2	-
Carbon dioxide	0.2	11.1	1.0	0.3	1.6	1.6	4.4	-
Hydrogen sulphide	-	2.7	-	-	-	0.1	1.7	-
Methane	85	48.1	83.6	74.9	85.9	78.2	76.4	66.8
Ethane	8	18.6	6.8	13.0	8.1	12.6	8.1	19.4
Propane	4.4	11.7	4.5	7.2	2.7	5.1	4.7	9.1
Butane	2	4.6	2.6	3.1	0.9	0.6	2.6	3.5
Natural gasoline	-	2.9	1.4	1.5	0.3	0.8	1.8	1.2
Helium	-	-	-	-	-	-	-	-

Table 10. Estimated world natural gas liquids, NGL, production, 1973

GEOGRAPHICAL AREA	PRODUCTION millions bbls.	PERCENT
NORTH AMERICA	781.2	75.2
U.S.S.R.	79	7.6
MIDDLE EAST	71.3	6.9
SOUTH AMERICA	53.3	5.1
AFRICA	25.2	2.4
AUSTRALIA	17.1	1.6
WESTERN EUROPE	10.4	1.0
FAR EAST	1.0	0.1
EASTERN EUROPE	0.9	0.1

(c) Restrictions imposed by hydrocarbon prices

The minor part taken by petrochemistry in the consumption of hydrocarbons means that this industry is subject to the scale of prices determined by energy uses. Considering the evolution of Rotterdam spot prices between mid-1974 and mid-1976, an important development appears: in 1974 the price margin between heavy and light products was fairly narrow. The considerable increase in the price of light products led to an appreciable widening of the margin. As will be seen later on, future tensions on light products will give rise to a price structure fairly similar to that existing in mid 1976. As only limited quantities are involved on the Rotterdam market, mid-1976 prices are compared below with average prices current on European domestic markets as a whole at the same period.

	Mid 1976 prices	
	Rotterdam $/ton	European average $/ton
Premium	163	175
Regular	143	165
Naphtha	134	150
Kerosene	119	138
Gas oil	105	121
Fuel oil (1,5)	70	77

The price margin between naphtha and gas oil is much greater than the break-even point of 15 $/ton for the preparation of ethylene. The margin is in fact 29 $/ton in Rotterdam and the same for the European average. This will, therefore, be an incentive to petrochemical manufacturers to choose gas oil rather than naphtha whenever possible and, at least for flexible crackers, during spring and summer when the gas oil market is depressed.

Another of the main basic petrochemicals, methanol, seems to be fairly flexible in respect to the corresponding raw material, since a range from methane to naphtha can be used; but as can be seen, the respective prices of the feedstocks (valorized in this production at more or less the calorific value) favour the use of natural gas.

	Price in $/ton	Price in $/million BTU
Naphtha	135-150	3.00 - 3.35
LPG	120-140	2.50 - 2.92
Imported natural gas		2.40 - 2.80
Domestic gas		1.60 - 2.40 or less

These conditions, which are valid for the European market, are also valid for the Japanese market, although no locally produced gas is available for the latter. In all the other gas-producing countries, the interest in natural gas is even greater for gas-rich countries such as Algeria, Saudi Arabia, the USSR etc. could become major exporters of methanol. Methanol, in fact, has the advantage of being easy to transport in conventional tankers whereas the corresponding raw material is very costly to transport in refrigerated tankers.

To sum up, price levels will favour natural gas as a raw material for methanol production, and gas oil as a raw material for ethylene production. LPG may eventually become a partial alternative to gas oil since the anticipated excess supply worldwide, could result in an appreciable drop in prices.

2.2.3.4 Availability of hydrocarbons

Known reserves of gas, oil and coal are shown in table 11. By the 1990s coal might have regained some of its former status as a source for petrochemicals. In the Federal Republic of Germany, for example, production of primary chemicals from coal reached a peak of 1 million tons in 1960.

Table 11. Reserves and fossil fuel resources in 1976
(millions of TOE)

Reserves	Natural gas	Crude oil	Coal	Total
NORTH AMERICA	7 904	5 116	124 880	137 900
E.E.C.	3 228	2 440	30 674	36 342
Others WESTERN EUROPE	808	913	1 340	3 061
JAPAN	60	4	687	751
EASTERN EUROPE	26 985	11 109	202 840	240 934
AFRICA	5 989	8 263	8 426	22 678
LATIN AMERICA	2 587	4 033 (4)	1 713	8 339
MIDDLE EAST	16 982	50 160	200	67 342
CHINA	716	2 729	67 533	70 978
AUSTRALIA-NEW ZEALAND	1 102	214	16 347	17 663
SOUTH EAST ASIA	2 270	2 619	8 846	13 735
WORLD (1)	68 631	87 606	463 486	619 723
World resources (2) Range of estimates	(171 to 344) $\times 10^3$	(184 to 1840) $\times 10^3$	(720 to 3600) $\times 10^3$	(1075 to 5764) $\times 10^3$
Expected value	300 000	300 000 (3)	2 200 000	2 800 000

(1) Proved and recoverable reserves at 1976 economic conditions

(2) Known, probable and undiscovered

(3) Oil recovered from tar sands and shale oil could double this value.

(4) Venezuela oil belt and large extension of Mexico oil reserves (claimed by Pemex) are not included in this figure.

The part taken by coal, on the other hand, has shown a constant decline: 71 per cent in 1958; 56 per cent in 1960; 28 per cent in 1965; 9 per cent in 1970 and 5 per cent in 1973. This situation points out that the proportions of known reserves do not correspond to consumption since coal, which accounts for 3/4 of all reserves, supplies only 1/4 of the consumption. Reserves are, in fact, as follows (as of 1976):

68,631	million TOE	of natural gas	(11.1 %)
87,606	" "	of oil	(14.1 %)
463,486	" "	of coal	(74.8 %)

Compared with these reserves, world energy consumption in 1976 was as follows:

1,143	million TOE	of natural gas	
2,879	" "	of oil	
1,941	" "	of coal	
470	" "	of electricity	(hydroelectricity and nuclear electricity)
6,433	" "		

The part taken by petrochemistry, (including ammonia, for which about 60 million TOE (*) of hydrocarbons were consumed in 1976) in the total consumption, is very small, amounting to approximately 250 million TOE or: 3.9 per cent of total energy consumption and 6.2 per cent of hydrocarbon consumption. Out of the 250 million TOE, only 200 were used as raw materials for the petrochemical industry, the rest being used as fuel. Known reserves of hydrocarbons would therefore be equivalent to more than 600 years of consumption by the petrochemical industry on the basis of the 1976 figure.

However, the part taken by the energy sector is such that sectoral and/or geographical problems of supply can be expected in the 1980s. In fact, the energy industry requires large amounts of capital as well as a highly complex infrastructure of production extending to consumer level. The replacement of oil by other forms of energy will therefore be a very slow process, all the more so since despite the sharp rise in oil prices in 1973, alternative forms of energy are rarely in a position to compete at the moment. Annex 2 gives the share of the different energy sources in world energy consumption.

(*) From this amount, only 8 per cent was used for petrochemical products.

Consequently the part played by oil in meeting energy requirements, which increased from 1962 to 1973 should, by 1985, have stabilized at a level slightly below that of 1973 (between 44 and 46 per cent). This result, which seems surprising in view of the 1973 oil crisis, can be attributed to 5 factors:

- The lack of flexibility in the energy sector, mentioned above.
- A slight decline in the part played by gas, due to the fairly swift replacement of this fuel in the United States in order to avoid exhausting reserves. This decline conceals fairly rapid expansion in the rest of the world (6.8 per cent per year between 1974 and 1985). However, since the United States accounted for 49 per cent of world gas consumption in 1974, developments in the United States easily counterbalance those in the rest of the world.
- A slight decline on the part of coal which, in countries with a planned economy (Eastern Europe and China), is facing increasing competition from oil and gas. In these countries 52 per cent of all energy needs were still met by coal.
- The increase in energy consumption in countries other than the OECD and planned economy countries concerns oil first and foremost and, to a lesser extent, gas. These countries have, in fact, relatively little coal and for various reasons cannot place much reliance on nuclear energy in the immediate future.
- The growth of nuclear energy, particularly in the OECD countries, more or less makes up for the slight decline of gas and coal.

Although the price of energy today acts as a brake on its growth (4.2 per cent per year from 1973 to 1985 compared with 5.6 per cent per year from 1962 to 1973), reserves of hydrocarbons and particularly oil are being fairly rapidly exhausted. Thus, out of the reserves known today, shown in table 11, there would remain by the beginning of 1985 only:

56,600 million TOE of natural gas, equivalent to 33 years' consumption at the 1985 rate;

58,200 million TOE of oil, equivalent to 13 years' consumption at the 1985 rate;

446,000 million TOE of coal, equivalent to 168 years' consumption at the 1985 rate.

As far as natural gas and oil are concerned, the problem from now onwards will be the optimum manangement of resources. The position with regard to oil is more worrying than that of natural gas, bearing in mind

Table 12. Utilities consumption
(per ton of product)

	Fuel 10^6 Kcal/ton	Electricity Kwh/ton	Steam ton/ton	Cooling water circulation (ΔT = 10° C) (4) m^3 /t
ETHYLENE-PROPYLENE (1)) BUTADIENE-BENZENE)	0.3 (5)	156	-	170
ETHYLENE (2)	0.2 (5)	120	-	100
BENZENE-TOLUENE-XYLENES (3)	2.5	60	1.6	-
METHANOL	-	40	-	230
VINYL CHLORIDE	1.1	140	2.3	300
STYRENE	1.4	110	4.2	50
CAPROLACTAM	0.5	380	13.5	1500
DMT	1.6	700	3.0	550
TPA	1.8	650	-	400
ADIPIC ACID	-	200	-	300
HEXAMETHYLENE DIAMINE	-	150	-	50
ETHYLENE OXIDE	-	650	-	360
ACRYLONITRITE	-	400	-	5500
PVC	-	230	0.9	50
HDPE	-	750	2.8	300
LDPE	-	1300	-	300
POLYPROPYLENE	-	840	3.2	330
POLYSTYRENE	-	410	0.5	50
ALKYLBENZENE	-	50	0.1	50
POLYESTER FIBRES	-	2000	-	200
NYLON FIBRES	-	2800	-	230
ACRYLIC FIBRES	-	1850	2.0	870
POLYBUTADIENE	-	250	-	1000
SBR	-	450	3.5	200

(1) Per ton of ethylene. Based on naphtha/gas oil steam cracking
(2) Ethane steam cracking
(3) Per ton of aromatics
(4) The corresponding electricity requirements are included in electricity consumption
(5) Excluding raw material used as fuel

that new finds between the end of 1966 and the end of 1976 totalled 58,700 million TOE of oil equivalent to 2.4 times the consumption during the same period and 49,000 million TOE of gas, equivalent to 4.9 times the consumption of oil.

This problem has become more pronounced over the last six years since oil finds have done little more than balance consumption (finds = 1.25 times consumption), while finds of gas have remained more or less at the same level (4.5 instead of 4.9).

The part played by petrochemistry in this optimum management will be minimal, considering the minor part it plays in the demand. However, the options taken in the energy field will open up new perspectives for petrochemistry according to the feedstock options discussed in 2.2.3.3.

2.2.3.5 Energy requirements

The energy requirements for fuel and electricity vary widely according to products and processes. Nevertheless, table 12 presents typical utilities consumption per ton of product for 24 main petrochemicals.

2.2.4 Investments in the petrochemical industry

The petrochemical industry is a capital-intensive industry that requires very high investments. In the developed countries large sums of money have been devoted to the construction of petrochemical plants. For example, in 1973 and 1974, the United States and Japan invested 2,500 and 1,950 million US dollars respectively in their local petrochemical industries. Investments by European countries, although considerable, are lower: between 1970 and 1975 the Federal Republic of Germany invested 1,504 million dollars in their local petrochemical industry, France 1,329 million, the United Kingdom 1,322 million and Italy approximately 1,200 million. Table 13. gives investment estimates in the petrochemical industry for some developed regions.

Table 13. Investments in the petrochemical industry (*)
(millions of US$)

	1965	1970	1973	1974
United States	1500	1500	1400	1100
Western Europe	500	2000	3000	2000
Japan	250	300	450	900

(*) Basic, intermediate and end-products including plastics, synthetic fibres, synthetic rubber, detergents, excluding fertilizers.

2.2.4.1 Current situation

Construction costs for petrochemical plants have risen sharply in the last few years and these changing costs can be expressed by construction cost indices. The construction cost indices established by BEICIP for petrochemicals are given in table 14. These indices are arrived at by breaking down the construction cost of petrochemical plants and following the development of each of the constituent elements of the cost, taking into account both official indices and observations based on actual construction.

The rise in construction costs was very steep in 1973/74: 20.7 per cent according to the indices given in table 14 compared with a rise of about 12 per cent from 1972 to 1973 and a yearly average of 8 per cent over the five previous years.

Table 14. Construction cost indexes

Year (average)	Index
1960	100
1966	132
1967	137.6
1968	145.9
1969	155.6
1970	174.9
1971	188.9
1972	202.2
1973	227
1974	274
1975	305.8
1976	340.6

The rise over the period 1972-74 is higher than the rate of inflation. This large increase can be considered as being only partly a direct result of the rising cost of energy; the effect of the cost of energy on the manufacturing cost of some building materials is shown in table 15.:

Table 15. Impact of energy in the production of some building materials

	Energy consumed for production (kWh/ton	Share of energy in the cost, 1974 (percentage)
Steel	3,600	4
Copper	16,000	3
Aluminium	1,300	23
Concrete	3,000	15

It is significant for some materials but it is out of proportion with the increase in investments for petrochemical plants leads to the conclusion that the major part of the increase which occurred from 1973-74 is more an indirect result of the rise in the cost of energy rather than a direct result. Since 1972, salaries have risen at the same pace as inflation; in addition, the cost of some basic items of equipment such as pipes and sheets has risen sharply. For example, between mid-1973 and the end of 1974, the price of large diameter pipes rose by approximately 270 per cent, that of carbon steel sheets by 45 per cent, that of stainless steel sheets by 25 per cent, that of bloom steel by 40 per cent and that of phosphorous cast iron by 80 per cent. These increases were caused principally by the supply and demand situation. Many companies, concerned about the rising cost and the supply of energy, bought equipment and plants in large quantities; this was also a time when major installations were under construction in certain sectors of industry, particularly fertilizers. From 1974 onwards, the demand fell away, the price of some materials also dropped and the average cost of construction rose by only 11.5 per cent between 1974 and 1975, a smaller increase than between 1972 and 1973. The rate of growth measured between 1976 and 1975 was similar. It is expected that in the future, the relationship between the supply and demand for plant and equipment will be more balanced and the index for petrochemical plants will rise at the same rate as inflation. It must be stressed however, that even if rates of increase similar to those in the 1972-75 period are not experienced again, their effect remains. A new petrochemical plant built in 1977 costs approximately twice as much as an identical plant built in 1970. Furthermore, extra investment will be required to comply with increasingly strict standards in connection with anti-pollution regulations.

These increasingly high investments, which correspond to a given output, would have the following consequences:

- major projects would be undertaken by joint ventures, constituted either by several companies or by governments and companies;

- there will be less reinvestment of profits, but more contribution from shareholders and more external financing through long-term loans.

- the oil-producing countries, who have considerably increased their financial resources, will be better placed to resolve these problems;

- because of the very considerable rise in fixed costs, production costs will be higher for new plants than for those built before 1974. Newcomers on a given market will therefore have a handicap to overcome, whereas those

Table 16. Estimation of installed cost for petrochemical plants

(Battery limits licence fees included - 1977 European conditions)

Product	Capacity range 10^3 t/year	Installed cost range $/ton of product	Process- remarks
Ethylene	200 - 400	650 - 500	Naphtha steam cracking
Propylene	100 - 200	(1) (1)	butadiene extraction
Butadiene	32 - 64		benzene extraction
Benzene	58 - 116		toluene hydrodealkilation
Ethylene	150 - 300	500 - 380	Ethane steam cracking
Benzene	40 - 66		
O.xylene	38 - 63	520 - 430	Catalytic reforming aromatics extraction
P.Xylene	100 - 165	(2) (2)	
Methanol	200 - 500	180 - 150	
Ethylene oxide	60 - 100	340 - 370	Oxygen basic process
Vinylchloride	100 - 250	370 - 250	Oxychloration including
Styrene	100 - 250	400 - 270	ethylbenzene production
Acrylonitrile	60 - 150	750 - 520	
Caprolactam	50 - 150	1800 -1150	
DMT	50 - 80	950 - 830	
TPA	70 - 100	880 - 750	Amoco process
Adipic acid	100 - 150	600 - 500	
Hexamethylene diamine	30 - 50	500 - 400	
Low-density polyethylene	50 - 150	800 - 600	
High-density polyethylene	50 - 100	1000 - 800	
Polyvinyl chloride	50 - 100	400 - 340	Suspension process
Polypropylene	50 - 100	900 - 750	
Polystyrene	30 - 80	700 - 460	
Alkylbenzene	20 - 40	200 - 170	
Polybutadiene	30 - 50	600 - 530	
SBR	30 - 80	300 - 250	
Nylon fibres (yarns)	5 - 12	2300 -1500	Caprolactam polymerization and spinning
Acrylic fibros (staples)	10 - 15	1450 -1400	Acrylonitrile polymerization and spinning
Polyester fibres (staples and yarns)	10 - 15	1450	TPA polymerization and spinning

(1) Per ton of ethylene (2) Per ton of aromatics

companies which already have large installations will be able to modify their prices as a greater proportion of the requirements is supplied by the new plants.

2.2.4.2 Ranges of investment cost for petrochemical plants

Estimated ranges of investment costs per ton of product for 27 major petrochemicals are given in table 16.

2.2.5 Petrochemical production costs

In practice, production costs vary greatly depending on the product, the process used, plant sizes, the price of raw materials and energy, manpower and total investment costs, the year in which the plant was built and the place where it was located.

The first factors are obvious and require no comments, but the importance of the last two is not always realized. Inflation, which has doubled plant costs in the last 6 years, and the erection of plants in locations with insufficient infrastructure, have made the attempt to produce generalized cost estimates a hazardous proposition.

To circumvent this difficulty and as a reference guide, we shall present typical production costs for conditions in Europe by mid-1977 for 19 major petrochemicals. Later on, with appropriate cost translation factors, those production costs may be estimated for any particular location. However, they will represent only an average. The real cost will depend on the knowledge, resources and staying power of the buyer.

2.2.5.1 Production cost of olefins

Table 17 presents the typical production costs of a naphtha-based 300,000 MT/year ethylene plant.

Table 17. Olefins typical production cost (mid-1977)

Process:	**Naphtha steam cracking**
Capacity (tons/year ethylene)	300,000
Fixed capital cost (million US$)	184.3

(cont'd)

Table 17. (cont'd)

Production cost (million US$)	
Raw materials [a]	129.6
Utilities	2.2
Catalysts and chemicals	1.0
Manpower	1.1
Other charges	12.0
Amortization and return	35.0
Total	180.9

Products prices and sales [b]

	Unit price ($/ton)	Sales (million $/year)
Ethylene	320	96.0
Propylene	280	30.6
Butadiene	370	14.1
LPG	130	7.3
Gasoline	168	32.9
Total		180.9

a/ Raw material naphtha = 960,000 ton/year

b/ Products: Ethylene - 300,000 ton/year
Propylene - 139,000 "
Butadiene - 38,200 "
Propane - 12,000 "
Butane - 44,200 "
Gasoline - 195,000 "

2.2.5.2 Production cost of aromatics

Table 18 presents the typical production costs of a naphtha-based 400,000 MT/year BTX plant. The materials balance of the plant showing raw materials feed and products output is presented in figure 2.

FIGURE 2

AROMATICS PRODUCTION

MATERIAL BALANCE

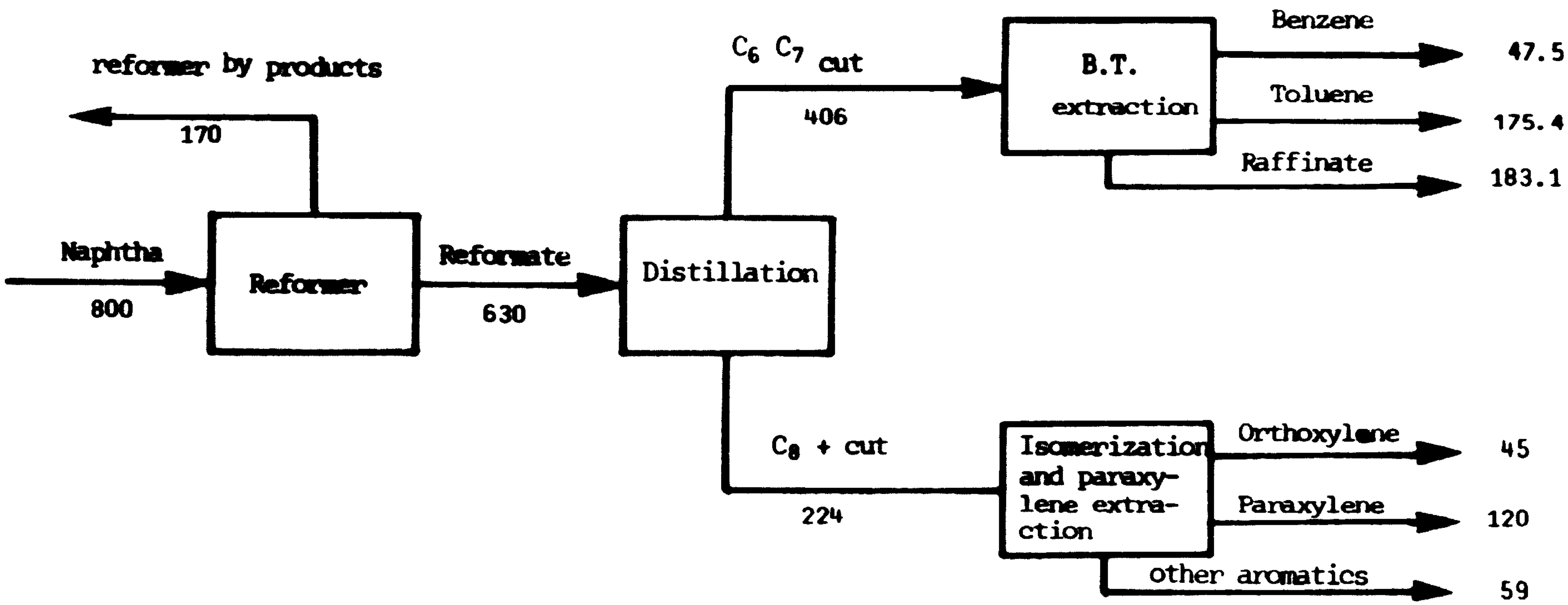


Table 18. Aromatics typical production costs (mid-1977

Fixed capital cost (million $)		106.0
Capacity (tons/year B-X)		215.0
Production cost (million $/year)		
Raw material (at 135 $/ton)		108.0
Utilities		11.9
Catalysts and chemicals		1.3
Manpower		1.3
Other charges		6.9
Amortization and return		20.5
Total		149.9
Products prices and sales		
	Unit price ($/ton)	Sales (million $/year)
Reformer by products	125	21.2
Raffinate	110	20.1
Fuel gas	75	1.1
Aromatics by-products	135	6.0
Benzene	230	10.9
Toluene	180	31.5
O.xylene	285	12.8
P.xylene	385	46.2
Total		149.8

2.2.5.3 Production of major intermediates and end petrochemicals

Table 19 presents the typical production costs of 17 major intermediates and end petrochemicals for average plant sizes.

Table 19. **PETROCHEMICALS TYPICAL PRODUCTION COSTS**

	Capacity 10³t/year	Fixed capital cost MM US$	MANUFACTURING COST 10³US$/year							
			Raw materials	Utilities	Catalysts Chemicals	Manpower	Other charges	Amortization and return	Total manufacturing cost	Product cost ($/ton)
Methanol	200	44	21 120	300	300	750	2 860	8 360	33 690	168
Vinyl chloride	150	50	37 560	4 515	1 900	1 065	3 250	9 500	57 790	385
Styrene	150	55	44 930	6 390	1 460	975	3 575	10 450	67 780	452
Caprolactam	80	120	18 400	9 624	12 000	1 215	7 800	22 800	71 839	764*
DMT	60	60	16 170	3 610	330	1 065	3 900	11 400	36 475	608
TPA	80	78	20 636	5 700	400	1 065	5 070	14 820	47 691	596
Ethylene oxide	80	27	25 600	1 328	200	750	1 755	5 130	34 763	435
Acrylonitrile	100	71	25 960	6 300	3 500	1 110	4 615	13 490	54 975	550
PVC	70	30	28 030	820	300	2 070	1 950	5 700	38 870	555
Hd polyethylene	70	65	23 700	2 620	1 000	1 395	4 225	12 350	45 290	647
Ld polyethylene	110	86	36 600	3 190	1 920	1 395	5 590	16 340	65 035	591
Polystyrene	50	30	22 600	620	200	1 920	1 950	5 700	32 990	660
Polyester fibres	12	20	8 894	50	400	3 750	1 300	3 180	17 574	1 460
Nylon fibres	10	25	8 404	59	300	4 500	1 620	4 750	19 633	1 964
Acrylic fibres	10	16	5 610	59	400	3 000	1 040	3 040	13 149	1 315
Polybutadiene	40	25	14 800	1 368	1 500	1 575	1 625	4 750	25 618	640
SBR	60	18	26 380	2 232	1 700	1 875	1 170	3 420	36 777	613

* Taking into consideration a by-products valorization amounting to 10.7 million $ year.

2.2.5.4 Changes in the production cost structure of petrochemicals

Among the various factors that are pushing production costs upwards, the more important is the price increase in oil products used as feedstock and energy. This situation affects petrochemicals in varying degrees. Figure 3 illustrates the effect of petroleum price rises on olefins and their main derivatives. This shows that the further down the stream, the lesser are the impacts of feedstock cost increases. Therefore in order to appraise the effects of the quadrupling of oil prices on petrochemicals in 1973, the analysis will be concentrated on the production of ethylene.

Table 20 gives detailed production costs for a 300,000 MT year naphtha-based ethylene plant in conditions prevailing in 1972 and 1977, before and after the large oil price hike. It can be seen that the cost of raw materials grew 6.13 times and the total manufacturing cost increased 3.6 times from 1972 conditions to those of 1977. Furthermore, the plant built in 1972 will have a 9 per cent total manufacturing cost advantage over a similar plant built in 1977.

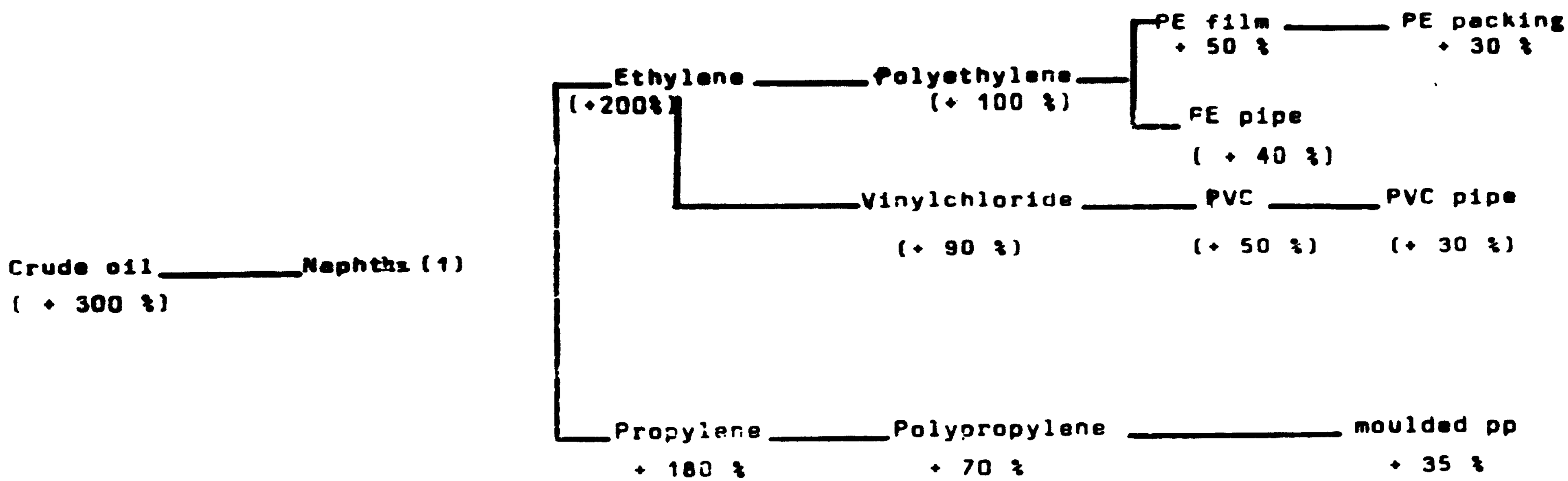
This shows the great change that has taken place in recent years in the production cost structure of petrochemicals, especially in ethylene. There has been a considerable decline in the fixed costs of total manufactured cost from 39.5 per cent in 1972 to 19.3 per cent in 1977. Conversely, the variable costs share mainly comprising raw materials and utilities rose from 44.4 per cent in 1972 to 72.9 per cent in 1977. Moreover, the variable cost share in a pre-1973 plant was 79.5 per cent in 1977. Since most developing countries are not planning ethylene capacities of 300,000 MT/year, table 21 was prepared to present a comparative analysis for 1972 and 1977 of two plant sizes, 300,000 MT/year and 150,00 MT/year, since the latter capacity is within reach of several developing countries. The changes in the production cost structure of the smaller plant are in line with that shown for the larger facility.

In 1972 the doubling of ethylene capacity would lead to a 17 per cent reduction in production costs. In 1977 the cost reduction would be only 8 per cent. Therefore the developing countries that can control their feedstock prices may set up a smaller capacity basic plant and still remain competitive with the larger plants. Unfortunately not all developing countries are able to realise this advantage for quite often incremental plant construction costs and infrastructure expenses charged to the plant may off-set a part of the variable costs advantage.

Figure 3.

Impact of the crude oil cost increases on petrochemical products cost between June 1973 and June 1974.

(Source: NEDO, Increased cost of energy - Implication for UK industry)



(1) Naphtha price is dependant on the offer and demand situation: it can vary up to some extent, independently from the crude price. During the considered period, the naphtha price increase amounted to 400 %.

Table 20. Increase in olefins manufacturing cost

		Naphtha Steam cracking	Naphtha Steam cracking	Naphtha Steam cracking
Capacity tons/y ethylene		300 000	300 000	300 000
Economic conditions		Prevailing in 1972	Prevailing in 1977	Prevailing in 1977. Unit erected in 1972. Investment in 1972
Fixed capital cost MM $		104	184.3	104
Manufacturing cost MM $				
Raw materials		21 150	129 800	129 800
Utilities		1 080	2 200	2 200
Catalysts & chemicals		620	1 000	1 000
Manpower		700	1 100	1 100
Other charges a/		6 750	12 000	12 000
Amortization & return		19 800	35 000	19 800
Total manufacturing cost		50 100	180 900	165 700
Products prices & sales	10^3t/y	$/ton	$/ton	$/ton
Ethylene	300	90	315 b/	280 b/
Propylene	139	55	193 b/	172
Butadiene	38.2	150	520 b/	465
Propane LPG	12	32	130	130
Butane LPG	44.2	32	130	130
Gasoline	195.8	45	168	168

a/ Maintenance, overhead expenses, insurance, general facilities, interest on working capital.

b/ Ratio of olefins prices have been kept constant in the table. In fact, ratio between ethylene and propylene prices is slightly decreasing from 1972 (1.6) to 1977 (1.4). Ratio of ethylene versus butadiene prices is now close to 0.9. Olefins prices corresponding to 1977 conditions, considering these present ratios, would be as follows:

Ethylene	320 $/ton
Propylene	220 $/ton
Butadiene	370 $/ton

Table 21. Steam cracking economics
(European conditions)

	Conditions prevailing in 1972		Conditions prevailing in 1977	
	Naphtha steam cracking	Naphtha steam cracking	Naphtha steam cracking	Naphtha steam cracking
Capacity t/y ethylene	300 000	150 000	300 000	150 000
Fixed capital cost MM US$	104	67	184.3	118
Production cost MM US$				
Raw materials	21 150	10 570	129 600	64 000
Utilities	1 080	540	2 200	1 100
Catalysts-chemicals	620	310	1 000	500
Manpower	700	700	1 100	1 100
Other charges	6 750	4 350	12 000	7 700
Amortization & return	19 800	12 750	35 000	22 400
Total	50 100	29 220	180 900	97 600
Products prices $/ton				
Ethylene	90	108	320	340
Propylene	55	66	220	230
Butadieno	150	186	370	390
LPG	32	32	130	130
Gasoline	45	45	168	168

2.2.6 Manpower structure

Although personnel requirements vary widely according to products, plant size, region and degree of vertical integration in complexes, an attempt is made at estimating the regional manpower structure at the end of 1976. Table 22 shows the total operating personnel required for typical plant capacity ranges. This manpower does not include the requirements of the utility plants, general units and maintenance. When those are taken into account, total personnel requirements would average twice the figure given in table 22, with the exception of the synthetic fibres plants that require about 130 per cent of the operating personnel figures given in that table

In general terms, administrative personnel is estimated at 10 per cent of technical manpower requirements, while marketing personnel is estimated at about 5 per cent of technical manpower. In addition, considering the investment pattern reflected in the plant capacity figures and the strong correlations between investment and manpower, an estimation,by region, of active manpower employed in the petrochemical industry was evolved. Further details on this matter are given in Appendix E.

Table 23 gives the estimated manpower structure of the petrochemical industry by region. It can be seen from it that the developing countries account for about 13 per cent of total world petrochemical manpower, while their share in world petrochemical plant capacity was below 8 per cent in 1977. This fact shows the emphasis on synthetic fibres production that is more labour-intensive than the rest of the industry.

Table 22. Total operating manpower

Production	Capacity range 10^3 tons/year	Operating manpower (Average) men
Ethylene	200 - 400	90
Propylene	90 - 180	
Butadiene	25 - 50	
Ethylene	100 - 200	60
Benzene	30 - 50	70
O.xylene	38 - 63	
P.xylene	100 - 165	
Methanol	200 - 500	50
Ethylene oxide	60 - 100	50
Vinylchloride	100 - 250	71
Styrene	100 - 250	65
Acrylonitrile	60 - 150	74
Caprolactam	50 - 150	81
DMT	50 - 80	71
TPA	70 - 100	71
Adipic acid	100 - 150	55
Hexamethylene diamine	30 - 90	25
Low-density polyethylene	50 - 150	93
High-density polyethylene	50 - 100	93
Polyvinylchloride	50 - 100	138
Polypropylene	50 - 100	93
Polystyrene	30 - 80	128
Polybutadiene	30 - 50	105
SBR	30 - 80	125
Nylon fibres (yarns)	5 - 12	300
Acrylic fibres (staples)	10 - 15	200
Polyester fibres (yarns and staples)	10 - 15	250

Table 23. Estimated manpower structure, by region (end-1976)
(thousands of men)

	Technical personnel	Administrative personnel	Marketing personnel	Total manpower	World total (percentage)
Western Europe	164.3	16.4	8.2	188.9	30.1
Eastern Europe	63.5	6.3	3.2	73.0	11.6
North America	167.8	16.8	8.4	193.0	30.8
Latin America	25.4	2.7	1.2	29.3	4.7
Africa	2.9	0.3	0.2	3.4	0.5
Asia					
Middle East	4.4	0.5	0.2	5.1	0.8
East Asia	27.5	2.9	1.1	31.5	5.0
Japan	75.8	7.6	3.8	87.2	13.9
South Asia	11.4	1.2	0.5	13.1	2.1
Pacific area	2.6	0.3	0.2	3.1	0.5
World total	545.6	55.0	27.0	627.6	100

2.2.7 Recent developments and future trends in the petrochemical industry

Over the past few years some important developments have taken place in the environment of the petrochemical industry that are markedly affecting it. They include a general economic slow-down in industrialised countries, the steep rise of energy costs, a major increase in plant construction costs, a growing awareness of pollution problems and the introduction of environmental regulations. Their impacts on this industry are given below:

(a) Increased production costs

Three factors have been affecting the costs of the petrochemical industry:

(i) The rise in the cost of energy, particularly oil, led to a considerable rise in feedstock costs and utilities that were translated in higher production costs of petrochemicals, which in turn decreasingly affected the products as they move down stream. This, in turn, is leading the industry to a resource conservation policy in order to more efficiently use the raw materials and the energy.

(ii) Rising construction costs and stringent antipollution regulations have resulted in substantial investment cost increases.

(iii) The current technological slow-down has, so far, not enabled the industry to push the production costs down as was customary during 1950-70. However, some important signs of a technological upswing are starting to appear that may help to slow down the rising production costs.

The effect of these factors, particularly the increase in the price of raw materials, has been to increase olefin production costs by 360 per cent between 1972 and 1977 under West European conditions as shown in section 2.2.5.4.

(b) Slower market growth

The general decline in industrial activity and the steep rise in production costs have brought about a slowing down of market growth. Nevertheless, the set-back of petrochemicals demand has been limited due to the simultaneous and in many cases higher cost increases of the competitive natural products as shown in annex 3. Furthermore, as petrochemical products are now increasingly accounting for toxicological and environmental consequences as well, all these factors are leading to changing demand patterns for particular products. Moreover, alternative products and/or technological routes may supersede some existing products, mainly intermediate petrochemicals. This trend reflects the fact that end petrochemicals are primarily performance chemicals required for their physical properties rather than for their chemical reactivity.

(c) Changes in the production cost structure

The sharp increase in the cost of energy has brought about a major change in the production cost structure as shown in section 2.2.5.4. Whereas in 1972 feedstock and energy represented 44 per cent of the production cost of ethylene, it now accounts for 73 per cent. On the other hand, the proportion represented by amortization and return of investment has dropped from 40 per cent in 1972 to the current 19 per cent of the ethylene production cost for new plants. Therefore variable costs now are much more important than fixed costs. This new situation will affect the petrochemical industry in two ways:

(i) Those countries having feedstocks cheaply available due to large petroleum reserves or a favourable market structure of petroleum products, or government aid to this industry, will be in the strongest position concerning basic petrochemical production.

(ii) Economies of scale will become less important since variable cost is the dominant factor in production, thus somewhat diminishing the effect of the limited market constraint to the development of the petrochemical industry.

(d) Difficulty in obtaining raw materials - trend toward flexibility

The fundamental situation is that petrochemicals usually have a higher hydrogen to carbon ratio than crude oil. For most products the ratio is around 2, whereas crude oil has a ratio of 1.6, tar sands 1.4 and coal 0.8. Therefore the lighter end of the oil barrel has been used as premium feedstock because of their ability to provide sufficient hydrogen for the interrelated processes in a petrochemical complex. Hence the trend is to upgrade the heavy end of the oil barrel mainly concerning the hydrogen required in a petrochemical complex. Therefore the greatly increased importance of feedstocks in the production cost has spurred a concern among petrochemical producers about securing their raw materials supply. Furthermore, the dwindling gas reserves in the United States, the need to import naphtha in Japan, and the trend among West European petroleum refiners to release decreasing amounts of naphtha to the petrochemical industry are aggravating the medium- and long-term feedstock supply problem. Hence, a renewed technological effort is being made toward flexible multiple feedstock crackers, even at the price of higher investment costs. Therefore the availability of raw materials and their price will affect the location of new petrochemical complexes and the type of oil fractions that will be used, with price being influenced by the ability to optimize the utilization of the "total" oil barrel.

(e) Excess capacity problems

As a result of the marked slow-down in petrochemical markets growth, the world industry is in an excess-capacity situation. Therefore one can expect delays in new capacity additions and/or the establishment of new petrochemical facilities. The most pressing problems at the moment are those of market outlets and competition. In the meantime, no major new investment commitments are likely to be approved until the supply/demand situation becomes more balanced and clear.

(f) Trends toward international co-operation

The above described situation tends to produce a polarization towards co-operation due to the following effects on the factors affecting petrochemical production:

(i) a decrease of the market-size constraint that nevertheless will still remain important;

(ii) the very high impact of feedstock availability at attractive prices;

(iii) the increasingly higher needs of financial means that entail either plentiful domestic financial resources, or external co-operation from other sources, or project implementation with foreign participation. This last alternative might help solve the market-outlets problem through the opening by the foreign participant of a share in its own traditional markets.

(iv) Participation of companies from industrialized countries in projects in developing countries would be accelerated due to raw material availability and environmental problems.

2.3 WORLD CONSUMPTION OF PETROCHEMICALS

2.3.1 Factors affecting the demand for petrochemicals

The principal factors responsible for variations in demand in the world's main consumer areas are the following:

(a) Existence of a market

In the early stages the quality of the petrochemical products which came on the market was far from perfect and in some cases this fact was detrimental to the trade image of petrochemicals and hindered their market growth. For example, the premature aging of plastics (PVC), and in general the lack of constancy in the technical characteristics of the products sold. However most of the problems have now been solved through several means, the more important of which is by increasing the range of grades of end petrochemicals, with each grade having its own specifications. It should be noted that the different grade characteristics of one product such as polypropylene, are determined not only by the physical and chemical properties of the product but also by the secondary processing method to be used (injection moulding, extrusion etc) and its expected speed of production. Hence, when a product grade does not meet its strict specifications it is usually sold more cheaply as off-grade material, generally without the manufacturer's brand name.

In some cases the inadequacy of product properties has limited the development of the demand for petrochemicals. For example, the poor receptivity of polypropylene to dyestuffs that for a long time limited its use in the textile industry; the inflammability and toxicity during combustion of polyurethanes and PVC that limited their use in the construction industry; the ability of vinyl chloride and styrene monomers to pass through the walls of the corresponding polymer has limited their use in the food industry.

Nevertheless the rapid growth in the demand for petrochemical products since the end of the Second World War is explained by the fact that these products:

(i) have properties, both physical and mechanical, which are perfectly suited to their uses;

(ii) can easily substitute natural products already on the market and

(iii) are sold at competitive prices.

In most cases petrochemical products have been able to partially supplant the products already on the market, mostly natural products, the competition between these two kinds of products being the strongest at the level of the relative prices. However, there are very few instances of total substitution since:

- a mixture between petrochemicals and natural products turns out to be the material best suited to the users for which it was developed. This is especially important for blends and composite materials.

- The stiff competition by petrochemicals has spurred the natural products to improve their productivity and quality, thus becoming more able to hold their ground in their traditional markets. Additionally, it has helped to stabilize the price of the traditional products.

(b) Standards of living

The main factor in the growth of the demand for petrochemicals is the rising incomes and standards of living of the population. The elasticity per caput of most petrochemical products has been quite high in almost all regions, the most dynamic of which are the plastics.

(c) Degree of penetration of petrochemical products in the sectors of use

This is the second most important factor in consumption growth for petrochemicals. If the product marketed is well suited to the demand in its sector of application, the initial growth rate is rapid with a subsequent tendency to slow down as a relative saturation point is reached. Then the petrochemicals market growth resembles that of the sector of application as a whole.

The market penetration is generally partial and in industrialised countries, where the penetration is greatest, it is seen to reach a ceiling at about 80 per cent of the total market. There are very few cases of total substitution such as low density polyethylene bags and woven polypropylene bags for paper bags.

(d) Potential market for petrochemical products

The potential market for plastics appears to be practically unlimited, considering their many possible applications in three end-use sectors: packaging, transport and especially the construction industry. It can be expected that future consumption will be in the order of hundreds of kilos per capita. By contrast, the potential market for synthetic rubber (mainly used in tyre manufacture) and for synthetic fibres (mainly used in clothing) is much smaller. The demand in these fields of application are not expected to exceed some tens of kilos per capita. As a result, the strong growth in the demand for these materials, still recently registered in industrialized countries, is expected to be limited in these countries on account of the present high degree of substitution already observed.

(e) Prices

As in the case of all consumer goods, the demand tends to vary in inverse proportion to the price. Thus, the sustained fall in the price (expressed as a constant value) of plastics during the sixties and early seventies, definitely encouraged the growth in demand in their various areas of use. Conversely, the considerable rise in the price of plastics and other petrochemical products would normally have resulted in a sharp drop in the demand for these products. However, this effect was limited due to the simultaneous rise, generally in at least equal proportions, in the price of competing products: wood, paper, cardboard, non-ferrous metals (in the case of plastics), natural rubber (in the case of synthetic rubber), natural fibres (in the case of synthetic fibres). Where the price competition between natural and petrochemical products is not limited by technical considerations, product substitution occurs readily. For example, variation in the proportions of the constituents of polyester/cotton mixtures from 65/35 to 50/50 and viceversa. In other cases, the requirements or habits of the processing industry must be closely adhered to, for example, slight variations in the proportion of synthetic rubber for each type of tyre. In addition, the part played by variations in the prices of petrochemical end products themselves should be mentioned. As a result of differentiated price increases in recent years, the price of the large tonnage plastics lies in the range of 25-30 UScents/lb. This, for instance, is favouring the demand of high density polyethylene and polyprolylene against low density polyethylene in many applications except films.

(f) Local production

Local petrochemical production usually leads to an acceleration of local demand. However, this effect is not always felt at once on account of:

- import restrictions (customs barriers set up to protect a new industry)
- the problems of supplying the market at the moment of start-up
- at the beginning, the reluctance of processors to use a locally made product whose specifications are often initially considered inferior to those of products previously imported.

(g) Local processing

The existence of a national processing industry has a definite influence on the development of local demand:

(i) The presence of this industry, generally spread over the country, tends to make the product better known to the consumers than it would be if it were merely imported (effect of diffusion)

(ii) Local processing with a high added-value (especially in the case of textiles, less so for everyday plastics) means that local production whould be cheap compared with imported end-products, particularly if labour costs are also low.

(iii) The case of tyre manufacture, by far the largest user of rubber, is different: the setting up of such an industry, (usually controlled by large international companies) has no appreciable direct effect on the local market. Besides, any one plant, even a fair-sized one, does not produce the whole range of tyres required by the consumers. The situation would be quite different in the case of a car assembly plant possibly using locally manufactured tyres.

2.3.2 Development of the demand for petrochemicals

During the sixties and up until 1973, world demand for petrochemical products grew considerably. By the end of this period, however, a certain decline in the growth rate was already being felt. 1974 was characterized by a slight but unprecedented drop in world demand, followed in 1975 by a further appreciable decline, but in 1976 it regained a level close to the 1974 maximum.

Two types of growth in regional demand for petrochemicals can be distinguished: the growth of the developed countries and the growth of the developing countries. The variations are obviously more pronounced at country level.

In the developed countries, the growth of demand is slow and steady due to the stabilisation of markets which are reaching a saturation level (particularly a high rate of substitution exists in these markets). The fall in the growth rate in 1974-75, due mainly to economic causes, also reflects a change of attitude on the part of producers and consumers toward petrochemicals. As was noticed previously, the effect of the rise in the price of these products on the level of the demand has been limited by a simultaneous rise in the price of competing products. As for the future, as already confirmed by the first results recorded for the years 1976-1977, a new growth pace of demand for petrochemicals will appear, in any case more moderate than before.

The growth in demand in the developing countries is typically higher - after a "take-off" phase - but also irregular. However, it must be noted that in developing countries as a whole, the growth in demand was much less affected in 1974-1975 than it was in the industrialized countries. This can be explained because economical growth was still generally sustained in developing countries and their potential demand remains relatively large.

Considering that the consumption of end petrochemicals is the key factor in assessing the evolution of the demand for petrochemicals, the data and analyses are concentrated on them. The demand for intermediate and basic petrochemicals is mainly derived from the production of end petrochemicals through the corresponding production factors. Their consumption is mainly located in petrochemical producing countries while end petrochemicals are consumed everywhere. Table 24 shows the world consumption breakdown for major petrochemical end products in 1974. The share of developing countries (excluding China for which statistics are not always available) in the world market was 11 per cent on average. This percentage corresponds to only 9.35 per cent of the total in the case of plastics but 19.3 per cent for synthetic fibres, 12.8 per cent for synthetic rubber and 20.3 per cent for synthetic detergents.

Latin America ranks first among developing countries regions with regard to the volume of demand for petrochemicals: 44 per cent of the total in 1974. South Asia is the second market, with 21 per cent of the total, whereas the East Asian (excluding Japan and China), African (except South Africa) and Middle East markets are roughly the same size: 13, 12 and 10 per cent respectively of the total for developing countries. In general terms in 1974 plastics accounted for 58 per cent of total world end petrochemicals consumption while man-made fibres, rubbers and synthetic detergents accounted for 14 per cent each, respectively. The detailed data on end petrochemicals consumption by major product, country and region from 1965 onwards is given in appendix B. From this basic data the corresponding tables have been prepared for the four main end product families giving their world consumption, their main economic characteristics and their structures of the demand. They are presented in annexes 4 through 7. To complement the economic indicators, data on income per capita and population are given in annexes 8(a) and (b).

TABLE 24

WORLD CONSUMPTION BREAKDOWN OF MAJOR

PETROCHEMICAL END PRODUCTS - PERCENTAGE

REGIONS OF THE WORLD	1974
WESTERN EUROPE	31.81
EASTERN EUROPE	11.91
NORTH AMERICA	31.88
LATIN AMERICA	4.71
AFRICA	1.81
NORTH AFRICA	0.54
WEST AFRICA	0.29
EAST AFRICA	0.28
CENTRAL AFRICA	0.14
SOUTH AFRICA	0.55
ASIA excl. CHINA	18.89
MIDDLE EAST	1.01
EAST ASIA excl. JAPAN	1.40
JAPAN	11.81
SOUTH ASIA	2.27
PACIFIC	1.39
TOTAL WORLD	100.0

2.3.2.1 Plastics

The evolution of the demand for plastics, by region, from 1965 to 1975, is shown in annex 4(a), as well as the corresponding market share of the developing countries. This share grew from 6.5 per cent in 1965 to 8.8 per cent in 1970 to 11.5 per cent in 1975, almost doubling their market share during the period.

Annex 4(b) gives the main economic characteristics of world plastics demand in terms of growth rates, consumption level and structure of the demand between thermoplastics and thermosetting resins. The structure is given as percentage of thermoplastics over total plastics, the balance being made up of thermosettings. Currently thermoplastics represent two thirds of the total plastics market.

(a) Concerning the developed countries, their demand for plastics grew during 1965-75 at rates between 7 to 11 per cent per year, depending on the country, this figure being adversely affected by the substantial drop in demand in 1974/75. As regards the levels of consumption against income, major consuming areas are found in about the same situation with the exception of Eastern Europe where this level is far lower than that of the developed market economy countries. This situation indicates that its market saturation is lower, hence its potential market development prospects are brighter. Therefrom its emphasis on a rapid plant capacity expansion through "buy-back" agreements.

(b) Concerning the developing countries, their demand for plastics over 1965-75 kept growing at a very fast pace with growth rates between 15 and 20 per cent per year in most cases. The 1974-75 market drop was quite limited in most countries, in contrast to the situation of the developed countries. This fact indicates how high the potential demand for plastics still is in these countries. Referring to the level of plastics consumption against income, most developing countries are found in about a similar situation, with the exception of East Asia where the existence of an agressive export-oriented plastic processing industry has speeded up the rapid development of its plastics market far above the average market expansion of the developing countries. In fact, it consumes 9 Kgs of plastic per capita against the 3 Kgs for the other regions having the same income.

2.3.2.2 Man-made fibres

The evolution of the demand for man-made fibres, by region, from 1965 to 1975, is presented in annex 5(a), and includes the corresponding market share of the developing countries. This share grew from 14.6 per cent in

1965 to 15.9 per cent in 1970 to 22.8 per cent in 1975, thus increasing their market share in about 50 per cent during the period.

Annex 5(b) gives the main economic characteristics of world man-made fibres demand concerning growth rates, consumption level and structure of the demand between cellulosic and synthetic fibres. The structure is given as percentage of synthetic fibres over total man-made fibres, the balance being made up by the cellulosic fibres. Currently synthetic fibres represent 71.5 per cent of the total man-made fibre market, whereas demand for cellulosic fibres has become stagnant in the last years.

(a) Regarding the developed countries, during 1965-75 the average growth rate for man-made fibres was in the range of 4.6 per cent to 7.2 per cent per year depending on the country. As observed in the plastics market, their demand also dropped substantially during 1974-75. This slow-down in the demand reflects the high degree of penetration of man-made fibres in these countries. Currently their market penetration is 50 per cent over that of total textile markets.

Likewise, the synthetic fibres kept on making deeper inroads into the total man-made fibre markets from about 65 per cent in 1970 to around 80 per cent in 1975. The far lower market penetration of synthetic fibres in Eastern Europe (50 per cent in 1975) indicates that this region has the highest market potential of the developed countries regions.

(b) Concerning the developing countries, the demand for man-made fibres over 1965-75 has been strong but irregular. This situation is typical of countries where the level of consumption is still low, below 1 Kg per capita in most regions and about 2 Kgs in Latin America and Middle East. An exception is East Asia where its aggressive export-oriented textile industry has boosted man-made fibres consumption to 4.3 Kgs per capita in 1975, a level comparable to that of Eastern Europe.

By contrast with the situation in developed countries, the market penetration of man-made fibres is still moderate at about 25 per cent of total textile markets. Likewise, the synthetic fibres made fast inroads into the man-made fibre market, at the expense of cellulosic fibres whose growth practically stagnated. Their market share went from about 50 per cent in 1970 to about 70 per cent in 1975.

2.3.2.3 Rubber

The evolution of demand for total rubber, by region, from 1965 to 1975, is shown in annex 6(a), and includes the corresponding market share of the developing countries. This share went from 12.8 per cent in 1965 to 14.1 per cent in 1970 to 17.3 per cent in 1975.

Annex 6(b) gives the main characteristics of total rubber demand regarding growth rates, level of consumption and structure of the demand. The structure is given as a percentage of synthetic rubber over total rubber, the balance being represented by natural rubber. Currently synthetic rubbers account for 69 per cent of total rubber consumption, but their dynamic market penetration has been checked since 1972 at about 70 per cent, due to the strong come-back of natural rubber and present trends towards using more natural rubber in tyres.

(a) Concerning the developed countries, during 1965-75 the demand for rubber rose in the range of 3.3 per cent to 8.8 per cent per year, depending on the country, with a marked drop during 1974-75. This evolution reflects developments in the automotive industry since about two thirds of rubber is devoted to tyres and related products. The market penetration of synthetic rubbers was about 72 per cent of the total rubber industry in 1975.

Although the level of rubber consumption in Eastern Europe has corresponded to the levels of other developed countries, its demand for rubber has been growing at a fast rate, specially during the 1970s. This expansion corresponds to a phase of intensive equipping in the road transport sector that has led it to beoome the first region to pass over the observed 80 per cent market penetration ceiling for synthetic rubber.

(b) Regarding the developing countries, their demand for rubber grew at an average of 10 per cent per year. However, there were considerable variations in the growth rate of the different regions, specially for those countries with a still low level of consumption, below 1 Kg per capita.

In many cases, market growth has been faster during 1970-75 than during 1965-70. This evolution is typical of regions with a large potential demand. The market penetration of synthetic rubber was around 56 per cent of the total rubber industry in 1975.

Referring to the level of rubber consumption against income, most developing countries are found in a similar situation with the exceptions of East Asia and China. In East Asia the existence of an export-oriented processing industry has accelerated the growth of its rubber market quite above the average market expansion of developing countries. In China, the very low level of rubber consumption stagnated over the past few years, remains quite below the level of other developing countries having the same income level, hence it has the larger potential demand.

2.3.2.4 Synthetic detergents

Data concerning the world detergent market is often lacking or contradictory. Nevertheless, annex 7(a) shows the evolution of demand for synthetic detergents from 1965-75 and the corresponding market share of the developing countries. This share rose from 16.9 per cent in 1970 to 20.5 per cent in 1975. The consumption figures correspond to a formulated detergent tonnage as delivered to industrial or domestic consumers. These synthetic detergents take the following forms:

(i) Surface-active finished detergent powder, that accounts for 65 per cent of total formulated detergents for Western Europe and 70 per cent for Japan respectively;

(ii) scouring powder, that on the average accounts for 7 to 8 per cent of the total;

(iii) liquid detergents that represent 27 per cent of the total for Western Europe and 23 per cent for Japan respectively.

The formulated detergents have many constituents in their formulae. The most used among them are sodium tripolyphosphate (30-35 per cent of formulations by weight) and other sodium salts. The active constituents of petrochemical origin account , on the average, for about 20 per cent of the tonnage of formulated detergents. This percentage greatly fluctuates from one country to another depending on washing habits. Among the petrochemical active constituents,the more important are the alkylbenzenes (branched and linear types), non-ionic, anionic and cationic surfactants. Annex 7 (b) gives the regional market consumption of the two more important petrochemical active constituents, alkylbenzenes and non-ionic surfactants, for 1975.

(a) Concerning the developed countries, during 1965-75 they had only a modest growth rate in formulated detergents consumption, which did not exceed 4 per cent per year. In 1974-75 the detergents demand was stagnant due to the world economic slump and changes in consumers' behaviour. The current slow-down in consumption growth is mainly due to the deeper market penetration of synthetic detergents in the soap, total detergent and cleaning agent markets. Hence its future growth in consumption would resemble that of the soap and total detergent markets as a whole.

(b) Regarding the developing countries, the demand for synthetic detergents has been growing at high yearly rates, comparable with those observed for other end petrochemicals.

This growth stems mainly from two factors: a strong development of the need for soap and detergents at the current level of consumption, and the still moderate degree of market penetration of synthetic detergents in the total soap-detergents market.

On account of these factors, the growth prospects for synthetic detergents remains favourable in most of these countries.

2.3.3 Major trends in the evolution of the demand for the main end petrochemicals

A detailed analysis of the major trends and the changes of end-use patterns of the four main end-products families by product is presented in appendix D. Based on that analysis the main trends affecting end petrochemicals consumption are given below.

2.3.3.1 Plastics

The major share of the plastics market is held by thermoplastics which account for about 70 per cent in developed countries and around 82 per cent in developing countries of total plastics. Concerning the situation and likely development of the main types of plastics, the following trends are observed:

(i) Polyolefins (LPDE, HDPE, PP) presently account for one third of the world plastics market. Taking into account the strong expansion of demand expected for high density polyethylene (HDPE) and polypropylene (PP), demand for low density polyethylene (LDPE) would likely grow at about the same pace as plastics on the whole. This situation should result in low density polyethylene concentrating in film applications whereas the other two polyolefins concentrate in more sophisticated applications like injection molding. Currently the prices for these three plastics are leveling off, thus favouring the cost/performance ratio of the more expensive HDPE and PP. Nevertheless, the penetration rate of HDPE and PP into polyolefin markets will likely remain lower in developing countries than in developed countries.

(ii) PVC is the first individual plastic in the plastics world market with 22 per cent of the total. Its future growth is expected to be lower than that of plastics as a whole, for it is besieged by high energy costs and health hazard problems. Nevertheless, PVC is expected to keep on holding its leading position supported by its forthcoming developments for rigid applications. This situation would change in 1985 should LDPE take the lead.

(iii) Polystyrene (PS) accounts for 10.5 per cent of the plastics world market and its share in this market is expected to remain constant as in the past. It is interesting to note that about the same percentage applies in most regions, therefore PS demand alone can be considered as characteristic of the plastic consumption level in any given area.

2.3.3.2 Synthetic fibres

Concerning man-made fibres, synthetic fibres alone will be responsible for its expansion, since cellulosic fibres, after years of stagnation, are gradually decreasing their market share. The major exception is Eastern Europe where cellulosic fibres have kept a very slight growth rate. The main reasons for the decline of cellulosic fibres are expensive raw materials and qualities below those of synthetics. Nevertheless, the high degree of substitution of cellulosics by synthetics (72 per cent of the total in developed countries), coupled with the high degree of penetration of synthetics into the textile market, will become an important limiting factor in slowing market growth for synthetics. In developing countries, synthetic fibres account for 63 per cent of the man-made market. In these countries, market growth would result from a deeper penetration of man-made fibres into the textile market (currently 25 per cent of the total as against 50 per cent in industrialized countries) and from the overall growth of the textile market. The demand pattern for the three main synthetic fibres is changing as follows:

(i) Polyester fibres, currently accounting for 46 per cent of world synthetic markets, will keep on increasing in importance.

(ii) Polyamid fibres, presently accounting for 33 per cent of world synthetic markets, will continue decreasing in importance.

(iii) Acrylic fibres should keep almost a constant share of the world synthetic market of about 20 per cent of the total.

2.3.3.3 Synthetic rubber

The ratio of synthetic rubber consumption to total rubber consumption has gone from 60.4 per cent in 1965 to 68.2 per cent in 1974. However, this percentage slightly decreased in 1975 as a result of a change in the rubber competition: the production cost of synthetic rubber has been rising whereas the production cost of natural rubber is on a downward trend. This new trend would lead to having about the same growth rate for natural and synthetic rubber, at least in developed countries which already have a high degree of substitution of natural for synthetic rubber.

The single most important synthetic rubber is SBR that accounts for 60 per cent of the total in developed countries and up to 80 per cent in developing countries. It is envisaged that SBR will remain in its leading position for all its current applications. Most of the other synthetic rubbers, with the exception of polybutadiene (that accounts for 10-15 percent of the total) and butyl rubber (used in tubes), are generally used in specialty applications. Polyisoprene, considered as a possible substitute of natural rubber, seems to have reduced chances of development in the near future due to the newly gained competitiveness of natural rubbers.

2.3.3.4 Synthetic detergents

Alkylbenzene sulfonates are by far the main active material used for preparing detergents. In 1975, its demand amounted to 1.2 million tons, of which 0.33 million were in developing countries. The relatively high volume of alkylbenzene used in developing countries partly results from washing habits: handwashing with cold water instead of machine washing with hot water requires substantially more of the active material. It is expected that alkylsulfonates will continue to develop at a moderate growth rate and will keep its leading position in detergent markets because no other surfactant can match this material on a cost/performance basis for spray-synthetic detergents.

Due to recent regulations on water pollution brought into developed countries, biodegradable detergents based on linear alkylate sulfonates have largely displaced "hard" detergents based on branched chain dodecylbenzene sulfonate. In developed countries there is a continuing trend toward liquid detergents that could alter the market structure and the linear alkylate sulfonate dominant position in it. These long-term threats come mainly from alpha olefin sulfonates and alcohol-based surfactants.

Detergent-range alcohols (non-ionic surfactants), second in importance as surface active material in developed countries, have very moderate prospects in developing countries.

2.4 INTERNATIONAL TRADE AND DISTRIBUTION

2.4.1 Evolution of international trade

Petrochemical products form a rather important share of international trade. In 1976, for instance, United States exports of synthetic fibres, thermoplastics and synthetic rubber amounted to 1,450 million dollars, i.e. more than 1 per cent of the total US exports. In 1975, the internal and external exchanges of the EEC relative to the main petrochemical end products alone (thermoplastics, synthetic fibres, synthetic rubber) were about 5,000 million dollars. Such a value is equivalent to 9-10 per cent of the total imported crude oil (but represented 25 per cent in 1973, before the quadrupling of crude oil prices).

The impact of petrochemicals is even higher if we consider the case of Japan. For that country, exports of synthetic fibres alone amount to about 2.5 per centof the total exports. The end products are higher price goods; the international trade in intermediate and basic petrochemicals has less impact than the end products. United States exports of benzene, toluene and xylenes, for instance, amounted to 250 million dollars in 1976, and Japan exported about 100 million dollars with the same products in 1975.

2.4.1.1. Trade exchanges

The differing evolution between regional consumption and production patterns and intercompany competition generated surplus or deficit balance situations, which in turn originated the trade flows and petrochemicals exchange patterns. Appendix C gives detailed data on regional trade flows by product for 1973-75. Based on this data annex 9 was prepared to show the trade flows for the main end petrochemicals.

The major part of international trade in petrochemicals is constituted by end-product exchanges: plastics, synthetic fibres, synthetic rubber, and to a lesser extent, detergent. In terms of tonnage, plastics account for about 70 per cent of this group.

Petrochemical end-product trade continues to grow, slightly faster than world production. In 1960 the volume of trade was of the order of 2 million tons; by 1965 3 million tons, and in 1970 more than 9 million tons. A peak was reached in 1973 with a figure of 12 million tons. Since then, international trade has suffered the effects of falling demand, and today's figure is equivalent to the 1973 level.

The traditional exporters are the EEC countries, Japan and the United States, with end product exports of 8.8 million tons, 1.6 and 1.4 million tons respectively in 1975. The main importing areas are the EEC countries: 6.1 million tons including 5.4 million of internal exchange; other West European countries: 1.3; Asia: 1.7 and Latin America 0.6 million tons.

Regarding exchanges, figures are given for 1973, the last "normal" year before the world economic slow-down, and for 1975, the last year for which comprehensive statistics are available. They do not represent the whole of international trade since, for example, tonnages exchanged between less developed countries, or between Eastern Europe and EFTA countries, are not always taken into account, due to the lack of statistics. However, the great bulk of tonnages exchanged is represented so that some conclusions can be drawn from the data given in appendix C and annex 9:

(i) Except for a few products, the EEC countries are a net exporter.

(ii) The United States imports mainly butenes, butadiene and benzene.

(iii) The export-import balance of Japan is favourable for all the products considered except for xylenes and methanol.

Taking into account the trade evolution, the main trade flows are as follows:

(a) Olefins. About 80 per cent of the world ethylene market is accounted for by the United States, Western Europe and Japan. Currently there is no significant trade in ethylene and propylene, except between the EEC countries and within CMEA members. On the contrary, there is a relatively large amount of butenes/butadiene exported from Europe to the United States.

(b) Aromatics. Despite current overcapacities in benzene in Western Europe and the United States, the latter still continues exporting benzene to Europe. The same observation applies to toluene and xylenes. European imports are partly due to growing aromatics needs in low-lead content gasolines. Whereas o-xylene movements from the United States to EEC countries have been decreasing since 1969, the EEC formerly an exporter of P-xylene, has become a net importer. Finally, in recent years there has been a significant movement of aromatics from Eastern to Western Europe.

(c) Intermediate products. The United States still exports methanol, styrene and cyclohexane to EEC countries, whereas raw materials for synthetic fibres and plastics are exported by the United States, EEC and Japan to developing countries that have recently built polymerization facilities such as South Asia and Latin America.

(d) End products. About 1.4 million tons of synthetic fibres in 1973 and 1.1 million tons in 1975 have been exported by the three main industrial regions. Japan and EEC continue to be the biggest exporters. For Japan, South East Asia remains its largest market due to the huge filament processing facilities in such countries as the Republic of Korea. Eastern Europe and EFTA countries constitute important markets for Western Europe in end petrochemicals, while Eastern Europe is emerging as an important synthetic rubber exporter. Concerning plastics, EEC is largely the main exporter with Japan a strong second exporter, while Eastern Europe still remains a large net importer.

2.4.1.2 Share of the international trade in the consumption

To assess this share one should compare the international exchanges of petrochemicals with their consumption, and measure the importance of the total exports compared to world production.

Data relative to the weight of inter-regional trade in world consumption is given in annex 10. Figures are shown for 1973, the last "normal" year. In fact, it is difficult to draw general conclusions from the exchange and consumption date, each product and each area being a particular case. Nevertheless, the following aspects can be pointed out:

(i) The ratio of exchanges (imports + exports) to consumption are of the same order of magnitude for Japan and the EEC countries, as far as end products are concerned (EEC internal trade not taken into account). The same ratio is far lower as concerns the United States.

(ii) The total exchanges relative to the EEC are very important when compared to the consumption. In 1973, the exchanges amounted to 89 per cent of the consumption for synthetic fibres, 58 per cent for plastics, 76 per cent for synthetic elastomers. In 1975 figures were 93 per cent for synthetic fibres, 67 for plastics and 84 per cent for synthetic rubbers, the higher figures for 1975 mainly reflecting a depressed consumption situation. Figures relative to intermediate products are often lower, though sometimes important.

(iii) Japan and EEC export a very large quantity of petrochemicals compared to their consumption, about 25-30 per cent for synthetic fibres and high density polyethylene, 22 per cent for low density polyethylene, 18 per cent for plastics and as concerns Japan 45 per cent for polybutadiene and 31 per cent for SBR.

(iv) The position of the United States is quite different. In fact the United States exports a rather minor quantity compared to their consumption: 6 per cent for synthetic fibres, 7 per cent for plastics, o-xylene exports (about 35 per cent of their production) represent an exception.

(v) The most important trade is in end products, while for most basic and intermediate products trade can be considered as marginal (less than 10 per cent of production).

(vi) Tonnages exchanged are relatively important for toluene and o-xylene (but not for benzene) and for end products, including synthetic rubbers (about 15 per cent), non-cellulosic man-made fibres (about 15 per cent), thermoplastics (up to 21 per cent for high density polyethylene).

(vii) The same ratios for 1975 could be slightly higher due to a poor production of most products in 1975 and to the fact that the decrease of exchanges has been more moderate.

2.4.1.3 Major trends in the international trade

From the above analysis the major trends in international trade are the following:

(i) The EEC internal trade should continue to be very active.

(ii) Propylene exports from EEC should develop due to a glut being formed by the faster-growing ethylene needs.

(iii) Butadiene export from EEC to the United States should continue as long as significant feedstock shift for basic petrochemicals is not implemented in the United States.

(iv) Aromatics, styrene and cyclohexane could continue to be exported from the United States to Europe in the same magnitude as now.

(v) Japanese export tonnages are likely to remain almost constant, with a slight decrease in the exports/consumption ratio due to the stronger international competition and the planned implementation of new petrochemical plants after 1980 in the Middle East and South East Asia.

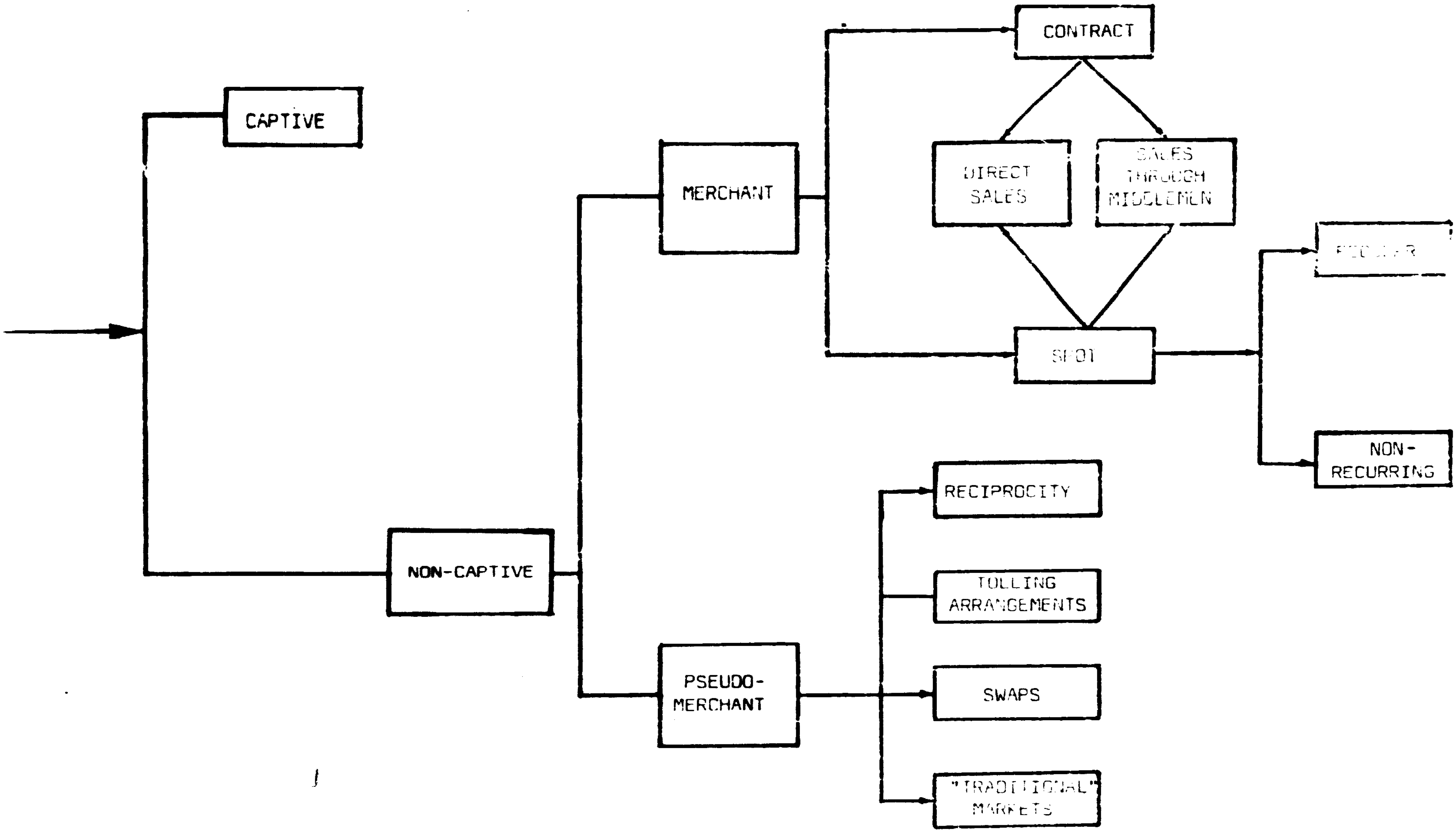
(vi) The prospects of huge capacity export-oriented plants emerging after 1980 in Eastern Europe and some oil producing countries with numerous buy-back deals betwen Eastern European countries and chemical companies or contractors might substantially alter the current trade situation by toughening the competition, increasing very substantially the trade in basic and intermediate products, and geographically broadening the whole petrochemical trade.

2.4.2 Market opportunities

2.4.2.1 Commodity chemicals

Commodity chemicals are defined as chemicals sold on the basis of their specifications only. They may be worth from a few cents/kg to many dollars per g, but they will always be identified by objective specifications, and not by their performance on a downstream processing machine, or in a product incorporating or made from the chemical in question. Intermediate and basic petrochemicals generally fall within this category. Figure 4 shows how the market for any commodity chemical can be broken down according to the type of commercial channel through which it moves or the manner in which it changes hands. This figure illustrates the fact that the market actually available to a new entrant is usually, in the case of heavy organic chemicals, only a small fraction of the actual overall demand. As an example, the West European ethylbenzene/styrene monomer market has been selected. Its captive consumption represents about 74 per cent of total demand. Of the remaining 26 per cent

Figure 4. Patterns of commodity chemical distribution



not all is accessible to a newcomer. For instance, some chemical companies or traders may have ethylbenzene available (e.g., from an unbalanced operation, or by superfractionation of a C_8 aromatics fraction) and have it converted to styrene on a toll basis. BASF is known to carry on this type of business with some leading trading companies. Similarly in propylene oxide, the Oxirane plant in the Netherlands is usually classified as "merchant" and such a large consumer as BASF is considered "buyer" but in this case Oxirane converts the propylene supplied by ROW (a 50/50 BASF-BP venture) to o-pilene oxide, so that sales are in the form of services but not of goods.

Returning to styrene, at least one case is known where a North American polymer producer located in Western Europe buys styrene monomer locally (although the parent company overseas is the producer) in exchange for which the North American producer sells a similar amount of styrene to the North American polymer plant of its West European monomer supplier. This results in freight savings. Once again, what appears as a non-captive user is, in fact, truly part of the merchant market.

There are frequent cases of business that are so "traditional" that it cannot properly be considered part of the available market. In the case of styrene, for example, Gulf has an entirely merchant plant, and Hoechst, a big user of styrene, has no production capacity of its own, and sales by the former to the latter are so well established that no outsider could aspire to a major part of this business. Taking another example, Shell, despite its size, does not produce caustic soda and chlorine, its needs being supplied by AKZO which in turn "traditionally" buy its fibre-grade ethylene glycol from Shell. Other such examples of "reciprocity" are not to come by in the chemical industry.

Although there are few examples of non-integrated styrene plants in Western Europe (Forth Chemical, for example, buys its ethylbenzene), it will nevertheless turn out in any given year that some theoretically balanced Ethylbenzene/styrene producers will have bought a certain amount of ethylbenzene. This may be due to accidents, malfunctioning of the plant, maintenance planned or not and similar causes, all these cases being included in figure 4 under "non-recurring" business.

The truly merchant business can be further broken down into contract sales and spot sales. Contract sales, in the case of styrene, make up 79 per cent of the merchant market, spot sales the remaining 21 per cent. Although prices are nowadays seldom fixed for more than three months (even monthly re-adjustments are not unknown) these contracts are usully established for periods of 3 to 5 years, and a producer new to the market will thus have to wait until going contracts expire before being in a position to compete for the business.

Spot sales include both regular business of a speculative nature and non-recurring business. Even a large buyer of a given commodity will cover no more than, say, 80 per cent of his requirements by contracts, the rest will be acquired on the spot market in the hope that by means of agile purchasing the weighted average cost of the commodity can be somewhat reduced without incurring too much outside risk. The spot market is handled mainly by brokers and traders.

The new entrant thus faces, at least initially, markets in which very little is left to chance and where structural shortages are at best rare. The new entrant must thus carve his share out of a market that is basically in balance. The extent to which this is possible will depend on, among other things, the number of companies already supplying the merchant market. Thus, there are, for example, six or seven habitual sellers of styrene in Western Europe, so that a new producer may aim at getting about 15 per cent of the true merchant market. This would mean that each merchant supplier would already have to give up around 15 per cent of his business which is generally considered to be an upper limit, and even so provided the newcomer is willing not to touch off a price war in the process of trying to capture a disproportionate market share.

2.4.2.2 Performance chemicals

Performance chemicals are products that are bought on the basis of both their specifications and the results obtained when using them. Thus, for example, two polymers (typical examples of performance chemicals) may yield extruded films of substantially identical properties and performance characteristics, but one may permit higher output from the extruder. Similarly, the properties of the films themselves may differ, affecting, for example, their performance on packaging machinery, which in turn will influence the market value of the various alternative resins from which the films can be made.

From these fundamental differences between performance chemicals and commodities, it can be realised that the marketing of the former requires a far greater effort than the latter. Thus, marketing a family of performance chemicals will require all or most of the following types of action:

- frequent technical service at the customer level
- occasional, although less frequent than in the case of customers proper, assistance to the customers' own clients

- back-up of a technical service laboratory
- advertising, both technical and institutional

Because of the diversity of the types of contacts needed between producer and market, it is usually impossible to sell performance chemicals from a distance without having a substantial supporting organization close to the market able to carry out the various types of tasks mentioned above.

2.4.2.3 Captive and non-captive petrochemical markets

To complement the above analysis, it is interesting to consider what the proportion is of petrochemical production actually delivered to consumers through dealers. Sales are defined as actual quantities of petrochemicals sold only by the original producers. They include: shipments of a commodity for domestic use and export, shipments of a commodity produced by others under toll agreements, and shipments to subsiduary or affiliated companies. Annex 11 shows the ratic of sales to production in the United States and Japan. The main conclusions that can be drawn are the following:

(i) end petrochemicals, being performance products, are almost wholly non-captive markets;

(ii) the situation varies for the different intermediate and basic petrochemicals but most of them have higher captive markets, in particular the olefins that in the United States have about two thirds of the market.

2.4.2.4 Costs of sales

In general, commodity sales costs should not exceed 2-3 per cent of sales in the case of bulk chemicals. Thus, assuming that the minimum cost of running a one-trader sales office is around $ 125-150 thousand/year, one concludes that the sales volume at which such an office would break even is around $ 6-7 million/year. At mid-1977 prices this corresponds to sales of around 20,000 tons/year of aromatics, or 15,000 t/yr of styrene, and correspondingly less of the more sophisticated organic intermediates.

The minimum running costs for an operation to back up the sales of performance chemicals are much higher, in the order of $ 500-700 thousand/year to cover all the various functions, but admissible sales costs as a part of business volume are also higher. The danger here is that the newcomer will have to support sales costs resembling those of introducing a new performance product, whereas for his established competitors these products are already mature. For instance, the costs for a new entrant of selling LdPE may turn out to resemble the costs that a more mature chemical company experiences when introducing, say, a new engineering resin.

2.4.3 Organization of markets and distribution systems

2.4.3.1 Trade practices

(a) Contract business, usually accounting for the bulk of the merchant market, consists of agreements between buyer and seller that cover a number of transactions over an extended time-period. Contract terms usually specify the following:

(i) Total volume and size of liftings. In the case of certain commodities, take-or-pay clauses may be included but these become less frequent as one moves down along the petrochemical stream.

(ii) Duration: three to five years is common, often with clauses that make renewal more or less automatic.

(iii) Prices and payment terms: although fixed prices are no longer practicable, there are usually clauses tying the initial price to a mutually agreed-upon benchmark such as, e.g. the Rotterdam naphtha price, or else to "market" prices which must likewise be defined.

Promptness in payment varies greatly from country to country. In some markets, e.g., the Federal Republic of Germany, an invoice three days overdue will already lead to a reaction on the part of the creditor; in France or Italy tolerance for delays is much greater. This is in part due to the fact that in certain countries the seller retains title to the goods until they are paid for, which constitutes a strong incentive to pay on time.

(iv) Currency clauses. These have become more important since the industrial countries have reverted to flexible exchange rates. The closer a product stands to the basic petrochemical building blocks, the more trade in this product will be found to resemble trade in the basic commodities such as naphtha or benzene. Thus, for example, a take-or-pay clause will be frequently found in the case of naphtha, less so in that of benzene, only very occasionally in the case of styrene, and practically never in that of a more sophisticated intermediate such as caprolactam or phenol.

(b) "Fidelity" bonuses are common in certain countries, for example, in the Federal Republic of Germany under this system the amounts to be bought are still estimated at the beginning of the period and if they are met or exceeded, a fidelity bonus will be paid. This bonus is usually around 2-3 per cent on the total amount purchased and varies with the deviation (if positive) between actual and target sales. Thus, for example, if a customer takes 60 per cent of his requirements from a given supplier, the latter will pay him a year-end bonus of, say, 2 per cent; but if the percentage rises to 70 per cent, the bonus will rise, say, to 3 per cent. In this example, it works out that the additional 10 per cent will have been bought at a marginal cost of only 91 per cent of the original price, which - and this is the whole purpose of this system - makes it all the more difficult for a newcomer to fight for a share of the contract business.

(c) Spot business is often handled by brokers, particularly in the case of hydrocarbons, benzene, xylene isomers, styrene. With the boom in prices following the shortages of 1974, the number of trading firms increased greatly and margins have consequently sunk to the point where even figures as low as 1 or 2 per cent are not uncommon in the case of heavy organics such as styrene. In 1977, however, a number of bankruptcies, and not always voluntary mergers, have had the effect of weeding out the less solid of these trading companies, and in particular those who were tempted into taking big positions as opposed to carrying out their traditional roles as brokers or back-to-back traders. Therefore, it would not be surprising if trading margins began moving upward again in due course.

Traders may also be of use to newcomers to the petrochemicals market in arranging toll conversion or swap delays. However, these have tended to be more profitable to the traders and thus less so to the sellers, often reflecting the availability of a given commodity at distress prices. Traders have been trying more and more to move into the contract end of the merchant petrochemicals business. One of their main incentives to do so has come from the relatively large amounts of some basic chemicals that certain West European engineering companies have had to accept in partial payment for plants delivered to the CMEA countries, and which usually they are not qualified to market themselves.

2.4.3.2 Distribution costs

In addition to the cost of the sales discussed in section 2.4.2.4, there are costs associated with distribution. Terminalling costs around \$ 2-5/ton in handling costs (in and out), to which must be added \$ 1-2/ton per month for storage. Thus, in order to ensure acceptable shipping costs, a product must not be stored more than two or three months. The cost of terminalling and storage can be as high as \$ 10/ton.

Drumming at destination may be necessary, especially in order to be able to serve the more highly dispersed segments of the spot market. Costs of drumming are around \$ 100/ton.

2.4.3.3 Organisation of distribution systems

The newcomer to a given market must be able to select an optimum combination of several types of distribution systems:

- own distribution force
- agents, exclusive or non-exclusive
- propers
- distributors having own facilities (terminals, warehouses etc)

Each of these have their advantages and drawbacks, and a suitable strategy will probably turn out the best possible combination. In the case of performance chemicals such as polymers, in some markets there may exist representatives so well entrenched that even a local manufacturer may prefer to deal through them. In Brazil, for example, a major LD polyethelene producer formed a joint company with a local trading firm that handles their entire output on the strength of the trader's position established during the years in which the entire demand was satisfied by imports.

It is impossible to affirm that any one method is preferable to another. It may, for example, be a matter of time-preference: for example, whereas the export-oriented nitrogen fertilizer company in Qatar decided to market their products through Nitrex (a multinational marketing consortium), that of Kuwait decided from the start to use a mixed strategy of independent traders and their own marketing force. Only time will tell which was the best option; the former is found to lead to better results in the short run, but the latter may prove to yield better returns over the long haul.

2.4.3.4 Transportation costs

From a general point of view, transportation costs do not play a prominent part in the petrochemical industry's economy. Usually transportation expenses are relatively low compared to production costs. The more the product is elaborated, the less is the impact of the transport. Inland transportation costs are of less importance compared to commercial net work storage and after-sales services expenses. The more significant transportation cost is relative to the long-range seaborne product movement. Orders of magnitude of operating transportation cost are given below:

Product	Average transportation costs (US ¢/nautical mile/ton)	Remarks
Solids (resins, rubber)	0.4	Return freight is considered; cargo capacity 12,000 m^3
Non-corrosive liquids (benzene, xylene, styrene)	0.25	No return freight; tanker capacity 23,000 m^3

Volatile and corrosive liquids (vynilchloride)	0.70	No return freight; tanker capacity 15,000 m^3
Ethylene	1.3	No return freight; 6,500 nautical mile trip, capacity 25,000 m^3

These operating costs do not properly reflect the current situation. The freight rates are presently determined by the law of supply and demand. Due to a very high over capacity for both tankers and dry cargoes, the freight rates levels are currently very low. According to experts it would be unwise to anticipate any rapid or radical transformation of the shipping trade; there are signs that the recovery of the market will prove to be a slow and painful process and that to reach a relative equilibrium between supply and demand will take several years.

The indicated transportation costs show that they become significant in the case of volatile and corrosive liquids and mainly in the case of ethylene. These transportation costs will probably be minimized.

2.4.4 Prices of petrochemical products

2.4.4.1 Definition of prices

From a number of sources, different kinds of prices can be found:

(i) international transaction prices which can be:

- spot prices, usually published in specialized reviews
- contract prices which are seldom published, but for which a range can be given
- average prices represented by average values calculated from the trade statistics of large developed countries or areas by dividing total sales (in US dollars) by tonnages traded for a given month. They are, of course, significant for products actively traded and actually available on the international market. However, such statistics have to be dealt with and compared carefully on account of particularities of the markets, at least for end-products, volumes, qualities (grades) geographic area, competition, custom duties etc.

(ii) domestic prices which can be:

- listed (or posted) prices, that give an order of magnitude, normally above the real prices, and permit comparisons from one market to another
- ex-factory prices as reported by the manufacturers, usually for non-captive sales.

2.4.4.2 Price evolution of petrochemicals

Before 1973 the price of petrochemicals varied through time, with a general trend towards decreasing. This was mainly due to the following factors:

- technological improvements
- greater diffusion of products, making it possible for larger units to be set up
- strong competition between manufacturers for the same products

As a result of these factors, combined in some cases with overcapacity, prices really decreased towards a level very close to production costs, until the end of the 1960s.

Prices has previously been considerably higher than production costs. They were chiefly determined by competition with natural products. Petrochemicals, on account of their quality and low production costs, could be valorized at prices substantially higher than their cost price, thus creating a sizeable profit which could be used to finance research and self-financing of new plants.

Up to about 1967 great advantages were still gained by producers able to use large single stream units, while the market was then still predominantly made up of small units. Thus in the early phase of the plant scale-up process the operators of large units were content to allow the smaller producers to provide a "price umbrella" under which they themselves collected large profits without having to disrupt the business of their competition.

Since around 1967 the impact of large plants on prices has made itself felt more and more to the point where today, apart from such transitory phases as the 1974 boom, prices are relatively down to the level needed by the largest operators to have an attractive return on investment.

Between 1972 and 1974 prices doubled or tripled. A slump in 1975 and a relative stabilisation in 1976 have been recorded. The doubling or tripling of prices was brought about by the rise in energy costs, with its consequences for petrochemical production costs, and in fact, bore no relation to actual production cost increases.

The 1973-1974 price boom was, in fact, essentilly caused by uncertainty as to the level of oil price increases; most petrochemical users overestimated the coming rise and its effect on the petrochemical industry, and so sought to build up their stocks against a future increase. The law of supply and demand added momentum to rising prices. A reverse trend began to make itself felt in 1975, and the tendency since then has been towards comparative stability. Present prices are very close to production costs and in some cases actually lower. This can be attributed to world overcapacity, and also to the fact that price is increasingly becoming the main criterion of choice on the part of purchasers.

Annex 12(a) gives the international price trends for 17 petrochemicals from 1970 to 1976. Annex 12 (b) illustrates the large price increases suffered by Western European contract prices for 21 petrochemicals between January 1974 to July 1975 in comparison to 1972. Two main conclusions can be drawn from those tables and recent developments:

(i) after 1975, contract prices have tended to stabilize in current terms with two exceptions:

- the price of aromatics has slumped, especially in the case of p-xylene the price of which has greatly decreased in more than 25 per cent, reflecting a poor market (and pessimistic medium-term forecasts) for polyester fibres.
- though olefin prices have stalled, the price of butadiene has seen a swift increase due to demand pressure from Japan and the United States.

(ii) spot prices, which represent prices of more or less marginal volume sales (in the case of ethylene, spot trade is quite negligible), are traditionally lower than contract prices in times of overcapacity and depressed markets. In that sense, the situation of petrochemical products can be compared to the case of petroleum products traded in Rotterdam and Italian spot markets, where prices are much lower than domestic ex-refinery price levels and often represent marginal production costs only. Spot prices see swifter fluctuations than contract prices, but they are taken into account when contracts are negotiated and give information on very short-term trends.

It should be noticed that contract price variations did not match the price escalations in feedstocks and investment costs that have so deeply affected the production cost structure of petrochemicals, specially basic products. Figure 5 illustrates the evolution of ethylene contract prices compared to the naphtha prices in Western Europe from 1960 to 1976. It shows that:

- from 1972 to 1976 naphtha prices have seen a 61 per cent increase
- during the same period, ethylene prices have undergone a 370 per cent increase
- the \$ 117/ton increase in naphtha prices has led to a \$ 240/ton increase in ethylene prices.

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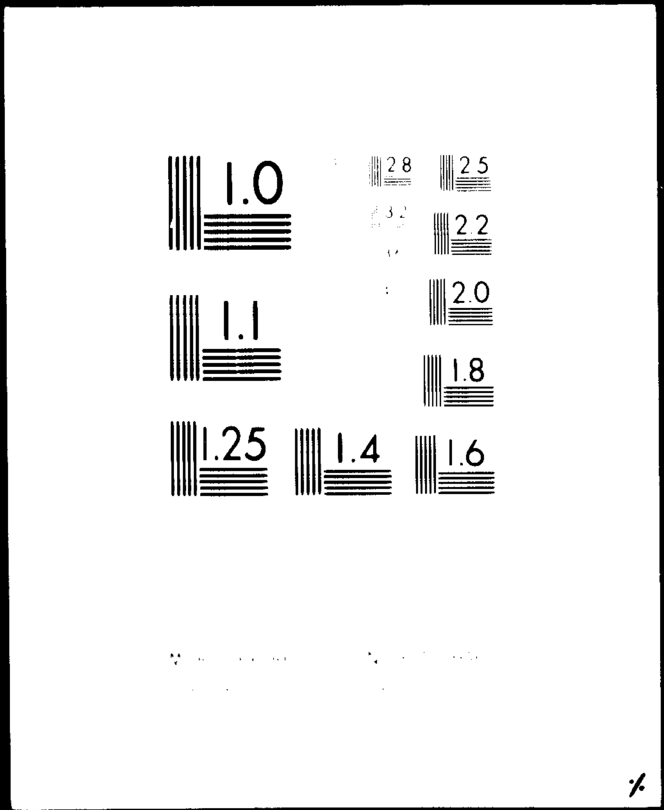

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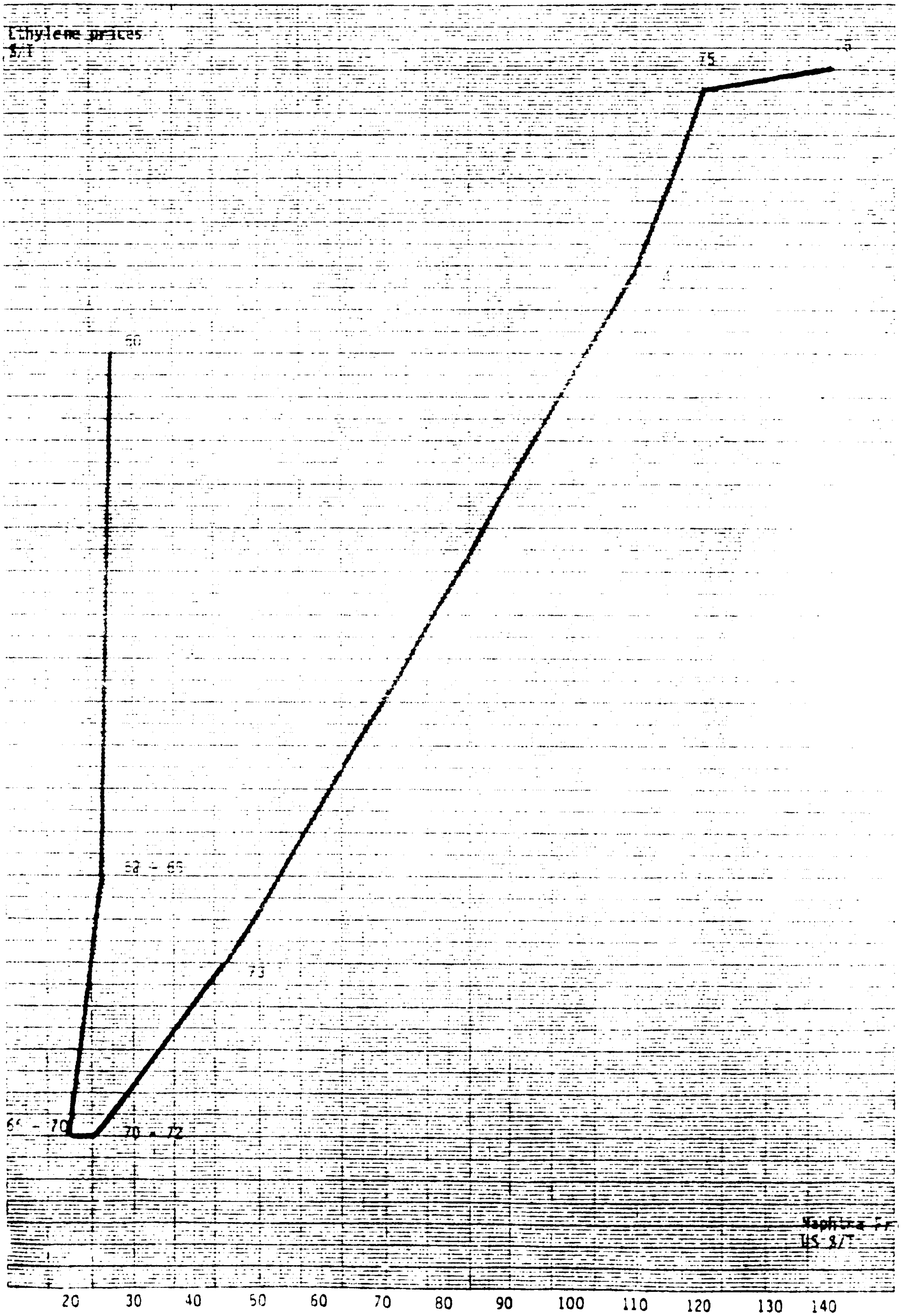
Figure 5. ETHYLENE VS. NAPHTHA PRICES



If naphtha-related production costs of ethylene are estimated to be about 72 per cent of total production costs, it can be concluded that ethylene market price-increases have rather well reflected the increase in naphtha prices, but have not followed the total increases in production costs. In other words, prices have not taken into account the capital-cost inflation. On the other hand, it is generally recognized that the $ 240/ton increase in ethylene prices only expressed the naphtha increase without taking into account other changes in production costs. This abnormal situation was mainly due to an overcapacity which kept prices depressed, but it can be assumed that prices would tend, in the long run, to cluster around a long-term-trend price determined by technical, economic and social considerations.

III. MEDIUM-TERM PROSPECTS: THE SITUATION IN 1985

3.1 MEDIUM-TERM PETROCHEMICAL DEMAND

3.1.1 Methodology

A combination of three approaches have been used for estimating the medium-term demand for plastics, man-made fibres and rubber:

(a) a macroeconomic approach based on trends observed over the 1965-75 period, with particular emphasis on the recession period that began at the end of 1973;

(b) assessment of structural changes and consumption end-pattern analyses for the major end petrochemicals;

(c) analysis of supply difficulties over the next few years.

Concerning the forecast for synthetic detergents, a simplified delphi method was used since the statistical base was not as comprehensive as for the other three main end petrochemical families. The macroeconomic approach underlies the existence of a highly correlated relationship between the consumption of end petrochemicals and the income per capita in a given country or region. To this end, different equations have been tested and the one that gives the best correlation coefficients is of the following form: $y = a \log x + b$, where y is per capita consumption, x is the GDP, and a and b are coefficients corresponding to a regression analysis using the least square method. However, although these equations lead to preliminary results of future demand for end petrochemicals, they cannot be used in a mechanical way based on past trends alone for they do not account for the entire effects of the current recession and the effects of a progressive market saturation.

Furthermore, even if this equation is a reliable approach for a given country or region, the same function cannot be applied directly to the world because of a too large scattering of results. However, the macroeconomic approach enables the use of a graphic extrapolation of consumption per capita levels against income per capita over a period of time as a very useful guide. A certain pace of growth and a particular end-uses breakdown of the demand generally correspond to different levels of consumption. The line representative of this evolution for petrochemicals is generally well established for the period 1965-75 except during 1973-75 for the high consumption per caput regions (say 10 Kgs per capita for plastics). For these latter regions the representative lines tend to become parallel among themselves. This situation shows that the income elasticity of these regions is almost constant and often about the same.

Furthermore, the representative lines of the evolution of demand against income over a long period for every region shape a "world master curve". This master curve represents the reference line of the world-wide demand for a product at a certain level of income. The individual position of each region with respect to the master curve shows its market potential.

These assessments complement the macroeconomic approach that is mainly based on an accurate analysis of the variations and trends of the per capita elasticity coefficients observed in the regions during 1965-75. The relevant data for the macroeconomic approach including its forecasts to 1985 is given in annexes 4(b), 5 (b), 6(b), 8(a) and 8(b). The forecasted coefficients of elasticity for the main end petrochemical families for 1975-80 and 1980-85 are given below. Their values have been selected based on the trends observed from 1965 onwards and foreseeable future developments. Coherence of these results between the regions and with those suggested by an end-uses analysis has been checked as well.

(a) Plastics

In developed countries, the coefficients of elasticity will keep higher than 3.0 up to 1980. Thereon, they would decrease to a limited extent corresponding to a still moderate degree of market saturation. Japan is the only exception among developed countries with a coefficient of elasticity of about 2.0. This situation reflects the relatively high GDP growth rate expected for the next ten years.

In developing countries, the coefficients of elasticity will, in general, keep higher than in developed countries, reflecting the large potential demand existing in these countries. However, there are two regions where the coefficient of elasticity will be close to 2.0: the Middle East, owing to the strong rise in income per capita, and East Asia, where the current consumption level is higher than those observed in other countries with about the same income level. Annex 4 (b) gives the main econometric characteristics of the world demand for plastics.

(b) Man-made fibres

In developed countries, current coefficients of elasticity of about 2.0 will significantly decrease over the next 5 years reflecting the saturation of textile markets. Likewise, Japan will have lower coefficients of elasticity for the same reason given above. Concerning the developing countries, the remarks given above for plastics also apply to man-made fibres. However, the coefficients of elasticity of Middle East and East Asia will likely be even lower (close to 1.0) than in developed countries. Annex 5(b) gives the main econometric characteristics of the world demand for man-made fibres.

(c) Rubber

With the exception of Eastern Europe, current coefficient of elasticity in developed countries is close to 1.0, thus reflecting the higher degree of market penetration and saturation. A coefficient of elasticity below 1.0 has been estimated for the next five years (between 0.85 and 0.95). In developing countries, the coefficient of elasticity will generally remain below 2.0. The remarks above concerning Middle East and East Asia also apply here. Annex 6(b) gives the main econometric characteristics of the world demand for rubber.

(d) Synthetic detergents

Based on the assessments of the delphi panel put forth by our technical consultants, the likely growth rate for synthetic detergents for 1975-85 was estimated. These estimates take into consideration the relative market stagnation in developed countries and the market expansion potential of developing countries as discussed in section 2.3.2.4. Annex 7(a) shows the estimated growth rates for 1975-80 and 1980-85.

3.1.2 Outlook on the evolution of the demand for petrochemicals to 1985

Taking into account the main factors of consumption growth for the four main end petrochemical families, forecasts of the demand for these products have been set up.

3.1.2.1 Main end petrochemicals

Based on the relevant data for the macroeconomic approach and an analysis of "world master curve" extrapolations, a preliminary set of medium-term forecasted demand figures was arrived at. This preliminary forecast was carefully checked, and in some cases corrected, taking into account several factors able to modify the long-term trend such as market saturation, improved competitiveness between polymers etc. These figures are shown in annexes 4(a), 5(a), 6(a), 7(a) and 7(b).

World demand figures are determined to a large extent by the developed countries' demand which in 1974 accounted for 89 per cent of the total and would still account for 81.5 per cent of the total in 1985. This means a substantial increase in the developing countries' share in total world demand: from 11 per cent in 1974 to 18.5 per cent by 1985. The share of the developing countries in 1985, by main end petrochemicals would be: 15.8 per cent of total world demand for plastics; 32.4 per cent of total world demand for man-made fibres; 21.2 per cent of total world demand for rubber and 26.1 per cent of total world demand for synthetic detergents. This new world market breakdown will be the result of sustained growth in demand amont the developing countries: 14.75 per cent/year, 13.8 per cent/year, 9.7 per cent/year and 6.6 per cent/year respectively over the 1974-1985 period.

(a) Plastics

The proportion of large tonnage plastics on the total plastics market will change moderately by 1985, thus continuing the trend established in past years. Thus LD polyethylene and PVC will lead with 22.7 and 20.7 per cent respectively of the total 1985 market, and polystyrene still about 10 per cent. On the other hand, plastics which have more recently come on to the market and whose growth is favoured at present by a relative price decrease, will certainly increase their share of the world market: from 7.0 to 10 per cent in the case of HD polyethylene; from 6.0 to 9.7 p. cent in the case of polypropylene and from 2.5 to 4 per cent in the case of ABS resins.

As a result of this, thermoplastics will increase their share of the total plastics market to the detriment of thermosettings. Such changes in the structure of plastics demand will continue to occur, to various extents, in almost every country. Annex 4(a) gives the forecasted demand for plastics for 1980 and 1985.

(b) Man-made fibres/synthetic fibres

Synthetic fibres today represent 71.5 per cent of the world man-made fibres market, having risen from 56 per cent in 1970, 38 per cent in 1965 and

and only 21 per cent in 1960. If this rate is sustained they will reach 77.5 per cent in 1980 and 83.5 per cent in 1985. This will be the result of demand for man-made fibres continuing to grow fairly fast while demand for cellulosic fibres alone remains static. Since by the eighties synthetic fibres will have supplanted cellulosic fibres to a great extent, demand growth for the former can be expected to be somewhat lower than in the past. The structure of the demand for synthetic fibres will continue to follow the trends established over several years, i.e.:

- stagnation as regards acrylics (18 per cent in 1975, 17 per cent in 1985)
- continuing decline in the case of polyamides (34 per cent in 1975, 27 per cent in 1985), matched by an increase of at least the same amount on the part of polyester fibres. On the long term, the potential market for the latter which lend themselves to the widest range of applications in the textile industry, will continue to be enormous. By 1985 polyester fibres could already represent about 30 per cent of all textile fibres (from 14 per cent in 1975 and 2. percent in 1980).

Annex 5(a) gives the forecasted demand for man-made fibres for 1980 and 1985. The corresponding figures for synthetic fibres can be derived by using the factor: percentage of synthetic fibres over total man-made fibres shown in annex 5 (b).

(c) Rubber, synthetic rubber

Synthetic rubber supplies nearly 70 per cent of the world's rubber needs today, in 1965 it had already reached 63 per cent. Market penetration seems slower, therefore, than in the case of synthetic fibres on the total man-made fibres market. This can be explained by the fact that the corresponding natural product was in a better position to compete. Natural rubber has, in fact, further improved its competitive position thanks to rising synthetic rubber prices and better yields from hevea plantations. In view of this, synthetic rubber should not be expected to significantly increase its share of the total rubber market in the next few years. The 1985 figure has been estimated at 72.5 per cent.

The structure of world synthetic rubber demand, in the light of previous years' trends, cannot be expected to vary greatly:

- stagnation or a slight drop in the case of SBR (63 per cent of the total)
- slight increase as regards polybutadiene (14 per cent of the total in 1985)

- stagnation or even a temporary decline on the part of other synthetic rubber (chloroprene, butyl, EPR, polyisoprene, etc).

Annex 6 (a) gives the forecasted demand for total rubber for 1980 and 1985. The corresponding figures for synthetic rubber can be derived by using the factor: percentage of synthetic rubber over total rubber shown in annex 6(b)

(d) Synthetic detergents

World demand for synthetic detergents is expected to be 17.2 million tons in 1985, whereas in 1974 it was 10.85 million tons, with an average annual growth rate of 4.3 per cent over 1974-85. Annex 7(a) gives the forecasted demand figures for 1980 and 1985.

Among the constituent elements of the synthetic detergents formulae, petrochemical-derived active ingredients represent about 20 per cent of the total. Therefore the demand for the two most widely used active elements, alkylbenzenes and non-ionic surfactants, was estimated. Annex 7(b) gives the forecasted demand figures for these products for 1980 and 1985. It shows that by 1985 the developing countries market share would be 31.7 per cent and 12.35 per cent respectively.

3.1.2.2 Main intermediate and basic petrochemicals

As intermediate and basic petrochemicals are mainly captive inputs of end petrochemicals production, their real markets are where the end petrochemicals plants are located. However, since there are many forms for arranging the production of intermediate and basic products to supply the end petrochemical plants, it was deemed convenient, instead, to estimate the potential market for intermediate and basic petrochemicals corresponding to end products demand as if all intermediates needed were locally produced in each region. Consequently, starting from the end petrochemicals forecasted demand the potential markets for intermediates and basics was estimated by applying technical factors obtained by up-stream integration. This potential demand represents by far the largest part of the total main intermediates market. The remaining part corresponding to miscellaneous uses has been estimated by referring to the structure of the demand in selected consuming areas. Annexes 13(a) and (b) give the estimated potential world demand for the main intermediate and basic petrochemicals.

3.2 MEDIUM-TERM PETROCHEMICAL PRODUCTION

3.2.1 Methodology

As the overall time required to implement a petrochemical complex takes between 5 to 7 years under normal conditions, the methodology used to estimate future plant capacities is as follows:

3.2.1.1 Capacities in 1980

The indicated capacities for 1980 are based on announced projects and facilities under design and construction. As concerns synthetic fibres, from habits and because of small size and easy construction of additional production lines that are usually implanted inside existing factories, companies are not accustomed to announcing their projects. The additional facilities have been estimated and must be considered as order of magnitude. These capacities by product and country are given in appendix A.

3.2.1.2 Capacities in 1985

The production capacities by regions in 1985 have been estimated, taking into consideration specific hypothesis indicated here below, product by product, and the following general assumptions:

(a) An overall trend to self-sufficiency in the developing countries reaching markets large enough to justify economic productions.

(b) Preferential locations in areas profiting by raw material availability and financial means.

(c) Solution of the problems that could rise in some countries by restraints such as personal formation or financial means availability, through international co-operation.

(d) Location of the most sophisticated products, preferentially in the developed countries.

(e) Imports of the non-producing developing countries from both their traditional supplier in the industrialized countries and the new producers of the area.

(f) Production capacities and consumptions in 1985 equilibrated at world level with an average plant capacity utilization rate of 85 per cent.

The petrochemical products have been classified into four groups:

(i) First group: final and intermediate that can be manufactured from imported raw materials. Their production can be contemplated individually.

(ii) Second group: ethylene and immediate derivatives of ethylene (and PVC). Their production is usually concentrated in complexes based on ethylene production because of high transportation costs of ethylene and vinyl chloride. (No significant ethylene transportation has been assumed).

(iii) Third group: other basic products: propylene, aromatics, butadiene and also polypropylene, the production of which is either linked to, or influenced by the ethylene factilities.

(iv) Fourth group: methanol, that can be produced from methane.

3.2.1.3 Plant capacity hypotheses, by product, to 1985

(a) First group products

S B R

The SBR production plant can be economically operated with capacities of about 50,000 ton/year based on imported raw materials (styrene and butadiene). In 1980, Western Europe, United States, Japan and East Asia will be in a position of over-capacity, the other areas being net importers. For 1985, it is assumed that Western Europe, United States and Japan will remain in over-capacity. In East Asia, no expansion is assumed. New plants would be erected in Middle East, South Asia and Africa, in order to meet locally a share of the local requirements. Eastern Europe will be balanced.

Polybutadiene

This product is more sophisticated than SBR. The outlets in tons are far lower. The production is and will probably remain concentrated in the developed countries, mainly in Western Europe, that will continue to export to other areas. For 1985, the following has been assumed: Eastern Europe and North America will be self-sufficient. Latin America, in over-capacity position in 1980 due to the new plants of Argentina and Brasil, will be close to equilibrium in 1985. In Africa, Middle East, East Asia, Pacific Area, the market of the individual countries will remain rather low and no additional units have been assumed. This hindrance will not exist in some South Asian countries where additional facilities of 80,000 tons/year have been assumed to have been added to the Indian plant presently under construction. Japan and Western Europe will remain high exporters, Japan mainly to Asian countries and Western Europe mainly to Africa.

DMT

In 1980, the offer and demand condition will be greatly unbalanced because of a large over-capacity at world level. Few units would have to be erected in order to meet the world requirements (corresponding to a 400,000 tons/year total capacity). It has been estimated that these plants will be located in Eastern Europe and Latin America. These areas would continue to be close to self-sufficiency as aggregates.

TPA

TPA also will be in a condition of notable over-capacity in 1980. The balance would still be obtained earlier and between 1980 and 1985 about 900,000 tons/year of additional capacity would be required, corresponding to about 10 new plants. It is assumed that these will be located in the United States, Europe and Latin America (self-sufficiency), in South Asia (300,000 tons/year) where several countries will reach notable individual markets, and in Middle East (1 plant of 80,000 tons/year).

Adipic acid Hexamethylene diamine

In 1980 both consumption and production facilities will be concentrated in the United States and Western Europe. From 1980 to 1985 few additional facilities would be required. It is assumed that they will be located in the United States and Western Europe according to the requirements.

Synthetic fibres

In 1980 Western Europe, Japan and East Asia will be in an over-capacity position as concerns synthetic fibres and will be able to export to the net consuming areas. Eastern Europe will be self-sufficient as concerns polyamids and polyesters, and Latin America as concerns polyamids.

In 1985 the following situation has been assumed: Latin America, Eastern Europe and United States would be self-sufficient. Africa would increase its production/consumption ratio, but would still be dependent on imports mainly from Europe. East Asia would remain net exporter, mainly to the South Asian countries, these would later nevertheless increase their production/consumption ratios. Japan and Western Europe would remain net exporters.

Polystyrene

This polymer can be economically produced from imported monomer at low capacity (lower than 50,000 tons/year). In 1980 at regional level, outlets and production facilities would be roughly equilibrated, except Japan and mainly Western Europe (over capacity) and Africa, with only one small capacity plant in South Africa. It has been assumed that in 1985 there will be an offer and demand situation roughly equilibrated at regional level in Africa except where only the South African requirements have been considered to be locally met. The outlays of North Africa have been preferentially estimated to be intended for the ethylene and immediate derivatives production. Export from Western Europe to Africa would go on.

Caprolactam

The order of magnitude of the new capacities is 80,000 tons/year. Such plants require high investments (about 180 million $). The main raw material, benzene, can be easily transported. In 1980, the offer and demand situation would be as follows: North America, equilibrium; Japan and Western Europe, over capacity; Latin America, trend towards self-sufficiency; other areas, need to import. In 1985, it has been assumed that Japan and Western Europe would continue in an over-capacity situation. Latin America, with the start-up of two 90,000 ton/year plants would be as a whole self-sufficient and Eastern Europe would head towards autonomy (nevertheless it would be reached because of the very high capacity to be erected). North America would be equilibrated. In South Asia a limiting factor will be the capacity of the polyamid fibres production facilities (estimated at 300,000 tons/year). However, it has been assumed that the production/consumption ratio will increase.

Acrylonitrile

This product can be easily transported. It needs propylene as raw material. The present unit capacities are around 100,000 tons/year. The corresponding investment is rather high (about 80 mil.$). In 1980, as in the present, the main exporting areas are Western Europe, North America and Japan. It is assumed that these areas will remain in an over-capacity situation in 1985. Eastern Europe would probably be self-sufficient. East Asian countries, in relative global over-capacity in 1980, would not erect additional plants. African and Middle East countries will not have individual internal markets high enough to back exports and would not erect facilities. On the other hand it has been assumed that the new facilities will be erected in Latin America and South Asia, where some countries like Brazil, Andean group countries, India, and Iran would be able to implement them.

(b) Second group products

These products are ethylene, low-density polyethylene, high-density polyethylene, vinyl chloride, polyvinylohloride, styrene, ethylene oxide. The following assumptions have been made:

Latin America

In the aggregate the requirements will be met by local production, with the exception of the equivalent of 300,000 tons/year ethylene corresponding to the production of sophisticated products (other than polyethylene, vinyl-chloride, styrene and ethylene oxide) and of about 5 per cent of the main ethylene derivatives, imported from the United States by the non-producing countries.

North America

The production will meet the needs of the region and the deficit of Latin America.

Eastern Europe

The area will be self-sufficient and, additionally, will produce about 400,000 tons/year of low-density polyethylene corresponding to buy-back deals with Western Europe.

Western Europe

Western Europe will import about 400,000 tons/year of low-density polyethylene from Eastern Europe (buy-back deals), about 400,000 tons/year of ethylene from Africa in the form of 200,000 tons/year of low-density polyethylene, and 400,000 tons/year of PVC and about 350,000 tons/year of ethylene from Middle East in the form of 200,000 tons/year of polyethylene and 300,000 tons/year of PVC. It will sell about 500,000 tons/year of ethylene to Africa, 150,000 tons/year in the form of sophisticated products, 250,000 tons/year in the form of polyethylenes, PVC styrene, polystyrene, ethylene oxide, and 100,000 tons/year to Middle East in sophisticated products.

Africa

Taking into consideration the already planned ethylene-based complexes of the Libyan Arab Jamahiriya, Egypt and South Africa, the only additional countries in a good positon to build new complexes are Algeria and Nigeria. At continent level, it has been assumed that the equivalent of 500,000 tons/year of ethylene will be imported from Western Europe, 150,000 tons/year in the form of sophisticated products; 250,000 tons/year in the form of polyethylenes, PVC, styrene and polystyrene and ethylene oxide. On the other hand, 400,000 tons/year of ethylene will be exported to Europe, mainly from plants located on the Mediterranean Sea in the form of high-tonnage products: polyethylene and PVC.

Pacific area

The region will be self-sufficient with the exception of the equivalent of about 100,000 tons/year of ethylene imported in the form of sophisticated products.

Middle East

The region will benefit from attractive raw material availability (mainly ethane) and of consequent financial resources coming from hydrocarbon exports. It has been assumed that international companies from Japan and Western Europe would participate in complexes in the region, providing technical assistance, skilled manpower, and opening a share of their traditional markets to the products. The region will export about 200,000 tons/year of polyethylene and

300,000 tons/year of PVC to Western Europe, 80,000 tons/year of high-density polyethylene, 150,000 tons/year of low-density polyethylene and 300,000 tons/year of PVC to Japan. It will import about 100,000 tons/year of ethylene from Western Europe in the form of sophisticated products.

East Asia

Several countries in the region have already entered into petrochemical activity and, according to the firm projects, the area will be ethylene-balanced in 1980. It has been assumed that the region will import from Japan about 100,000 tons/year of ethylene in the form of sophisticated products, and that complexes will be erected with Japanese participation in the region (in order to decrease pollution problems in Japan and to benefit from a share of the local market), exporting to Japan 80,000 tons/year of high-density polyethylene 150,000 tons/year of low-density polyethylene and 300,000 tons/year of PVC.

South Asia

In this area, Iran will benefit from raw material availability and financial resources. It has been assumed that complexes will be erected there with Japanese participation, exporting to Japan 80,000 tons/year of high-density polyethylene, 150,000 tons/year of low-density polyethylene and 300,000 tons/year of PVC. On the other hand, the region would import from Japan about 150,000 tons/year of ethylene in the form of sophisticated products, and 150,000 tons/year of ethylene in the form of polyethylenes, PVC, polystyrene and ethylene oxide, corresponding to a share of the non-producing countries' market.

Japan

Japan would be mainly an exporter of sophisticated ethylene derivatives, corresponding to 250,000 tons/year of ethylene and would import from complexes erected with Japanese participation in the Middle East, East Asia and South Asia 240,000 tons/year of high-density polyethylene, 450,000 tons/year of low-density polyethylene and 900,000 tons/year of PVC.

(c) Third group products

Butadiene

Butadiene can be extracted from the C_4 cuts of the naphtha and gas oil steam-crackers. At world level it will be a relatively low deficit, made up through butane dehydrogenation facilities located in the most deficit-showing areas, North America and Eastern Europe. For reasons connected with relative locations of surplus and deficit, these butane dehydrogenation facilities have been assumed to be slightly higher than the total world deficit.

Propylene

Propylene is a co-product of ethylene when using liquid feeds steam-cracking; it is also produced in catalytic cracking facilities located in refineries. Taking into consideration the estimated ethylene and catalytic cracking facilities, the offer/demand situation would be balanced in 1985. At that time, North America and, to a far less extent, Western Europe and East Asia would be net exporters. The other regions would import a share of their needs in the form of propylene derivatives, except Eastern Europe, that are balanced. The following propylene movements in 1985 in the form of derivatives have been assumed:

- North America will export the equivalent of about 650,000 tons to Latin America, 100,000 tons to the Middle East, 330,000 tons to Japan, 400,000 tons to South Asia, 170,000 tons to Pacific Area.

- Western Europe will export the equivalent of about 120,000 tons to Africa and 110,000 tons to Middle East.

- East Asia will export to Japan the equivalent of about 370,000 tons year.

Polypropylene

It has been assured that the polypropylene production demand situation will be balanced at regional level in 1985, with the exception of Japan, who will import 400,000 tons: 200,000 from East Asia and 200,000 from North America.

Ortho- and paraxylene

C_8 aromatics are produced in both steam-cracking and catalytic reforming units. However, C_8 cut from steam-crackers is used as solvent; the only commercial production of o- and p-xylene is based on catalytic reforming. o- and p-xylene are produced in the same facilities. The designs of units allows the adjustment, o/p-xylene production ratio to the needs. This production induces toluene and benzene production. The actual outlets of p-xylene are the DMT and TPA plants. It has been assumed that a global self-sufficiency will be reached at regional level with the exception of Africa importing from Western Europe and exports from Eastern Europe to Western Europe. As concerns o-xylene, it has been assumed that a global self-sufficiency will be reached at global level, with the exception of Africa importing from Western Europe and South Asia importing a share of its needs (about $\frac{1}{2}$) from Japan.

Benzene

A share of the benzene production is linked with the ethylene production: benzene is produced in naphtha and gas oil steam-crackers at the rate of about

0.18 tons of benzene per ton of ethylene. Benzene is also produced in the xylenes production facilities: about 0.29 tons of benzene per ton of xylenes. The totality of this benzene by-product has been assumed recovered. Small amounts of benzene are also recovered from coal processing (coke-oven).

These co-productions are not sufficient enough to meet the benzene requirements at both world and regional levels. A share of the toluene produced from steam-cracking and xylene facilities has been assumed to feed hydrodealkylation units producing benzene. Due to the high energy consumption of these units, it can be considered more attractive in some cases to extract benzene from aromatic cuts produced in the catalytic reformers for gasoline pools.

The notable benzene outlets are in the form of numerous and sophisticated products the production of which has been assumed to remain in the developed countries; a notable share of benzene would be exported from North America, Western Europe and Japan to the developing countries.

(d) Fourth group product

Methanol

Methanol is the chemical commodity easiest to transport on long haul. It can be produced from methane, the cost of which represents about 60 per cent of the production cost. The countries having cheap natural gas resources available will rapidly grow as producers. In 1985, 94 per cent of methanol units will produce methanol for export, for example the USSR and Saudi Arabia signed contracts for 2,500 tons/day and 2,000 tons/day units. Western Europe will import methanol (about 2 mil. tons) from the USSR and Africa. Japan will import about 2 mil. tons from other Asian countries. North America will import about 1 mil. tons from Latin America and Middle East. This important international trade (20 per cent of methanol production) assumes methanol consumers will grasp opportunities offered by cheap natural gas resources and low freight rates tied to massive transports by tankers.

3.2.2 Production outlook for petrochemicals to 1985

Few developing countries will enter the petrochemical industry between 1977 and 1980. As far as basic and intermediate products are concerned, the new producing countries would be Egypt, the Libyan Arab Jamahiriya, Iraq, Qatar and Iran. Other developing countries that are already producers such as Venezuela, Brazil, Mexico, Argentina and Republic of Korea, will increase their capacities a great deal; nevertheless the share of the developing countries will remain low.

Annexes 14(a), (b) and (c) show the estimated production capacities for the main petrochemicals, by region. If the assumptions leading to the 1985 estimates would be confirmed, the share of the developing countries in the world petrochemical production would be as follows:

Share of the developing countries in world production capacities
(percentage)

	1977	1980	1985
Ethylene	6	11	17
Benzene	3	7.5	15.5
Xylenes	6.4	13.5	16
Monomers for synthetic fibres production	4	10.5	14
Synthetic rubbers	8	10	13
Synthetic fibres	16	18	23
Plastics (thermoplastics)	6	9.3	20

3.2.3 Feedstock supply and energy requirements to 1985

Based on the estimates for petrochemical plant capacity arrived at in section 3.2.2, the requirements for feedstocks and utilities were calculated. On a world basis, the hydrocarbons required to produce the eight main basic petrochemicals represent 95.8 per cent of all hydrocarbons used as feedstock. Other hydrocarbons are more commonly used as fuel by the industry. However, the net requirements are limited because petrochemical plants based on steam-cracking units produce large amounts of fuel (or equivalent) as by-products. The plant capacity values for basic products given in annex 14(c) converted into production figures allow the estimate of net utilities consumption, by main petrochemicals. In these estimates fuel, electricity and steam requirements are mainly met by fuel oil and gas, for in many cases petrochemical complexes self-produce their steam and electricity. They also include fuels recovered as steam-cracking by-products in calculating the net utilities needs. Annex 15 gives the petrochemical industry's hydrocarbon requirements in 1985 for feedstock and utilities. As only 8.6 per cent of ammonia is used for petrochemicals production, the amounts of ammonia for other uses are also given. The petrochemicals' hydrocarbon requirements in 1985 represent about 4.6 per cent of the total energy needs in 1985 and 7.3 per cent of total hydrocarbon consumption in that year, discounting non-petrochemical ammonia uses.

The situation by main type of hydrocarbons is as follows:

(i) Methane: about 7 per cent of the 1985 gas consumption is used for ammonia, methanol and minor petrochemicals manufacture. No problems of feedstock availability is foreseen at world and regional levels (except for Japan).

(ii) Ethane: assuming a recovery of 31 per cent on ethane contained in associated gases (and some natural gases), 42 per cent of available ethane will be used for ethylene production. This limited availability will act as a brake on the development of ethane crackers.

(iii) LPG: about 9 per cent of the 1985 availability of LPG will be used in petrochemicals. Foreseeable surplus of LPG in the 1980's will open opportunities for each petrochemical firm meeting problems of feedstock for a steam cracker.

(iv) Naphtha: on a world-wide basis 28 per cent of the naphtha available from topping-reforming type refineries will be used for petrochemical production. Due to the competition of feedstocks with the gasoline pool, a more precise analysis is necessary.

(v) Gas oil: about 5 per cent of gas oil produced in refineries will be used as petrochemical feedstock. However, as gas oil is extensively used for transportation and heating, and by the industrial sector, its availability has to be seen more precisely.

(vi) Fuel oil: only 1 per cent of available fuel oil will be used as petrochemical feedstock (and 6 per cent if all net utilities requirements are met by fuel oil).

Annex 16 gives an estimate breakdown of world consumption of crude oil products by the main energy users. Consequently, the regional supply of feedstocks for petrochemical production is as follows:

(a) The supply of raw materials for the petrochemical industry accounts for only a small part of total hydrocarbon consumption. Problems concerning the availability of raw materials for the petrochemical industry will continue to be very much a function of the economic situation.

(b) With regard to gas, the main raw material used for the production of methanol and also ammonia, only Japan being entirely dependent on imports, can be expected to have a significant problem with regard to supplies. North America and Europe will, in certain areas, have to face price problems, since these regions make up their deficit of gas by relatively costly imports of LNG.

(c) Everywhere but in Eastern Europe there will tend to be a deficit of naphtha. Some regions, particularly Western Europe and Japan, will have to set aside a large amount of their straight run naphtha for use in the petrochemical industry (about 48 per cent and 38 per cent respectively in 1985). More costly refining schemes and strong tension on naphtha prices can be expected in these areas.

(d) In the developing countries the low consumption of fuel oil and the high demand for naphtha will present big problems. If ethane or LPG are available they will have a privileged place as steam cracking feedstocks; the use of gas oil may lead unavoidably to the production of poor quality fuel oil, which it will be very difficult to sell on account of the lack of major industrial development and the very low requirements of the domestic heating sector. The extensive use of naphtha without the required upgrading facilities will have the same adverse effect because for one ton of naphtha produced in a refinery, three tons of fuel oil are also obtained. It appears this will be the major problem for developing countries as far as petrochemical feedstocks are concerned.

3.2.4 Capital requirements to 1985

Investments for petrochemical plants vary according to the plant location and the technical options relating to production and financing conditions.

In plant location, local conditions substantially affect the main constituent elements of the construction cost such as engineering services, plant and equipment, plant erection and civil works. Construction costs are generally higher in developing countries than in developed ones due to several reasons such as lack of adequate infrastructure, construction management to avoid cost overruns, the greater distance from equipment suppliers etc.

Concerning the technical options, there are many factors affecting investment. The more important ones are the choice of process and of raw materials, plant sizes and degree of integration within a complex, and the policy adopted for production schemee and the supply of utilities.

In view of the considerable variation in investment that is possible for a given output, the investment estimates represent a regional average for typical plant capacities in US dollars of 1977. The total investmente for 1980 and 1985 were estimated based on the battery limite investment cost estimates shown on table 17. The cost of the correeponding off-sites that varies considerably according to the technical options chosen, has been estimated on average as 25 per cent of battery limits coste.

As the plant location also greatly influences the cost of local factors on the total investment cost, specific regional construction cost indexes were estimated based on field surveys in developing and developed countries. The construction costs indexes are as follows: developed countries: 100, Latin America: 1.25, Africa: 1.30, Middle East: 1.35, Other Asia (excluding Japan and China): 1.25.

The cost of administrative expenses, project management and follow-up, initial supply of catalysts and chemicals, spare parts, training and start-up, represent on average 14 per cent of additional costs over the battery limits investment.

Based on the above and the corresponding plant capacity estimates for main petrochemicals, annex 17 was prepared to show the investment requirement estimates to 1980 and 1985. These estimates include the investments for plant replacement assuming a 30-year plant life.

3.2.5 Manpower requirements to 1985

Manpower requirements depend essentially on plant size, average level of qualifications, production plant automation policy and the degree of plant integration within a complex. In general terms, total technical personnel break-down for petrochemicals production, except synthetic fibres, is as follows: engineers and managerial staff: 5 per cent, foremen and technicians: 15 per cent, skilled workmen: 55 per cent and unskilled workmen: 25 per cent. Total technical personnel in synthetic fibres production is about 130 per cent of the technical personnel of other petrochemicals production, and is broken down as follows: engineers and managerial staff: 3 per cent, foremen and technicians: 8 per cent, skilled workmen: 49 per cent and unskilled workmen: 40 per cent.
In general terms, administrative personnel is estimated at 10 per cent of technical personnel requirements, whereas marketing personnel is estimated at 5 per cent of technical manpower. Annex 18 gives the manpower requirements for 1985.

3.2.6 Technological developments

In addition to the trends and changes described in section 2.2.7, further developments in production technology can be expected. In general, the expected changes are more likely to result from further improvements on existing processes than from the introduction of new routes on a commercial scale. The more likely technological changes by products are the following:

(a) Basic products

(i) Olefins

The main changes anticipated in the production of olefins will be brought about by problems in connection with the availability and price of raw materials and the cost of energy: these have already been discussed. There will be a general tendency towards greater flexibility at all levels: in raw materials, fuel and also in the distribution of products.

(ii) Aromatics

The production of aromatics will be more closely linked to the production of olefins and the part played by catalytic reforming in benzene production will diminish. With regard to catalytic reforming units, the tendency towards the use of increasingly greater severity which is already apparent, will continue.

In the field of the production of benzene by toluene hydrodealkylation, thermal processes have, thanks to recent progress in the improvement of yields, partly caught up with catalytic processes, which still have the disadvantage of making frequent de-coking necessary. The toluene dealkylation method will meet strong competition in the future from a new method based on toluene and with a lesser degree of aromatics in C_9 transalkylation. Both benzene and xylenes are obtained. Transalkylation takes place on a catalyst during the gaseous stage, in the presence of hydrogen.

(b) Intermediate products in the production of plastics

(i) Vinyl chloride

Some units which use acetylene are still operating, but this method is likely to be discontinued. The oxychlorination process will remain the mose widely used. The only changes anticipated are connected with safety and pollution problems: elimination of the risk of leakages, and greater control over the VCM contained within the battery limits of units; reduction and incineration of non-valorizable chlorine residue.

A new route for the production of VCM from ethane has been developed: the corresponding process, which is called Transcat, is based on direct synthesis by oxychlorination, from ethane and chlorine. The potential licensors claim that the chlorinated by-products of the reaction can be recycled with an increased yield of VCM. The main advantage of this process is the direct use of ethane instead of ethylene. It could be used where there are not enough outlets for ethylene (apart from VCM production) for a steam cracking unit to be required, and of course, where ethane is available.

(ii) Styrene

The changes which can be expected in the next few years in the manufacture of styrene are linked to the development of new, high-yield catalysts which affect the alkylation of benzene and ethylene at the steam stage. When these new catalysts are used, the catalysis is truly heterogenous: no trace of the catalyst leaves the reactor and the operations of separating and recycling the catalyst are therefore unnecessary. The recently discovered method which uses butadiene dimerization does not appear to be sufficiently developed for industrial use; besides, butadiene would have to be obtainable at a very low price in order to compete with the classical route using ethylene and benzene.

(c) Intermediate products in the production of synthetic fibres

(i) Dimethyl terephthalate (DMT) and terephthalique acid (TPA)

These two monomers are in competition with each other in the production of polyester fibres. The DMT route has been the predominant one in the past, due to technical difficulties in obtaining TPA pure enough for use in the production of fibres. However, over the last few years, the proportion of polyester fibres produced from TPA has risen steadily, chiefly thanks to improvements offered by the TPA process developed by AMOCO. The quantities of raw materials used are not the same: the production of 1 ton of polyester fibres requires 0.91 tons of TPA, or 1.1 tons of DMT. As far as the producer is concerned, there is no difference in the quality of fibres produced from DMT or from TPA. The technical problems presented by the use of TPA have been resolved, and the world's largest producers, such as ICI, Rhone Poulenc, Monsanto and Toray generally use TPA. However, if a producer of fibres who uses DMT decides to switch to TPA as feedstock, some modifications to the plant will be required. From the fibre producer's point of view, the TPA route offers more economic advantages such as: fuel consumption is reduced by about 20 per cent; the investments required are slightly lower; less TPA is consumed than DMT whereas their cost prices are very similar in large capacity units.

TPA will gradually replace DMT. In particular, all the main new plants being set up by the world's largest producers will use the TPA route which is very advantageous. However, DMT is still competitive where smaller capacities are involved, and DMT units will continue to be built during the next few years, mainly to supply fibre producers whose plants are designed to use these products.

(ii) Caprolactam

The method involving Beckmann's rearrangement of cyclohexanone oxime will continue to be the most widely used, with benzene via cyclohexane remaining the predominant raw material. The chief drawback of this method used to be that considerable quantities of ammonium sulphate, for which there are generally very few outlets, were produced as a by-product. Some companies have, however, developed processes by which the amount of the ammonium sulphate by-product is reduced from 4.5 tons to 1.8 tons per ton of caprolactam (Stamicarbon's HPO process) or even totally eliminated at the cost of higher investments and greater consumption of energy (Stamicarbon's bisulphate lactam process). Research is being carried out at the moment with the aim of making the latter method more economical, and it will probably be widely used in the future in areas where there are no outlets for ammonium sulphate.

(d) Plastics

No spectacular developments are expected in the field of polymerisation methods. Changes in the production of polystyrene and PVC will essentially concern the reduction of the quantity of monomers in the resins, in order to meet new, stricter specifications. With regard to high-density polyethylene and polypropylene, more active catalysts will be used, and this will lead to a significant reduction in production costs due to sections for the removal of residual catalyst that are no longer required.

(e) Synthetic fibres

The case of the production of synthetic fibres is similar to that of plastics: few new methods will be introduced. One development that can be anticipated, however, is the integration of the texturation of polyester yarns into their manufacture, resulting in a marked decrease in the cost of texturation.

(f) Synthetic rubbers and monomer

In the field of high diffusion synthetic rubbers, no technological changes are expected to take place. In view of the existence of ever larger capacity steam cracking units, production of isoprene by extraction from C_5 cuts from steam cracking will increase. Production from one steam cracking alone would not be economical as the isoprene obtained is equivalent to only about 3 per cent of the ethylene. Therefore the C_5 cuts from several steam cracking units would have to be used together to give an economical size. The proximity of steam cracking units and transport facilities will be important factors in the development of this method.

3.3 DEVELOPMENT OF THE INTERNATIONAL TRADE

3.3.1 Evolution of trade exchanges

According to the estimates made for 1985 the international trade of petrochemicals would be highly altered. The main new trends would be:

(i) a global increase in self-sufficiency at regional level,

(ii) a less prevailing positon of the developed countries,

(iii) despite the trend toward regional self-sufficiency, the trade volume would keep at least its present order of magnitude because of consumption increases and the appearance of new trade streams,

(iv) the appearance of new trade streams such as sophisticated products exported from developed to developing countries (currently of little importance), commodities and high consumption products exported from developing countries (mainly hydrocarbon-producing countries) to developed countries.

These trends will demand greater efforts and resources in the areas of marketing and distribution by the emerging exporters in order to benefit from their attractive production costs.

3.3.2 Future price trends

In recent years petrochemical prices have been upset both by sudden changes in some manufacturing cost elements (raw material, investment) and by a situation of general overcapacity. It is expected that in the future the overall situation will tend towards equilibrium, and that price trends will be more linked with changes in the production cost elements. From a general point of view the production cost evolution can be practically tied to two main factors: crude oil prices and overall inflation (general price index related charges: investment related, manpower, maintenance tec.). The impact of changing crude oil prices (via naphtha, LPG, fuel etc) becomes less important when working from basic to intermediate to end products.
Annex 19 presents the respective shares of the present prices of some petrochemicals that will move accordingly with the crude oil price and the general inflation.

IV. LONG-TERM PROSPECTS: THE SITUATION IN THE YEAR 2000

4.1 METHODOLOGY

When considering the future, a distinction should be made between the future - that is, the foretelling of happenings at any given time horizon - and the futures - the exploring of possible economic situations in the future based on the probably extension of current trends, the happening of probable events and possible variations of present sectoral restrictions.

The first concerns mankind as a whole and cannot be described in detail. Moreover, even if it could be described, it would represent a point function in the future without explanation as to how one got there from the present. Thus it would not be a very useful aid for immediate decision-making. The second kind of future pertains to the world's economic game board that, to a large extent, influences and is influenced by the economic players or actors. This means that, as in every human contest, the setting of agreed economic rules of the game and the skills, resources, knowledge and strategy of the economic players make all the difference between belonging to the winners or the losers. Therefore it is in this second context that three broad approaches are possible:

(i) The opportunistic approach that concentrates on short-term options and leaves the future to take care of itself. These practices usually create increased turbulence in the international environment, decisions become erratic and often work against other decisions.

(ii) The deterministic approach based on the extrapolation of past trends and an analysis of possible events. This view involves two modalities:

- forecasting models that are mechanistic time series extrapolation techniques based on past trends alone. The methods can be graphical, mathematical or statistical but all are functions of time as the only independent variable;
- simulation models built on structural relationships of quantitative variables used to analyze, through simulation, alternative hypotheses and strategies within the model in order to appraise the results of alternative decisions before a final decision is taken.

(iii) The normative approach views the future in terms of alternative desirable possibilities for whole systems (futures). It involves the use of prognostics that are futures research techniques enclosing qualitative and quantitative variables. It also implies the intentions of the economic players or actors to influence the current deterministic trends and steer them towards a desirable alternative possibility along defined strategic options.

For the purposes of this study, a World Petrochemical Industry Simulation Model has been used to explore various development alternatives to the year 2000 based on a combination of macro-economic, regional and product hypotheses. By using scenario methodologies further on-going studies will more deeply explore the implications on the petrochemical industry of the normative aim stated in the Lima Declaration and Plan of Action.

4.2 THE WORLD PETROCHEMICAL MODEL

When analyzing a sector, two main factors help its definition: its characteristics and its dynamics.

The characteristics of the petrochemical sector are given by its physical internal structure that mainly includes its stoichiometric relationships from feedstocks to basics to intermediates to end petrochemicals. These characteristics are shown in figure 1 (page 7a). The dynamics of the petrochemical industry are given by its social structure that includes the sectoral environment and the strategy of the actors. Figure 6 shows the environmental structure of the industry including the main actors.

4.2.1 Description of the method

The futures explored are based on a small number of hypotheses and the relationships of the sector to its environment. Based on them, the world demand and world production can be estimated and the constraints on inputs such as feedstocks, investment and manpower can be brought to light for further calculation.

Considering that the variables of the model influence each other mutually, a computerized iterative process has been used at every stage and for the whole model to express such relationships between variables in order to arrive at consistent and coherent pictures of the year 2000 compatible with the main hypotheses explored. The general steps of the method are as follows:

(i) Stating of the main hypotheses to be explored.

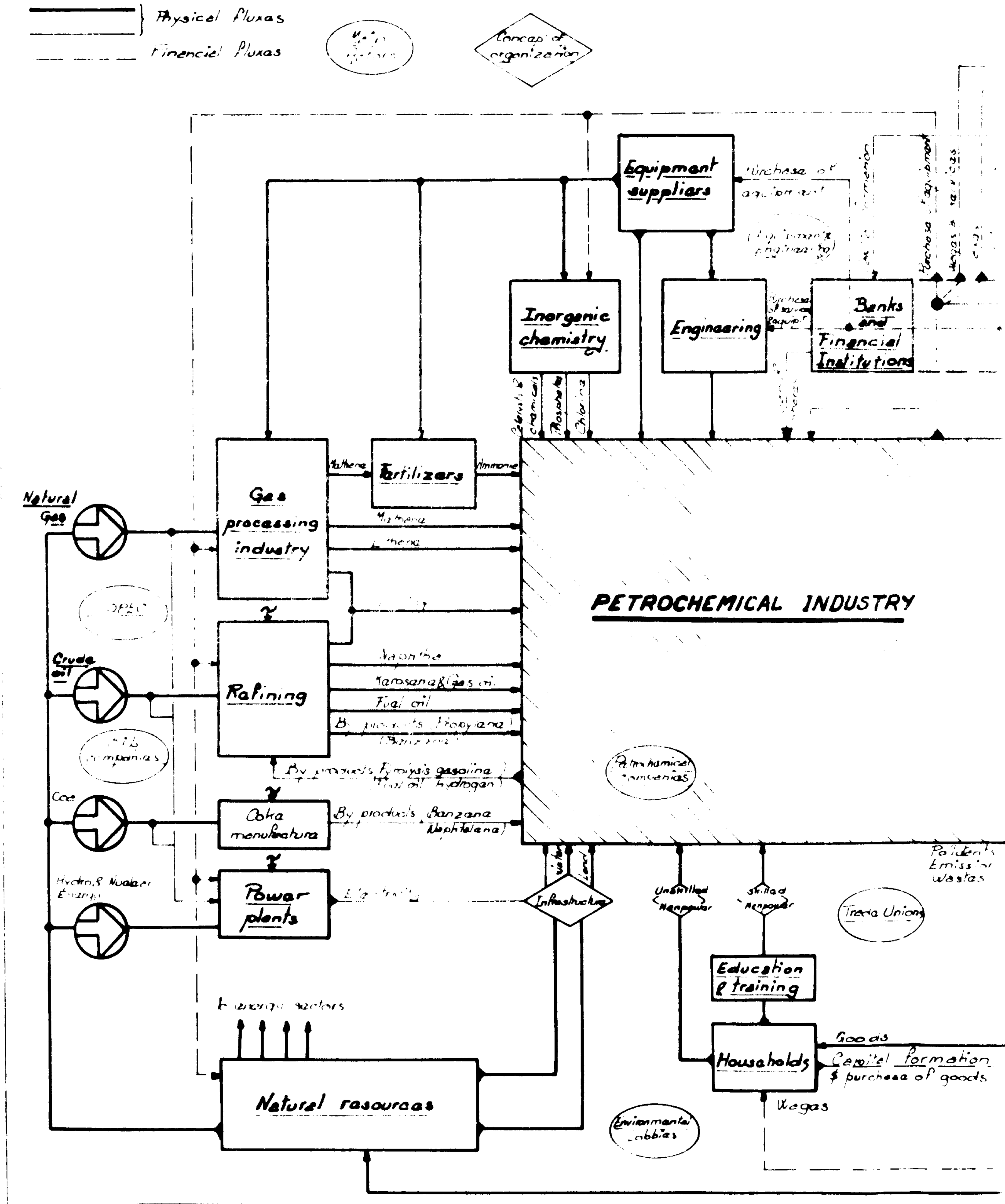
(ii) Then, formulating a preliminary set of consistent assumptions relative to key variables such as GDP growth rates, coefficients of elasticity, trade exchange etc. The preliminary set of assumptions are based on a previous analysis of the characteristics and dynamics of the petrochemical industry that identify the main variables and actors.

(iii) From there on, the consumption of the main end petrochemicals is determined for each main hypothesis. Intermediate and basic product requirements are estimated based on the stoichiometric relationships of the internal structure. Exchange level assumptions are used to assess the necessary production, by region.

(iv) The production capacity requirements can be established from the figures in (iii) above and hence estimate the finance, manpower and raw material needs, by region.

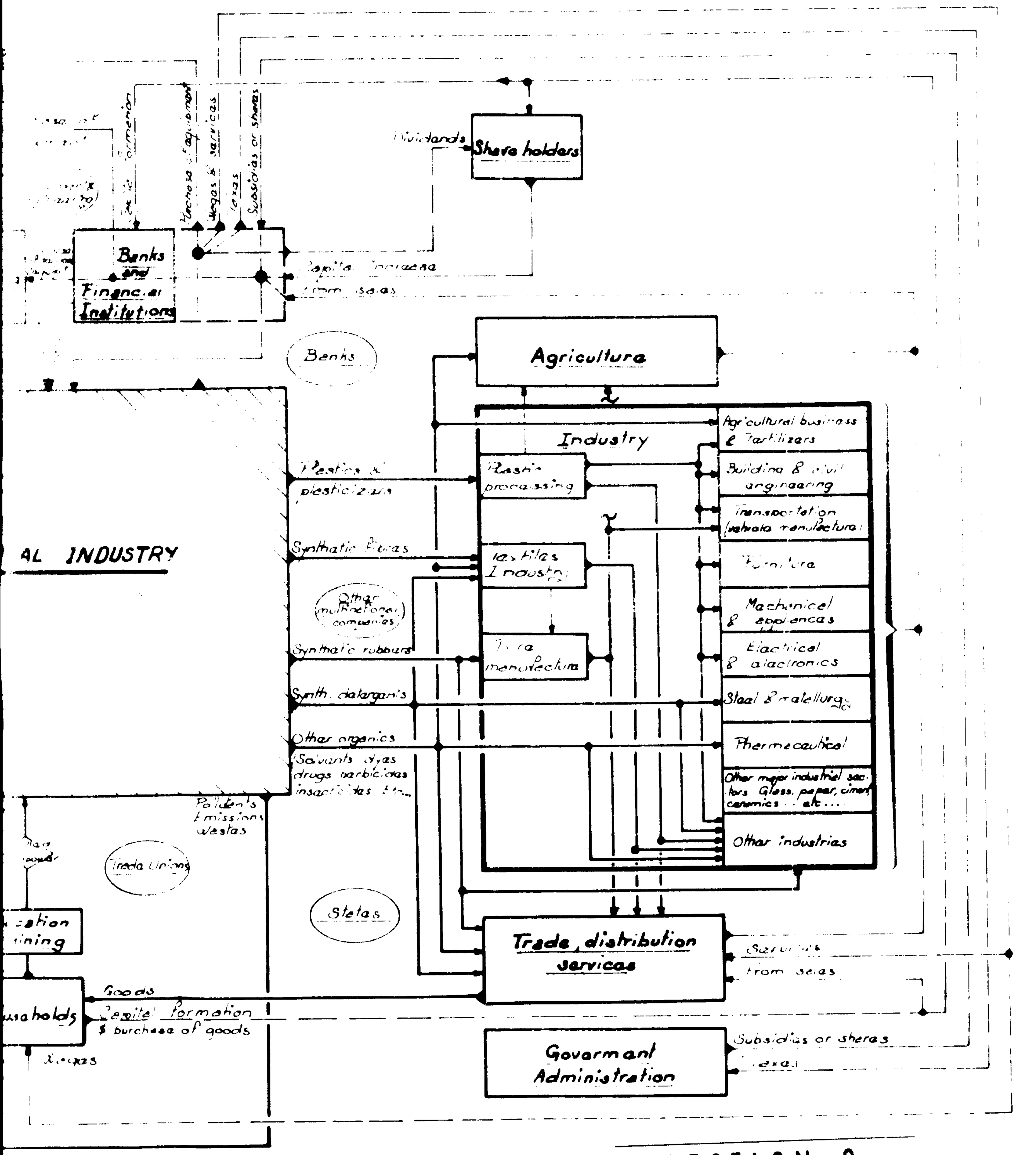
ENVIRONMENTAL STRUCTURE OF THE PETROCHEMICAL INDUSTRY

Figure 6

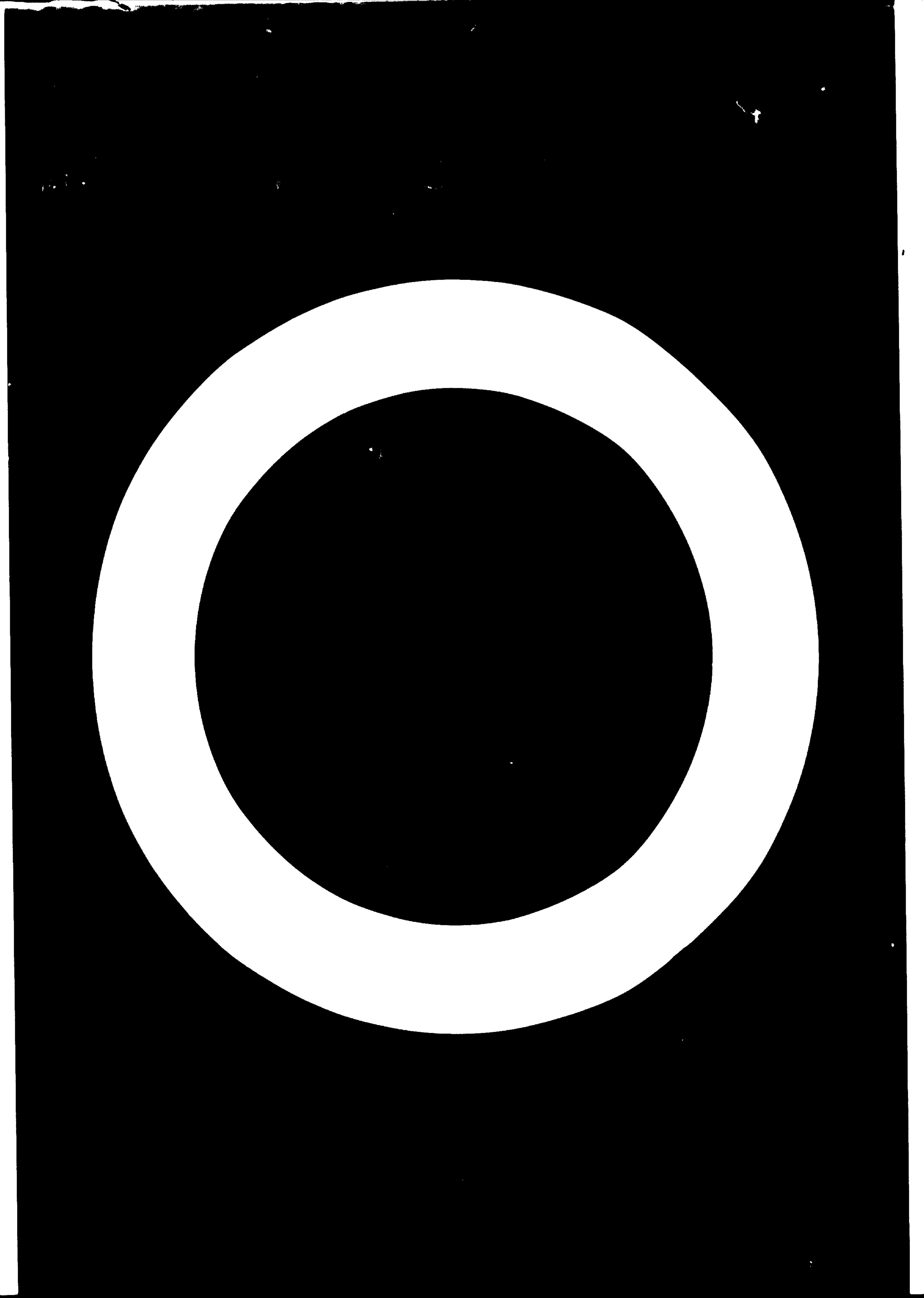


SECTION 1

Figure 6



SECTION 2



(v) In the light of a critical examination of constraints to be overcome and the feedback of the iterative process, certain preliminary assumptions may be modified in order to obtain a set of quantified and consistent pictures of the year 2000 for the main hypotheses.

4.2.2 Structure of the model

The World Petrochemical Model is a simulation model operating on sets of hypotheses applied in the input to the parameters affecting the various activities considered. The model comprises several aggregation levels (108 countries, 15 regions) and two main structures: a dynamic structure expressing demand growth and a static structure reflecting the situation at a given period.

(a) Dynamic structure of the simulation model

This structure expresses end product consumption growth, country by country, up to a fixed horizon, dealing with successive time periods. The method employed is based on the build-up of an elasticity network (GDP capita - consumption), this type of link depends on market saturation, diffusion and penetration etc .

(b) Static structure of the simulation model

This structure generates a quantified picture of world petrochemical activity for a given year. The situation scenario thus obtained is governed by sets of assumptions such as:

- demand levels to be reached before the decision to build production plants is taken,
- the extent of regional and inter-regional co-operation,
- import opportunities offered to developing countries by the developed countries.

Technical aspects of the petrochemical industry are expressed by sets of technical and economic coefficients, relating in particular to:

- obtainment of basic products from raw materials,
- obtainment of intermediates and end products from basic products,
- investment and manpower requirements for construction and operation of new plants.

Products flow patterns are described by means of inter-regional exchange coefficient matrices.

(c) Aggregation levels

The model operates on various levels, according to the aspect under consideration:

- at national level (population, GDP, consumption growth and plant construction decisions);

- at regional level (exchange patterns, raw materials requirements, investments)

The world has been divided into 15 geographical regions, 13 of which represent the developing countries, each country being considered individually, the other two aggregates being developed regions.

- Africa: North Africa (7 countries), West Africa (14), East Africa (17), Central Africa (8)
- Latin America: Andean countries (8), Argentina, Brazil, Caribbean and Centre (18)
- Asia: East Asia (4 countries), South Asia (15), Middle East (13), China
- Developed countries: Eastern Europe - 1 aggregate
  Others - 1 aggregate

Figure 7 gives the classification of products used in the model.

4.3 HYPOTHESES TO THE YEAR 2000

4.3.1 Main hypotheses

The attainment of the Lima objective of 25 per cent share of world production by developing countries in the year 2000 can be expressed by a growth relationship between GDP, population and MVA (manufacturing value added) by regions. Therefore the main hypotheses for the model concern GDP growth rates that are then translated into demand figures using macro-economic relationships and a preliminary set of assumptions. In order to properly explore the future, at least three GDP growth rate hypotheses should be considered:

(i) the attainment of the Lima objective as the minimum;

(ii) a reference trend if things continue as they are;

(iii) the probably share of world production that developing countries may achieve as viewed by the business community.

It should be noted that each hypothesis involves two factors: one, a world GDP growth rate; the other, the relative share of developing countries in petrochemical world production by the year 2000. To make the three main hypotheses comparable, their respective world GDP growth rate should be about the same. No major conflictual or catastrophic hypotheses has been considered here.

- Hypotheses A is based on a simplified simulation model developed by UNIDO to assess the implications of the Lima target. It shows the different speeds at which developed and developing countries should grow to attain at

Figure 7. World Petrochemical Model - Classification of products

FINISHED PRODUCTS MANUFACTURED IN DEVELOPING COUNTRIES

FIBRES
- Polyester
- Polyamides
- Acrylic

PLASTICS
- L.D. polyethylene
- H.D. polyethylene
- Polyvinyl chloride
- Polystyrene
- Polypropylene
- ABS resins
- Methanol based plastics

RUBBER
- Styrene butadiene rubber
- Polybutadiene

FINISHED PRODUCTS NON MANUFACTURED IN DEVELOPING COUNTRIES

SOPHISTICATED FIBRES
- Polyvinyl alcohol and chloride
- Polypropylene

SOPHISTICATED PLASTICS
- Polyurethane
- Polyester
- Polyvinyl acetate and alcohols
- Acrylic
- Methyl methacrylate
- Epoxy, polyacetal
- Others

SOPHISTICATED RUBBER
- Butyl rubber
- Polyisoprene, polychloroprene
- EPR, nitrile rubber
- Others

OTHER PRODUCTS
- Detergents
- Solvents
- Specialty chemicals

BASE PRODUCTS EQUIVALENT

ETHYLENE
PROPYLENE
BUTADIENE
BENZENE
XYLENES
METHANOL

RAW MATERIALS

ETHANE
LPG
NAPHTA
GAS OIL

TOTAL NEEDS IN T.O.E.

least the 25 per cent world production target. From the wide range of growth-rate relationships, the one giving the following values was chosen: world GDP growth = 4.0 per cent; developed countries = 2.9 per cent and developing countries = 6.8 per cent.

These figures were chosen because they were the ones nearer to the historical growth rate achieved by developing countries during the high economic growth period 1960 - 1973, while developed countries still retained an attractive GDP growth rate.

- Hypotheses B is based on Leontief's "The Future of the World Economy" and corresponds to the passive scenario X. It was chosen because it has a world GDP growth rate of 4.8 per cent, the nearer to ensure comparability with hypotheses A, while providing a different world production target.

- Hypothesis C. Seven different GDP growth rate hypotheses given by different business organizations were analyzed. The one given by the Cavendish Laboratory (UK) that corresponds to its high estimate was chosen. Its world GDP growth rate of 4.0 per cent ensures a proper comparability with the other two hypotheses. These estimates were presented in the energy consumption growth scenarios for the World Energy Conference held in Istanbul, September 1977.

Annex 20(a) gives the GDP growth rates, by region, corresponding to each of the main hypothesis for 1985-2000.

4.3.2 Preliminary set of assumptions

4.3.2.1 Main variables of the petrochemical industry

Based on the analysis made in chapters 2 and 3, the internal structure of the industry and its environmental structure shown in figures 1 and 6 respectively, it was possible to draw a long list of variables, internal and external, that influence this industry and its future development. Since the list includes hundreds of variables, a suitable elimination process was carried out based on analytic reduction techniques. These main variables are the following:

(i) availability and distribution of raw materials, especially oil;

(ii) stability of the international monetary system and trade balance;

(iii) availability of financial resources in developing countries;

(iv) the existence of a supply and distribution infrastructure.

4.3.2.2 Main actors of the petrochemical industry

From the large number of actors and power relations between them, only a small number have enough economic weight as to become the main actors of this industry. To ascertain that, an economic weighting analysis was carried out, by country, based on the 1976 GDP values and demographic weight as well as current sales and personnel employed by companies.

The results show that the main actors are the following:

(i) the government in developed countries;

(ii) the government in developing countries;

(iii) oil multinationals;

(iv) petrochemical multinationals;

(v) financial institutions.

Concerning the first two, figure 8 gives a graphic view of the relative economic weight of the countries in terms of GDP and population in 1976. Regarding oil and petrochemical multinationals, the number of individual actors is limited and their operations are highly integrated. After an initial period of competition, this situation tends to favour inter-company agreements, hence the markets left that can be classified as spot are relatively small.

Regarding the last actor, a comparison of oil and petrochemical company sales with GDP shows that the amount a company or a country has available for investment in the manufacturing industry is about one-tenth of sales or GDP. Hence, with the sharply increased investment costs, the financial institutions would play a greater role.

The main power relationships between actors are the following conflict-co-operation relations:

(a) Relations between developing countries.

(b) Relations between developed and developing countries.

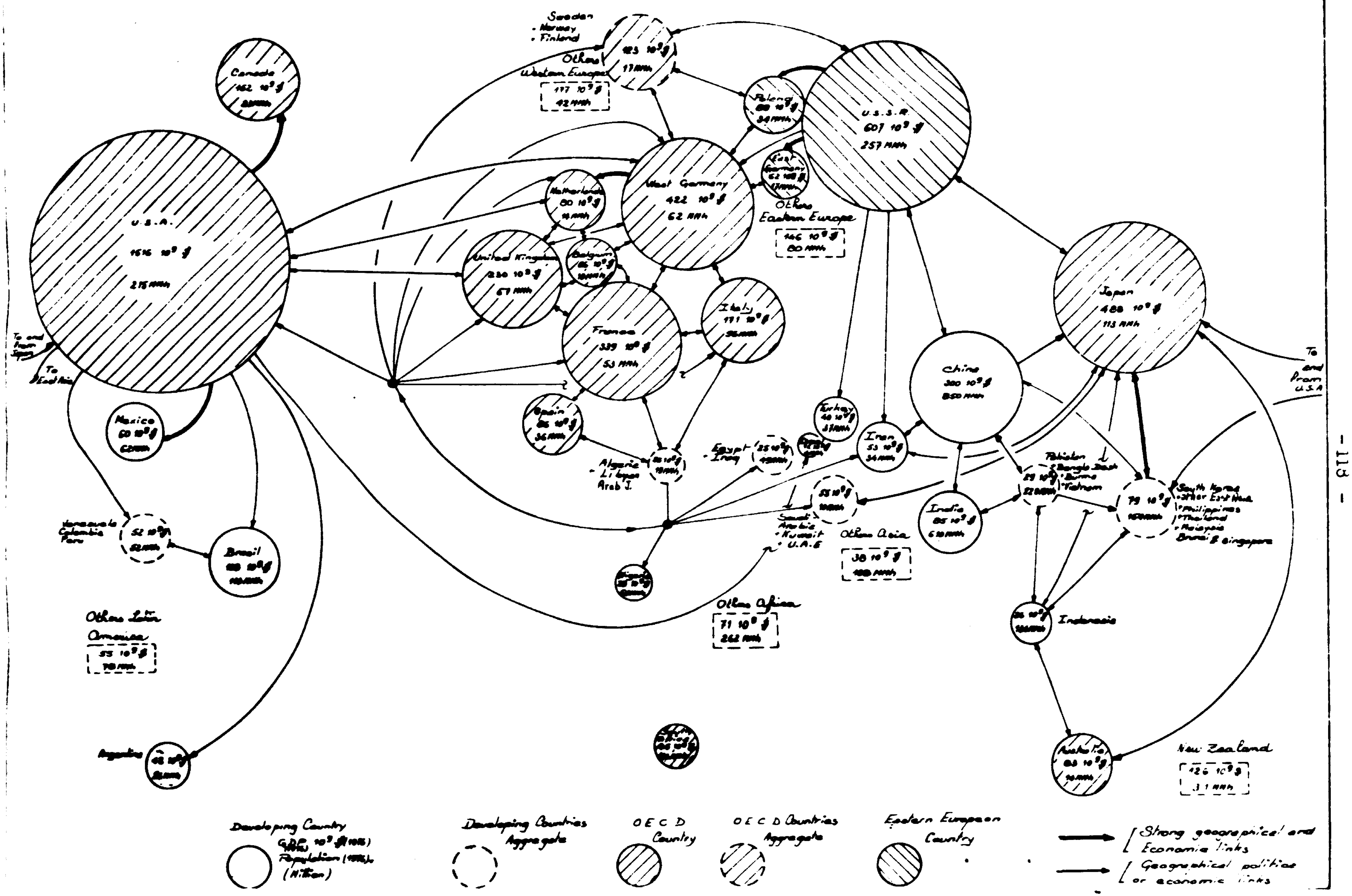
(c) Relations between governments and multinational companies (oil and petrochemicals).

(d) Commercial practices (of countries, national and multinational companies).

4.3.2.3 Assumptions concerning the main variables

The preliminary assumptions on the main variables shown in section 4.3.2.1 consistent with the main hypotheses given in section 4.3.1, are the following:

Figure 8. **INTERRELATIONS BETWEEN STATES**



Main variable	Hypothesis A	Hypothesis B	Hypothesis C
Availability of crude oil	Appropriate	Very difficult	Difficult
International monetary system, trade balance	Satisfactory	Very poor	Satisfactory
Developing countries' financial resources	Excellent	Very limited	Limited
Infrastructure	Developed	Unequally spread	Limited

4.3.2.4 Assumptions concerning the actors

The realization of any of the main hypotheses will depend primarily on the actors' behaviour. Therefore three strategic policy lines were assumed that are consistent with the main hypotheses. They are:

Power relationships	Hypothesis A	Hypothesis B	Hypothesis C
Assumed strategic policy	High degree of co-operation among all actors.	Minimal co-operation between the actors.	Developing countries give priority to sectors other than petrochemicals.
Relations between developing countries	Excellent	Bad	Good
Relations between developed and developing countries	Excellent	Bad	Good
Relationships between governments and multinationals	Developed co-operation	Very slight	Slight
Commercial practices	Many agreements	Aggressive	Countries relatively isolated.

4.3.2.5 Assumptions derived from the actors' behaviour

(a) These assumptions relate to petrochemical trade between the regions that are directly influenced by the behaviour of the actors. These trade assumptions can be expressed as a degree of openness to imports, by region, for the main hypotheses. These are:

Trade pattern	Hypothesis A	Hypothesis B	Hypothesis C
Openness of OECD countries to exports from developing countries (percentage of total demand)	10 %	2 %	2 %
Openness of Eastern Europe to exports from developing countries (percentage of total demand)	4 %	1 %	1 %
Openness of developing countries to exports from developed countries to make up trade deficits (percentage of the deficit) a/	10 %	80 %	40 %

a/ The rest of the deficit is made up by other developing countries, taking into account their respective export possibilities.

(b) A second set of assumptions relates to plant sizes that are also decided upon by the actors. It has been assumed that the various plant sizes adopted are determined by domestic demand and exports, the size being about three times larger in hypotheses A and C than in hypothesis B. In the first two hypotheses the aim is to minimize investment through economies of scale in plant sizes. The assumptions on production options are:

Production options	Hypothesis A	Hypothesis B	Hypothesis C
Plant size	Rather high	Low	Rather high
Degree of regional integration in petrochemical production	High	Low	Mean
Degree of priority given to the petrochemical industry in developing countries	Rather high at regional level	High	Low

The preliminary trade and plant capacity assumptions presented above span a fairly wide range of possibilities, each of which has been quantified. Through the model's feedback and iterative processes, the quantified assumptions concerning power relations between actors, degree of the internal market opening of the developed countries to imports from developing countries, and minimum economic plant capacities that are optimally consistent with the three main hypotheses, are given in annex 20 (b).

4.3.3 Description of consistent pictures for the main hypotheses

4.3.3.1 Hypothesis A

Realization of this hypothesis depends on a great number of favourable circumstances involving, in particular, reversal of many short-term trends.

The high degree of co-operation called for between actors would mean a reversal of the present situation. States would be required to commit themselves at last to a new distribution of the world's wealth and means of production without any opposition on the part of the most powerful economic actors. The situation would have to be free from major conflicts of interest between actors; energy supplies would be adequate in this case, but given the quantities of energy needed if the developing countries' high growth rate is to continue, a large number of sizeable oil finds would be required in addition to present known reserves.

A further requirement would be that the developed countries, despite their slower GDP growth rate, make a major contribution towards financing investment in the developing countries, otherwise the developing countries' indebtedness and dependence would only increase. In order to achieve a balance of payments equilibrium the less populated among the OPEC countries, Saudi Arabia, Kuwait, the Libyan Arab Jamahiriya and the United Arab Emirates would also have to contribute financially.

A final consideration is that the developing countries' rapid growth should not be impeded by infrastructure limitations.

4.3.3.2 Hypothesis B

This hypothesis is somewhat the opposite of the hypothesis A in that it assumes failure in instituting international co-operation over the long period leading up to the year 2000.

Relations between developed and developing countries are assumed to be more or less as they have been since 1973. In particular, since the developed countries of the OECD cannot supply their own oil requirements, the main OPEC exporting countries would probably maintain fairly close connections with the major OECD countries - France, Federal Republic of Germany, Japan, United States - to help them make up their oil deficit.

With a fairly high rate of growth continuing in the developed countries, the demand for energy will be high. Oil supplies will thus be barely adequate and some developing countries may suffer as a consequence. GDP growth is average but unequally distributed, on account of permanent conflicts of interest in which the more powerful contenders tend to obtain the upper hand. Industrial development financing will thus be difficult, with each party trying to find a means, to the detriment, if need be, of other major sectors of the economy such as agriculture.

This conflicting situation will be reflected by an unsettled monetary system struggling to maintain a precarious balance over a long period, and unfavourable trade balances for countries.

4.3.3.3 Hypothesis C

This hypothesis envisages a continuing fairly high growth rate in the developed countries that, in order to avoid any barriers to growth, would adopt a position of relative co-operation with the developing countries that supply part of their raw material requirements.

The developing countries would try to develop as autonomously as possible with little dependence on international trade. Their population being rural, the agricultural sector would be considered as first priority. Since the productivity increase of this sector would be slight, this strategy policy is linked to a fairly low growth rate in developing countries.

This choice of priorities may result from awareness of the difficulties of obtaining oil and may be associated with a conservative forecast of oil supplies. If, on the other hand, it derives from other considerations, it may lead to improved oil supplies when the priority economic sectors have a low energy consumption level.

This choice could also be a consequence of the difficulty in raising sufficient finances to allow rapid growth in those sectors of the economy where major investment is required. In this case, infrastructure development would also suffer.

4.4 OUTLOOK OF THE PETROCHEMICAL INDUSTRY IN THE YEAR 2000

On the basis of the preceding sections, three consistent pictures of the year 2000 emerged from the world petrochemical model corresponding to the three main hypotheses analysed. A detailed comparison of the principal results is given in annex 21(a). Annexes 21(b to (d) give a graphic picture for each of the three main hypothesis analysed.

4.4.1 World demand to the year 2000

Annex 21(a) gives the main macro-econometric characteristics and demand figures in the year 2000 for the main end petrochemicals: thermoplastics, synthetic fibres and synthetic rubbers, for each main hypothesis. The quantities of intermediate and basic products are then deduced from the end products' demand using the corresponding technical factors. To help assess the implications of the demand figures for the year 2000, table 25 gives the corresponding world demand figures for the main end petrochemicals in 1990.

4.4.2 World production in the year 2000

Annex 21(a) gives the main end petrochemicals production figures in the year 2000 for each main hypothesis. The production figures represent total regional production including export oriented production. The policies and strategies pursued by the actors will determine where the new productions needed to meet world demand is going to be located. The production of end petrochemicals inolude those products shown in figure 8.

The production of intermediates and basic products are derived from the regional production of end products according to production factors. Annex 21(a) shows the estimated production of ethylene in 2000, for it is the single most important petrochemical building blook. The developing countries' share in world petroohemical production by 2000 would be 35 per cent for hypothesis A and 18 per oent for the other two hypotheses.

Table 25. Demand for the main end petrochemicals in 1990
(millions of tons)

	Developed countries	Developing countries	Total world
Hypothesis A			
Thermoplastics	88.35	23.84	112.19
Synthetic fibres	18.33	9.52	27.85
Synthetic rubber	17.12	5.32	22.44
Hypothesis B			
Thermoplastics	110.95	20.30	131.25
Synthetic fibres	22.20	8.27	30.47
Synthetic rubber	20.06	4.84	24.90
Hypothesis C			
Thermoplastics	97.96	18.28	116.24
Synthetic fibres	20.05	7.48	27.53
Synthetic rubber	18.49	4.54	23.03

4.4.3 Raw material requirements to the year 2000

In the World Energy Conference held in Istanbul in September 1977, the French Petroleum Institute presented the results of a very comprehensive delphi survey on ultimately recoverable oil reserves. From the data of this survey it is apparent that oil production is not expected to exceed 6.5 billion tons in the year 2000 and may be as low as 3 billion tons, thus giving an average of 4.5 billion tons. Oil requirements, however, vary between 4.5 billion to 6.3 billion tons as shown in annex 21(a).
Thus a situation of potential scarcity emerges which, if it is to be avoided, calls for immediate action on the part of the developed countries, both in reducing high energy consumption levels and in finding oil substitutes wherever possible. Tensions on the oil market would have an adverse effect on the world economy and in particular, on the petrochemical development plans of the developing countries. Additionally these tensions would lead to substantil oil price increases that would only accentuate an already difficult trade balance.

4.4.4 World trade developments to the year 2000

In the calculation of regional production figures and based on the behaviour of the actors, estimations were made concerning total trade exchanges between the regions that are consistent with the main hypotheses. However, when comparing them with the current trade situation, very important differences appear that will require substantial efforts by the actors to redress the present structural imbalance. In 1972 world trade totaled 415 billion US dollars and it grew to 980 billion in 1976, including 67 billion worth of chemicals and about 160 billion dollars for oil and petroleum products. It is the large price increases in oil since 1973 that account for the step rise in the trade of the developing countries. In 1976 oil represented 59 per cent of exports to developed countries of market economies (108 billion), 50 per cent of exports to Eastern Europe (5 billion) and 37 per cent of trade between developing countries (20 billion dollars).

This new situation has given rise to a structural imbalance which will take much time and effort to redress. Of the two billion tons of oil to be exported by the OPEC countries in 1985, 60 per cent will originate from the Libyan Arab Jamahiriya, the United Arab Emirates, Kuwait, Qatar and principally, Saudi Arabia. These are all countries with a low population and limited import potential, which means that they will continue for some time to show favourable balance of payments with regard to developed and other developing countries. The likelihood of a tense situation and high prices on the oil market before 2000 will only exacerbate the condition, with increased stress, for the international monetary system.

Developed and non-oil producing developing countries may thus be expected to seek to correct their trade balances through reduced imports and increased exports. If the developed countries fail to cut down their energy consumption and hence oil imports, this strategy, if pursued, will be detrimental to the economically weaker countries whose balance of payments would show a permanent deficit, as is in fact the case at present.

This situation would considerably hold back petrochemical development in many non-oil-producing developing countries. Indeed, while such countries continue to lack equipment and industrial plant construction industries, the creation of which is a long-term process, they will be obliged to pay most of their petrochemical investments in foreign currency (at present 75-85 per cent of the total according to country and type of plant). Removing a barrier of this type would probably involve financial co-operation between those oil-producing countries with a low population and the other developing countries.

4.4.5 Financial requirements to the year 2000

Annex 21(a) shows the total investment figures for the period 1977-2000 in US dollars of 1977 and includes all petrochemicals included in figure 8. Likewise the ratio of total investment to GDP shows the percentage of GDP to be invested in petrochemicals between 1980-2000, that ranges between 0.19 and 0.32 for developing countries indicating the really heavy committments that will have to be met.

Not only will financing petrochemical development in the developing countries require financing mainly by foreign currency, but the necessary investment must not be such as to represent an intolerable burden on the country's economy by consuming too great a part of savings.

While the petrochemical industry was expanding rapidly in the developed countries from 1960 to 1974, the share of gross fixed-capital formation allocated to petrochemistry generally ranged from 0.6 to 1.6 per cent, i.e. 0.15 to 0.40 per cent of GDP. The developed countries' average is fairly close to the lower figure. Short- and medium-term estimates put petrochemical investment at 0.16 per cent of GDP over the 1977-1980 period (projects in hand), with 0.17 per cent for the 1981-1985 period.

In the case of developing countries projects in hand or scheduled for implementation between 1977 and 1980 involve investments equivalent to 0.25 per cent of GDP.

The petrochemical industry's period of rapid growth in the developed countries was favoured, as far as investments are concerned, by two major factors: (i) a large industrial and commercial network which favoured capital build-up and (ii) considerable market domination by the major petrochemical companies, resulting in limited competition and hence larger profits which could be used for a high degree of self-financing (70 to 75 per cent of investments).
Of these two factors, the first does not apply to developing countries, while the second depends on the implementation of a first petrochemical complex, which of course will not enjoy such benefits.

With regard to the implementation of an initial petrochemical complex, it can be noted that for 1970-78 investment costs would remain within 0.7 to 2.0 per cent of GDP.

4.4.6 Manpower requirements to the year 2000

Annex 21(a) shows the manpower needs related to the petrochemical plants to be built from 1980 to 2000 and cover all technical, administrative and marketing personnel according to the manpower breakdown factors given in section 3.2.5.

The estimates of the three hypotheses give preliminary indications about the intensity of manpower training and development problems which could appear in different regions in this period. Appendix E elaborates further on this matter.

The main problem in providing the skilled manpower according to the expansion of the petrochemical industry in developing countries is the structure disproportions between graduates supply and demand, which is due to the lack of sufficient specialization of chemical and mechanical engineers and all kinds of skilled manpower, as well as graduates of secondary schools and vocational educational institutes. Aside from the shortage of qualified personnel in the developing countries, there is a lack of qualified trainers and adequate training programmes, insufficient finance and a climate which favours "academic" study rather than vocational and technical training.

To achieve the target of providing required personnel for the petrochemical industry, the policy-makers should be aware of not only the above problems but also the positive and negative implications in the field of job-generation and induced employment. The positive implication is the backward and forward linkage of the petrochemical industry with other sectors of the economy; the negative implication is the influence of the industry on labour-intensive industries, i.e. development of synthetic fibre production competes with labour-intensive jute production in some developing countries whose exports revenue is heavily dependent on jute and the same could be said about substitution of natural rubber by synthetic. However, taking into consideration positive and negative effects in job-generation in developing countries as a whole, it must be stressed that the net employment-creation effect of the petrochemical development is a positive one. Most of the specialists, both in developing and developed countries, believe that for the conditions in the developing countries on the average one new job in petrochemicals could create five to seven jobs in other industries.

Thus, the main policies which could be helpful to meet the growing requirements of the rapid petrochemical expansion in developing countries on the manpower development side are in the following areas of activity:

(a) manpower planning;

(b) co-operation and co-ordination of activities between the petrochemical industry and the educational system;

(c) training policy and development of the institutional training;

(d) co-operation among developing countries in the manpower training field and

(e) assistance of the developed countries in the manpower development field.

The above policy measurements mainly underline that the policy-makers should formulate manpower planning at the same stage that they formulate petrochemical expansion, and closely integrate it into the overall plans for economic and production development of the petrochemical sectors. Moreover, they should coordinate the activities of the existing educational and training systems with industry in order to avoid duplication and overlapping between them, and to avoid the waste of human and financial resources nationwide. The next step would be to identify the right training system and to institutionalize this training, including the right mix between on-job and off-job training. The developing countries in their effort to provide required manpower for the petrochemical expansion could save a considerable amount of scarce resources by pooling them to create common support-services for the petrochemical industry, such as training institutions, research centres, marketing organizations etc. In addition, the assistance of the educational institutions of developed countries is vital in encouraging the transfer of know-how needed for training the required personnel.

4.4.7 Infrastructural requirements

One factor which partly accounts for the high growth rate in petrochemicals demand in developed countries is the existence of a highly developed infrastructure, as regards both raw material supplies and distribution of petrochemicals. For example, Western Europe is characterized by a large number of deep-water harbours and very few instances of highly populated industrial regions situated far inland. The few which do exist have good communication lines with ports, either via major navigable waterways or else via crude oil pipelines. The major European refineries are consequently supplied with crude oil at a cost only fractionally higher than in the Middle East, on account of the moderate transport costs made possible due to tankers and crude oil pipelines.

Energy requirements for industry in general, and raw material requirements for the petrochemical industry in particular, were thus met at low cost throughout the European petrochemical industry's rapid growth period. The supply infrastructure is matched in Europe by a highly developed distribution infrastructure: major industrial centres, roads, motorways, railways and canals, all contribute to keeping transport costs to a minimum and in addition, urbanization has made possible large mass distribution centres.

Japan, thanks to its geographical features, has enjoyed the same advantages as Europe and though having very limited energy reserves of either oil, natural gas or coal of its own, provides a good example of access to world-wide oil and petroleum product sources for countries with easy maritime access.

North America, characterized by a large land mass and lack of deep water harbours, has been able to overcome the resulting difficulties through construction of a suitable infrastructure. Part of the continental mass can be penetrated, at lower transport costs, thanks to the large rivers (Mississippi, Missouri), the Great Lakes and their navigation systems. Population and centres of industry thus tend to be concentrated along sea coasts and the major inlets. A series of crude oil pipelines from the Texas oilfields and, more recently, from import terminals, bring oil to all these centres of industry as well as to the refineries supplying them with petroleum products. The petrochemical distribution infrastructure makes use of the same types of facilities as in Europe.

Lack of a similar infrastructure is likely to inhibit rapid development of the petrochemical industry in many developing countries. The benefit, in social terms, will be derived from investments if petrochemical development is accompanied by development of the infrastructure (harbour, roads, railways, refineries and possibly rivers and canals). In grass root locations investments in infrastructure may be as high as doubling the total costs of a petrochemical complex. The practice in many developing countries of charging infrastructural investment costs to the project contrasts markedly with the well developed infrastructural facilities the developed countries furnish free to a project.

4.4.8 Assessment of the pictures described in the main hypotheses

Hypothesis A

This case enables the attainment of the Lima Declaration goal for it is based on economic growth hypotheses through which the income gap between developing and developed countries may be narrowed.

It therefore contains a major break away from the present economic order and nature of the relationship between developed and developing countries. Sustained co-operation over the next 21 years leading up to 2000 represents the only means of achiving a sufficiently high economic growth rate. In the case of the petrochemical industry, this means that technical training will have to be organized sufficiently in advance to ensure that costly petrochemical plants operate with maximum efficiency.

Investment finance will also constitute an obstacle as it is equivalent on average to 0.32 per cent of GDP over a period of more than 20 years. It could, however, be brought down to about 0.27 per cent by securing finance from the developed countries to cover the proportion (16 per cent of production) which accounts for exports to such countries. The burden will nevertheless be a heavy one, but an increased assistance from the developed countries could build up considerable funds that would be for a time made available to the petrochemical industry in developing countries if this was considered a priority industry.

Supply of raw materials would not become a problem as long as international co-operation is achieved, petrochemistry being considered as having priority over other uses for oil. It is important, nevertheless, that costs be minimized through a judicious opportunities selection between refining and petrochemistry.

This hypothesis is the only one to surpass the Lima objective in that developing countries account for 35 per cent of world petrochemical production. It must be emphasized, however, that this can be achieved only by a major political and economic effort on the part of every country.

Hypothesis B

This hypothesis corresponds more or less to a continuance of the present economic order, and emerges as a hypothesis that not only fails to realize the Lima objective but postulates many apparently insurmountable physical obstacles. This alternative involves the highest oil consumption. Without co-operation, the less wealthy countries might find themselves deprived of the vital raw material for their petrochemical industry in the event of the occurrence of a relative shortage.

Financial outlay is almost as great as in hypothesis A but it is difficult to envisage how some countries could manage this in the absence of international co-operation; this latter factor would, moreover, constitute a barrier to technical staff training.

This picture, which excludes any desire to achieve a fairer world income distribution, clearly does not offer a means of attaining the Lima objective since developing countries are to account for only 18 per cent of world production.

Hypothesis C

This hypothesis involves a fairly minor political and economic effort, yet at the same time this is taken into account in the objectives.

Investments, equivalent to 0.19 per cent of GDP, are intended only to satisfy immediate domestic demand through production capacities which use economy of scale to advantage. The need for qualified personnel is consequently less, and fairly moderate world oil demand would mean relatively few raw material supply problems.

This picture, with 18 per cent of production in developing countries, is as far from meeting the Lima objectives as is hypothesis B through constraints appear that would be much more easy to overcome.

V. THE ESTABLISHMENT OF THE PETROCHEMICAL INDUSTRY IN DEVELOPING COUNTRIES

The aim of this chapter is to set out the practical criteria and factors that affect the establishment of the petrochemical industry. It is based on practical cases of setting up this industry in developing countries. It analyses the reasons for its establishment, the problems of its implementation and its impact on the national economy. The analysis shows that no country can afford to neglect the proper weighing of these factors to avoid future unnecessary problems or very costly plants that are uneconomical. Experience has shown that only a properly started and equipped petrochemical industry can fulfill its economic promises to the country.

5.1 TECHNICAL ASPECTS

5.1.1 Criteria for the selection of technologies

The judicious choice of technologies to be used in petrochemical plants is vital to the success of any undertaking in this field. The wrong choice may seriously compromise the future of a project which has involved considerable outlay, chiefly on investments and staff recruitment.

(i) Adaptability to market requirements

This will determine the operating rate of the plant, which is an essential condition for profitability, especially in the developing countries whose plant size is often limited. The choice of petrochemical intermediates and end products and their specifications should be in accordance with the specifications and, in some cases, even the habits of the immediate customers, the processing industries. The choice of monomer for polyester fibres is a typical example: if the synthetic fibres industry is already established on a large scale in the country and equipped to use DMT, production should be geared to the manufacture of this monomer, even in cases where from a production point of view TPA would be more economical. The fibre manufacturing industries would, in fact, continue to import DMT, thereby depriving the monomer production plant of a large proportion of its local market. Similarly in most countries tyre manufacturers use well defined formulae which they are most reluctant to change and this must be borne in mind when deciding on the type and specifications of synthetic rubber to be manufactured. The definition of products to be made and their specifications should thus be based on a precise and thorough market survey of both the existing client industries and projects under way. A survey of this kind was particularly important for the definition of the Bahia petrochemical complex in Brazil, this country being relatively well provided with processing and synthetic fibre industries.

As a number of countriee are considering the export of petrochemical products to international markets and not only to export surplus capacity to spot markets, production must be internationally competitive, meeting the product specifications prevailing in the target markets.

(ii) Ease of operation, adaptation to local conditions

It is even more important for the developing countries than for other countriee to select techniques which will provide for easily operated plante, particularly in view of the relative inexperience of operating staff. They should use processes which have been tested in industry and employ sound, reliable equipment. They should be wary in particular of technical innovations which have not yet acquired industrial references and techniques which can be used only by extremely experienced, highly qualified personnel.

On example of this problem is that of a large plant manufacturing basic products in one of the countries of Latin America which has never operated satisfactorily, with the result that for some years a number of derivative plants have been deprived of their raw material and thus have been reduced to relative inactivity. Before choosing a technology, future operators in the developing countries would find it helpful to contact and visit users of the technology in question in order to hear their point of view, to benefit from their experience and to establish whether the necessary conditions for the satisfactory use of the technology are present in the developing country. The technology chosen must be adapted as closely as possible to local conditions: a plant producing 50-80,000 tons per year of polypropylene or low density polyethylene, sited in a developed country and owned by a company which has other production units, will comprise only one production line for reasons of economy of scale; a plant of similar capacity sited in a developing country where there are no other plants manufacturing the same product would in many cases have two production lines, each of which would specialize in a certain range of products; the drawback of higher investments would be amply compensated by greatly increased ease of operation and limited losses when product quality is changed.

A petrochemical company setting up a plant in a country which already has a chemical or refining industry using a given type of instrumentation (pneumatic or electronic) will find it in their interest to use the same type of instrumentation, since trained personnel will be available and the stock of spare parts which has to be kept is minimized.

In countries where a large labour force is available but where there is a shortage of specialists, the adoption of highly automated techniques, resulting in a saving on staff but on the other hand requiring highly specialized maintenance personnel, would not be desirable. Plants in developing countries, which are usually at some distance from plant and equipment manufacturers, must have a much larger stock of spare parts available than is necessary in developed countries, so that failure of a key item of equipment does not result in too long a standstill of the plant, which would seriously affect the profitability of the undertaking.

Local conditions and their consequences for the selection of technologies and plant design are at times little known to, and scarcely considered by the companies who supply the technologies and build the plants. In order to be competitive, these companies may regard a low price as being the main criterion to the detriment of local requirements. Companies intending to set up a petrochemical industry in one of the developing countries should analyze local conditions as thoroughly as possible, assess their implications for optimum plant design and specify them in the invitation to tender documents sent out to process owners and construction companies. This type of work calls for experienced personnel and companies new to petrochemistry would be well advised to seek external aid from an experienced source, for example a producing company or firm of consultants.

(iii) Profitability of the process

The process adopted must be able to face competition from rival producers. This point is obviously not specific to the developing countries but it may be more difficult to achieve in these countries due to a relative lack of in-depth knowledge of the petrochemical industry. The wrong decision on this question may be disastrous. An example is provided by a butadiene production plant in Latin America based on alcohol dehydrogenation which was obliged to shut down entirely as it was unable to complete with imported petrochemical butadiene.

5.1.2 Transfer of technology

5.1.2.1 Plant construction

The technologies used in the petrochemical industry have been developed in the developed countries. Their use in the developing countries therefore involves a transfer which essentially takes the form of production units designed and built by companies from the developed countries and the licensing of processes they have developed.
As far as the construction of petrochemical plants is concerned, contractors generally conform to the invitation to tender documents drawn up by the client and containing construction procedures and a general statement of all the conditions governing the submission of bids by the contractors.

The situation with regard to the licensing of production processes, however, is different. In the field of petrochemistry, most companies which own a production process technology are also producers. The licensing side is usually only marginal compared with the sale of petrochemical products and may, in some cases, be considered as detrimental to the latter since it consists in handing over to rivals a technology which has been perfected within the company. This accounts for the fact that in the petrochemical industry competition between process licensors plays a relatively minor part and that the conditions governing the award of a licence remain very varied, depending on the policy of the licensing company. These conditions usually remain confidential but mention can be made of some major differences which have been noted in licence contracts proposed in developing countries for identical production schemes. These differences involve the following points:

(i) continued access for the licencee to later developments of the process;

(ii) assistance from the licensor's after-sales service in order to facilitate market promotion of the product;

(iii) possibility of using the brand name owned by the licensing company;

(iv) limitation of export rights for the products;

(v) exclusive use of the process within a given country or region;

(vi) assistance with start-up and in some cases commercial operation of the plant.

Some of these points may be vital to the success of a petrochemical project in a developing country,and a company intending to set up a petrochemical industry may,in some cases, find it worthwhile to secure a licence contract involving maximum assistance, even at the price of higher fees. In order to facilitate the launching on the market of a product corresponding to a given production licence, the future producer may negotiate with the licensor and the authorities in the developing country for sale of import rights for the licensor's products in the years prior to plant start-up. This allows the process industry to adapt progressively to the use of these products. An agreement of this type was put into effect in Venezuela in respect of a polyethylene plant.

The transfer of technology is not confined to the sale of plante and production licences but covers various other aspects, the most important of which is staff training. The presence of qualified and trained personnel is indispensable for the proper operation of a petrochemical industry and such personnel can be trained only through the assistance of companies which have the necessary experience: engineering companies, producers, or specialized staff training organizations.

5.1.2.2 Manpower formation and training systems

An estimate of the total personnel needed for the development of the petrochemical industry in the developing countries is contained in the preceding chapters. Additional information can be found in appendix E. The requirements are considerable and since the greatest part is made up of skilled workers, the recruitment and training of staff present some problems. These problems occur at different levels according to the country and depend essentially on the general level of education and industrialisation in the country. In some cases the population of the country may be a factor of some importance. On account of the levels of education and industrialisation in certain of the developing countries, as in Brasil and India, the recruitment and training of personnel for the petrochemical industry does not present any particular problems. In other countries where technical education in particular is under-developed and where there are no existing petrochemical plants, the recruitment and training of the personnel required for the successful operation of a petrochemical industry can constitute a serious problem.

In the majority of cases, the importance of staff training prior to any commercial operation is underrated in the developing countries. Awareness of the lack of training comes when the moment to start the plant up arrives and in many cases expatriate workers have to be called upon; or it may even be necessary to hand over responsibility for the management and operation of the plant to specialized companies for a period of some years; in this event the local personnel gain experience progressively on the job by working alongside the specialists and can eventually take over from the expatriates.

It has been seen that manpower problems can vary considerably depending on the country in question. The capital structure is also of prime importance. Petrochemical projects undertaken in joint ventures with international petrochemical companies, e.g. complexes in Brazil, Venezuela and in the Republic of Korea, benefit from the assistance and experience of these companies which supply the local industry in the developing country with skilled personnel and work methods. In addition, they are also able to train local personnel through training systems worked out on the basis of their own experience and also by involving them in the operation of plants of their own which are already operational.

On the other hand, projects undertaken without the assistance of international companies and in countries which do not yet have an established petrochemical industry such as Algeria or Morocco, come up against great difficulties in respect of staff recruiting and training within the context of specific projects. In such cases, the recruitment and training of all or part of the staff is carried out with the assistance of the contractor within the framework of a specific training contract. This is so in particular in the petrochemical complex (chlorine, VCM and PVC) presently being implemented in Morocco where the operating company has signed a contract with the contractor for staff training. The contractor implements this contract with the help of a specialist company in the field of industrial training.

In all cases the creation of a staff recruitment and training policy should be based on a study of the local availability of manpower. This study should be carried out in great detail and should specify the different types of manpower available by geographical area and classify them by level, e.g. workmen, foremen, technicians, office staff, salesmen, administrative staff, management, engineers, also indicating mobility and changes through time.

The main difficulties connected with the availability and training of personnel in the developing countries are that:

(i) Persons having a wide general as well as specialized educational level must be available. Some of the jobs will inevitably require industrial experience and the suitable personnel will have to be taken from other industries (chemical, mechanical, refining, plastic processing etc). These industries must already exist and be able to support such transfers. Some posts require experience in a specific job and, in many cases, technical assistance will be necessary.

(ii) Training is usually given partly by instructors from more developed countries and partly through training periods spent in other countries. However, here some language and cultural barriers may occur.

(iii) Recruitment may be difficult in some cases, particularly where diploma-holders are concerned, as they may consider a career directly linked to production as not very attractive.

(iv) On completion of their training some people may prefer to look for work in an area other than the petrochemical industry where they would be able to put their training to equally good use.

(v) On account of the secrecy attached to manufacturing processes, acceptance for a training period in a similar plant may prove difficult.

It should be mentioned that some developing countries have started to organize training courses within the petroleum industry, generally through specialized training organizations, which could also be useful for the petrochemical industry.

5.1.2.3 Strategies to develop national engineering capabilities

At the moment, most engineering companies working in the field of petrochemistry are concentrated in the developed countries and most of the plant construction work in developing countries is carried out by these companies. This concentration can be explained as follows:

(i) Existence of a market. Engineering companies need to pool a certain amount of work in order to remain operational and this possibility arises chiefly in the developed countries.

(ii) Proximity of suppliers of plant and material. In order to be able to offer satisfactory, competitively-priced plants to their clients, engineering companies must have several competing suppliers of equipment available to be able to select the best and should carry out constant checks at different levels during the manufacture of a given item. This is greatly facilitated by the presence of several suppliers in the area.

(iii) Availability of a skilled labour force. The engineering work is partly the responsibility of specialists who are usually available in the developed countries.

(iv) Access to financing. The construction of petrochemical complexes requires very high investments usually leading to financing by developed countries which insist on measures that in many cases restrict the choice of the engineering company. In addition, the construction of plants involves the need for the engineering company to secure pre-financing over the whole construction period, to allow them to commit part of the considerable funds required for construction while awaiting payment from the client. This is possible only when having access to large sources of financing that are mainly found in developed countries. These requirements give some idea of the scale of the problems in expanding engineering activities in the developing countries.

In view of the various kinds of specialists needed such as process engineers, mechanical engineers, estimators, draughtsmen, pipefitters, instrumentation specialists, plan controllers, purchasing, follow-up and start-up personnel etc., the establishment of a petrochemical plant of the styrene, polystyrene, vinyl chloride, PVC type requires the presence of a minimum of about 200 people corresponding to an annual cost of approximately 12 million US dollars. To ensure the viability of such an undertaking, the size of the turnover would be such that investments of about 100 million US dollars per year would be required. The magnitude of this sum shows that an engineering undertaking should not be confined to petrochemistry but should also aim at other markets such as refining or chemistry and even at other industries where the technology is rather different, for instance food and textiles.

An effective way of developing national engineering capabilities in the developing countries is the transfer of technology from foreign to local engineering companies via subcontract or implementation as a subsidiary.

This transfer of technology would permit an increase in the possibility and share of the local engineering work in future jobs.

Some kind of engineering activities already exist in most of the developing countries such as civil and erection works. According to the opinion of this industry the development of engineering activities in these areas can be envisaged and, in fact, some successful examples have been noted. The engineering industry is automatically associated with the construction of petrochemical plants through sub-contracts with the foreign engineering company who acts as the main contractor. During the implementation of such projects sub-contractors in the developing countries benefit from an extensive transfer of technology in the form of testing methods, ways of organizing the work and standards; thus these companies become more capable of undertaking an increasingly large share of the engineering work. A number of successes have been registered in this field in the last few years, particularly in Brazil, India and Mexico. One of the most notable examples is the case of a steam cracking plant in Brazil for which all the detailed engineering work was carried out by a Brazilian firm under the supervision of the French company who was the main contractor. It should be pointed out that such situations are only possible when a deliberate decision is taken by the government or company buying the plant to make use of the services of local firms.

The development of engineering activities in the petrochemical field in the developing countries can only take place progressively, by increasing participation in the work initially carried out by companies from developed countries. Caution must be exercised in this respect as the problems stemming from faulty design and construction due to lack of experience may increase to such an extent that they become out of proportion with the advantages ensuing from the use of local engineering firms.

5.1.2.4 Identification of constraints on the development of national research and development capabilities

The tremendous development of the petrochemical industry has been made possible only by constant improvement of production methods and product quality. This is the result of intensive research stimulated by inter-company competition, sometimes on a world-wide scale. This research, facilitated by the relative profitability of the petrochemical industry, has proved very worth while in that it has led to continuous lowering of production costs and constant improvements in product quality. Any company or country intending to launch into the petrochemical industry was more or less obliged to undertake research and each newcomer had to develop their own manufacturing process as existing producers had no wish to help set up rival companies by granting licences. The situation today is, however, no longer the same and the developing countries in particular may have access without much difficulty to the process-licences and know-how necessary for most petrochemical processes. The development of research is no longer indispensable. Nevertheless, some of the developing countries will have to undertake research unless they want to remain in a state of constant dependency with regard to the acquisition of technology and some steps have already been taken in this direction. Activities and purpose of research and development are very diverse and the problem must be approached by taking this diversity into consideration.

The constraints on the expansion of research and development in the developing countries are considerable.

(i) Some research and development activities call for great resources in terms of both investment and qualified personnel. In the petrochemical industry, they cannot be undertaken without expensive equipment which has to be purchased and paid for in currency and it is often difficult to secure financing on account of the aleatory and long-term nature of the profitability of the undertaking. In addition, research and development require highly qualified personnel who may not always be available in a company and whom the management might be reluctant to take away from other work directly connected with production or sales.

(ii) The result of some research and development activities are of an aleatory nature and will only make themselves felt in the long term. For instance, the expenditure on fees involved in a licence agreement, though sometimes considerable, can often be offset by the technical advantages offered by certain processes or products. There are numerous examples of companies particularly in the field of monomers for synthetic fibres who, although they have developed and perfected a process or product of their own, build commercial plants based on licence bought from other producers.

(iii) Research and development work, if it has to be profitable, should aim at reaching a large market. In order to undertake research in petrochemistry on a national level, the substantial growth of this industry within the country must be certain as it is becoming increasingly difficult to find a market for processes or techniques which have not yet been used on an industrial scale.

On the other hand, some activities in the field of research and development are within the possibilities of some developing countries and the results have proved to be very useful. These activities are mainly aimed at improving existing plant operation, to adjust it to local conditions, to solve specific problems linked with domestic raw materials utilization and to improve and increase after-sales services and market development. They are usually performed inside operating companies.

Some developing countries which have a large capacity or a specific aptitude for the oil industry have already launched themselves into longer-term research and development work, initially in sectors of more immediate application such as production and refining, rather than in the field of petrochemistry directly.

Most of the research organizations which have been successful in the field of petroleum and petrochemistry have the following characteristics in common:

- they started up production with the help of experts from developed countries,
- their early activities consisted of services such as analysis of crudes, checking of product specifications, physico-chemical tests with immediate application,
- initial research and development work concentrated on the solution of specific local problems such as the use of local raw materials, testing of catalysts for use in commercial plants in operation in the country etc.,
- they make an important contribution to the training of personnel for the oil and petrochemical industry.

Developing countries intending to set up research and development activities would be well advised to follow this pattern. There are some organizations in developing countries which have built up experience in these fields over a number of years and are in a position to help newcomers. Co-operation between such organizations would be very profitable. Some of these organizations and their main activities are indicated in appendix F.

5.1.3 Infrastructural requirements

An infrastructure is essential for the setting up and satisfactory operation of the petrochemical industry. In particular, land, water, electricity and roads are required as well as harbour facilities for the delivery of raw materials, the dispatch of products and for unloading material used in the construction of petrochemical units.

To give an idea of magnitudes, a petrochemical complex producing 300,000 tons per year of plastics based on naphtha steam cracking, requires an area of about 100 hectares, 1,000 m^3/h water, and 83,000 kWh/h of electricity.

These prerequisites do not all fall within the same category and may be classified according to two main types: natural facilities which must be present on the site such as land and make-up water; and those which may be provided by means of additional investment; for example, harbour facilities, power stations.

The natural prerequisites do not present any problems specific to developing countries. As far as other requirements are concerned, each country and even each complex is a specific case. For example, the construction and operation of the Bahia complex in Brazil involved considerable specific requirements in terms of infrastructure including a harbour, accommodation and the creation of new towns but these were built up within the framework of the general industrialization of the region (mechanical, food, textile, tyre and plastic industries, etc.) where the petrochemical industry itself, although important, does not predominate. The SKIKDA complex in Algeria involving petrochemistry, gas liquefaction, refining and fertilizers, has necessitated the construction of a large harbour and the extension of the road network.

A petrochemical project presently under construction in Iraq involves the building of a harbour exclusively for the complex as the harbour at Basrah is already overcrowded, which naturally leads to an appreciable rise in investment and prolongs construction time. In contrast, a petrochemical complex of the same size planned for one of the south-east Asian countries and presently in the design stage, will require only the construction of a pier, in view of the natural facilities already existing.

The supply of electricity also depends on local conditions: existing generating stations, reliability of the supply and amount of local consumption. In the Bahia petrochemical complex, the electricity needed for its operation is produced by a utilities centre within the complex itself. At SKIKDA, all the requirements of the petrochemical industry, gas liquefaction and the fertilizer plant are to be supplied by one common power station. In a complex presently being started up in Morocco, the entire supply of electricity, amounting to 30 Megawatts, can be supplied by the national grid without requiring any additional infrastructure. The situation will be similar in the case of a complex in Asia presently under study, which is to produce approximately 300,000 tons per year of plastics and will consume 650×10^6 kWh/year.

It is a fact, however, that the developing countries generally have a much less developed infrastructure than the developed countries Thus, when a petrochemical industry is to be set up in a developing country, some expenditure in this connection will be necessary, adding to the investment costs, sometimes considerably, as far as the petrochemical industry itself is concerned.

In such cases, government support in providing infrastructure not charged directly to the project is desirable. Otherwise, the new company will be placed in a very weak financial position compared with similar plants that are located in places with adequate infrastructural facilities provided at no cost to the project.

5.1.4 Plant capacity

Certain technical problems specific to the developing countries tend to reduce plant capacity utilisation in the petrochemical industry. These problems can be traced to the following main causes:

(a) lack of training and experience among personnel;

(b) distance from equipment suppliers;

(c) unreliability of certain services outside the petrochemical complex such as the supply of electricity in particular.

(a) The lack of training and experience of the staff makes itself felt at two levels:

(i) At the level of plant design, choice of technology and contractor and construction follow-up; wrong choices may result in serious operating difficulties at a later stage.

(ii) During operation itself, errors may lead to lengthy stoppages and even to damage to the plant. Problems of this kind arise at the beginning of commercial operation and become less frequent as improvements take place within the plant and the personnel become familiar with the correct operating methods. In several developing countries such as in Brazil and Mexico, such incidents are no more frequent than in the developed countries.

(b) The distance which separates most of the developing countries from equipment suppliers may have important consequences for the production rate of the units. In the event of a breakdown it may take several weeks to send replacement equipment from Europe or Japan to a petrochemical complex located in Latin America, so that the plant is at a stanstill during this period if no spare parts are held in reserve. Therefore the spare parts stock has to be larger in those countries located far from the equipment suppliers. The amount of investment earmarked for spare parts for a petrochemical complex being designed for the Middle East is in the order of 15 million US dollars. These extra costs, though sizeable, must be allowed for they are fairly low compared with the consequences of the prolonged stoppage of a plant or complex.

(c) The unreliability of certain services outside the petrochemical plant inevitably affects the rate of production. The most common problem concerns the supply of electricity. In the majority of the developing countries, the electricity supply is more frequently subject to failure and voltage fluctuations than in the developed countries. When the electricity supply is interrupted, all machines run by electricity stop and production comes to a standstill. Furthermore, the prolonged stoppage of some machines, such as furnace feed pumps, polymerisation reactor agitators or cooling water circulating pumps would result in serious damage to the equipment. For this reason, emergency equipment must be provided for the production of electricity (diesels and alternators) which would automatically take over at once from the failing grid. Such equipment would have to be more extensive in those countries where the electricity supply is inadequate. In many cases a specific power supply would be needed in order to avoid the problems linked with the deficiencies of the local grid and this means additional investments.

In a complex designed for a South Asian country, the local grid was found to be so unreliable that production of the electricity required for the petrochemical processes had to be included in the plans, whereas from a purely economical point of view it was not recommended.

5.2 ECONOMIC ASPECTS

5.2.1 Marketing structure and product promotion

5.2.1.1 Marketing aspects

The existence of a potential market is insufficient to ensure the disposal of the petrochemical output. The market has to be penetrated and if possible expanded; competition has to be faced; products have to be dispatched to clients who may require assistance in making use of the products to their fullest advantage. Marketing thus covers all these various activities.

Petrochemical marketing varies greatly depending on the type of product, producer's degree of vertical integration, type of market to be aimed at, domestic or export market, and competition encountered.

Marketing differences according to product type have been analyzed in chapter 2. In the case of intermediate and basic products, classified as commodity chemicals, marketing is relatively uninvolved: one plant usually supplies only a limited number of clients; often a large part of production is disposed of under long-term contracts, some of which are negotiated prior to construction of the producing and consuming plants. In some cases, e.g. ethylene marketing, production plants are linked to consumer plants by fixed transportation facilities (i.e. pipelines) thus making flexibility of supply and delivery practically impossible.

In contrast, clients for end products, the majority of which belong to the category of performance chemicals, are dispersed and marketing involves a wide variety of major activities such as:

- frequent technical services at customer level;
- occasional, though less frequent than in the case of customers themselves, assistance to the customers' own clients;
- support by a technical service laboratory;
- advertising, both technical and institutional;
- financing the working capital for clients in the form of raw materials credit.

The type of market is also a major factor in marketing: for instance less problems will be involved in respect of the domestic market which is often concentrated and where competition may be restricted by protective measures or high transport costs. If the aim is to export, the importance of competition, organisation and transport cost factors increases.

In the case of end product export, because of the diversity of the types of contracts needed between producer and market, it is usually impossible to sell large quantities of performance chemicals from a distance without having a substantial supporting organization close to the market which is able to carry out the various types of tasks needed.

5.2.1.2 <u>Characteristics of marketing structures</u>

(a) <u>Developed countries</u>

There is a large diversity in the petrochemical marketing of the developed countries. This diversity depends on economic systems but also on geographical, demographical and economic conditions and even on traditions.

In the United States and in Western Europe, a large share of petrochemical output is directly sold by manufacturers either to other producers (often subsidiaries or affiliated companies) as in the case of basic products and intermediates, or through their own trading network to processors in the textile, plastic or rubber industry as in the case of related performance products. Whereas producers usually deal with large and medium-size customers (for whom selling often includes technical assistance), sales to other customers are channelled through trading firms.

In the United States trading firms operating throughout the country form a wide system consisting of:

(i) large firms opering on a national basis (including international and foreign companies); these firms are partly interlinked with local producers but operate independently, they are affiliates of international trading firms;

(ii) regional distributors covering territory of one or more federal states who are largely independent;

(iii) local dealers (three-tier system) who are also largely independent.

In some European countries where the petrochemical industry is dominated by one or two producers (e.g. ICI in the United Kingdom, Anic and Montedison in Italy), this is a decisive factor in shaping the pattern of trade in chemicals. In the United Kingdom, by far the major part of ICI's business in petrochemicals is channelled through ICI's own sales network. However, despite the difficulties for a chemical trader to hold his own against such a strong competitor, large import firms have a relatively good position in the British market and foreign chemical manufacturers are widely represented by them.

In Japan trading firms play a larger role in selling petrochemicals than in any other developed country, about half the petrochemical output being sold through them. Japan's major trading firms (the ten largest account for about 80 per cent of the chemical trade) are active in the import-export trade and in the wholesale business, while their affiliates are engaged in regional trading. There are no brokers and only a few independent dealers. As a general rule, trading firms are merged with banks, producers and insurance companies, forming concerns which contribute to the financing of production. The close inter-relationship between production and trade leads to long-term distribution agreements which prevent any significant structural changes or any intrusion by outsiders. A noticeable aspect of this situation is that agents are usually 100 per cent affiliates of foreign companies.

Marketing structures are quite different in Eastern European countries where all the petrochemical output is channelled through state-controlled organisations such as Soyuschimexport in the Soviet Union, a branch of Soyusneftexport.

(b) Developing countries

As observed in the case of developed countries, marketing structures also differ between developing countries. Marketing structures in Brazil and Mexico are described below as examples.

(i) Brasil. The production of basic petrochemicals is in the hands of large state-owned enterprises (mainly Petroquisa). The major part of this output is sold directly to a number of end product manufacturers already operating in the country most of whom are foreign (e.g. Union Carbide, Dow, Hoechst, Dupont, ICI, Rhone Poulenc). These and other private companies together with their affiliates operate side by side with the national trading agencies. In addition, the affiliates of foreign companies also safeguard the imports of their parent company's products. A few international chemical trading companies (e.g. Fallek, Klockner, Helm, Nissho-Iwai) are responsible for the sales of foreign producers who have no affiliates in Brasil. They promote direct sales to consumers and have practically no stocks. The international trading companies active in Brazil are all located in three consuming centres: Sao Paulo, Rio de Janeiro and Porto Alegre.

(ii) Mexico. Most of the output is produced by state-owned enterprises (mainly Pemex) that are in direct contact with the consumers and who have their own distribution network. The same applies to affiliates of foreign chemical producers with plants operating in Mexico. In some cases the chemical production of small Mexican companies is distributed by themselves on a regional basis. As in Brazil, there are almost no private enterprises offering trading in chemicals in Mexico. The state-owned chemical enterprises actually control imports either for their own use or for their customers. Whenever problems occur in their own production, these companies import chemicals and sell them on a nation-wide basis.

5.2.1.3 Government regulations - Tariff protection

The situation in two major developed countries can be summarized as follows:

(i) In the United States, domestic trade is completely free; the main restrictions come from the Federal Department of Transportation. Imports are restricted through the American Selling Price system.

(ii) In Japan, although imports and exports are officially free, they are in fact controlled through the Ministry of International Trade and Industry. Licences are required for some products. Customs duties range from 6 to 16 per cent.

By comparison drastic measures have to be taken by developing countries with a new petrochemical industry. In Brazil, with a view to saving foreign currency and stimulating local production, the government has imposed heavy import restrictions; an import licence must always be obtained and an interest-free 12-month deposit put down (without any inflation adjustment) equivalent to 100 per cent of the value of the chemicals. Letters of credit also require a 100 per cent deposit. In addition, imports are subjected to high import duty, depending on the protection required by the relevant domestic industry.

5.2.1.4 Transport

The choice of means of transport closely depends on local conditions:

(i) in the United States chemicals are transported by road (dense network, vehicles well suited to the traffic: containers, tank trucks) rather than by rail.

(ii) In Japan, on the contrary, chemicals are mainly shipped by rail (favourable freight rates) whereas the road network allows only relatively small consignments.

In some cases transport problems can, for a time, be a limiting factor in petrochemical trade. In Brasil, areas in the north and the north-east can be supplied only by ship since other forms of transportation are very difficult. However, in spite of the large dis[illegible] to be covered, the importance of road transport is on the increase.

It should be kept in mind that there are great differences between the transportation and storage conditions of petrochemicals such as plastics, rubber and some non-corrosive liquids (aromatics, styrene monomer) on the one hand and petrochemicals such as volatile and corrosive liquids (vinyl chloride monomer, propylene and particularly ethylene due to its physical characteristics) on the other hand. In the former case, the transportation and storage of petrochemicals are basically not very different from that of many industrial solids or petroleum white products. In the latter case, the means of transportation and storage have to be well matched to the traffic, resulting in higher costs (limiting factor). For example, maritime transport of ethylene for "peak saving" is only possible financially when fixed costs of liquified gas carriers are met entirely by a large complementary consignment of LPG. The maritime transportation of ethylene may be economically viable on a large scale when integrated into a whole system including terminals, storage and other facilities, possibly pipelines.

5.2.1.5 Marketing cost

As a general rule, commodity selling costs usually do not exceed 2 to 3 per cent of sales in the case of bulk petrochemicals whereas a significantly higher percentage is required when selling performance chemicals. Salesmen's salaries and commission account for about 40-50 per cent of total marketing costs in the case of petrochemicals.

Generally a petrochemical producer should turn out at least 100,000 tons/year to justify having his own sales network. However, even at this level a better solution would be to channel petrochemical exports through traders. Another alternative would be to make buy-back or compensation agreements, a practice currently adopted by Eastern European countries when the necessary services for a new plant (such as supply of equipment, engineering, basic design etc) are provided by a western partner in exchange for a share of the plant's exports.

5.2.1.6 Specific problems of the developing countries

(a) Domestic market

Intermediate and basic product marketing does not present any specific problems as far as the developing countries are concerned. There is generally little competition, the number of producers and clients tend to be limited and the limited amount of petrochemical projects which are generally small in sise usually leads to harmony between the respective capacities of producer and client. Moreover, markets are often protected by customs tariffs and monopolies.

On the other hand, end product marketing in developing countries is more complex being relatively easy in some aspects but with major difficulties in others. As in the case of basic products and intermediates, on the one hand, the market is usually protected with little competition and a clientele possibly unaccustomed to efficient after-sales service which facilitates marketing; on the other hand, the marketing involved requires considerable competence and experience. New local products are often at a disadvantage compared to those hitherto imported, processing equipment having been adjusted to suit the latter and brand names being well known. Market development, involving in particular research into new applications for products, requires a major outlay on research and development which is often considerable compared to the size of the manufacturing company,

In the case of new plants in developing countries, a solution is often provided in the form of a joint venture with international end product manufacturers. In addition, assistance may be obtained from process licensors during the negotiation of the licence contract in such matters as the organization of marketing services, setting up and operation of after-sales service and use of the brand name. Access to future developments regarding product applications may also be negotiated. Finally, it may prove profitable to make use of the existing marketing network for imported products with possibly the added benefit of an in-depth knowledge of the clientele and their requirements.

(b) Export markets

The main factor in marketing commodity chemicals is the price. The only condition which applies to the developing countries in this respect is that they are generally less able than the leading developed countries to subsidise exports through a large domestic market. Prices, however, are determined by a number of very different factors, thus making each case different.

It is very difficult to export performance chemicals without the assistance of a large supporting organisation to maintain the vital link between producer and clients. The developing countries face a specific problem in this respect due partly to a relative lack of experience and partly to the disparity between the size of domestic manufacturers and that of their international competitors on the export market; domestic producers being relatively small, export activities may be restricted or non-existent. Very few developing countries are, in fact, concentrating on chemical exports at the moment. As can be seen from the case studies below, most of the countries in the Middle East carry out their marketing through major international companies in the form of a joint venture project.

(i) Saudi Arabia. Saudi Arabian Basic Industries Corp. (SABIC), a corporation established to help implement industrial development plans and represent the government in joint venture partnerships, and Shell International have formed a 50-50 venture to build a complex at Yanbu (450,000 tons/year ethylene plants and downstream units). The production will be mainly for export and Shell will handle marketing in south-east Asia, Japan, Europe and the United States. The complex is due to start production in the second half of 1981.

(ii) Iran. Iran's National Petrochemical Co (NPC) has formed a joint venture with Japanese partners (Toyo Soda, Mitsui Toatsu, Mitsui Petrochemical, Japan Synthetic Rubber) for the construction of one of the largest grass-roots chemical complexes ever set up (due to start production in 1980). After 10 years, ownership of the project is planned to be entirely in NPC hands. The Japanese partner will handle the marketing at the beginning (about 70 per cent of production will go to Japan).

(iii) Qatar. A complex of 300,000 tons per year of ethylene at Umm Said is a joint venture between the Qatar government and the foreign partner, France's CdF Chimie (16 per cent share), with the latter being responsible for the petrochemical production (polyethylene) for the export market (local market is very small).

(iv) Venezuela. Ethylene Plastique, the French partner of a joint venture formed with I.V.P. is in charge of selling LD polyethylene soon to be produced in a new plant (local market is sizeable).

As can be seen from the above examples, marketing operations are generally entrusted to foreign partners in joint ventures formed in order to achieve and operate export-oriented complexes. Generally such partners are in a better position to do so, having experience in marketing operations from selling their products either through their own sales network or through major trading firms on both local and export markets.

In some cases, exports are under consideration for economical reasons. In Egypt, for instance, the output of the future complex at Alexandria may be exported to the extent necessary to pay off construction loans and interests. The same would apply to the future petrochemical production in Pakistan. In such cases, exports are likely to be channelled through traders.

Trends in the Japanese plastic export marketing policy illustrate the difficulties which may be encountered by performance product exporters. Within a few years Japanese exporters succeeded in becoming Asia's leading suppliers with an extremely low export price policy even to the point of an internal price war. The sales volume (15-20 per cent of total sales) was achieved through a higher price system on the domestic market. However, when in 1976 Japanese exporters applied a floor price system to plastic exports to south-east Asian countries, they rapidly lost ground in these markets to the profit of United States and European exporters (taking advantage of their more favourable naphtha position) even though their customer service was better. Faced with this situation, Japanese exporters decided to stop fixing floor prices and come up with a short-term, more flexible export price fixing system. Despite this, the average gap between the lowest export prices for general purpose resins and the highest Japanese ones was still 20 per cent (July 1977) not allowing for recovery of lost ground in Asian markets. As a result, Japanese exports may be reduced in 1980 to one-half of the present level.

In anticipation of this adverse situation arising in the near future, the Japanese plastics industry as a whole is making a deliberate effort to promote sales of special resins and to cultivate the overseas market for special secondary resins and sophisticated moulding machines. It is essential for this purpose to train local dealers by providing full technical service and sufficient materials. This will help Japanese companies to escape excessive price oompetition for exports among themselves and foreign companies.

Another difficulty producers are faced with when marketing petrochemicals abroad on their own, is the recruitment of qualified, well-trained personnel (mainly foreigners) for trade agencies.

5.2.2 Downstream and connected industries

Downstream and connected activities are necessary for the development of the petrochemical industry. Downstream industries provide a local market for petrochemical products, while connected industries facilitate production. The relative importance of the presence of these industries is, however, very different, the downstream industries being absolutely indispensable for the satisfactory operation of the petrochemical industry; however, the industry can operate, whether or not connected industries are established in the country, by providing or importing the necessary services.

5.2.2.1 Downstream industries

The existence of local downstream industries which use petrochemical products is indispensable where the production of the petrochemical industry is aimed at the domestic market. Downstream industries include: the textile industry (spinning, weaving, knitting), the plastics processing industry (extrusion, moulding, blow moulding, calendering etc), the tyre industry and other rubber processing industries.

These downstream industries already exist in the majority of the developing countries where they were established before the petrochemical industry. They naturally have to rely on imported petrochemicals and they supply the main share of the demand for end products. In most of the non-producing developing countries, 85 to 90 per cent of the ultimate consumption of plastics is accounted for by polymers, the remainder being in the form of plastic products. The same can be said for synthetic fibres where most of the needs of the non-producing countries are met through the importation of fibres. Therefore the choices of end products, its grades and quality, are greatly influenced by the processing industry, for example the tyre industry that has fairly rigid formulae may determine which type of synthetic rubber is to be produced; or a study of the type of equipment used in the plastics processing industry would provide a guide to the plastic grades and quality to be produced.

In some cases, the existing processing industries may not be capable of absorbing the entire production of a new petrochemical complex, in which event the processing industries would have to be expanded when the petrochemical industry is created. It is therefore important in the developing countries to carry out a detailed inventory of the downstream industries (existing and planned) when setting up the petrochemical industry and, where necessary, to take steps to promote them.

In many developing countries the problem of producing or leasing the moulds, dies, jigs, required mainly in plastic processing industries, is a real constraint since usually the cost of the moulds is much higher than in developed countries. The local mould processing industry often does not have the precision machine tools, thermic treatment equipment and skilled labour needed to produce low cost high quality moulds, and mould leasing from abroad demands scarce hard currency while the plastic products are usually sold locally. Additionally, most plastic processors end up with very substantial capital investments in moulds, which accumulate once their specific production runs are over. The organization aiming to set up a petrochemical industry might assist in rationalizing this kind of problem by finding a more permanent solution.

The processing industries are very different in nature from the petrochemical industry: the unit size is much smaller; lower investments are required; the labour force is larger; since problems are not the same as those faced by the petrochemical industry it is essential to assess precisely the barriers to their expansion in order to attempt a solution. In some developing countries, on the contrary, the dynamic nature of the downstream industries greatly favours the development of the petrochemical industry as well as substantially affecting market development and offering the petrochemical industry an opportunity for more rapid growth. The downstream industries employ a large labour force so that labour costs form an important element of the cost price. In countries where cheap labour is available, conditions are highly favourable and may in some cases lead to the export of petrochemical products in the form of end products, for example, synthetic fibres exported from the Republic of Korea in the form of fabrics and clothing.

It should be pointed out that the downstream industries, boosted by the presence of a local petrochemical industry which provides them with a reliable source of supply as well as permanent assistance with after-sales service, can at times be put at a disadvantage by an increase in the price of petrochemical products caused by local production being uneconomical and highly protected; such increases have at times been considerable in periods of world over-capacity when import prices were relatively low.

5.2.2.2 Connected industries

The petrochemical industry requires the services of other industries for its establishment, operation and maintenance, e.g. engineering, civil engineering, equipment supplies, mechanical industry. The existence of these industries in the area is not a prerequisite to the setting up of a petrochemical industry, as most of the necessary services can either be imported or provided within the petrochemical complex itself, but their presence does allow a saving in foreign currency during construction and operation of the plants.

In most cases the civil engineering industry is sufficiently well established in the developing countries for the major part of the work to be carried out by local firms. With regard to engineering, its development is very progressive and should not be founded on the petrochemical industry alone; the same is true for the production of equipment: the development of these two activities cannot be based on the petrochemical industry but depends on the general state of industrialization of the country. The impact of the mechanical industry is less important since plant maintenance requirements are usually met within the complexes themselves.

5.2.3 Plant location

The location of petrochemical plants should take into account the following:

(i) ease of operation: a reliable supply of raw materials, ease of product flow, waste disposal facilities, minimization of labour problems;

(ii) lowest possible investments and operating costs;

(iii) maximum benefit for the country: a plant should be set up preferably in a region where industrialization is being encouraged or in one most likely to benefit from the presence of a petrochemical plant.

In deciding on the location of a petrochemical plant, many factors should be considered and the final choice may in some cases be a compromise between conflicting factors. The region where the production unit is to be set up is determined first of all and then a more specific choice of site can be made.

(a) Determining of the region

The following considerations have to be taken into account when deciding on the region where a petrochemical plant is to be set up:

(i) a reliable supply of raw materials;

(ii) minimization of the cost of obtaining raw materials and of dispatching products to the consumer;

(iii) availability of an existing or potential labour force;

(iv) existence of, or cost of setting up the infrastructure necessary for the implementation and operation of the petrochemical industry;

(v) advantages for each of the regions under consideration for establishing this type of industry;

(vi) geographical features: climate, altitude, earthquake danger and consequences of these on investment and operating costs.

In practice, in the developing countries the basic petrochemical industry is often situated close to the source of raw materials, usually a refinery, and to harbour facilities which are used for unloading equipment and for dispatching some of the products. It is difficult to isolate a petrochemical plant from the refinery supplying it with raw materials. On the one hand, the quantities of raw materials to be transported are quite large: a plant producing 300,000 tons/year of ethylene requires over one million tons of naphtha; and on the other hand, some by-products of the basic petrochemical industry cannot be fully valorized except by blending with refinery products. Where the petrochemical industry is based on gas, there is a wider choice of locations.

It is useful to group different petrochemical plants together into complexes so that they may benefit from common facilities and avoid having to transport basic or intermediate products over long distances. The transportation problem becomes greater with the lessening of the price of the product and the difficulty of liquefying the product increases because it requires complicated and troublesome means of transportation and storage. Intermediate production units are therefore in most cases installed close to basic products.

More elaborate products, in a solid or liquid state as necessary, are much less difficult to use at a distance from their area of production: storage and transportation are relatively easy and the influence of the cost of transport on their price and on the price of end products is proportionally smaller. This is particularly so in the case of the intermediates used in the production of synthetic fibres: synthetic fibre plants are often close to major consuming centres and in some instances quite far from the site where the intermediates are produced.

(b) Choice of site

Once the region has been decided upon, the choice of the site itself can be made according to criteria relative to the available land and infrastructure. The most essential prerequisite is that an area of land suitable for a petrochemical plant should be available. To give some idea of the area involved, a complex producing 300,000 tons per year of plastics based on steam cracking requires about 100 hectares. It is advisable to allow for possible future expansion when selecting and purchasing the site. The choice of the land itself is important because its nature, configuration and present use can have quite an effect on investment in such aspects as civil works and the possible expense when relocating its present occupants.

The chosen site should comprise the infrastructure indispensable for the setting-up and proper functioning of the petrochemical plant. The infrastructure includes the following main items:

(i) Facilities for the delivery of the equipment. Some pieces of equipment in a petrochemical plant are very heavy and bulky. In the developing countries most of the equipment must be imported, usually by sea.

Bearing this in mind, harbour facilities for the unloading of equipment will have to be available as well as means of transport from the port to the site. If such facilities do not already exist, they will have to be constructed.

(ii) A water and electricity supply. The complex taken as an example would require about 1000 m^3/h of water and 8,300 kWh/h of electricity. The electricity can of course be supplied from within the complex itself at additional cost but little can be done to provide a water supply where none exists.

(iii) Effluent disposal facilities. The petrochemical industry generates effluents, particularly waste water which has to be disposed of into a water course or into the sea, according to the regulations in force. Pollution risks for inhabited areas must be considered, e.g. the relation of the site with inhabited areas and taking into consideration prevailing winds.

(iv) Transportation facilities. The site selected should have or must be provided with a network to handle the delivery of raw materials and the dispatch of products to the consumer (pipelines, roads, railways, harbour facilities).

(v) Housing. If the plant is not to be near an existing urben centre, accommodation will have to be provided for the operating personnel as well as for the labour force engaged in the construction of the plant.

The factors to be taken into account when choosing a site can be divided into three categories:

- Absolute essentials which must be taken into consideration: availability of land (minimum area required); water supply (minimum flow); restrictions arising from pollution problems.

- Factors affecting investment: the price of the land; site development and cost of rehousing occupants; supply of utilities: water supply and electricity generating systems; harbour facilities: extensions or dredging required; cost of pipelines for the supply of raw materials and possibly for the dispatch of products; road and rail access: links where necessary; pollution control facilities requires; investment in connexion with personnel accommodation; external factors affecting plant design.

- Factors affecting operating costs: cost of raw material brought to the site; end product transportation costs (from plant to markets); cost of utilities; waste disposal restrictions; local taxes.

5.2.4 Plant size

The main factor which determines plant size is the market. The amount of investment involved in the setting up of a petrochemical plant is such that the plant has to operate at a rate as close as possible to the full production capacity. It is therefore desirable to assess the market accurately so that its demand can be matched as accurately as possible. To illustrate this point the production costs for a 200,000 tons/year styrene plant working at 80 per cent capacity, are equivalent to those of a 100,000 tons/year plant working at full capacity.

Production costs are higher for low capacity plants, basically due to the fact that investments do not vary as a linear function of capacity but are governed by a power function whose exponent is somewhere between 0.60 and 0.90, hence the desirability of building large capacity units costing proportionally less than small or medium capacity plants. The same can be said with regard to manpower, plant and office overheads, as well as maintenance, which represent less expense per ton of products for large capacity plants.

These differences lead to the notion of economy of scale. It must be emphasized, however, that this notion can be considered only in certain particular cases and that plant size is only one of several factors governing operational profitability. For instance, a 15 per cent rise in the cost of raw materials for a 100,000 tons/year styrene plant operating at full capacity would bring production costs to the same level as those of a 65,000 tons per year plant. A 20 per cent increase in investments, due perhaps to a location involving higher construction costs on account of unfavourable local conditions, would have the same effect.

Competitive conditions also vary greatly from country to country, being influenced, for example, by the proximity of exporters which may sometimes lead to very different CIF prices for products.
Some typical examples of the effect of capacity on production costs are given in table 26. The ranges correspond to different economic conditions. Plant capacity generally has a greater influence on production costs in the developing countries due to higher investments leading to higher fixed costs. Where attractively priced raw materials are available, the impact of fixed costs is even greater andproduction capacity becomes an even more important production cost factor.

Table 26 PRODUCTION COSTS

- ETHYLENE (naphtha steam cracking)

Production capacity	10^3t/year	300	150
Related production costs	%	100	106-112

- LOW DENSITY POLYETHYLENE

Production capacity	10^3t/year	150	75	75
Relative production costs	%	100 (1)	110-112 (1)	110-113 (2)

(1) *Ethylene from 300,000 t/year steam cracking*
(2) *Ethylene from 150,000 t/year steam cracking*

- AROMATICS

Production capacity	10^3t/year	165 (O + P xylenes)	82.5 (O + P xylenes)
Related production costs	%	100	108-115

- DMT

Production capacity	10^3t/year	60	30	30
Related production costs	%	100 (1)	114-116 (1)	114-117 (2)

(1) *P-xylene from 165,000 t/year plant*
(2) *P-xylene from 82,500 t/year plant*

- POLYESTER FIBRES

Production capacity	10^3t/year	12	6	6
Related production costs	%	100	113-115 (1)	121-123 (2)

(1) *DMT from 60,000 t/year plant*
(2) *DMT from 30,000 t/year plant*

It is of course possible in many cases to stimulate the creation of a petrochemical industry based on relatively low production capacity by means of reasonable customs protection, as shown in table 26. Although percentage cost increases are not excessive, in the case of more sophisticated products they correspond to a considerable sum in absolute value. Thus an increase of 12 per cent for LD polyethylene and 15 per cent for DMT means extra costs of approximately 80 dollars per ton. Where part of the production is for export these figures should be compared with transportation and marketing costs with regard to the particular market.

The advantage of large capacities has declined sharply in recent years due to variations in the structure of production costs. These can be attributed basically to the rise in the cost of raw materials and energy. There has been a considerable drop in fixed costs essentially linked to investment, with a rise in variable costs, particularly raw materials and utilities as shown in section 2.2.5.4.

The problem of the rate of return of low capacity units, though less significant than formerly, still remains and may affect the planning of petrochemical development in developing countries. For instance, concerning synthetic fibres plants, several of the developing countries commenced production with spinning plants having a capacity of 1,000 to 3000 tons/year. Once the market has reached more than 6000 tons per year, they were able to consider polymerization plants but the monomer, caprolactam or DMT plants require an annual market of more than 25-30,000 tons.

In some cases, in addition to purely economical considerations, technical constraints accentuate the advantage of large capacities. This situation arises in the case of methanol production in particular, where at capacities of less than 150-200 tons/day it is impossible to use centrifugal compressors due to the volumetric rate of delivery; thus alternating compressors have to be used and these are not only more costly but also much less reliable. Therefore there are very few modern plants with a capacity of less than 150 tons/day.

In the case of very small capacities, it may be of interest to consider technologies which are different from those used in medium-size plants, some of which have been practically discontinued on the world scale. It should be stressed, however, that such plants are not very economical unless the local conditions are exceptional or where they are intended to supply a protected market. Examples are provided by an alcohol dehydration plant in Peru producing about 3000 tons per year of ethylene and supplying a 6000 tons/year vinyl chloride plant; and a vinyl chloride plant in the Philippines based on acetylene produced from calcium carbide.

5.2.5 Financing sources and schemes

The petrochemical industry is a capital intensive industry that requires high investments. In the case of developing countries, the petrochemical industry usually imports from developed countries most, if not all, of the equipment which means high investment in a foreign currency. While this aspect may not be so important for petroleum-producing countries it remains significant due to the level of investment required.

In selecting the best financing combination for petrochemical projects in developing countries the most important considerations will be the availability of funds, the conditions in which such funds may be raised and the need or the opportunity for participation of foreign companies in the venture.

5.2.5.1 Equity/debt ratio - Foreign participation in equity

The relationship of debt to equity in a project is subject to many considerations. Maximum debt/equity ratios may be controlled either by the central bank in the developing country or by the financial institution providing outside financing to the project. Of prime importance is the need for the project to obtain a quality rating that will entitle it to borrow at the most favourable rates and for the longest terms.

The capital structure is therefore quite important. A high debt ratio will cause many lenders to view their loans as a substitute for the absent equity and their conditions for such loans will reflect this position. Similarly a conservative debt proportion should afford greater confidence and, of course, will demonstrate greater asset protection for the lender who should react accordingly to the request for loans.

Equity capital may come from the government of the developing country, local private investors or foreign investors. The present trend in the petrochemical industry in developing countries indicates a preference for 100 per cent participation of governments in basic units, i.e. ethylene, propylene and caustic-chlorine plants plus infrastructure, while downstream plants are owned by joint venture companies.

International joint ventures involving the participation of chemical companies from developed countries appear to be more and more common, rather because it involves the provision of know-how and assistance to operation and marketing, than basically as a source of financing. Also some international development institutions which will be reviewed below, may invest in equity capital of companies in developing countries.

5.2.5.2 Loan financing

Financing can be arranged through several agencies, the most important sources being the World Bank, regional development banks and certain forms of government assistance such as the export-import banks of many developed countries. Details on these various financing sources are given in appendix G. Here are briefly some of their characteristics:

(a) World Bank. The largest and most important source of international development financing is the World Bank group, whose lending and investment activities help serve the capital requirements of developing countries. The group consists of three financial institutions: the International Bank for Reconstruction and Development (IBRD), the International Development Association (IDA) and the International Finance Corporation (IFC).

Loans from the first two bodies are mainly made to governments and government agencies. IFC makes loans to private enterprises and invests in equity capital but usually the loan investment has been considerably larger than the equity part. It is also worth noting that the use of funds provided by IFC is not tied to the purchase of specific equipment or to disbursements for imports from a specific country. However, as it appears from the data in appendix G, the World Bank group has been investing rather in infrastructure projects than in industrial projects and its participation in petrochemical projects is minimal.

(b) Regional development banks, such as the Inter-Am rican Development Bank (IDB) or the Asian Development Bank (ADB) or the European Development Fund (EDF) provide funds for the financing of projects that are considered of importance to the economic development of the area they serve. They are usually owned by participating governments although privately owned regional development banks exist also. The conditions for obtaining funds from the regional development banks are generally based on the same criteria as those used by the World Bank group.

(c) Arab funds. The availability of funds resulting from the increase in crude oil prices since 1974 has given rise to a new source of financing. While this financing is primarily intended to cover the needs of Arab countries, it is becoming more often available for other developing countries.

(d) Government-sponsored export credits

Because of continuing efforts by governments of most developed countries to get a greater share of the export market, nearly every developed nation has set up its own export credit institutions. Basically the terms are very similar from one country to the other, especially since the most important exporting countries agreed in 1976 to apply the same rules regarding duration of credits, interest rates and percentage of credit versus total foreign currency required. However some differences may exist: for example the United States Export-Import Bank in the past used to provide only 40 to 50 per cent of the foreign currency required at a reduced rate of export credit, leaving the rest for financing by a commercial bank. Usually in Europe, export credits at the preferred interest rate cover 85 per cent of the foreign currency required.

Of course the credits sponsored by an exporting country must be used by the foreign recipient of the loan for financing the purchase of goods from the country providing the funds. Generally the credit is provided to the foreign buyer through a bank consortium in the so-called buyer's credit. The procedure of supplier's credit by which the financing conditions are directly a part of the commercial contract between the foreign buyer and the supplier, is decreasingly being utilised, except in some exporting countries such as Italy and the Federal Republic of Germany.

Most of the loans for petrochemical industry investment in developing countries come from the export credit programmes of the developed countries. It is worth noting that the modalities of these credits generally allow the investor to benefit from the same interest rate during the construction period as the rate applicable during the repayment period which starts generally six months after the plant construction is completed. Modalities of these credits in most cases also provide for the possibility of financing part of the local currency costs under the same conditons as the foreign currency part.

Government-sponsored credits can also be granted in the form of government to government loans which offer more favourable conditions than conventional export credits (long term and low cost interest rates). These loans are generally designed for a sector of activity rather than for a particular project.

(e) Commercial credits. Generally, funds which may be raised from export credit sources (and or possibly international institutions) are not sufficient to cover the requirements of investment in the petrochemical industry of developing countries. In this case, consideration must be given to raising commercial loans.

Finding private money, especially in the medium-term and long-term area, will be generally subject to the establishment of satisfactory guarantees and conditions may vary widely. Euro-currency loans are a common example of such a source of financing. They generally have a floating interest rate, the spread being one percentage over Libor (London inter-bank rates).

(f) Payment in goods. Most contracts for [illegible] plant construction in Eastern Europe contain provisions for payment in goods and often in products from the plant [illegible] annexed to appendix [illegible]. Up to now, such provisions, called compensation agreements, seem to have been restricted to Eastern European countries. Such arrangements are attractive to these countries because of the non-convertibility of their currency. However, recent trends show an increasing resistance to such compensation agreements on the part of authorities in plant-exporting countries and of manufacturers whose markets are affected by them.

[illegible].2.5.3 Financing schemes utilized for petrochemical industry investment in developing countries

Data publicly available or collected from companies and banks relating to financing schemes for petrochemical plants in developing countries are summarized in appendix C. From this data the following conclusions regarding currently utilized financing schemes can be drawn:

- In many cases, companies set up for the development of the petrochemical industry are joint ventures including a foreign partner (generally the process licensor for the relevant plant which is often a manufacturer itself of the relevant products). However, for basic plants and infrastructure, local government participation is generally close to, or is 100 per cent.

- In a very few cases, the World Bank group or regional banks participate in petrochemical industry investment.

- Loan financing is mainly based on exporting country credits (with preferential conditions and commitments to purchase the plant in that country. The rest of the funds are generally raised through commercial credits.

5.3 SOCIAL AND POLITICAL ASPECTS

This chapter aims at analyzing the impact of the petrochemical industry on a country as a whole. The analysis will cover benefits to the national economy, including the creation of employment; the effect of the petrochemical industry on the environment will be considered, along with the various policy measures to be taken for the establishment of petrochemical industries from planning to production and marketing at national, regional and international levels.

5.3.1 National economic benefits

Historically, the industrial sector has been the most dynamic force in contributing to structural change in the economic and social system. It has attained growth rates that generally are in excess of those for the population increase.

The growth rates for manufacturing reveal that the pace of industrial development in many of the developing countries quickened in the early 1970s. The manufacturing output of all the developing countries increased by 8.2 per cent in 1971, 8.8 per cent in 1972 and 11.2 per cent in the first months of 1973. This indicates that the developing countries had made a good start towards achieving the target of a minimum average growth rate of 8.0 per cent per annum as set by the International Development Strategy for the Second United Nations Development Decade.

A sample of 29 developing countries has been selected to study the stage of industrial development to which the petrochemical industry has evolved and is beneficial to the economy of a country. The method adopted here is to classify a country according to the share of the manufacturing sector in the GDP. Thus a country is industrialized when the share of the manufacturing sector in GDP is more than 30 per cent; it is in the process of being industrialized when this share is between 10 and 20 per cent. It is non-industrialized when this share is less than 10 per cent (see Industrial Development Survey, UNIDO ID/134, p.12-14).

According to table 27, 7 per cent of the 29 developing countries (Argentina, Brazil, Chile, Iran, Republic of Korea, Mexico and Venezuela) had reached the semi-industrialized stage of development in 1970 compared with 4 countries (Argentina, Chile, Iran and Venezuela) in 1960. In 1970 seventeen countries were classified as industrializing countries and five as non-industrialized countries as compared with 18 industrializing countries and 7 non-industrialized countries in 1960. At present, most of the developing countries characterized as semi-industrialized also have populations of over 20 million. It is noteworthy that the two exceptions, Chile and Venezuela, are both economies in which natural resources endowment plays a particularly important role.

It should be noted that the share of manufacturing output, especially value added, in each sector of industry varies among the countries. The variations are caused not only by differences in the stage of industrialization but also by differences in the size of the countries involved and in the extent of their natural resources. Thus size and natural resources appear to be influential factors affecting the industrial structure of a country. In Latin America and Asia, for example, such countries as Argentina, Brazil, Chile, India, Iran and Mexico that are important in terms of size (measured by population and GDP) or extent of resources, all have a relatively large value added in capital and intermediate goods. By contrast, in small countries such as Costa Rica and Paraguay, the share of value added in consumer goods is considerably larger. One probable reason is that many economic activities classified as capital goods industries require large markets owing to economies of scale and it is relatively easy for a large country to establish these markets domestically and to induce development of other sectors of industries such as chemicals and petrochemicals.

The conclusion may be drawn from the above factors that the countries that had reached the semi-industrialized stage of development, with a higher share of manufacturing output in GDP especially in branches of intermediate and capital goods, which are important in size (measured by population and GDP) and/or resources endowment, are those with a developed petrochemical industry.

The experience of those countries which have developed their petrochemical industry to a certain level of industrialization indicates that a number of national objectives have been set up which are closely related to their overall industrial development objectives in assigning priorities for the development of the petrochemical industries. Thus, the benefit of the petrochemical industry should be envisaged within the overall national

Table 27. Growth rates of manufacturing output and share of manufacturing output in GDP for 29 selected developing countries, 1960-1970

(percentage)

Country a/	Average annual rate of growth of manufacturing output	Share of manufacturing output in GDP	
	1960-1970	1960	1970
Population over 20 million			
India	4.9	13	13 b/
Pakistan	8.1 c/	9	13
Indonesia	2.9	8	9
Brazil	6.4	18	20 b/
Nigeria	11.8 d/	4	7 b/
Mexico	9.5	19	23
Philippines	4.2	16	16
Thailand	11.1	13	16
Republic of Korea	17.2	14	22
Iran	13.1	25	28 c/
Burma	1.0 e/	10 f/	9 g/
Ethiopia	11.3 h/	6 i/	10
Argentina	5.7	29	28 c/
Colombia	5.7	18	19
Population less than 20 million			
Morocco	4.0	13	14
United Republic of Tanzania	10.9 j/	6 k/	9
Sri Lanka	7.4 l/	8 m/	9
Kenya	7.9 j/	10 k/	11
Venezuela	6.7	21 n/	21
Chile	5.5	23	28
Guatemala	8.2	13	15 c/
Bolivia	7.[illegible]	13	14
Haiti	-0.1	10	10
Zambia	12.5 p/	6 k/	11
Dominican Republic	4.3	17	19
El Salvador	8.8	15	19
Honduras	7.[illegible]	11	12
Jamaica	5.9	12	11
Panama	10.[illegible]	12	15 n/

Sources: Based on Monthly Bulletin of Statistics, May 1974; and Yearbook of National Accounts Statistics, 1972, vol.III (United Nations publication)

a/ Countries arranged according to decreasing population

b/ 1969 | g/ 1967 | l/ 1963-1970

c/ 1960-1969 | h/ 1961-1970 | m/ 1963

d/ 1960-1966 | i/ 1961 | n/ 1968

e/ 1962-1967 | j/ 1964-1970 | o/ 1965

f/ 1962 | k/ 1964 | p/ 1965-1970

economy of a country and particularly its influence on the gross domestic products, foreign currency savings, valorization of raw materials and acquisition of raw materials for other sectors of industry.

5.3.1.1 Raising the Gross Domestic Product

The petrochemical industry affects the GDP in two ways: directly and indirectly. Its direct effect essentially concerns the industry's very high added value. When the raw material, either naphtha, gas oil or gas, is priced at approximately 100 US dollars/ton, then its plastics and synthetic rubbers are priced at around 600-700 dollars/ton, while synthetic fibres are priced at approximately 1800 to 2200 dollars/ton. As an indication of the manufacturing value added by the petrochemical industry, a recent report shows that in the United States the value added to a $ 9 barrel of crude oil rises to $ 13/barrel when refined and sold as gasoline. The same barrel of crude oil upgraded to a petrochemical intermediate such as glycerine is worth about $ 50. Further processed into petrochemical end products, the value of the barrel of crude oil goes up to between 100 and 200 dollars. In addition, the setting up of a petrochemical industry has a positive influence on the development of other industries, particularly the downstream industries.

The direct impact of the petrochemical industry on the GDP varies considerably from one country to another and at the moment can be said to be significant only in the case of the developed countries. Table 28 shows the proportion of added value attributable to the petrochemical industry, in the GDP of some representative developed countries.

Table 28. Share of the petrochemical industry in the economies of some developed countries

(percentage)

Country	Share of value added in GDP formation		Share of investments in the gross fixed-capital formation		Share of investments in the manufacturing industries	
	1971	1974	1971	1974	1971	1974
United States	0.8	0.7	0.6	0.5	na	3.5
Fed.Republic of Germany	1.5	1.7	0.5	0.2	1.3	1.8
France	0.9	1.2	0.5	0.2	2.0	2.8
Japan	1.6	1.3	0.3	0.3	1.6	na

5.3.1.2 Foreign currency savings

Setting up a petrochemical industry always causes a drop in imports and, in some cases, makes it possible to export products at a relatively high price. However, the foreign currency saving effected by setting up a petrochemical industry depends on many factors, so that a detailed study is necessary in order to appreciate it fully. The investments required and the operating cost of a petrochemical plant include factors involving the spending of foreign currency, sometimes in large sums where the developing countries are concerned.

A representative example of foreign currency saving is provided by a petrochemical complex project in south-east Asia, designed to produce 230,000 tons/year of plastics. Investments amounted to 400 million dollars, more than three-quarters of this being in foreign currency. The setting up of such a complex will allow an average saving of $ 25 million/year over a 10-year period of operation or $ 45 million/year over a 15-year period. The greatest spending of foreign currency falls in the early years of operation on account of the size of the loans to be paid back together with the interest. The foreign currency balance does not become positive until the third year of operation. Taking an actualization rate of 15 per cent, foreign currency savings are reduced to an average of $ 19 million/year over ten years.operation.

The same complex in a country where 85 per cent of the investment had to be paid in foreign currency (instead of 75 per cent as in the previous example) would allow an average saving (without actualization) of $ 17 million/year over a period of 10 years operation, corresponding to a 30 per cent decrease.

In the above examples, raw material costs account for over $ 30 million/year in foreign currency; in a country where unexportable local raw material is used, savings of foreign currency would be more than doubled.

5.3.1.3 Supply of raw materials for other industries

The petrochemical industry provides raw materials for a wide variety of other industries, involving several important sectors of the national economy. The main industries concerned are plastics, textiles and tyres. These industries are much less capital intensive than the petrochemical industry; they employ a much larger labour force and they have a higher added value. These industries generally benefit from a local petrochemical industry if it can supply them with reasonably-priced products. They tend to be set up and expand in areas where they have a reliable source of supply and where they can take advantage of after-sales services and efforts to develop their main markets, i.e. in the neighbourhood of the petrochemical industry.

These processing industries in turn supply a variety of other industries which will thus also derive benefit from the presence of the petrochemical industry. Those chiefly concerned include building and construction, transport, furnishing, agriculture and, through packaging, a large number of fields such as fertilizers, the agriculture and food industries, transport.

5.3.1.4 Valorization of local raw materials

In some cases, setting up a petrochemical industry can lead to the valorization of local raw materials. One instance in particular, is in gas-producing countries where the fuel price per calory is relatively low. The production of some petrochemicals such as methanol will, under certain conditions, produce a good valorization of available raw materials; in some areas the large quantities of LPG inevitably produced with the oil are difficult to dispose of and since the cost of transporting them is fairly high, using them in the petrochemical industry can, under certain conditions, result in good valorizations.

5.3.2 Policy and institutional measures

As part of the motivation generated by governments, incentive measures have been adopted to promote a wide range of objectives dealing with petrochemical industries. Investigations of several case studies of developing countries that have or plan to have a petrochemical industry show that the process of instituting a package of incentive measures has several elements: namely, promotion of the objectives either at the national and/or sectoral level and removal of the difficulties confronting the development of the petrochemical industry. Further information is given in appendix H.

The main obstacles in the development of the petrochemical industries in a number of developing countries that have been reported in the past 15 years are the following:

(i) The small size of the market for petrochemical products as compared with the relatively large plant capacity required for economic production.

(ii) Uncertainty as regards natural resources and raw materials for the industry.

(iii) The private monopoly in petroleum industries and the shortcomings in legislation governing its operation.

(iv) The capital intensive nature of the industry.

(v) The difficulties in exporting to international markets because the developed countries possess large integrated plants which are operated around their nominal capacity and therefore having lower production costs. This factor combined with the marketing experience and resources of large companies, result in low-priced products against which it is not possible for small plants to compete.

(vi) The problem of valorizing the by-products due to the lack of a chemical industry able to use them.

(vii) Shortage of technicians and skilled personnel.

In view of the above, developing countries have taken a number of policy measures to facilitate and protect the implementation of their petrochemical industries. These policies may be classified under the following areas of incentives:

(a) Import duty concessions

Import duty concessions are one of several types of incentive measures which can be used to enhance the profitability of a new industrial project. Where import duties are levied on imports of machinery and equipment, it will serve to reduce the capital cost of a project; where concessions are also granted on the duties levied on the import of raw materials and supplies, it will serve to reduce the operating costs of the project.

(b) Tariffs and other types of protection

By raising the price of the imported product relative to that of the home-produced substitutes, tariffs improve the competitiveness of the latter. Moreover, tariffs are sometimes resorted to as a means of correcting external imbalance or to improve the terms of trade. Tariffs, subsidies and foreign exchange controls represent the major form of protection and have been used in some developing countries for the protection of private enterprises, e.g. in Argentina, India and Mexico.

(c) Tax incentives

The tax incentives are intended to encourage private and foreign investment by raising the potential profitability of new investment. Many different taxation forms are used in protecting petrochemical projects. The income or profit tax is the main instrument used in different forms such as holiday tax, accelerated depreciation allowances, investment allowances etc.

(d) Investment promotion of private sectors

The investment in private sectors is promoted by import duty concessions, tariffs and other types of protection and other tax incentives. Examples of the countries using such incentive measures are Brazil, Chile, India, Iran and Venezuela.

(e) Foreign investment promotion

The measures which developing countries use to attract foreign investment depend on the extent to which they facilitate foreign investment and minimize the risks involved in the eyes of potential investors. Some of these measures are inter-related with the other types of incentives mentioned above. However, the main measures are set out below: an adequate framework, assurances and guarantees, a favourable policy on the remittance of capital and dividends; favourable treatment under an agreement; favourable policy on employment of foreign personnel.

(f) Development of industrial estates

The establishment of industrial estates or areas has been used in several developing countries as an incentive for expansion in the petrochemical industry. The countries using such incentives are Brazil, Malaysia and Trinidad and Tobago.

(g) Assistance in skilled labour

The governments of developing countries have tried to reduce this deterrence in two ways: by adjusting the education and training system of certain institutions and universities, and by encouraging the enterprises to play a part in training. Examples are to be seen in Iran and Mexico.

(h) Export promotion

Promotion of exports by indirect measures such as export guarantees, marketing surveys, short term export credits at reasonable cost and integrated efforts at a regional level.

(i) Encouragement of local demand

In order to increase per capita consumption, efforts have been concentrated on the developing of manufacturing industries which require petrochemical products, and by modifying consumer habits, for example by encouraging consumers to buy national goods made of plastic and synthetic fibres.

5.3.3 Supporting activities

One of the most important features of the petrochemical industry is the continuous introduction of new products and rapidly changing production processes which can be achieved through research. Supporting activities have been encouraged in most developing countries which have developed a petrochemical industry.

The degree of involvement in research varies in developing countries. In some countries, a number of bodies are studying in considerable depth and scale national problems in the field of petrochemical industries and are engaging in scientific research, e.g. Argentina. In other countries, there are a number of research laboratories and institutes connected directly or indirectly with the chemical industry but they have not yet reached the stage where they can provide substantial assistance with respect to process and design know-how in sophisticated technologies, such as in Iran.

5.3.4 Promotion of co-operation

Regional and semi-regional co-operation has developed with certain political conditions attached. Apart from the political influence, several factors encourage co-operation at the regional and international levels, the most important of which is the rapid growth of the economic interdependency in the world.

The expression "world interdependence" refers to a variety of international links or flows: the transfer of technology from the developed to the developing countries; flows of natural resources and semi-processed goods; large-scale investments of foreign companies; the operation and location of the transnational corporations and their subsidiaries; international labour migration; the creation of regional schemes of economic integration; and above all, international trade.

If the normal trade is considered as a guage of world interdependence, table 29 shows that total exports and manufactured exports have grown at higher rates than world growth of GDP. Thus, if the GDP is considered as the yardstick for economic growth and development, and the trade of manufactured goods is taken as indicators of world interdependence, the data support the opinion that world interdependence has been increasing at a more rapid rate than world economic growth.

Table 29. Average annual growth rates of GDP
Total exports (SITC 0-9) and exports of manufactures (SITC 5-8) for the world and the developing countries, 1960-1970

(percentage)

	GDP	Total exports	Manufactured exports
Developing countries	5.2	6.8	12.2
World	5.6	9.4	11.2

Sources: Based on Monthly Bulletin of Statistics, March 1966 and July 1973 and Yearbook of National Accounts Statistics, 1972, vol. III (United Nations)

Industrial progress in the developing countries is tied to the growth of world interdependence and specialization. Just as trade-oriented economies may be specially vulnerable to the vicissitudes of world market conditions and trade policies, developing countries are susceptible to world economic changes and shocks that are transmitted through the network of international links. Examples include the rapid changes in world production technology, the energy shortage, the breakdown of the monetary system, the world food crisis, the impact of the transnational corporations on international investment flows, and tariff barriers.

The economies of the developing countries lack the resources and the skills as well as the size and breadth and markets to adjust to these changes independently. Their insulation from such fluctuations can be achieved only within the framework of the international community.

Accompanying growing world interdependence are social and humanitarian problems that are specially pronounced in the developing countries. These include mass poverty and starvation, serious urban unemployment, steadily mounting population pressures and the inability of large groups and social strata to share in the process of economic development and industrialization. It is not surprising that governments faced with such immediate problems do not have the perspective necessary to contemplate or facilitate international co-operation. (For further details see UNIDO Industrial Development Survey, ID/134).

Regional economic integration

The principle of international efficiency and equality is also applicable at a regional level. Regional integration schemes have appeal for medium-sized and small countries where the limited size of the market and production efficiency through specialization are important.

Industrialization is the basic economic justification for regional integration[a]. Two secondary benefits may be pointed out. Often, economic integration encourages a more rational formulation of economic policy at the national level. It may also make a decisive contribution to joint political and economic action vis-à-vis the rest of the world.

Traditionally, the approach to economic integration has emphasized the reduction of tariffs and the liberation of quotas. Experience has indicated, however, the fragile nature of many schemes that have relied solely on a

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a/ See "The economic integration of developing countries and the function of joint industrial planning" (E/AC.54/L.65), p.3

liberalization of community trade and external tariff barriers. Often, one or more participating countries have found that they are dissatisfied with the share of new industrial activities coming to them through the integration process. In some cases, the attainment of free trade has not been accompanied by the expected alterations in industrial structure. In other instances, trade liberalization has created certain inflexibilities in production that oppose national objectives. Finally, the scope for the expansion of trade on the basis of an existing industrial structure may be particularly limited in the case of some developing countries. Most observers and participating countries are of the general opinion that many regional schemes have fallen short of expectations.

Experience has led to a search for new means to co-ordinate national objectives and the distribution of benefits in the regional schemes of the developing countries. The crucial problem, especially for the less developed countries, is the formulation of an integration scheme that will result in an equitable distribution of industries and benefits. Although the importance of comparative advantage is acknowledged in determining which integration industries should be established[a], countries tend to attach greater weight to the anticipated alteration in their industrial structures that integration industries could bring about. The issues to be discussed go beyond trade and encompass questions such as the volume of investment, income and employment generation and technology.

The composition of the membership of integration schemes is important in terms of the appropriate balance between efficiency on one hand and the distribution of integration benefits on the other. A stable association requires an agreement that incorporates these principles satisfactorily. The process naturally requires some reconciliation of national aims but the exact nature of the agreement will depend on the economic characteristics of the countries involved. The weak or least developed countries in an integration scheme will not normally attract integration industries to the extent that their more developed partners will. Consequently, in an equitable scheme, the weaker countries may be expected to benefit more from regional co-operation in relative terms than the stronger countries. At the same time, there are natural limits to which the principle of equity may be carried without jeopardizing the stability of the regional organisation.

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a/ Integration industries are new industrial activities made possible by the merger of national markets.

Examples of ways in which efficiency and equity may be combined include: equitable distribution of capital investment; fair division of the number of industries assigned to different countries or of income generated by the project; and the elimination of disparities in levels of per capita income and of differences in rates of economic growth. Essentially, there seems to be no single approach that would provide a basis for an objective measurement of an equitable distribution of integration benefits. Some form of regional planning is frequently adopted as a necessary adjunct to the free play of market forces, to the comparative advantage of the participants.

The ideas of the form that integration industries should have vary among regional organizations. The sectoral complementarity agreements of LAFTA provide for the opening of regional markets in specific industrial sectors. The Central American Common Market (CACM) attempts to promote new industries through tariff protection and tax incentives and the industries are distributed through rounds of negotiations at which a second plant is not allocated to any country until each member has one plant in conformity with the specifications of the agreement. Joint purpose enterprises are a third type employed by the organization for Regional Co-operation for Development (RCD). Flexibility is an important feature of the RCD since few rights or obligations are specified. The industries involved require markets larger than any member country canprovide. The only obligation is that the commodities should be supplied at internationally competitive prices; participants are not required to grant tariff preferences for joint purpose enterprises. The industrial licensing system of the East African Common Market (EACM) is a fourth approach to regional integration. The main problem arising under this system has been that of intra-regional trade flows; it has been dealt with by devising a system for the redistribution of tax revenue coupled with a transfer tax to protect specific industries in the least developed countries of the EACM.

More recently, the innovations of the Andean Group in adopting a form of joint industrial planning, represent a step further towards realising the principles of efficiency and equity in a regional context. This particular approach is still too new to permit judgement, although it offers several promising features. The practice of joint industrial programming of investments in key industries has been described as a necessary complement to trade liberalization if success is to be lasting.

Industrial programming can take two forms: sectoral programmes of industrial development and rationalization programmes. Sectoral programmes apply to the priority industries that are being introduced, while rationalization programmes deal with existing industries in the context of the general liberalization of tariff barriers. The Board of the Cartagena Agreement is a subregional body that has well defined powers to take action and make proposals to the government representatives. The Board is responsible exclusively for safeguarding subregional interests and special treatment of the least developed members is carefully specified in the Agreement. These characteristics of flexibility in joint planning and programming as well as of equity may allow the necessary degree of stability which is so often lacking in other attempts at regional co-operation.

5.3.5 Manpower

The petrochemical industry is a capital intensive industry which employs a relatively small number of highly qualified personnel. It is among the industries requiring the highest investment per directly created job, approximately 200-300,000 dollars/job throughout the petrochemical industry as a whole. The manufacture of synthetic fibres constitutes a special case within the industry: about 55 per cent of the personnel in the petrochemical industry are employed in this field and the investment per directly created job is not more than 60,000 dollars.
This industry employs a large proportion of unskilled workers (about 40 per cent). The setting-up of a petrochemical industry creates, in addition to direct employment, various indirect employment. This is due to the impact of the creation of a petrochemical industry on the development of other industries. Foremost among these other industries are the downstream industries which are direct clients of the petrochemical industry.

The labour force required for the processing of petrochemicals is more than 10 times larger than that required for production; moreover, investments per job created are very much lower: aproximately 20-30,000 dollars per job in the conventional plastics processing industry and the textile industry downstream from synthetic fibre production. As already mentioned, since these industries had been set up before the petrochemical industry, it is difficult to express in terms of figures the direct effect of setting up a petrochemical industry on the creation of employment in the downstream industries. Very little information is available on this point but it is interesting to note from the result of a study on a petrochemical complex in France, orientated chiefly to the production of plastics, that in the surrounding region three new jobs were created in the downstream industries for every one in the petrochemical industry.

Jobs are also created in connected industries such as transport, mechanical and various services, but it is difficult to assess these as they depend on the level of industrialization and infrastructure in the region and also on the degree of autonomy of the petrochemical industry. Nevertheless, in general terms it is estimated that one new job in petrochemicals could create five to seven jobs in other industries. However, from the national economy view point, the main problem is the supply of the skilled manpower required for the growth of the petrochemical industry in the developing countries, and for the other job places it creates. Furthermore, this industry may create substantial relocation and retraining needs in the personnel currently employed in the traditional products industries that petrochemicals substitute for. The implications concerning the general education policy, the development of a training capability able to meet both training and retraining needs are discussed in detail in appendix E and section 4.4.6.

5.3.6 Environmental problems in the petrochemical industry

This section is designed to give an overview of environmental problems in the petrochemical industry and their effective remedy. An environmental impact evaluation procedure raises the key environmental issues that should be dealt with in the initial stages of planning a new petrochemical plant. Pollution regulations and the importance of maintaining pollution control standards are discussed. Air and water pollution problems are summarized and costs of pollution abatement are given.

This report contains an appendix (appendix I) on environmental problems intended for technical persons responsible for planning and managing petrochemical plants in developing countries. There, the environmental impact evaluation procedure is dealt with in depth, key questions being posed in respect of each of the nine steps in the procedure. The problems of air and water pollution are also covered in depth, as are the technical means of combating these problems. Estimated costs for reducing pollutant emission levels are indicated for many air pollution solutions used in certain chemical processes and the overall costs of treating plant waste water in activated sludge and anaerobic-aerobic treatment procedures are given. Disposal of solid wastes is presented in conjunction with the air or water pollution control device which also give rise to a solid waste requiring disposal.

(a) Evaluating the environmental impact of a new petrochemical plant

An environmental impact evaluation procedure should form part of the planning procedure for any new petrochemical plant. The purposes of evaluating environmental impact are twofold:

(i) To prevent the deterioration of natural resources such as the river which is to receive plant waste waters, so that these resources can continue to provide a basis for further economic development and

(ii) To give ample warning of deleterious side-effects of the products, which may result in economic or social costs not normally identified in the project review procedure.

The environmental impact procedure sets out a series of analytical steps applicable to environmental problems that may occur during the raw materials phase right through to the final disposal of materials produced. The definitions of these steps are:

(i) Raw materials linkage. Environmental considerations beginning with extraction or arrival in the country, up to the project under evaluation.

(ii) Site assimilative capacity. Present and baseline analysis of air, land and water carrying capacity to determine original conditions and effects of the project.

(iii) Project design and construction. Analysis of alternative possibilities for unit operations and energy sources.

(iv) Operations. Maintenance of project and monitoring (analysis of outputs, including by-products and wastes for treatment and reuse; monitoring waste discharges).

(v) Social aspects. Social implications of project.

(vi) Health aspects. Safety and welfare of population affected by plant.

(vii) Place of ultimate deposit. Recycling, reuse or assimilation of product and future products.

(viii) Long-term considerations. Plant expansion.

(ix) Optimization. Cost of analysis of alternatives.

The environmental impact guidelines cover a broad array of problems. They are designed to assess costs that would result if the project were to impair the future productivity of a country's natural resource base or result in other adverse side effects of investments. As indicated in the nine analytical steps, the impact of investments on the human environment requires a systematic and integrated view, focusing on materials flow within production processes and outside the plant.

Proceeding through the nine steps from the raw materials linkage to optimization, attention is called to the interrelationship between the choice of process and recycling and or reuse potential, between plant location and urbanization issues, between waste management and process design. These connections are an effort to impress upon the project manager the need to design an integrated project which is sensitive to environmental needs.

(b) Pollution regulations

In recent years, an increasing number of countries have expanded or adopted new environmental legislation. Governments have created official bodies which are responsible for the elaboration of new legislation and its application and enforcement. As a guide to present practice, a comprehensive listing of air quality[a] and pollutant emission[b] standards from a number of countries, including Japan, USSR, United States and several European countries, are to be found in a recent World Bank publication[c] which also refers to criteria for maximum concentration of various water pollutants in public waterways.

A problem specific to the developing countries when endeavouring to protect the environment through regulation is lack of experience. Never previously having had to face environmental problems due to industrial pollution, a large number of the developing countries have no specific regulations at hand. Such regulations are, however, indispensable to the contractor for the design of pollution control systems and should be in effect at the time the tender documents are sent out. It is recommended, therefore, that the ministries concerned such as those of industry, health or development, should draw up the relevant regulations referring as necessary to the experiences of other countries cited in the previous paragraph.

(c) Air pollution

Air pollutants emitted by the petrochemical industry include the following: Hydrocarbons, mostly paraffins, olefins, nitriles, chlorinated hydrocarbons; carbon monoxide; oxides of nitrogen; particulates, hydrochloric acid; sulphur dioxide (mostly from combustion of sulphur-containing fuel).

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a/ An air quality standard requires that the concentration of a pollutant in the atmosphere at the point of measurement shall not exceed a specified amount.

b/ An emission standard requires that the amount of a pollutant emitted from a specific source shall not exceed a specified concentration.

c/ "Environmental, Health and Human Ecologic Considerations in Economic Development Projects", World Bank.

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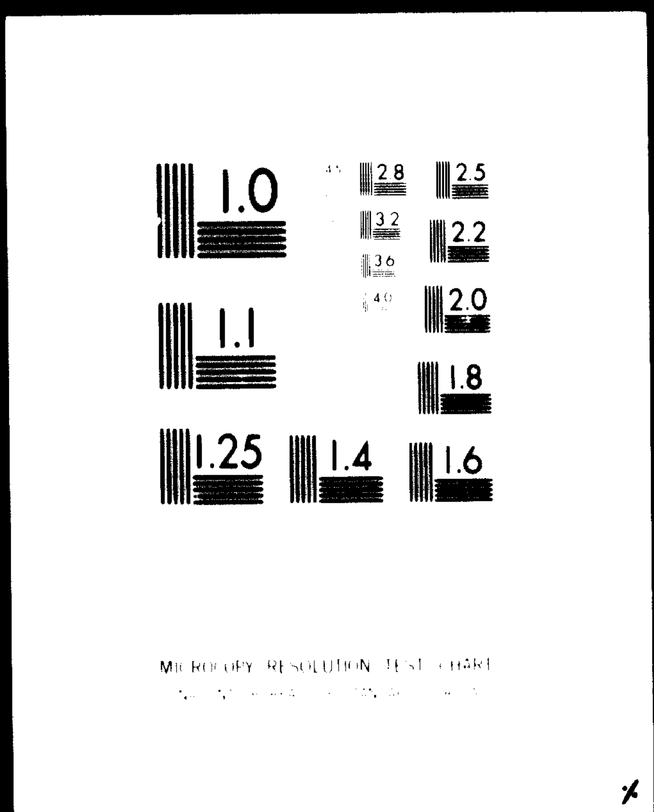

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The following are means of reducing air pollutants in the petrochemical industry: process changes; incineration of waste stream for heat value; flares; scrubbers; condensors; carbon adsorption; absorbers; bag filters (for particulate control); cyclones (for particulate control).

There are more than 200 different petrochemicals produced in large volumes in the world. It is obvious that it is necessary to control emissions from the processes which yield the largest tonnage, which are fastest growing and which produce the most air pollution.

The most toxic high-volume petrochemical is vinyl chloride which was reported in 1974 to be carcinogenic. Control of pollutants from the processes for manufacturing vinyl chloride and polyvinyl chloride are therefore especially important. A model polyvinyl chloride plant which incorporates improved stripping, refrigeration of the vinyl chloride recovery system vent, canned pumps and a leak detection programme, would reduce the vinyl chloride content from about 0.035 lbs/lb of polyvinyl chloride produced to about 0.016 lbs/lb. A capital investment for a 200 million lb/year plant would represent about 1 million dollars and add annual operating costs of 125,000 dollars.

In order to reduce total vinyl chloride emissions by about 55-60 per cent for a 700 million lb/year vinyl chloride plant, a total capital investment of 650,000 dollars would be required. A 90 per cent reduction of vinyl chloride emissions would require a capital investment of about 2 million dollars. These pollution control costs would be additional to a total plant capital investment of 42 million dollars.

There are 32 chemicals produced by 41 processes which require special control. Several of the chemicals are produced by two or more processes which are sufficiently different to warrant separate study. There are 12 chemicals that are causing the most severe air pollution problems: VCM, acrylonitrite, ethylene oxide, pthalic anhydride, PVC etc.

(d) Water pollution

The petrochemical industry presents a waste water treatment problem because production processes are so widely varied. Therefore waste streams are complex. One must focus on the ability of known methods of waste treatment to handle the key materials, intermediates and end products of the industry.

The sources of wastes generated by petrochemical operations can be divided into seven general categories:

(i) Wastes containing a principal raw material.

(ii) Product remaining in solution after separation.

(iii) By-products produced during reactions.

(iv) Spills, washdowns and vessel clean-outs.

(v) Cooling tower and boiler blow-down, steam condensate and water treatment waste.

(vi) Storm water run-off.

(vii) Sanitary wastes.

The principal contaminants in the waste waters include oils, organic chemicals, suspended solids, acidity, heavy metals and other toxic materials; colour, taste and odour-producing compounds.

The sources and quantities of pollutants should be considered during the design phase of a petrochemical plant and overall process waste-water treatment facilities should be incorporated in the construction of new facilities or additions.

The most effective petrochemical waste water collection system incorporates the segregation of waste streams. These can be classified as the following: "clean" water contained in cooling tower or boiler blow-down; highly contaminated process wastes including spills, batch dumps etc.; oily water; contaminated storm run-off; uncontaminated storm run-off; sanitary sewers.

The types of waste treatment methods applicable to the petrochemicals industry can be categorised as physical, chemical, biological and special in-plant methods. An evaluation of the treatability and pre-treatment requirements of each waste stream is a prerequisite to determing the integration of processes constituting the overall waste treatment system of the plant.

Physical methods include gravity separation, air flotation, filtration, centrifugation, vacuum filtration, evaporation and carbon adsorption. Gravity separators and air flotation units are designed to remove floating oil and settleable solids. Filtration is used primarily as a pre-treatment. Centrifugation and vacuum filtration are used for sludge dewatering. Evaporation is utilised when available land permits ponding and the climate is favourable. Carbon adsorption removes refractory organic materials.

Chemical treatment methods include coagulation-precipitation, chemical oxidation, ion exchange, chemical pre-treatment and sludge conditioning.

Biological treatment methods which are available include waste stabilization ponds, aerated lagoons, trickling filters and activated sludge. Prior to biological treatment, pre-treatment is usually necessary. When designing the biological treatment unit for the overall facility, consideration must be given to the possibility of spills, storm run-off, variations in flow and contaminants, and toxic or inhibitory substances.

The activated sludge process is generally considered the most effective biological process for treating petrochemical waste, with removal efficiencies in the range of 70-95 per cent of BOD (biological oxygen demand), and 30-70 per cent of COD (chemical oxygen demand). The activated sludge process allows the continuous mixing of biological growths and waste-water in the presence of dissolved oxygen. The micro-organisms remove organic material from the waste primarily through biological oxidation and to a lesser extent by physical absorption. The suspension of biological floc is then separated by settling. A portion of the sludge is recirculated to the aeration basi for additional contact with the waste.

Oxygen and mixing in the basin can be provided by diffused or mechanical aeration. Extended aeration is particularly useful for petrochemical waste treatment. The longer detention times allow the micro-organisms more time to degrade the complex organic chemicals.

In any waste-water treatment plant, large quantities of sludge accumulate daily and the cost of its dewatering and disposal may exceed the cost of any other unit process. Facilities for treating accumulated primary and secondary sludges represent a substantial capital investment. The processes involved are sludge concentration, dewatering, transportation and final disposal.

The first rule of in-plant waste treatment is good waste control practice in the different process operations. These practices may include the recovery of unreacted chemicals and by-products, multiple reuse of water, where permissible,and good housekeeping techniques. In-plant control methods include stripping and other recovery and temperature control. In some cases, product recovery will result in a cost credit for the particular process. These practices and controls will not only reduce the waste loadings given to the plant-wide treatment facility but will enhance its operation.

A major new waste treatment plant for treating petrochemical wastes is under construction for the El Tablazo petrochemicals complex in Venezuela. The plant will utilize the activated sludge process. A large waste treatment plant recently began operation at the Waterton Gas Plant of Shell Canada Ltd. Two sequential aerobic biological treatment processes are utilized together with chemical treatment, filtration and carbon adsorption. The influent has a COD of 3200 mg/l and is very toxic. The effluent has a COD of 25-50 and is non-toxic to rainbow trout fingerlings.

Regarding costs of water pollution control, one study of a 10 million gallon/day flow of waste-water of BOD of 800 mg/l showed that secondary treatment by an anaerobic-aerobic series cost about 3.40 ¢/lb of BOD removed, whereas treatment of the stream by activated sludge cost 4.3 ¢/lb of BOD removed (both in 1971 dollars). A study of treatment by activated carbon showed a cost of 18 ¢/lb of COD removed (1975 dollars). Effective performance of the anaerobic-aerobic system is restricted to the temperature range of 20-43°C, whereas the activated sludge system is efficient at much lower temperatures.

VI. ACTORS IN THE PETROCHEMICAL INDUSTRY AND INTERNATIONAL CO-OPERATION

The present situation of the world petrochemical industry is characterised, at least in the developed countries of market economies, by a serious crisis. The demand is way below on-stream plant capacities and under current market conditions, production cost increases are leading to the erosion or disappearance of profits. The future looks uncertain.

This uncertainty is mostly due to the questioning of the very dynamics of this industry in the future and to the problems connected with the emergence of new producers in net importing areas. Moreover, this outlook is further compounded by the generalized practice of top decision-makers in this industry to limit forecasts to only 5 years ahead. They claim that up to 5 years in the future it is still statistics but beyond that, becomes anybody's guess. However, decisions taken now or in the near future will substantially determine the future world petrochemical industry from 10 to 20 years ahead. Consequently there is a large gap that needs to be bridged between the customary forecasting horizon and the far-reaching impacts of the decisions taken.

This chapter attempts to analyze that situation by determining the main problems that influence the decision process, to explore the long-term implications in terms of the strategy of the actors, and to present an approach aiming at strengthening the international co-operation between countries. This analysis is particularly difficult in view of the general characteristics of this industry given in section 2.1. The difficulties are of three kinds:

(i) Structural, for its production complexity allows the multiple choice of alternative products, processes and raw materials, according to evolving changes in the economic conditions.

(ii) Forecasting, since the dynamism and competitiveness of this industry is based and will continue to be based on research and development, as shown in section 2.2.1 (f). Therefore the difficulties of economic forecasting derived from the uncertainties of economic growth now common to all economic sectors, is compounded to that of technological forecasting both of which are more sensitive in this industry. The technological developments do influence the physical structure of the petrochemical industry and are quite likely to destabilize it in the medium to longer run, according to the magnitude of the breakthrough and the speed of its commercial spread.

The evolution of technological structures are driven by power-invested actors, whose power positions are usually unequal as regards the access and control of raw materials, market areas, financial means and technological capabilities. Hence a proper forecasting involves the identifying of the actors, their projects and aims, and the influences of these on the petrochemical industry.

(iii) Informational, for on the one hand it is difficult to keep track of the aims, decisions and strategies of the main oil and petrochemical companies, and on the other hand, the reliability of the information tends to diminish with the increase of economic competition. This last point is particularly important for projects usually become unstable due to internal political changes in the countries that host and/or support them.

The announcement of investment projects (real or fictitious) can be a deterrent weapon to discourage and block adverse developments as well as the entrance of new competitors. The action of informing or withholding information provokes reactions and anticipations that slow down or accelerate other projects.

However, co-operation implies informed partners. The biases and gaps of reciprocal information are doubtlessly the most serious obstacles to the dialogue between developed and developing countries[9/]. Despite these obstacles, reciprocal information is progressing. The Euro-Arab dialogue is one of these channels. The recent OPEC[10/] seminar marks, perhaps, a decisive turning point in the identification of reciprocal positions between the developing oil exporting countries and the large market economy developed countries. If the general conclusion is the recognition of short-term conflict of interests, the perspective is possible co-operation in the long run[11/]. The conflict zones are beginning to be located with more precision, which is the first condition to solving them. The implementation of a realistic co-operation implies the identification of conflict situations and their analysis.

More recently, three other meetings[12/,13/,14/] laid more ground for international co-operation. They have enabled knowing with more precision the projects and intentions of the countries which in their respective zones plan the start or the development of a petrochemical industry.

9/ Only one example will be given: after mentioning "one piece of good news: attempt by some OPEC countries to arrange oil supplies in return for a guaranteed offtake of their petrochemicals output in the 1980s have fizzled out", the commentator adds: "The oil glut and uncertainty over what the Arab countries actually will have on stream before 1985 have killed the plan" (The Economist, 3 June 1978).

10/ Seminar on Downstream Operation in OPEC member countries: Prospects and Problems (OPEC Headquarters, Vienna, Austria, 9-11 October 1978)

11/ "In spite of the disparity that exists between the two groupings and the existence of a short term conflict of interest, emphasis is placed on co-operation in the long term through the development of a concept of inter-dependance and the common endeavour to formulate global stratagies" (Chairman's review of the OPEC seminar 1978, by H.E. Ali Khalifa Al-Sabbah, Minister of Oil, Kuwait).

12/ Regional meeting for Arab States to prepare for consultation on the Petrochemical Industry, Doha, Qatar, 21-24 October 1978.

13/ Second Latin American Congress on Petrochemicals, Cancun, Mexico, 12-18 November 1978.

14/ Global Preparatory Meeting for Consultation on the Petrochemical Industry, Vienna, 27-29 November 1978.

The first world consultation on the petrochemical industry[15] should permit taking new steps. For this purpose, on the basis of the material gathered in those meetings and recent developments in the industry, it has been attempted to isolate the main problems facing international co-operation in the petrochemical industry.

6.1 IDENTIFICATION OF THE MAIN PROBLEMS OF THE PETROCHEMICAL INDUSTRY

Since the original medium-term forecasts were made over a year ago a number of developments have taken place that significantly affected the forecasted figures. It should be noted that during 1977 many medium-term international forecasts were around the 9 per cent annual growth rate range based on 1976 trends and figures that pointed to a good recovery of petrochemical markets. However, a number of forecasts made in 1978 show a 4 per cent annual growth rate range based on: the larger plant overcapacities in OECD countries built on the misreading of the 1974 consumption boom, the 1977 market depression out of which this industry is just about to come, the current depressed situation of most petrochemical prices, and the general slow-down of the economy. Furthermore, during 1978 several new trends emerged that should change some of the plant capacity and demand assumptions for 1985. Some of these new trends will be presented in section 6.2.

As there is not much time left at the present to attempt a thorough adjustment of the 1980 and 1985 forecasted figures before the first consultation meeting on the petrochemical industry, the example of ethylene will be given in section 6.1.1.1 to illustrate the effect and magnitude of the changes that current developments have brought about in the original figures.

Based on the preceding points, three main categories of problems have been identified in the petrochemical industry. These are:

(a) the overcapacities of production and the exportable excedents;

(b) the medium-term transparency of the markets and evaluation of the long-term prospects of the petrochemical industry;

(c) the barriers to the entrance of new producers.

6.1.1 The overcapacities of production and the exportable excedents

The existence of substantial overcapacities of production in the developed countries of market economies is a demonstrated fact. Therefore the real questions today are: How was this situation reached? How are the exportable excedents distributed?

15/ Mexico City, 12-16 February 1979

6.1.1.1 The present production overcapacity in the developed countries of market economies.

It is interesting to try to define the reasons for the present imbalance between supply and demand.

In the first place it should be noted that the lucidity of professional organizations has not been caught at fault. As a matter of fact, as of October 1971 the European Petrochemical Congress Association (EPCA) at Monaco insisted on the necessity to adopt at the world level, a more strict discipline for investments in petrochemicals. The European Economic Community elaborated co-operative projects among enterprises and market regulating projects[16/].

Before 1973 the United States situation differed substantially: the crisis in the United States chemical industry was mainly an investment crisis[17/]. In the plastics sector, the United States capacities failed for polyethylene (low density and high density), polyvinyl chloride and polystyrene; only polypropylene was manufactured in sufficient quantity[18/].

In recent years, the United States production capacities of basic products jumped from 35,640 million lbs at the end of 1974 to 56,600 million lbs at the end of 1978[19/], this being an increase of 58 per cent. From the published data, it could be calculated that 85 per cent of the new production capacities in basic products are to be credited to the oil companies and 15 per cent to the United States petrochemical companies.

A similar calculation at world level meets statistical difficulties. It is well known that the specialized agencies encounter difficulties in producing reliable statistics for their respective regions. It should be agreed that this exercise is far more risky at world level. This is why it has been limited to only one representative case: ethylene, for the reasons explained in the introductory part of section 6.1.

16/ Institutional project of a European co-operation group (G.E.C.) presented to the Council on 21 December 1973, see Bulletin of European Communitiss supplement, January 1974

17/ François Guinot, Les strategies de l'industrie chimique (Calman Levy, 1975)

18/ Plastics Engineering, February 1974, and European Chemical News, March 25, 1974

19/ First Boston Corporation study, cited by European Chemical News, 11 November 1977.

(a) The example of ethylene

Two statistical series related to supply and demand are utilized and compared: the first is the data which appear in the study (up-dating in the middle of 1977); the second is data revised in November 1978 and deriving from different sources[20], [21], [22], [23], [24], and given in section 6.1.1.

As previously explained, it should be noted that these data are only relatively reliable. However, despite this reservation, they do represent likely orders of magnitude. Thus, because of the economic recession, it is probable that within the EEC, the additional foreseen capacities of 2.4 million tons/year[23] would be reached not in 1980 but will spread until 1982[25]. A certain indecision also exists for some United States prospects[26]. The same is the case for the prospects in the CMEA countries. The other data result from other projects in the course of implementation in the developing countries. Doubtless further adjustments to the data presented would be necessary, and the first world consultation on petrochemicals is an opportunity to make them. However, they do not appear to be likely to affect the following essential conclusions:

(i) The world ethylene production capacities should increase about 54 per cent from 1975 to 1980 and 42 per cent from 1977 to 1980, at the annual rates of 9.1 per cent and 12.5 per cent respectively.

20/ OCDE Study on Petrochemicals. This study has not been officially diffused, but excerpts of it have been published in European Chemical News, 9 June 1978). This information is therefore given with the necessary reserve.

21/ Revaluation of the demand in Western Europe, United States and Japan, UNIDO, November 1978

22/ Reference material of the Group de Recherche sur l'espace les Sociétés l'environnement (GRESE) on the petrochemical industry in the Mediterranear. Documents presented at an international seminar on "The future of international relations for petrochemicals", Montpellier (France, 26-27 October 1978.

23/ OPEC (Vienna) 1978 seminar documents, op.cit.10

24/ op.cit.12

25/ This deployment of projects explains the difference between the estimates in the report for 1985 (85,800 T- see Annex 14 c) and the present estimate (66,570 T). However, if account is taken of the projects after 1985, the figures agree.

26/ Three projects seemed undecided in October 1978: 600,000 t/yr by EXXON at Baytown (Texas), 540,000 t/year by ICI and others at Corpus Christi(Texas) and 540,000 t/year by Gulf Oil on the coast of the Gulf of Mexico. At any rate, if they are implemented, they will be felt beyond 1980.

The annual growth rates for both the five and three-year periods are 6.9 and 9.9 per cent for the developed countries of market economy, 10.8 and 16.2 per cent for Eastern Europe, and 31.2 and 33.8 per cent for the developing countries respectively. The growth rates of the developing countries is comparable to that observed in the past in the developed countries during their fast-growing phase. It is interesting to notice that in all three groups the tendency seems to speed up the growth rate in the last period, including the OECD countries, despite the economic recession.

(ii) The higher growth rates in the developing countries reflect their low starting point and their small share in world petrochemical production. Thus in 1980 the share of the developing countries in world ethylene production capacities would be 12.6 per cent based on the revised data, and up from the 11 per cent capacity share originally estimated.

The share of Eastern Europe in world ethylene capacity would increase from 7.5 per cent in 1975/77 to 8.3 per cent in 1980/85. The corresponding share of the developed countries of market economy would diminish from 85 per cent in 1977 to 79 per cent in 1980.

(iii) In relation to the additional ethylene capacities from 1977 to 1980, 65.3 per cent of the growth would originate from OECD countries, 10.1 per cent from the CMEA countries and 24.6 per cent from the developing countries. Even if the spreading of current projects with the EEC until 1982 is taken into consideration, OECD countries would still account for the same two thirds of the increase in ethylene world production capacities. Nearly half of this increase is located in Western Europe. Thus it becomes clear that the OECD countries' large overcapacities are at the source of the serious imbalances brought upon their own domestic markets.

(b) The reasons for over-investment

Although in section 2.2.2.1 the main causes that led to excessive overcapacities during this decade are analyzed, two factors need to be highlighted to better grasp the roots of the problem.

At the beginning of the 1970s the strong demand in Western Europe coupled to deficits in the United States markets and export expectations to developing countries determined the speeding up of the EEC petrochemical industry investments. Thus in 1972 over 10 new steam crackers were scheduled to come on stream after 1975[27]. Likewise in 1974, further new steam crackers were committed in all OECD countries but especially in EEC countries, in order to meet the expected future market bonanza heralded by the 1974 market boom that

27/ The problems of investment in the petrochemical industry, J.S. Hunte, EPCA Congress, Montecarlo, October 1972 later proved to be short-lived. Nevertheless, the plant committments were made to come on-stream after 1977, although later on some of the plant committments were cancelled or postponed.

From all the above, it seems that the over-investments were the result of the following four interconnected reasons:

(i) The own dynamics of the petrochemical industry, that brought about a crash between the pre 1973 super-growth factors (see page 14) and the post 1973 structural recession factors (see page 16), particularly concerning the slow-down in market growth that recently emerged as a 4-year market stagnation between 1974-78 in most OECD countries. The effects of this crash was compounded by the behaviour of the actors explained in the preceding paragraphs.

(ii) The industry's delay in perceiving the depth and duration of the economic recession specially in OECD countries during the 1970s. Warnings relating to the end of the fast market growth phase have been sounding since the late 1960s[28/]. However, the reassessment of the medium and longer-term significance of the changing market growth rates in the light of the economic recession took place later than expected, for at that time the economic recession was perceived as a shorter-term event. Therefore the petrochemical companies moved ahead with their plans. It is only recently that the OECD chemical industry has realized the magnitude of the current structural crisis[29/].

(iii) The lack of medium-term market transparency, that brought surprises and disappointments to the industry's planners, does influence and/or restrict the number of real alternatives open to individual companies thus hightening the competitive conditions in the market. Therefore the only certainty the companies have is their determination to face squarely this hightened competition in order to keep their market's share, and this entails further investments. The least risk from the company's point of view is to remain always competitive, but the aggregation of these individual risk stands does not minimize the industry's collective risks. As an alternative to this, in Western Europe and Japan there have been proposals for a temporary plant capacity rationalization programme in order to enable the affected industries to readapt to the changed conditions. So far no such programme has yet been approved

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28/ For instance, during the UNIDO-sponsored conference on petrochemicals at Baku, USSR, in October 1969, a market growth reduction was predicted for Western Europe from 22 per cent per year during 1967-70 to about 13 per cent a year for 1970-75.

29/ In a recent speech Shell's E. Werner said "Plants are still being built that were planned before the economic downturn of 1975, and although a marked decline in growth rates was foreseen, the fact that demand would hardly rise at all over the period 1975-77 was not. The chemical industry is now confronted with the problems caused by these plants planned after 1975 on the assumption that demand would return to its previous forecast levels". European Chemical News, 22 Sept.1978.

within the EEC, whereas Japan has approved some "anti-recession cartels" and "consolidation plans" to assist its distressed industries to streamline and/or convert into higher-growth more profitable market areas 30/.

(iv) The difficulty in idlying or scrapping older plants. Despite being fully depreciated and considered rather obsolete by modern standards, these plants are nevertheless kept in production, thus significantly contributing to accentuate the over-capacity situation while holding down market prices 31/. However, in the case of expensive plants such as steam-crackers, the plant repayment debt burden is so large that industry considers it preferable to run the plant even a little above the variable costs than to close it down, for labour cost savings by plant closure are relatively small 32/. Furthermore, the close interrelationship of plants within a single complex makes it very difficult to close down any of the major installations because the economic effects to be felt by the rest of the plants would be very severe.

In addition to the four reasons given above, social and political pressures, particularly on government-owned companies, make it very difficult, if not impossible, for them to close down inefficient or unproductive older plants. In several countries, the closure of one or two major plants may entail practically the disappearance of that country's petrochemical industry, which is politically unacceptable to them.

To sum up, the petrochemical industry is at the same time frail and resilient. It is frail because the setting-up of a few major plants can substantially disrupt the balance between supply and demand. It is resilient because it is concentrated in fewer large-scale plants whose idlying or scrapping meets with stiffer resistance than that expected under normal market conditions. The magnitude of the investments committed, the quasi-monopolistic position of certain companies in their national markets, the social pressures to maintain employment, and the political pressures to preserve some technological advantages are among the principal factors restricting the free operation of the market.

30/ See European Chemical News, page 6, 12 August 1977, and Chemical Week, page 44, 7 June 1978.

31/ See Petrofina's P. de Tillese' speech, European Chemical News, page 28, 7 October 1977.

32/ op.cit.9

6.1.1.2 The exportable excedents

Based on the analysis of chapter 2.4, it has been noted that the international trade in petrochemicals presents three important characteristics: exports represent a rather small proportion of world production, the main trade streams are intra-regional, and OECD countries hold in exports a more dominant position than in world production. Therefore any major modifications in the world production structure will produce far reaching impacts on international trade. Some major structural shifts in world production are now taking place that will affect primarily the OECD countries. From those, the impacts are being felt more strongly in the EEC countries, for it is one of the world's largest markets that has the most plant overcapacities.

As has been pointed out in a recent study[33/], the EEC countries will be receiving three waves of new productions during the next ten years which, according to the study, will change the EEC countries from a net exporter to a net importer position.

(i) The first wave will come soon from Eastern Europe mainly through buy-back agreements. A recent study by CEFIC[34/] on this subject estimates that from the 28 billion US dollars worth of compensation deals concluded prior to 1978 an estimated 2 billion dollars/year in payment and products will be flowing back to the EEC. This amount corresponds to about 60 per cent of total EEC chemical imports from Eastern Europe in 1977. The study warns that in these deals "there is far more involved than the short-term support of jobs in the engineering sector" for there are at stake some 2.2 million jobs directly involved, and between 6.6 and 10 million jobs indirectly supported by the EEC chemical industry.

Consequently there is a growing unrest within the EEC chemical industry and the consideration that "compensation deals cannot be more than an emergency solution[35/]." The core of the problem is, according to CEFIC's chairman K. Lanz that "payment is effected by giving an EEC market share to the buy-back contract". Therefore if its marketing is arranged in the EEC by a chemical enterprise, the price level would correspond approximately to the prevailing price level. If,however, marketing is arranged by independent merchants with no longer-term committment to the business, there is a grave risk of irresponsible pricing, market instability and under-utilization of existing EEC capacity".[35/]

33/ "Study on the Western European Markets for petrochemicals by Eurofinance", European and Chemical News, 14 July 1978

34/ European and Chemical News, page 4, 10 November 1978

35/ "Are East-block buy-backs worth the price?", Chemical Week, 8 Nov.1978

Nevertheless, some Italian producers[35] see the deals "as a way of eventually freeing themselves from the need to make low profit basic chemicals", that, adds Montedison's Gatti, "can lead to the harmonious development of commerce at world level".

Thus a promising co-operation effort has started sounding very conflicting tones whose outcome would have far reaching repercussions.

(ii) The second wave will come from non-EEC Western European countries who are now establishing and/or expanding their petrochemical industries, and would become a net aggregate exporter of petrochemicals around 1985.

(iii) The third wave will come from OPEC countries, especially from Arab countries, and would start arriving in the EEC in significant amounts around 1985 and beyond.

The effect of Eastern European and OPEC imports are feared not because of their volume but because of their possible marketing channels, "especially if they enter through independent traders or other channels not having a direct stake in the present market system[33]. Therefore the estimation of world-wide exportable excedents by region, becomes a crucial issue in the quest to achieve a lasting co-operation in the petrochemical industry.

As an example of this type of analysis, the case of the ethylene is presented according to the information given in section 6.1 and 6.1.1 and the general assumptions to estimate plant capacities to 1985 given in section 3.2.1.2. The results concerning the exportable excedents by region, for both the original and the revised sets of data are given in tables 30 (a) and (b) for 1980, and in tables 31(a) and (b) for 1985. The results of the calculations are naturally subject to reservations inasmuch as the reliability of statistics and projections is concerned. Under these reservations, they lead, however, to the following conclusions:

(a) For 1980, the original data shows a world potential excedent of 26.2 per cent of installed capacity but an estimated excedent of 13.2 per cent of the estimated supply capability (85 per cent plant operation rate). The revised data shows excedents of 29.1 per cent and 16.6 per cent respectively. These are large figures indeed for excess capacity that give an average world capacity utilization rate of between 71 per cent to 74 per cent. In both cases, OECD countries are responsible for between 87 per cent to 91 per cent of the total excess capacity.

(b) For 1985, the original data shows a world potential excedent of 15.4 per cent of installed capacity but an estimated excedent of only 0.5 per cent of the estimated supply capability (85 per cent plant operation rate). The revised data shows excedents of 18.2 per cent and 3.8 per cent respectively. In both cases OECD countries are responsible for 61 per cent and 102 per cent respectively of the total excess capacity.

However, since the resulting average world capacity utilization rate of 82 to 85 per cent is higher than past records, it may turn out that additional steam crackers may be needed just to meet the expected 1985 demand. Furthermore, if the current budding market recovery in OECD countries does speed up a bit, then the world may be facing a potential undercapacity situation. This possibility does show that there may be enough room for setting up more steam-crackers in developing countries instead of continuing to enlarge capacities in OECD countries.

(c) The above analysis shows the substantial changes that can take place in the forecasted figures and hence in the exportable excedents in a little over one year. It points out to the sensitiveness and the insecurity of results when taken as an isolated exercise and not as a continuous monitoring of events. Therefore it becomes indipensable to set up a permanent information and forecast analysis system in order to achieve a market tranparency useful to the actors.

(d) The analysis of exportable excedents and its geographical location should enable the identification of the "hot issues" for the future of the international co-operation in this industry. The anticipation of problems is a very reliable way for their timely solution.

TABLE No 30(a)

ORIGINAL POTENTIAL BALANCE IN 1980 FOR ETHYLENE BY REGIONS[1/]
(thousands of tons)

REGIONS	ORIGINAL CAPACITY	ORIGINAL DEMAND	POTENCIAL BALANCE 3/	ESTIMATED SUPPLY 2/	ESTIMATED BALANCE 4/	
					EXEDENTS	DEFICITS
Western Europe	19,030	13,400	+ 5,630	16,180	2,780	
Eastern Europe	4,905	3,860	+ 1,045	4,170	310	
North America	19,850	13,930	+ 5,920	16,870	2,940	
Latin America	3,155	2,490	+ 665	2,680	190	
Africa	1,320	1,010	+ 310	1,120	110	
Asia (except China)	1,760	2,170	- 410	1,500	[illegible]	670
Middle East	1,095	665	+ 430	930	265	
Japan	6.110	4.440	+ 1,670	5,195	755	
Pacific Area	590	715	- 125	500		215
TOTAL WORLD	57,815	42,680	+ 15,135	49.145	7.350	885

1/ All these figures are to the nearest 5 or 10

2/ An average plant capacity utilization of 85%

3/ Potential balance in the deference of capacity less demand

4/ Estimated balance in the supply less demand

TABLE No 30(b)

REVISED POTENTIAL BALANCE IN 1980 FOR ETHYLENE BY REGIONS[1/]
(thousands of tons)

REGIONS	REVISED CAPACITY	REVISED DEMAND	POTENTIAL BALANCE 3/	ESTIMATED SUPPLY 2/	ESTIMATED BALANCE 4/	
					EXCEDENTS	DEFICITS
- Western Europe	19.765	12,000	+ 7,765	16.800	4.800	
Eastern Europe	4,635	3.360	+ 775	3,940	80	
North America	18.410	12,480	+ 5,930	15.650	3.170	
Latin America	3.355	2,490	+ 865	2,850	360	
Africa	1.040	1,010	+ 30	885		125
Asia (except China)	1,970	2,190	- 220	1,675		515
Middle East	820	670	150	700	30	
Japan	5,610	4,420	+ 1,190	4,770	350	
Pacific Area	590	710	- 120	500		210
TOTAL WORLD	56.195	39.830	+16.365	47.770	8.790	850

1/ All these figures are to the nearest 5 or 10

2/ An average plant capacity utilization of 85%

3/ Potential balance is the deference of capacity less demand

4/ Estimated balance is the estimated supply less demand

TABLE No 31(a)

ORIGINAL POTENTIAL BALANCE IN 1985 FOR ETHYLENE BY REGIONS 1/
(thousands of tons)

REGIONS	ORIGINAL CAPACITY	ORIGINAL DEMAND	POTENCIAL BALANCE 3/	ESTIMATED SUPPLY 2/	ESTIMATED BALANCE 4/	
					EXCEDENTS	DEFICITS
Western Europe	24,500	21.400	+ 3,100	20.825		575
Eastern Europe	8,100	6.150	+ 1,950	6,885	735	
North America	28,000	23,380	+ 4,620	23,800	420	
Latin America	5,200	4,990	+ 210	4,420		570
Africa	2,200	1,940	+ 260	1,870		70
Asia (except China)	5,300	4,195	+ 1,105	4,505	310	
Middle East	3,000	1,425	+ 1,575	2,550	1.125	
Japan	8,200	7,860	+ 340	6,970		890
Pacific Area	1,300	1,220	+ 80	1,105		115
TOTAL WORLD	85,800	72,560	13,240	72,930	2.590	2.220

1/ All these figures are to the nearest 5 or 10

2/ An average plant capacity utilization of 85 %

3/ Potential Balance is the diference of capacity less demand

4/ Estimated balance is estimated supply less demand

TABLE No 31(b)

REVISED POTENTIAL BALANCE IN 1985 POUR ETHYLENE BY REGIONS[1]
(thousands of tons)

REGIONS	REVISED CAPACITY	REVISED DEMAND	POTENCIAL BALANCE 3/	ESTIMATED SUPPLY 2/	ESTIMATED BALANCE 4/	
					EXCEDENTS	DEFICITS
Western Europe	21,065	14,960	+ 6.105	17,905	2,945	
Eastern Europe	5,735	6,150	- 415	4,875		1,275
North America	22,310	17,090	+ 5,220	18,965	1,875	
Latin America	3,355	4,990	- 1,635	2,850		2,140
Africa	2,290	1,940	+ 350	1,950	10	
Asia (except China)	4,225	4,200	+ 25	3,590		610
Middle East	3,520	1,420	+ 2,100	2,990	1,570	
Japan	7,310	5,620	+ 1,690	6,215	595	
Pacific Area	590	1,220	- 630	500		720
TOTAL WORLD	70,400	57,590	12,810	59,840	6,995	4,745

1/ All these figures are to the nearest 5 or 10

2/ An average plant capacity utilization of 85 %

3/ Potential balance is the diference of capacity less demand

4/ Estimated balance is estimated supply less demand

6.1.2 The medium-term transparency of the market and the long-term prospects of the petrochemical industry

As was already explained at the beginning of chapter 6, lasting co-operation implies informed partners. This necessity concerns not only the medium-term future but goes beyond. An improvement in the transparency of the markets, the predictability of credible future demand levels, and the development prospects of this industry based on the strategy of the actors, have become an indispensable condition of co-operation. Therefore in order to pave the way for attaining a future transparency of this industry and its markets, some of the more pressing problem areas will be briefly reviewed.

6.1.2.1 The permanent updating of information on the petrochemical industry

This problem area pertains to the continuous and timely access by the co-operating partners to accurate information on the current situation and future prospects of this industry, especially information on present and future plant capacities and the evolution of the markets. In this regard, projects are more than a declaration of intent, they are the concrete operational form of the strategies of the actors. This is why their identification and regular accounting are essential, as was shown in the preceding section 6.1.1 Experience has also shown that in a world of generalised interdependences only a world view could provide a clear picture of the complex and dynamic realities underlying this industry up to the end of the century. An international organisation such as UNIDO can contribute to facilitate the flow of this reciprocal information, but it can only do so with the active support and the co-operation of all the actors concerned. Such a role has been already recommended by the global preparatory meeting for consultation on the petrochemical industry[36].

36/ op.cit.14

6.1.2.2 The identification of the strategies of the actors

This requires specific type of information that is not always readily available because the identification of an actor's strategy involves a definition of its aims, means, constraints and ways of action. Consequently the strategies of the different actors vary according to the significance of those factors. Later on, section 6.2 will attempt to present the elements of the strategy of the actors in more detail. However, it should be noted that no lasting co-operation can be achieved without a mutual acknowledgement of the compatibility of aims. In this regard three problem areas have been identified:

(a) The increase of the share of developing countries in the world petrochemical production that reflects a number of conflicting situations between the claims of developing countries to become world petrochemical producers and the reluctance of developed countries to facilitate the access of the new producers to their domestic markets. However, in the recent global preparatory meeting for consultation on the petrochemical industry 37/ that included representatives from developed and developing countries, the need was expressed throughout the meeting to increase the developing countries' share in world petrochemical production through broad range co-operation efforts in a number of areas but especially on markets and technology. Nevertheless the current conflictual positions of two of the strongest groups of actors, that of the OPEC countries from the developing countries and that of Western Europe from the developed countries, illustrates the problem that can be summarised as follows:

(i) The OPEC position expressed by its chairman in a recent OPEC meeting 38/, states the OPEC countries decision to become world petrochemical producers regardless of the attempts to dissuade them to do so. In this regard the OPEC chairman viewed the viability of petrochemical production in their countries within the wider context of their socio-economic development. However, he welcomed the commercial approach of multinational companies, and pointed out that it "would not rule out the economic feasibility of downstream operations in OPEC countries where a higher comparative cost advantage was secure on the one hand a greater absorption capacity of the world market on the other hand".

37/ op.cit. 14

38/ op.cit. in 10 and 11

(ii) The perception of the future developments of this industry expressed by several Western European business leaders in last year's meetings of the Society of Chemical Industry, Continental European Section, in Vienna and the European Petrochemical Association in Venice, have been further clarified by recent statements from Hoechst's K. Lanz, current chairman of CEFIC, and Shell's E. Werner 39/, concerning a probable geographical distribution of future world petrochemical production. The business leaders envisage for the late 1980s and beyond, that North America, Western Europe and Eastern Europe each would account for about 25 per cent of world petrochemical production and Japan would account for a further 10 per cent, despite the construction of more petrochemical complexes in developing countries, particularly in oil producing countries. Therefore the developing countries' share in world petrochemical production during the 1990s may become about 15 per cent, a situation that is way below the expectations of the Lima Declaration's aim that they should reach at least 25 per cent of the world industrial production by the year 2000.

(b) <u>The strategies of oil and petrochemical companies</u>

These strategies show that oil and petrochemical companies have been moving in opposite and potentially conflictual directions:

- the downstream integration of oil companies moving from basics to intermediates to end products;
- the upstream integration of petrochemical companies aiming at achieving a larger degree of independence concerning feedstocks and basic petrochemicals.

However, with the exception of a few countries, there is a good co-ordination and/or integration between oil and petrochemical companies in most countries since a number of those companies are either government-owned or government-influenced. Nevertheless a number of the main oil and petrochemical multinationals do go their own independent ways and the response of both industries to this potentially conflictual situation will strongly influence the future shape of the petrochemical industry.

In the developing countries the oil producing countries are finding the strategies followed by the oil companies is the logical path for them to follow, as expressed by OPEC's Secretary General in their recent seminar 40/. Likewise, the non-oil producing developing countries eager to develop their petrochemical industry may find the stratagies followed by petrochemical companies more akin to their own needs.

39/ *European Chemical News*, page 4, 9 June 1978 and op.cit. 29, respectively

40/ op.cit.10

(c) The assured supply of petrochemicals to the markets

Since changes in the production cost structure have shifted the comparative cost advantages to oil producing countries at least for basic and intermediate products, then the problem of the assured supply of those products to existing markets becomes crucial if it is to be a real alternative for their potential buyers, who will otherwise consider enlarging capacities in order to produce them. For instance, this assured supply guarantee is one of the important factors that lies at the root of most buy-back agreements signed between OECD countries and Eastern European countries, based on the latter's track record in keeping up with their contractual committments 41/. As a matter of fact, the assured supply factor may become one of the key practical elements in implementing a new world petrochemical production structure by regions based on co-operation between the actors, be they governments and/or companies.

6.1.2.3 The time factor in the long-term prospects of this industry

The importance for the developed countries of timely investments and the need to know the precise schedule for the on-stream entry of additional capacities, underlies the painful effects now being endured by their petrochemical industry due to the excessive over-capacity probleme as explained in section 6.1.1. Likewise, the developing countries and especially OPEC countries, are dependent on the time factor. In a recent speech 42/, the Secretary General of OPEC stressed the urge to prepare now the economic and industrial structure that will support those countries in the future, in order "to provide against the day when there is no more oil and gas".

In the meantime, new developments indicate that reserves of oil and gas appear larger than previously envisaged, and that a coal-based synthetic fuel industry may make a commercial start-up at the end of the 1980s. Under these changed conditions, it seems that the establishment of petrochemical industries in oil producing countries is becoming a race against time. This situation appears to have been keenly perceived by OPEC countries, hence their political decision to go petrochemical as indicated in section 6.1.2.2 (a).

Furthermore, the still fast-growing ever larger investment requirements for the same plant capacity due to inflation and the skyrocketing increases in equipment and construction costs, urge against further delays in plant committments if developing countries are to raise their present low share in the world petrochemical production during the next two decades. This effort would require active co-operation between the actors involved, at the earliest.

41/ "Are East-block buy-backs worth the price?" Chemical Week, 8 Nov.1978

42/ op.cit. 10

6.1.2.4 The technological factor

Technology is one of the main prime movers of this industry. However, current major technologies are at least 10 years old 43/ but at present the industry is seeing the emergence of new technologies that streamline the processes, reduce investments and improve the products. These forthcoming innovations are likely to modify the constraints, the means, and consequently the strategy of the actors. This is why the need for technological forecasting and the discussions of long-term development alternatives for this industry are likely to influence the projects of developed and developing countries, in order to avoid the pitfalls of a chaotic growth in plant capacities.

6.1.3 The barriers to the entrance of new producers

These barriers are objective hindrances resulting from the structure of the sector and the market game of the actors. The aim of this section is on the one hand, to realistically appraise the existence and level of objective barriers, and on the other hand, to raise or reduce the level of the barriers resulting from the actors.

Co-operation implies contributions and counterparts. The lowering of entry barriers is a part of the latter. The entrance of new producers is not only beneficiary to the consumers in their own countries, but also to equipment suppliers in the developed countries. As the OPEC chairman aptly said: "After all, the world economy is not a zero sum game where somebody has to lose for another to benefit".

In the petrochemical industry game, however, actors are not subject to the same constraints and do not dispose of the same means of action. The following table summarises in general the analysis of the barriers to the entrance of new producers: 44/

(a) Cost advantage for established firms

(b) The differentiation of products (market segmentation)

(c) The economies of scale

(d) The technological capability (including management and marketing)

(e) Availability of capital goods

(f) Financial requirements

(g) Institutional barriers (tariff and non-tariff barriers)

The customary market hindrances include:

(i) The agreements covering, among other things, price fixation among producers, the sharing out of markets and the commercial organization.

43/ op.cit. 1

44/ This table has been based on works by J.S. Bain, Barriers to New Competition, Cambridge 1956, Harvard University Press, and more recent works particularly by Roger Sherman. The Economic of Industry, Boston, Little, Brown and Co,1974; Alexis Jacquemin, Economie Industrielle Européene; Structures de marché et Stratégies d'Entreprises, DUNOD 1975, Jean Marie Chevalier; l'Economie Industrielle en Question, Calmann Levy, 1977.

(ii) The leadership effects shown by price fixations by the leading firms or, under their influence, by collective prices among a group of firms.

(iii) The discriminating effects on a market occur directly through prices or by the preferences of buyers. These "horizontal" effects are completed by "vertical" effects. The latter include the refusal to supply, the cancelling out of a market, and the squeeze of prices. The squeeze of prices implies the vertical integration of producers. The simple squeeze consists in an upstream action on the integrated producer through the jacking up of prices for intermediate products and feedstocks; the double squeeze consists in completing the simple squeeze by a downstream pressure on the end products prices.

A thorough analysis of the interactions of all these elements is at this stage beyond the scope of the present study. However, a brief overview of the barriers and hindrances in the petrochemical industry will be given. Figure 9 presents them in graphic form.

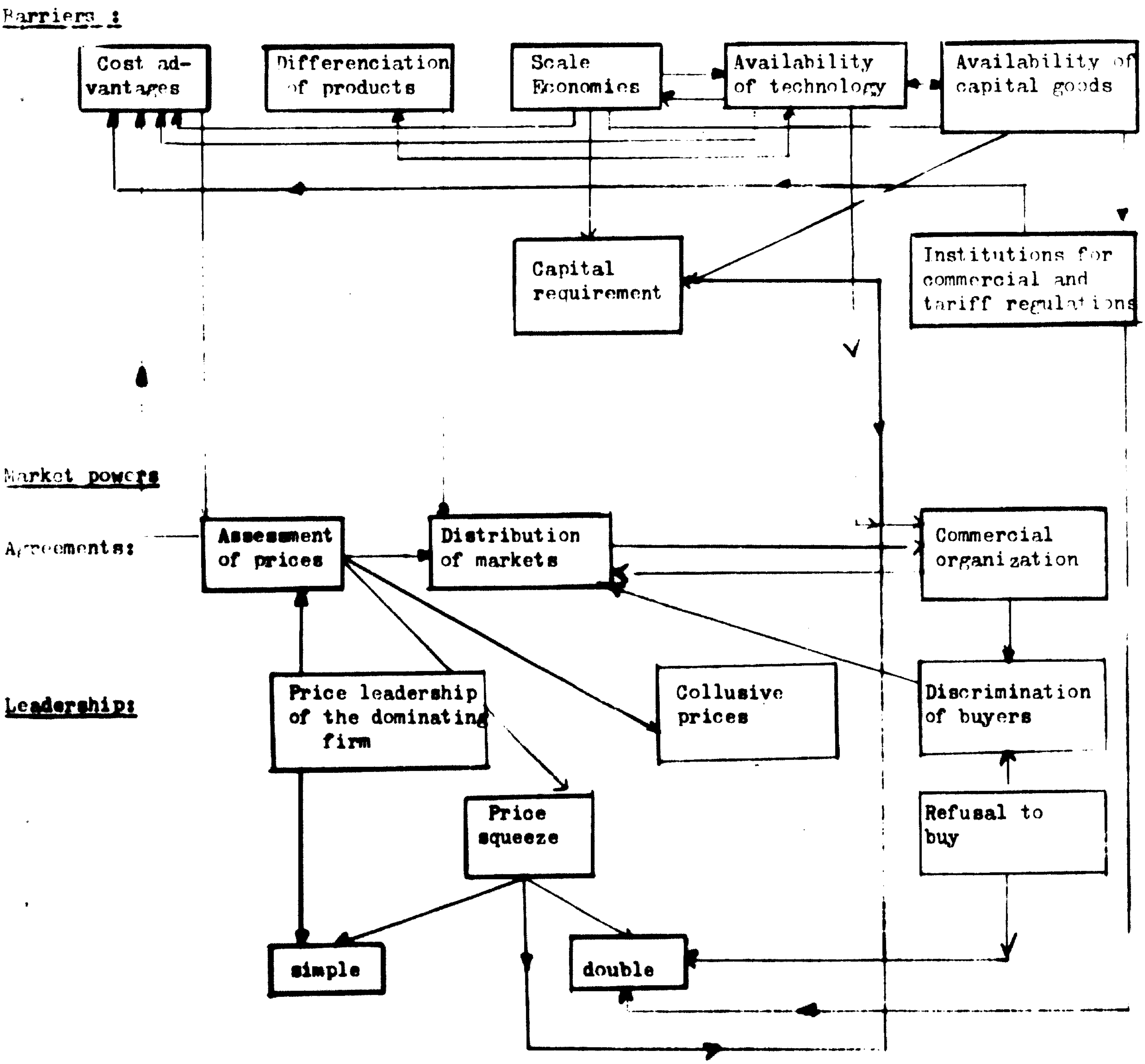
6.1.3.1 Main barriers to the entrance of new producers from developing countries

(i) The cost advantage of established firms undoubtedly exists and supports a dissuasive argumentation against the entry of new producers into the sector. The oil producing developing countries feel they should compensate this disadvantage by the lower cost of their raw materials in order to fully benefit from the recent shifts in the production cost structure shown in section 2.2.5.4. This cost advantage may suffice in commodity chemicals provided that suitable longer term supply contracts are concluded. However in performance chemicals the situation varies for unless appropriate marketing arrangements are oconcluded, the cost of establishing independent marketing channels could be very steep indeed, as shown in sections 2.4.2 and 2.4.3.

(ii) The differenciation of products makes the emergence of new producers more difficult in connexion with the marketing of a competing product. This phenomenon is especially relevant for performance chemicals where changes in the specifications of products may create new markets or the disappearance of existing markets in a rather short period. This market segmentation has little influence on commodity chemicals, although new prooesses may change the market importance of many intermediate products.

(iii) The economies of scale. The scaling-up of plant capacities has been one of the essential characteristics of the petrochemical industry leading both to a drastic reductionof costs and to a considerable increase of investment costs. The economies of scale does not play directly the role of a barrier, but it does hinder potential new producers through the conditions associated with them, such as cost competitiveness, needs of capital and know-how, management and marketing etc.

Figure 9. BARRIERS TO THE ENTRIES OF INDUSTRY AND MARKET POWERS



(iv) Technological capability. There is a total asymmetry between the countries and companies creating technological innovation, holding know-how and having the property of manufacturing processes, and the developing countries, which own none of these essential elements that could have enabled them to negotiate from a stronger position in the present industrial world.

It is appropriate to distinguish the levels of technology transfers. The assimilation difficulties are not linear but exponential between transfers of technology for production and the transfer of technological ability that besides production includes the management of complex units and the reproduction or setting-up of technology.

Currently the transfers of technology are rarely refused for commodity products including bulk end products because of the existence of competing processes[45/]. However, this is not the case for specialty performance chemicals. Concerning the transfer of technological ability, this has been very limited and most new producers have had to learn the hardway, by trial and error.

(v) The availability of capital goods. It is usually possible to buy all the equipment needed for petrochemical production. However, the developing countries are finding equipment buying a barrier due to soaring equipment prices, the difficulties of their balance of payments, and the lack, with few exceptions, of a domestic equipment manufacturing industry able to supply their needs. However, the other current modality of buying equipment through buy-back agreements is at present restricted only to OECD and CMEA countries.

(vi) Financial requirements

This is one of the most immediate and pressing barriers that has led to the delay and/or shelving of many petrochemical projects in developing countries. Even for OPEC countries the very large amounts to be invested are not without difficulties and this is compounded at a time when most OPEC countries are having a deficit in their balance of payments although their borrowing ability and credit rating remain high.

The petrochemical industry is a high-risk industry for developing countries in view of the large sums committed. If plant delays and/or operating difficulties do occur, then developing countries may easily find themselves in a very tight financial bind to repay the large debts incurred on time. At present, there is no inclusive insurance to shore up the huge losses to be incurred in case of plant failure. Consequently the co-financing of projects through joint-venture agreements may be a way out of this barrier. In this regard the OPEC

45/ "Licensing: are sellers moving more cautiosly?", P.R.Savage, Chemical Engineering, 28 August 1978 countries have clearly stated their willingness to co-finance downstream projects in the Arab countries and other developing countries 46/.

(vii) The institutional barriers are the well-known tariffs and quantitative non-tariff barriers that countries impose to protect their markets and/or the petrochemical industry.

6.1.3.2 Main market hindrances

(i) The market agreements. So far the highly competitive environment on most OECD petrochemical markets seems to have excluded formal market agreements among end products manufacturers. The only exception is Japan 47/ and the EEC proposed "crises cartel on synthetic fibres" that has not yet been approved. However, the social organization of the CMEA countries bestows considerable market leverage through their monopoly of international trade. Similarly, the OPEC countries exercise a considerable market leverage on the fixation of crude oil prices and consequently on the costs of petrochemical products.

In the above examples the actors are not exercising simply "bargaining power" but indeed more permanent "structural power" 48/. The developing countries without oil or large domestic markets are devoid of the elements of a structural power.

(ii) The leadership effects. The leadership in prices is a strategy whereby market prices are periodically announced by a leading firm. A variation of this policy is that of collusive prices practiced by firms of similar size. In those cases the agreement takes place on a bottom price guaranteeing a minimum profit.

The existence of "barometric firms" in the petrochemical industry is a fact and they deserve a more thorough analysis. Likewise the discrimination of buyers through differential price policies exists at all levels such as the oil policies practiced by some OPEC countries.

(iii) The commercial organization is one of the essential elements of market leverage and it is a structural weakness of most developing countries, the projects of which are directed mostly towards exports to the developed countries. One of the few alternatives to a main actor's refusal of co-operation in this field would be to circumvene barriers through the channel of independent traders, but this solution involves a very costly confrontation.

46/ op.cit. 10 and 12

47/ op.cit. 30

48/ According to the distinction made by Northwestern University's J.A.Caporasso "Dependence, dependancy and power in the global system - a strucural and behavioural analysis", International Organisation, Winter 1978

(iv) The "vertical" market leverage is based on the production rigidities of a vertically integrated complex. They include the "squeeze of prices" and the refusal to supply.

(a) The price squeeze occurs mainly in two forms:

- The simple squeeze happens when for instance feedstock prices rise and an economic recession prevents their downstream repercussions. It may mean a pressure on the intermediate products' prices and a vanishing of profits.
- The double squeeze takes place when to the upstream squeeze a downstream one is added, i.e. the pressure on the final or intermediate price of products. These complex relations do not only have effects at the international level but also within national boundaries. For instance, the move by oil companies into petrochemical markets may have two opposite consequences according to the policies followed through their control of feedstock prices and the production at the same time of basic, intermediate and end products. Either they may be tempted to foster higher prices for oil and gas or they would moderate these increases as producers of intermediate and final products. Naturally the OPEC petrochemical companies could also, according to the circumstances, play this alternative.

(b) The refusal to supply is certainly the most effective weapon to attain market leverage. It has been used in various circumstances[49/]. Therefore the clear warning of the OPEC representatives to resort ultimately to this weapon if co-operation does not permit the access of the markets in the industrialized countries, should be taken seriously[50/]. Fortunately, however, these extremes have not been reached and a large margin for negotiations and co-operation exists.

49/ Among others by the Arab countries in Oct. 1973 during the oil crisis and also in the home American market by the big oil companies towards independent refineries and distributors (see Federal Trade Commission, Preliminary Federal Trade Commission Staff Report on its investigation of the Petroleum industry. Rapport Jackson 1974)

50/ "As far as the problem of market penetration is concerned, the producers emphasize the collective approach as the most effective means of increasing their bargaining power. On the other hand they cannot dissociate the market penetration for their products from their considerable weight as the major supplier of crude oil. This means that ultimately the oil producers may be forced to link the export of products to their exports of crude oil." H.E. Ali Khalifa Al-Sabah. Op.cit. 10 and 11.

6.2 STRATEGY OF THE ACTORS

6.2.1 Actors and power relationships

6.2.1.1 Conceptual approach to power relationships

Within a simplified framework, the power relationships evolve from conflict-co-operation tensions between actors that involve, basically, direct or indirect negotiations. The object of the negotiations comprises all the elements desired by the actors such as entry to markets, market shares, financing conditions, supply of feedstocks and petrochemicals, transfer of technology etc.

In order to better understand the significance of the power relationships that are taking place in the petrochemical industry, the following concepts will help to clarify the nature and characteristics of those relationships:

(a) Power positions of the actors: considering that in order to assume the role of an actor any organization, group or individual must have an object of negotiation, there are two main power positions available:

- (i) bargaining power, that involves the actor's possession of part of, or access to, an object of negotiation;
- (ii) staying power[51] implies the dominant possession and/or control of an object of negotiation.

(b) Approach to the negotiation: comprises two main categories of thorough preliminary preparation by the actors in order to use their relative power positions advantageously:

- (i) strategic posture, implicitly or explicitly enounced, and the accompanying tactical and operational measures;
- (ii) lack of strategic posture, having only overall planning that aims at implementation through tactical and operational measures.

(c) Types of actors: include two main categories of actors according to their ability to polarize the development of the negotiations to their advantage:

- (i) primary actors who are usually those who have staying power and approach the negotiations through stategic postures;
- (ii) secondary actors who are usually those who have bargaining power and approach the negotiations with or without strategic postures.

51/ This concept is akin to that of structural power, op.cit.48

Based on these concepts, the following types of power relationships can be evolved within the conflict-co-operation framework:

Main types of power relationships between actors

Power relation	Characteristic	Conflict-co-operation framework
staying/staying	mutual respect	lasting co-operation
		↕CO-OPERATION AREA
bargaining/bargaining..	agreement	contractual co-operation
		↕CONFLICT AREA
staying/bargaining	latent conflict	lasting conflict

In the practical application of this scheme three major problem areas arise due to the dynamism of the power relationships and their speed of change in time, when actors manouvre to maintain or shift their relative power positions and strategic postures:

1. Degree of abstraction in identifying the actors concerns the identification of the specific actors involved at a level of aggregation that becomes meaningful for the analysis. This is specially relevant in assessing the effective resources available to the actors in order to determine their particular power positions.

2. Degree of relativity involves the varying power levels between one actor and each of the other specific actors for every object of negotiation.

3. The complexity of the negotiations, for it usually involves a number of objects of negotiation that are closely interrelated in complementary and/or antagonistic ways.

As a result of the above, the negotiation struggle becomes a complex matter whose outcome, within a time perspective, is difficult to predict although it is usually possible to envisage its main alternatives for appraisal. The outcome of the struggle is influenced by a number of factors such as the ranking of the objects of negotiation, the quality and completeness of the information, the accuracy of the actor's reading of reality, the negotiating skills, the degree of committment and risk taking, the resources involved etc. Therefore this section aims at presenting a first analysis of the dynamics of the petrochemical industry through the assessment of the power relationships between the actors.

6.2.1.2 Main actors

Based on the economic weighting analysis presented in section 4.3.2.2 the primary actors of the petrochemical industry were identified. The most important actors are the following:

(i) The government of developed countries of market economies

(ii) The government of developed countries of centrally planned economies

(iii) The government of oil exporting developing countries

(iv) The government of non-oil exporting developing countries but with large domestic markets for petrochemicals

(v) The oil multinationals

(vi) The petrochemical multinationals

These actors are usually organizations, governments, common-interest groups and individuals whose relative power positions, expectations and intentions determine the duration, intensity and type of the power relationships between each other. These relationships usually evolve within a framework of conflict-co-operation according to the degree of concurrence or disagreement reached by the actors.

As a result of the above, most actors implicitly or explicitly determine their actions in terms of strategic postures that could be enounced by them and/or perceived by the other actors. The strategic posture indicates the ways (decisions, major action programmes) in which actors intend to use their means (the resources available to the actor) in order to achieve their aims/objectives and overcome their constraints.

It presents a conceptual approach to the actors and their power relationships, the main economic gameboard areas of this industry, and the perceived strategies of the ma. actors.

6.2.2 The main economic gameboard areas of the petrochemical industry

The main internal and external factors that affect this industry can be grouped into four ec ic gameboard areas: markets, production costs, raw materials and econom financial aspects.

6.2.2.1 Markets

The principal factors of this gameboard area are the following:

(i) Market growth that shows the differing growth prospects for the main regions. In this regard, the developing countries, despite their overall economic difficulties, still keep a dynamic market growth rate in petrochemicals although a bit below the rates achieved during the 1960s. This is especially true for the more advanced developing countries and reflects the fact that the substitution process of petrochemicals for natural products is far from being exhausted.

Likewise, Eastern Europe still has sizeable potential markets for petrochemicals growth through substitution of natural products. Furthermore, the substantial new capacities under construction may spur this growth further when part of this additional production becomes shortly available in their domestic markets.

The market situation in the OECD countries ie relatively etagnant for the peak 1974 demand levels are just being regained in 1978 in basic products and many end-products but plastics. The latter has shown good growth prospects especially in the United States. However, the situation is not the same in all OECD countries. Japan is looking to further growth prospects through a production restructuring that concentrates on specialty products at home while internationalizing its production structure of commodity chemicals. Western Europe's market growth prospects look dimmer due to a deep structural change (large plant overcapacity, greatly depressed prices, greater maturity of its petrochemicals substitution process, anticipated increased competition for domestic and export markets from other emerging producers etc), that may change the EEC countries of this region from being a net exporter to become a net importer of petrochemicals some time during the 1980s 52/. The United States shows good growth prospects ahead, specially in plastics, as a result of the industrial drive towards energy conservation spurred by the large oil price increases of 1973. This drive has brought about a deeper market segmentation and the emergence of entirely new markets such as fiber optics and thermoplastic elastomers 53/.

(ii) Changing patterns of consumption that point to deeper changes in market outlets for the main end products based on three new trends:

- the emergence of plastics as the most desirable manufacturing material for it became a more energy-efficient material to produce and to transform by the processing industry;
- the evolving of a new market eegmentation where general purpose end products became more "commodity" chemicale along with the basic and intermediate petrochemicals, while a faster-growing and more profitable market segment of performance chemicals is coming out made up of specialty products such as special-purpose bulk resins, engineering thermoplastics, composite materials and other emerging new markets.
- the economic evaluation of manufacturing materials in terms of cost/performance advantages for specific processing industries and not only in terms of lower coste or performance advantages as was customary in the past. This trend may spur a new round of product substitutions both between petrochemicals themselves and against such bulwarks as steel and steel alloys.

52/ "Eurofinance's study on the situation in the European petrochemicals market", European Chemical News, 14 July 1978.

53/ "What ie happening in the US plastics industry", Modern Plastics International, July and October 1978.

(iii) Access to the markets, reflects the legal tools and business practices used by actors in order to assure supplies to the markets and/or obstruct the entry of newcomers to existing markets. They include tariff and non-tariff barriers, marketing arrangements, licensing and trade mark restrictions etc., as shown in section 6.1.3.

6.2.2.2 Production costs

Two main factors play the leading roles in this area:

(i) Shifts in international production cost advantages that reflect the major shifts towards the predominance of variable costs over fixed costs and shown in section 2.2.5.4. This gives an important production cost advantage to feedstock producers specially concerning commodity chemicals. These shifts favour oil producing countries and the oil multinationals that are the major refinery operators. Nevertheless, this leaves the question open concerning the ability of those actors to take full advantage of the production shift, specially concerning infrastructural cost and techno-managerial capability.

(ii) The role of technology that customarily gives the edge to check raising production costs, streamline processes, valorize co-products, reduce investment costs and further market developments. Usually the dominance over this factor is one of the main strengths of petrochemical multinationals although some oil multinationals are becoming strong in this field specially concerning commodity chemicals.

6.2.2.3 Raw materials

This area deals mainly with the threshold of economic substitutability between competing feedstocks that have a hydrogen to carbon ratio of around 2, and the life span of their recoverable reserves at the expected consumption levels.

Current developments point out that oil reserves may be larger than previously estimated, that LPG production will be in excess of demand in the medium term, that natural gas reserves may be several times larger than estimated as technologies able to tap gas resources other than from dry gas fields become commercially available, that some coal liquefaction technologies, specially direct liquifaction processes able to produce fuels and chemical feedstocks are already in the large-scale pilot plant stage and may become commercially available by the end of the 1980s, while further developments on oil shale and biomass conversion technologies may make them effective contenders in supplying chemical feedstocks by the end of the 1990s.

6.2.2.4 Economic and financial aspects

The principal factors of this area are the following:

(i) The inflation factor that makes cost accounting and cash flow generation for new fast-growing investment needs much more difficult to undertake, while current depressed prices of petrochemicals do not help generate enough cash flow for majority self-financing of new investments as was customary in the past.

(ii) Effects of fluctuating currency exchange rates, that is producing a shift of petrochemical investments from Western Europe and Japan mainly to the United States because of substantial depreciations of the United States dollar in recent years against other major OECD currencies. The fall of the United States dollar has resulted in substantial investment savings for other OECD investors engaged in business transactions in the United States. However, in general, developing countries do not enjoy the same investment attraction for OECD investors since most of the equipment needed for petrochemical production is imported anyway, thus they do not provide an investment advantage comparable to that of the United States.

(iii) Speculative behaviour: the previous two factors have created a speculative behaviour in oil and petrochemical multinationals in order to use more efficiently their cash flows, both as a hedge against inflation and as an extra source of income. This may explain the care with which these actors are screening future investment programmes,specially in developing countries, where once favourable conditions may change almost overnight.

(iv) Financing has become a difficult problem for all but some OPEC countries and oil multinationals. This situation is a major problem especially for non oil exporting developing countries that have medium-sized markets and balance of payments difficulties. However, developing countries with larger and dynamic domestic markets protected by adequate trade barriers continue attracting petrochemical investments.

6.2.3 Perceived strategies of the main actors

6.2.3.1 Perceived aims and power positions of the main actors

The perceived main aims and relative staying power positions of the primary actors of this industry at a very broad level of aggregation are as follows:

(i) The governments of developed countries of market economies have a perceived aim of encouraging new investments and/or plant capacity retionalization programmes, with increasing regulation of the petrochemical industry by environmental, social, health hazard and industrial security issues. Their staying power is based on the setting and applying of the economic rules of the game for their countries, their capacity to spur or depress their own and the world's economies, and bargaining power in dealing with other governments.

(ii) The governments of developed countries of centrally planned economies have a perceived aim to accelerate their industrial development to cater for their population's expectations in raising living standards, and to achieve growing exports in order to finance a sizeable part of their needs to import technology and equipment. Their staying power is based on their almost total control of the economy, resources and priorities, and bargaining power in dealing with other governments and with multinational companies especially within the buy-back agreement framework.

(iii) The governments of oil exporting countries have the perceived aim of making a downstream integration of their oil activities from basic to intermediates to end petrochemicals, and to get favourable access into the larger markets of the developed countries in order to secure outlets for their future petrochemical output. Their staying power is based on the control of most world flared gas and oil exports, and their large financial resources and bargaining power in dealing with other governments and oil and petrochemical multinationals.

(iv) The governments of non oil exporting developing countries but with larger domestic markets for petrochemicals have the perceived aim of speedily meeting their domestic demand and to export if feasible. Their staying power is based on their control of the access to their domestic markets by external suppliers, the setting and applying of the economic rules of the game for their countries including government support and incentives for this industry, and bargaining power in dealing with other governments, oil and petrochemical multinationals, and financial organisations.

(v) The oil multinationals have the perceived aim of diversifying their resources to become energy companies and to find profitable outlets for their large cash flows. To this end, oil companies are diverting a larger portion of their investments to downstream petrochemical operations from basic to intermediate to "commodity type" end petrochemicals. Their staying power is based on the control of a variety of feedstocks some of which may be cheaper than others at any given time, and their advantage, through further processing, in upgrading the sales value of return streams from steam crackers based on liquid feedstocks. Furthermore, this feedstock cost preponderance enables them to take full advantage of the major shifts in the international production costs shown in section 2.2.5.4, thus extending their cost edge down to the main large tonnage thermoplastics. Their staying power is enhanced by their large self-financing capability, their control of basic petrochemical markets and their fast growing market share in several intermediates and "commodity type" end products. They have bargaining power in dealing with governments.

(vi) The petrochemical multinationals have the perceived aim of becoming specialty producers of end petrochemicals in order to achieve higher market growth and enhance profitability and cash flow. Their staying power is based on the control of sophisticated technologies, a still dominant market share of end petrochemicals, the excellent co-operation track record with the processing industry in order to develop new market segments and custom-made grades of polymers, resins and compounds more cost-advantageous for that industry, their strong customer service organizations, and their competitiveness in terms of cost efficiency through their closely integrated operations and the production of a full range of end products. They have bargaining power in dealings with governments, and with oil multinationals concerning feedstocks, basic and intermediate products.

The above analysis shows that not all the actors' staying powers are equal but that within each broad category of actors there are many individual actors that have conflicts of interest with another. Therefore the interplay between individual actors does produce a number of mixed conflict/co-operation situations where one or the other prevail.

6.2.3.2 Some perceived power relationships

Although the analysis of the main power relationships between primary actors is not yet completed, one simplified example of this analysis shall be given to illustrate its application. The power relationships between oil and petrochemical multinationals conform to a pattern approaching lasting co-operation, where the strength of their respective staying powers is basically complementary and not conflictual, and it is characterised by a mutual respect. This situation is reflected in their long-standing involvement in basic product, where oil companies through joint ventures and/or supply arrangements do provide the larger portion of the petrochemical industry's needs for basic petrochemicals. This situation is practically generalised throughout the world with the exception of several United States petrochemical companies (that have basic olefins production based on associated gas) and some EEC petrochemical companies (that, as in ICI's case, produces basic petrochemicals in collaboration with Phillips Petroleum at the oil refining end)54/.

Since the large oil price increases of 1973 that brought about a shift in the production cost structure linked to large plant overcapacity in OECD countries, coupled to depressed market prices, a potential area of conflict came forth in the major bulk thermoplastics. The response of both industries that emerged recently does reflect the co-operation power relationship between them: the gradual separation of plastics suppliers, those who primarily handle commodity-type resins (generally oil companies) from those that concentrate on specialties (generally petrochemical companies)55/.

6.3 CONCLUDING PROPOSAL TO SPUR CO-OPERATION IN THE PETROCHEMICAL INDUSTRY

After assessing three alternatives that explore the possible participation of the petrochemical industry in achieving the 25 per cent of total world industrial production by developing countries in the year 2000 and presented in the previous chapters of this study, the conclusion is that the only way of attaining a 25 per cent share or higher is through a high degree of co-operation among the countries.

The preceding sections of this chapter 6 show, on the other hand, that the forthcoming years will be under varying tensions among the actors. The current outlook points out that market realities and the projects of the actors dwell more in the conflict area in the hort term but have interesting possibilities of co-operation in the medium and long term. Neither conflicts nor co-operation are irreversible, but of the two the latter requires more sustained efforts to bear lasting fruits. Co-operation then becomes the outcome of the images of the future as perceived by the actors and the efforts at organizing these actors in co-operative rather than conflictual ways. This organization implies continuous action backed by information systems, by consultations, and by a progression towards a global transparency of this industry able to create consensus for joint action.

A proposal to actively organize co-operation is suggested here below. It comprises four stages:

(a) The establishing of a working group to set up a reliable information system and achieve medium-term market transparency.

(b) The analysis of the actors' strategy.

54/ "Oil and/or chemical refineries", W.C. Thomson, Hydrocarbon Processing, February 1978.

55/ Modern Plastics International, August and October 1978, pages 4 and 38 respectively.

(c) The elaboration of alternative scenarios or comprehensive images of the future.

(d) The selection of a reference scenario that includes the analysis of the ways and means for its implementation, and the search for a global consensus for further joint action.

These stages are briefly described as follows:

(a) The establishing of the Working Group has already been recommended by the Global Preparatory Meeting for Consultation on the Petrochemical Industry[56] including its suggested terms of reference and potential membership. Doubtless the representative character of this Group would lend it authority to validate information and elaborate forecastings.

(b) The analysis of the strategies of the actors involves the identification of the actors' projects, perceived strategies and probable evolution. Its simplified analysis has been shown in section 6.2. A more systematic approach would consist of the following steps:

(i) the identification of the variables of the petrochemical industry

(ii) to classify them in "mover" and "dependant" variables

(iii) to select the key variables of this industry

(iv) to formulate hypotheses on their evolution.

All primary actors are usually among the most important "mover" variables of this industry. The remaining key variables correspond to factors which are constraints or means of action for the actors concerned. Their interaction would determing the compatibility or incompatibility of the actors' projects

(c) The elaboration of scenarios. Taking the hypotheses of the evolution of the strategy of the actors as a starting point scenarios would be elaborated. It should be noted that a scenario is not a simple image of the future but the coherent combination of several hypotheses. A scenario is not, therefore, a simple extrapolation directed by a main hypotheses, for the future is not always taken into account by the trend alone. It depends on the explicit projects of the actors. It can tend to one aim (for instance the aim of the Lima Declaration). There are several types of scenarios, such as the tendencial scenarios (the future is the continuation of the past although it can be unacceptable by the developing countries interested in a structural change in the petrochemical industry), the normative scenario (inspired, for instance, by the Lima Declaration) and the most probable scenario resulting from an objective analysis of the constraints and implementation possibilities.

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[56] op.cit. 14, draft report, 29 November 1978

(d) From this moment the negotiations would consist in choosing a reference scenario, midway between the normative and the most probable, and trying to get as close as possible to the normative scenario (assuming naturally that the normative scenario and the most probable would be different).

The conditions for the realization of this reference scenario would then be analyzed and submitted for discussion by the actors. It would include a proposed plan of action concerning co-operation in production and trading, transfers of various types including financing, as well as a programme for the progressive development of the petrochemical industry in the developing countries.

The choice of a reference scenario would already reflect a certain degree of consensus among the actors. Hence, a sectoral plan of action may take the form of an indicative contract for the development of the world petrochemical industry.

When considering objectively the barriers, the market powers, the respective constraints and strengths of the various actors, the general conclusion is that the joining in the petrochemical industry of new producers could be stopped with difficulty should there be an intention in this direction. A discussion over the entry or non-entry seems to be a wrong approach: the real problem is in which conditions this joining will take place. The alternative is therefore: either this participation will be conflicting, with a confrontation worsening the market conditions and likely to create a chaotic situation, or it will be co-operative, that is negotiated in an exchange of concessions on the penetration of certain markets, the new producers accepting a certain discipline in production and marketing. As this study underlines, serious problems of exportable surplus exist for certain products. The situation in 1985 appears, however, less dramatic as certain analyses imply. Beyond that date the future depends mainly on international relations either of concensus or of conflict.

The study suggests also that the regional framework is not the adequate dimension for a market regulation. The proper dimension is not regional but global.

It might sound paradoxical to propose widening this frame although the overwhelming difficulties of reaching consensus on a more restricted scale are known, such as the EEC market and the debates between the followers of free trade and those in favour of trade control. Precisely these contradicting points of view, however, show that there are consensus possibilities without being obliged to resort to control at the borders between countries.

The borders of the petrochemical industry, at the time of generalized inter-dependences, are on a world scale, therefore it is the petrochemical project that should be the object of a negotiation. In fact, the petrochemical industry should be co-ordinated as a whole, the non-consideration of the inter-dependence linkages would risk to destabilize the best established regional or national projects.

It is also clear that the sole agreements at the enterprise level are not sufficient to overcome the problems. The question is not that of an ideological preference but a matter of fact: the existence of national enterprises (particularly in the OPEC countries) and the recognition of the petrochemical industries as a sector of national interest.

Consequently the idea of an indicative contract for the development of the world petrochemical industry comes up. The question would be to elaborate and negotiate among the interested actors an indicative medium- and long-term reference framework for the development of this industry.

- This framework would include updated information on the projects and the prospects of the market.
- It would work out a schedule, as precise as possible, of the commissioning of installations and of the excedents to be exported.
- It would contain a negotiated market sharing out objectives for the petrochemical products exported by the developing countries.
- It would contain agreements on marketing policy including market channels.
- This "contract" would be neither a plan nor a programme in its economic sense but would assume the role of a "doubt reducer".
- This very flexible framework will not be substituted for national or inter-enterprise bilateral agreements for which, after all, there is no substitute.

It would serve, however, as a reference framework to direct particular agreements.

In order to be operational, such an agreement should not remain at the level of principles and generalities but be based on an in-depth appraisal of the markets for the main products and their prospects, the analysis of which was only outlined in the present study. It necessitates also the devising of a method and a step-by-step progression, which would, under certain circumstances, be linked to the various stages of the UNIDO world-wide consultations on this industry.

UNIDO is aware of the still general character of the proposal and of the embitious scope. It is, however, also convinced that without an effort of inventiveness it will not be possible to solve the accumulating problems. The new economic order has still to be created.

Annex 1(a) - Existing capacities - Basic products (mid 1977)
(thousands of tons/year)

COUNTRIES \ PRODUCTS	Ethylene	Propylene	Butadiene	Benzene	P.xylene	O.xylene	Methanol
WESTERN EUROPE	14 165	8 020	2 153	5 802	1 220	848	3 320
EASTERN EUROPE	2 955	1 553	340	3 460	327	285	2 513
NORTH AMERICA	14 450	7 100	2 270	6 400	1 908	603	4 624
LATIN AMERICA	1 455	418	205	349	100	75	264
NORTH AFRICA	120	-	-	-	-	-	110
EAST AND WEST AFRICA	-	-	-	-	-	-	-
SOUTH AFRICA	200	-	20	-	-	-	17
MIDDLE EAST COUNTRIES	190	40	33	-	-	-	54
SOUTH ASIA	192	100	36	69	17	-	33
EAST ASIA (1)	480	215	77	134	42	-	585
JAPAN	4 510	2 800	872	2 550	636	315	1 164
PACIFIC AREA	290	80	34	-	-	-	33
WORLD TOTAL	39 007	20 326	6 040	18 764	4 250	2 126	13 317

(1) excluding JAPAN

Annex 1(b) - Existing capacities - Intermediate products (mid 1977)

(thousands of tons/year)

PRODUCTS / COUNTRIES	Ethylene oxide	Vinyl chloride	Styrene	MONOMER FOR SYNTHETIC FIBRES					
				Caprolactame	Acrylonitrile	DMT	TPA	ADIPIC ACID	HEXAMETHYLENE DIAMINE
WESTERN EUROPE	1 730	4 860	2 945	800	1 110	1 220	515	840	255
EASTERN EUROPE	302	1 195	164	419	275	667	45	9	n.a.
NORTH AMERICA	2 450	3 100	3 580	430	745	1 923	890	795	470
LATIN AMERICA	85	357	150	74	23	149	55	32	12
NORTH AFRICA	-	-	-	-	-	-	-	-	-
EAST AND WEST AFRICA	-	-	-	-	-	-	-	-	-
SOUTH AFRICA	-	42	18	-	-	-	-	-	-
MIDDLE EAST COUNTRIES	-	69	25	-	-	-	-	-	-
SOUTH ASIA (1)	12	191	36	20	-	24	-	-	-
EAST ASIA	-	166	100	80	102	77	-	-	-
JAPAN	490	2 290	1 535	460	675	740	750	30	5
PACIFIC AREA	15	47	30	-	-	-	-	-	-
WORLD TOTAL	5 084	12 317	8 583	2 283	2 930	4 800	2 255	1 706	> 742

(1) excluding JAPAN

Annex 1(c) - Existing capacities - End petrochemicals (mid 1977)
(thousands of tons/year)

REGIONS \ PRODUCTS	Main plastics (2)	Synthetic rubber(3)	Detergents(4)	Synthetic fibres
WESTERN EUROPE	15 416	1 884	1 114	3 397
EASTERN EUROPE	3 170	1 407	> 52	1 058
NORTH AMERICA	12 265	2 195	755	3 970
LATIN AMERICA	1 061	285	605	687
NORTH AFRICA	-	-	-	3
EAST AND WEST AFRICA	-	-	-	5
SOUTH AFRICA	189	30	-	51
MIDDLE EAST COUNTRIES	163	45	10	131
SOUTH ASIA (1)	403	30	> 31	270
EAST ASIA (1)	551	148	13	> 867
JAPAN	5 623	739	330	≥1 145
PACIFIC AREA	300	70	7	32
WORLD TOTAL	39 141	6 833	2 917	11 616

(1) *Excluding JAPAN*
(2) *Includes : LD polyethylene, HD polyethylene, PVC, Polypropylene, Polystyrene*
(3) *Includes : styrene butadiene rubber and polybutadiene*
(4) *Includes : alkyl-benzene and detergent range alcohols*

Annex 2 - World energy consumption

Year	Total consumption Million ton oil equivalent	% share in total			
		Crude oil	Natural gas	Solid fuels	Others
1962	3 335	37.3	13.6	42.7	6.4
1968	4 536	43.0	16.3	34.4	6.3
1972	5 657	46.5	17.9	29.2	6.4
1973	6 039	47.5	17.6	28.5	6.4
1974	6 066	46.4	18.0	28.6	7.0
1975	6 155	43.9	17.8	30.7	7.4
1976	6 433	44.8	17.8	30.2	7.3
1985 forecast	9 870	46 *	17	27	10

* Corresponding to 4 520 million ton oil equivalent. Lower estimates for energy consumption will allow saving about 300 million T.O.E. of crude oil. Then crude oil share would be reduced to 44 %.

Annex 3 - Energy requirements - Final products

	Tons oil equivalent required for *
	1 million fertilizer bags
Polyethylene bags	470
Paper bags	700
	100 kilometers of 1-inch diameter service pipe
Polyethylene pipe	57
Copper pipe	66
Galvanized steel pipe	232
	100 kilometers of 4-inch diameter drainage pipe with fittings
P.V.C. pipe	380
Asbestos cement pipe	400
Cast-iron pipe	1 970
Clay pipe	800
	1 million liters
PVC	97
Glass	230

* including both raw material and energy for processing

source : ICI Plastics Division

Annex 4(a) - World demand for plastics, by region (excluding China)
(millions of tons)

Region	1965	1970	1973	1974	1975	1980	1985
Western Europe	4,800	9,770	14,660	15,430	12,330	22,520	36,330
Eastern Europe	n.a.	n.a.	3,803	4,500	5,150	8,680	13,975
North America	5,869	9,336	14,036	13,872	11,185	19,940	33,575
Latin America	350	921	1,634	1,923	1,907	3,884	7,886
Africa	181	391	632.5	724	610	1,700	3,255
Asia (excl.China)	2,116	5,488	7,450	7,554	6,429	12,660	23,310
Middle East	92	243	390	405	445	1,035	2,210
East Asia	125	350	583	576	659	1,350	2,525
Japan	1,700	4,355	5,600	5,800	4,470	8,330	14,675
South Asia	199	540	877	773	855	1,945	3,900
Pacific area	185	369	550	600	650	1,170	1,975
Total world	13,501	26,275	42,765.5	44,603	38,461	70,554	120,306
Share of developing countries (percentage)	6.5	8.77	8.95	9.35	11.48	13.37	15.77

Annex 4(b) - Main characteristics of the world demand for plastics, by region

Region	Average growth rate (percentage per year)				Consumption level (kg/capita)	Elasticity (per caput)		Structure of the demand % thermoplastics/total plastics			
	1965/70	1970/75	1975/80	1980/85	1975	1975/80	1980/85	1973	1975	1980	1985
Western Europe	15.20	4.87	12.69	10.03	36.0	3.5	2.7	67.9	65.8	73.0	75.5
Eastern Europe	n.a.	n.a.	11.0	10.0	13.5	3.35	2.6	-	46.7	66.0	71.5
North America	9.70	3.63	12.27	10.98	47.2	3.2	2.8	66.2	68.6	73.5	79.0
Latin America	21.30	15.68	15.28	15.22	5.89	4.3	4.0	67.3	67.2	74.5	78.0
Africa:											
North Africa	19.10	18.42	17.46	15.35	2.4	3.7	3.5	82.2	82.8	82.5	84.0
West Africa	19.80	16.52	18.52	16.56	1.0	3.2	2.9	84.0	82.6	84.0	86.0
East Africa	18.70	12.79	16.30	13.88	1.05	5.6	4.5	87.8	83.4	83.5	84.5
Central Africa	9.40	20.71	16.28	13.26	1.65	4.3	3.6	81.9	83.3	83.0	84.5
South Africa	14.90	13.18	13.05	10.89	9.4	5.0	4.0	70.0	70.1	74.5	78.5
Asia(excl.China):											
Middle East	21.50	12.90	18.36	16.40	5.17	2.0	1.85	80.2	83.2	85.0	88.0
East Asia	22.90	13.50	15.40	13.36	9.47	2.15	1.9	78.9	79.9	81.5	83.5
Japan	23.40	0.53	13.26	11.99	40.2	2.0	1.7	72.2	73.0	75.0	78.0
South Asia	22.10	9.80	17.97	14.91	0.80	5.7	4.2	79.8	79.9	81.5	84.0
Pacific area	14.80	11.99	12.47	11.04	38.6	3.6	2.6	67.8	70.0	73.5	78.5
Total world	14.24	7.9	12.9	11.3				66.6	66.4	73.4	77.4

Annex 5(a) - World demand for man-made fibres, by region
(thousands of tons)

Region	1965	1970	1973	1974	1975	1980	1985
Western Europe	1,431.0	2,168.0	2,790.0	2,570.0	2,231.0	3,055	3,820
Eastern Europe	950.0	1,380.0	1,700.0	1,850.0	1,900.0	2,655	3,645
North America	1,590.0	2,380.0	3,363.0	3,128.0	2,839.9	4,015	4,845
Latin America	206.5	344.7	593.1	650.6	628.9	1,030	1,675
Africa	186.5	242.4	345.5	361.9	370.2	609	955
Asia	934.1	1,527.9	2,370.4	2,306.6	2,410.0	4,171	6,665
China	83.8	122.1	362.0	282.0	350.0	722	1,270
Middle East	75.7	97.9	143.4	166.7	150.0	266	435
East Asia	36.8	162.0	202.0	233.0	295.0	478	740
Japan	466.5	732.2	1,064.3	931.5	885.0	1,380	1,915
South Asia	271.3	413.7	598.7	693.4	730.0	1,325	2,305
Pacific area	80.7	103.7	140.1	193.3	160.0	239	328
Total world	5,378.8	8,146.7	11,302.0	11,061.0	10,539.0	15,774	22,033
Share of developing countries (percentage)	14.62	15.89	18.73	20.36	22.76	26.94	32.34

Annex 5(b) - Main characteristics of the world demand for man-made fibres, by region

Region	Average growth rate (percentage per year)				Consumption level (kg/capita)	Elasticity (per caput)		Structure of the demand % synthetic fibres/ total man-made fibres			
	1965/70	1970/75	1975/80	1980/85	1975	1975/80	1980/85	1970	1975	1980	1985
Western Europe	8.7	0.69	6.37	4.57	6.52	1.70	1.15	62	74	78	84
Eastern Europe	7.8	6.62	6.91	6.54	4.97	2.0	1.6	30	50	62	72.5
North America	8.4	3.63	7.16	4.25	12.0	1.75	0.9	69	87	89	92
Latin America	10.8	12.81	10.66	10.75	1.79	2.6	2.4	60	77.5	83	89
Africa:											
North Africa	10.7	7.39	11.94	10.36	1.26	2.3	2.1	34	46	59	75
West Africa	7.4	21.07	15.07	12.33	0.48	2.5	2.0	52	60	75	85
East Africa	-1.94	7.6	7.92	7.82	0.44	2.1	2.0	33	48	58	69.5
Central Africa	10.0	7.26	9.54	8.39	0.33	2.2	1.95	61	73.5	79	83
South Africa	3.5	7.18	7.53	7.14	4.51	2.3	2.05	57.5	62.5	72	81.5
Asia:											
China	7.8	23.44	15.43	11.96	0.42	3.3	2.6	47	57	75	85
Middle East	5.3	8.9	12.16	10.28	1.74	1.2	1.0	57	74	81	87.5
East Asia	34.5	12.76	10.13	9.17	4.24	1.3	1.2	77	78.5	85.5	90
Japan	9.5	3.85	9.32	6.74	7.96	1.35	0.9	65	74	78	87
South Asia	8.8	11.93	12.87	11.68	0.68	3.8	3.10	40	52	70	80.5
Pacific area	5.1	9.1	7.33	6.50	10.0	1.8	1.35	66	80.5	85	89
Total world	8.66	5.3	8.4	6.9				56	71.5	77.5	83.5

Annex 6(a) - World demand for total rubber, by region
(thousands of tons)

Region	1965	1970	1973	1974	1975	1980	1985
Western Europe	1,582.5	2,357.5	2,730	2,650	2,647	3,150	3,810
Eastern Europe	1,117	1,520	2,100	2,300	2,450	3,200	4,040
North America	2,230	2,703.1	3,376	3,299	2,813	3,780	4,660
Latin America	210	353	500.5	550	562	812	1,180
Africa	162.5	203	269	308	326	465	658
Asia	837	1,504	1,969	1,913	1,926	2,853	4,080
China	170	265	280	285	290	412	575
Middle East	55	80	105	125	140	220	340
East Asia	30	70	110	105	115	166	235
Japan	377	779	1,045	927	870	1,255	1,715
South Asia	205	310	429	471	511	800	1,215
Pacific area	86	116	139	147	119	150	190
Total world	6,283	8,756.6	11,083	11,167	10,843	14,410	18,618
Share of developing countries (percentage)	12.77	14.14	14.80	15.94	17.30	19.31	21.90

Annex 6(b) - Main characteristics of the world demand for total rubber, by region

Region	Average growth rate (percentage per year)				Consumption level (kg/capita)	Elasticity (per caput)		Structure of the demand % of synthetic rubber/ total rubber			
	1965/70	1970/75	1975/80	1980/85	1975	1975/80	1980/85	1970	1975	1980	1985
Western Europe	8.3	2.34	3.54	3.87	7.2	1.05	0.95	61.5	63.5	66	67
Eastern Europe	5.3	10.0	5.49	4.76	6.47	1.4	1.1	69.5	81.5	83	84
North America	3.9	0.8	6.1	4.25	11.9	1.05	0.9	77	74	77	79
Latin America	10.95	9.77	8.05	8.35	1.60	1.7	1.6	64.5	73	75	77
Africa:											
North Africa	7.8	6.0	7.6	7.15	0.90	1.2	1.2	60	64.5	68	71
West Africa	0.0	5.78	8.19	7.63	0.64	1.1	1.0	56.5	57	61	64
East Africa	4.85	14.44	7.2	7.10	0.65	1.8	1.7	58	57.5	61	64
Central A rica	4.6	15.02	8.25	7.95	0.45	1.8	1.8	58	57.5	61	64
South Africa	7.5	9.52	6.51	6.21	2.45	1.8	1.6	25.5	42.5	50	60
Asia:											
China	9.3	1.82	7.28	6.89	0.34	1.45	1.35	21	24	32	37
Middle East	7.8	11.79	9.44	9.20	1.62	0.85	0.85	62.5	63.5	69	72
East Asia	18.5	10.41	7.65	7.08	1.65	0.9	0.85	65	67	72	74
Japan	15.6	3.53	6.95	6.41	7.83	0.9	0.85	64	67	71	73
South Asia	9.6	10.58	9.37	8.75	0.48	2.5	2.10	47	48	65	68
Pacific area	3.85	0.57	4.58	4.71	7.10	0.9	0.85	57.5	51.5	59	65
Total world	6.86	4.37	5.85	5.26				65.3	69	71.5	72.5

Annex 7(a) - World demand for synthetic detergents, by region

Region	(thousands of tons)					Average growth rate (percentage per year)			
	1965	1970	1975	1980	1985	1965/70	1970/75	1975/80	1980/85
Western Europe	2,995	3,186	3,300	4,400	4,800	1.25	0.7	5.9	1.76
Eastern Europe	-	-	1,500	2,200	2,700	-	-	5.9	6.19
North America	1,970	2,410	2,700	3,300	3,600	4.1	2.3	4.1	1.76
Latin America	330	600	900	1,300	1,850	12.7	8.45	7.63	7.31
Africa	-	164	245	380	580	-	8.35	9.18	8.83
Asia (excl.China and Japan)	-	588	1,100	1,520	2,090	-	13.35	6.68	6.58
Japan	720	800	850	1,050	1,150	2.1	1.2	4.32	1.84
Pacific area	90	170	250	320	410	13.6	6.8	5.1	5.1
Total world	6,105	7,918	10,850	14,270	17,180	-	6.5	5.6	3.8
Share of developing countries (percentage)	-	16.9	20.51	22.21	26.10				

Annex 7(b) - **World demand for major active constituents of synthetic detergents of petrochemical origin**
(thousands of tons)

Region	Alkylbenzenes			Non-ionic surfactants		
	1975	1980	1985	1975	1980	1985
Western Europe	270	430	440	265	420	540
Eastern Europe	140	180	230	140	205	300
North America	280	380	390	510	740	860
Latin America	120	160	220	30	50	80
Africa	50	75	115	20	30	40
Asia (excl.China and Japan)	180	240	315	70	115	180
Japan	130	180	185	137	180	210
Pacific area	30	35	45	20	25	35
Total world	1,200	1,680	1,940	1,192	1,765	2,245
Share of developing countries (percentage)	27.5	26.79	31.7	8.8	9.9	12.25

Annex 8(a) - Per capita gross domestic product (GDP), by region
(in constant US dollars of 1971

REGIONS OF THE WORLD	1965	1968	1969	1970	1971	1972	1973	1974	1975	1976	1980	1985
WESTERN EUROPE	1.865	2.070	2.180	2.280	2.340	2.430	2.553	2,520	2.530	2.600	3.005	3.570
EASTERN EUROPE	1.545	1.680	1.770	1.830	1.895	1.960	2.035	2.100	2.150	2.200	2.490	2.960
NORTH AMERICA	4.220	4.695	4.780	4.760	4.860	5.100	5.350	5,240	5.130	5.400	6.090	7.235
LATIN AMERICA	472	507	528	548	567	590	616	632	648		745	865
AFRICA excl. S. Africa												
NORTH AFRICA	225	245	250	260	260	265	270	280	290		350	415
WEST AFRICA	130	135	135	153	160	165	170	180	190		240	300
EAST AFRICA	95	105	110	110	115	115	117	120	123		138	155
CENTRAL AFRICA	136	140	145	153	157	162	168	174	180		210	242
SOUTH AFRICA	630	675	705	715	725	730	745	765	780		860	950
ASIA												
CHINA	188	205	215	225	235	257	270	280	290	302	355	432
MIDDLE EAST	385	410	425	435	465	490	510	600	650		935	1.310
EAST ASIA (excl. Japan)	175	220	250	260	270	285	310	330	350		470	625
JAPAN	1.150	1.575	1.720	1.890	2.000	2.150	2.335	2.300	2.350	2.450	3.145	4.310
SOUTH ASIA	110	120	125	127	128	130	135	140	145		165	190
PACIFIC AREA	1.940	2.605	2.715	2.761	2.830	2.910	3.035	3.000	3.050		3.535	4.200

Source: UN Office of Statistics, New York (GDP figures for 1965-75)

Annex 8(b) - **World population, by region (Millions of inhabitants)**

REGIONS OF THE WORLD	1965	1968	1969	1970	1971	1972	1973	1974	1975	1976	1980	1985	2000
WESTERN EUROPE	323	328.8	330.7	332.8	334.6	338.2	340.1	342.2	343.9	343.9	350.7	359.9	387.3
EASTERN EUROPE	350.3	360.1	363.1	366	369.2	372.3	375.3	378.8	382.5	386.0	400.0	417.5	402.3
NORTH AMERICA	214	221.6	223.9	226.4	228.7	230.8	232.6	234.5	236.8	239.1	248.8	262.3	296.2
LATIN AMERICA	247.1	262.0	275.3	282.8	290.7	298.6	306.7	315.4	323.8	332.8	371.4	425.5	619.9
U.S.A.	194.3	200.7	202.7	204.9	207.0	208.8	210.4	211.9	213.9	215.8	224.1	237.5	264.4
AFRICA													
NORTH AFRICA	75.3	81.9	84.2	86.8	89.2	91.6	94.1	96.7	99.4	102.1	114.5	131.9	194.1
WEST AFRICA	89.1	95.7	98.0	100.34	103	105.7	108.5	111.3	114.2	117.4	131.0	151.4	189.5
EAST AFRICA	87.7	94.7	97.2	99.8	102.5	105.4	108.3	111.4	114.5	117.8	132.0	152.9	239.9
CENTRAL AFRICA	35.7	38.5	39.5	40.5	41.4	42.3	43.3	44.3	45.3	46.4	51.2	58.3	87.7
SOUTH AFRICA	20.8	22.8	23.5	24.2	24.9	25.6	26.2	26.9	27.7	28.5	31.9	36.8	55.7
ASIA													
CHINA	710.3	746.5	759.1	771.8	784.9	798.1	811.5	825.1	838.8	852.6	907.6	973.2	1 148.0
MIDDLE EAST	65.03	70.56	72.53	74.75	76.9	79.1	81.4	83.8	86.2	88.7	99.2	115.5	170.7
EAST ASIA (excl. JAPAN)	55.9	60.0	61.3	62.5	64.	65.3	66.8	68.	69.6	71.1	77.1	85.1	110.3
JAPAN	99.0	101.9	103.2	104.3	105.6	106.9	108.3	109.0	111.1	112.5	117.5	122.5	132.9
SOUTH ASIA	826.5	889.3	912	936.6	961.2	986.5	1 012.4	1 038	1 064.8	1 097.0	1 213.8	1 378.9	1 905.2
PACIFIC AREA	14.0	14.8	15.0	15.4	15.6	15.9	16.1	16.6	16.8	17.1	18.4	20.0	24.5
TOTAL WORLD	3408.0	3 589.9	3 661.2	3 729.9	3 799.4	3 871.1	3 942.0	4 013.9	4 089.3	4 168.8	4 489.2	4 929.2	6 228.[illegible]

Source: United Nations publication, "World population prospects as assessed in 1973"

Annex 9 - World trade patterns for the main end petrochemicals, by region, 1973
(percentage)

Exports — From / To	E E C		U S A		JAPAN		Other countries		Total import
	Import	Export	Import	Export	Import	Export	Import	Export	
E E C	89.05	60.72	5.34	21.38	2.10	7.48	3.50	35.07	100
Other Western European countries	91.21	17.04	3.80	4.17	1.49	1.45	3.50	9.62	100
Eastern Europe	81.52	6.56	0.55	0.26	6.34	2.67	11.59	13.70	100
United States	40.63	1.71	-	-	29.55	6.49	29.82	18.43	100
Canada	7.90	0.39	87.36	25.23	3.61	0.93	1.13	0.82	100
Japan	35.72	0.61	56.49	5.67	-	-	7.79	1.96	100
Latin America	35.76	3.00	39.87	19.62	20.93	9.15	3.44	4.24	100
Other countries in Asia and Oceania	26.00	5.69	17.27	22.17	52.92	60.41	3.81	12.24	100
Africa	61.27	4.29	3.65	1.50	31.27	11.42	3.81	3.92	100
Total export		100.00		100.00		100.00		100.00	

Annex 10 - Weight of inter-regional trade compared to production (main exports/world production) 1973

PRODUCT	%
Ethylene	0.7
Propylene	0.6
Butadiene, butenes	3 - 4
Benzene	5.4
Toluene	12.7
O.xylene	14.1
Mixed xylenes	5.6
Styrene	8.3
Methanol	8.8
Phtalic anhydride	6.9
Ethylene glycol	11.0
Formaldehyde	1.5
Acetone	5.7
Cyclohexane	9.0
Caprolactame	9.5
Acrylonitrile	8.4
Dimethylterephtalate	5.9
Synthetic detergents	4.5
Styrene-butadiene rubber	11 - 15
Polybutadiene rubber	12.7
Synthetic rubber	15.0
Acrylic fibres	> 14
Polyamide fibres	> 11
Polyester fibres	> 6
Synthetic fibres	15.2
L.D. polyethylene	14.4
H.D. polyethylene	20.7
Polypropylene	20.1
Polyvinylchloride	9.8
Polystyrene	6.8

Annex 11 - Ratio of sales to production (percentage)

	U.S.A.	JAPAN	
	1974	may 76	dec 78
Ethylene	29.5	82	77
Propylene	41.5	72	82
Butadiene (rubber grade)	68	56	59
Benzene	50.5	65	50.5
O. Xylene	79.5	73	62.5
P. Xylene	69.5	75	58
Methanol	51.5	72	97
Ethylene oxide	80.5 •	20	18
Vinyl chloride	55.5	48	49
Styrene	47.5	72.5	65
Acrylonitrile	38.5	100	71
Capudactam	n.a	48	68
DMT	18	82	50
TPA	n.a	55	86
Adipic acid	8.5	n.a	n.a
LD polyethylene	88.5	100	100
HD polyethylene	92	92	100
Polypropylene	86.5	93	100
PVC	83.5	100	92
Polystyrene	89	90	88
Polybutadiene	71	100	100
SBR	79	77	77
Polyamid.	n.a	n.a	n.a
Polyester	n.a	n.a	n.a
Acrylic fibers	n.a	n.a	n.a
Alkylbenzene	91.5	100	100
Synthetic organic chemicals of which:	55.5		
. Plastics	88.5		
. Synthetic rubber	81.5	89	86
. Surface-active agent	53.5		

• Ethylene glycol

Annex 12(a) - Petrochemical products prices (FOB USA)
(current US ¢ per lb)

PRODUCT \ YEAR	1970	1971	1972	1973	1974	1975	1976
Ethylene						11.8	12.9
Butadiene			8	9.6	18.2	15.6	18.6
Benzene	21.2	19.8	21.4	35.8	113	29.3	80.8
O.xylene	3.5	3.1	3.1	5.0	10.4	7.4	10.9
P.xylene	5.9	5.9	5.6	6.9	11.5	14.4	18.7
Styrene	6.3	5.5	5.8	13.6	24.0	17.8	19.3
Caprolactam	18.8	19	20	21.7	53.0	39.7	40.4
DMT	15.2	14.1	14.1	14.3	25.4	22.8	23.4
VCM	5.2	5.0	5.0	5.8	11.3	10.5	13.8
Ld polyethylene	13.5	13.7	12.1	16.8	33.8	26.4	27.3
Hd polyethylene	13.4	12.8	12.2	16.0	34.6	24.6	28.3
PVC	19.2	19.7	20.1	24.7	34.3	28.5	27.4
Polybutadiene	18.7	20.1	19.7	19.4	32.7	30.1	32.0
SBR	17.7	17.6	17.4	19.1	27.4	29.8	30.7
Nylon yarn not text	151	138	104	104	139 + 14	114	149
Polyester staple	49.5	40.2	36.2	48.5	66.5	47.2	51.2
Acrylic staple	65.6	61.2	55.5	51.0	63.2	58.1	59.0

Annex 12(b) - Contract prices indexes

PRODUCT	AVERAGE 1972	JAN. 1974	JULY 1974	JAN. 1975	JULY 1975
ETHYLENE	100	280-345	310-340	290-350	290-340
PROPYLENE	100	200	325	310	295
BUTADIENE	100	260	290	255	210
BENZENE	100	350-380	435-470	370-400	310-335
ORTHOXYLENE	100	405	425	290	250
PARAXYLENE	100	160	375	350	260
PHENOL	100	395-465	465-475	310-375	250-295
ACETONE	100	290	420	320-370	320
PHTALIC ANHYDRIDE	100	420	370	210	210
DIOCTYLPHTALATE	100	215	290	225	195
STYRENE	100	300	360	240	200
ETHYLENE OXIDE	100	110	250	250	225
LOW-DENSITY POLYETHYLENE	100	130-160	185-210	165-185	115-125
HIGH-DENSITY POLYETHYLNE	100	170	185	160	150
POLYSTYRENE	100	135-150	190-250	180-240	140-170
POLYPROPYLENE	100	140	150	130	115
P.V.C.	100	135	170	155	145
NYLON YARN		100	135	115-120	80-85
POLYESTER YARN		100	100	78	60-70
ACRYLIC FIBRE		100	130	105	90-95
S.B.R. (Early 1973)	100	140	187	178	175

Source: **European Chemical News**, 3 October 1975

Annex 13(a) - Potential world demand for main petrochemical intermediates

Forecast 1985

(thousands of tons)

REGIONS OF THE WORLD	Vinyl chloride monomer	Styrene monomer	Acrylonitrile	DMT	TPA	Caprolactam	Ethylene oxide
WESTERN EUROPE	7 935	5 123	1 464	978	560	546	1 800
EASTERN EUROPE	2 260	1 985	832	1 090	165	932	950
NORTH AMERICA	6 110	5 935	1 086	1 680	1 185	625	2 600
LATIN AMERICA	1 600	1 089	380	561	350	300	500
AFRICA	845	465	149	244	212	181	160
NORTH AFRICA	294	148	53.5			75	
WEST AFRICA	155	86	23.5			48	
EAST AFRICA	132	75	11.3			21	
CENTRAL AFRICA	80	40	5.0			8	
SOUTH AFRICA	184	116	56	62	53	29	
ASIA excl. CHINA	3 424	3 243	1 460	1 744	1 547	1 384	1 215
CHINA	-	-	205	392	226	256	-
MIDDLE EAST	598	309	63.3	97	123	112	75
EAST ASIA	577	312	133	215	195	169	150
JAPAN	3 357	2 041	701	280	565	394	730
SOUTH ASIA	892	581	358	760	438	453	260
PACIFIC AREA	451	268	89	105	60	59	135
TOTAL WORLD	24 625	18 118	5 460	6 402	4 079	4 027	7 560
of which developing countries	4 328	2 640	1 232	2 207	1 491	1 442	

Annex 13(b) - Potential world demand for main basic products

Forecast 1985

(thousands of tons)

REGIONS OF THE WORLD	ETHYLENE	PROPYLENE	BUTADIENE	BENZENE	P.XYLENE	O.XYLENE	METHANOL
WESTERN EUROPE	21 400	11 064	1 766	8 669	1 060	1 526	6 100
EASTERN EUROPE	6 150	3 050	2 156	4 098	873	699	4 700
NORTH AMERICA	23 380	11 056	2 569	10 640	1 970	1 175	7 500
LATIN AMERICA	4 990	2 149	684	1 848	627	308	800
AFRICA	1 938	772	322.2	947	79	162	180
NORTH AFRICA	661	245	97	290	-	57	
WEST AFRICA	356	121	75	173	-	30	
EAST AFRICA	300	87	70	121	-	25	
CENTRAL AFRICA	181	51	23.6	56	-	15	
SOUTH AFRICA	440	268	56.6	307	79	35	
ASIA excl. CHINA	13 480	7 990	1 973	6 112	2 258	1 044	3 660
CHINA	-	-	158	505	425	-	-
MIDDLE EAST	1 424	587	183	563	150	115	120
EAST ASIA	1 616	583	129	635	281	111	380
JAPAN	7 860	5 400	888	3 394	574	646	3 000
SOUTH ASIA	2 580	1 440	615	1 015	828	172	260
PACIFIC AREA	1 218	557	93	520	113	87	150
TOTAL WORLD	72 536	36 638	9 563.2	32 834	6 980	5 001	23 090
of which developing countries	12 108	5 243	2 034.6	5 206	2 311	833	

Annex 14(a) - Production capacities - End products - 1985
(thousands of tons/year)

REGIONS OF THE WORLD / PRODUCTS	Main plastics	Synthetic fibres	Synthetic rubber
WESTERN EUROPE	29 400	4 400	2 500
EASTERN EUROPE	9 500	3 050	2 700
NORTH AMERICA	29 400	5 350	3 200
LATIN AMERICA	6 690	1 700	680
AFRICA	3 320	300	200
ASIA			
MIDDLE EAST	3 430	350	220
EAST ASIA	3 120	1 150	200
JAPAN	9 160	2 140	1 600
SOUTH ASIA	4 250	1 250	400
PACIFIC AREA	1 710	300	120
TOTAL WORLD	101 030	20 000	11 820

Annex 14(b) - Production capacities - Intermediates - 1985
(thousands of tons/year)

REGIONS OF THE WORLD / PRODUCTS	Vinyl chloride	Styrene	Caprolactam	DMT	TPA	Acrylonitrile
WESTERN EUROPE	8 600	6 300	1 200	1 595	650	2 150
EASTERN EUROPE	2 700	2 350	900	918	200	900
NORTH AMERICA	7 300	7 200	750	2 663	1 400	1 400
LATIN AMERICA	1 800	950	350	500	400	300
AFRICA	1 400	200		25		
ASIA						
MIDDLE EAST	1 500	350		60	80	
EAST ASIA	1 100	350	250	485	250	200
JAPAN	2 900	2 750	700	740	1 220	1 100
SOUTH ASIA	1 400	650	250	114	300	150
PACIFIC AREA	500	300				
TOTAL WORLD	29 200	21 400	4 400	7 100	4 500	6 200

Annex 14(e) - Production capacities - Basic products - 1985
(thousands of tons/year)

REGIONS OF THE WORLD	Ethylene	Benzene	Ortho and para xylene	Methanol
WESTERN EUROPE	24 500	10 900	3 200	4 800
EASTERN EUROPE	8 100	5 000	2 000	7 000
NORTH AMERICA	28 000	12 500	4 200	7 700
LATIN AMERICA	5 200	2 200	950	1 200
AFRICA	2 200	1 100		1 500
ASIA				
MIDDLE EAST	3 000	650	230	1 700
EAST ASIA	2 200	750	640	430
JAPAN	8 200	4 000	2 180	1 200
SOUTH ASIA	3 100	1 200	400	1 000
PACIFIC AREA	1 300	600	100	650
TOTAL WORLD	85 800	38 900	13 900	27 180

Annex 15 — Hydrocarbons required for the manufacture of petrochemicals - 1985
(millions of TOE)

REGIONS OF THE WORLD	Feedstock requirements	Net utilities requirements (excluding fuel recovered as by products)	Total requirements	Of which Hydrocarbons for non petrochemical ammonia
WESTERN EUROPE	112.4	29.1	141.5	(15.4)
EASTERN EUROPE	68.9	12.7	81.6	(27.9)
NORTH AMERICA	129.4	29.4	158.8	(19.7)
LATIN AMERICA	21.9	6.9	28.8	(4.8)
AFRICA	9.5	2.5	12.0	(2.8)
CHINA	16.7	4.4	21.1	(10.5)
MIDDLE EAST	8.5	2.6	11.1	(1.4)
EAST ASIA	11.3	3.8	15.1	(1.7)
JAPAN	39.3	11.4	50.7	(1.9)
SOUTH ASIA	22.5	4.3	26.8	(11.3)
PACIFIC AREA	4.3	1.4	5.7	(0.6)
TOTAL WORLD	444.7	108.5	553.2	(98.0)

NOTE : World hydrocarbons required for all purposes
Crude oil 4520 million tons
Gas 1730 million TOE

Annex 16 - **World consumption of oil products - 1985**
(millions of tons)

	Energy 10^6 TOE	Gas 10^6 TOE	Crude oil 10^6 T	Petroleum fraction availability 10^6 T				Feedstocks requirements for petrochemicals * 10^6 T					Rough estimate of main energy requirements covered by oil products		
				C5- 5 %	Naphtha 13 to 15.5%	Kero. gas oil 35 to 32.5%	Fuel oil 47 %	LPG**	Naphtha	Kero gas oil	Fuel Oil	Liquid fract. Total	Motor gasoline	Kero. gas oil	Fuel oil
NORTH AMERICA	2 800	580	1 280	64	156 to 198	448 to 416	602	11.7	34.6	40.5	5.8	92.6	430	350	220
WESTERN EUROPE	1 800	320	930	46	121 to 144	326 to 303	43[illegible]	1.1	68.4	16.8	5.4	91.7	130	300	[illegible]
JAPAN	650	60	420	21	55 to 65	147 to 137	197	0.1	25.0	7.8	2.6	35.5	40	110	150
EASTERN EUROPE	2 600	500	920	46	120 to 142	322 to 300	432	1.3	22.7	4.0	3.5	31.5	90	360	310
OTHERS ≠	2 020	270	970	49	126 to 150	340 to 316	456	4.1	43.8	0	3.2	51.1	170	330	320
WORLD	9 870	1 730	4 520	226	588 to 699	1 582 to1471	[illegible]124	18.3	191.5	69.1	25.5	302.4	860	1 450	1 310

* Excluding gaseous feedstocks
** L P G share in C_5 fraction on crude is 30 %
≠ Mainly developing countries, Australia, New Zealand and South Africa's share in others will represent 8.4 % for energy
9.3 % for gas
7.2 % for oil

Annex 17 - Investment requirement estimates (billions of US$ of 1977)

AREA	UP TO 1980*	1980 - 1985
WESTERN EUROPE	14.5	14.9
EASTERN EUROPE	6.7	13.2
NORTH AMERICA	12.8	27.2
LATIN AMERICA	5.9	15.3
AFRICA	1.2	5.8
ASIA		
MIDDLE EAST	2.2	5.7
EAST ASIA	3.5	5.3
JAPAN	4.9	8.1
SOUTH ASIA	2.4	10.2
PACIFIC AREA	9	2.9
TOTAL	55.0	108.4

* Corresponding to the plants that will start up before 1981

Annex 18 - Estimated manpower requirements, by region, in 1985
(thousands of men)

Region	Technical personnel	Administrative personnel	Marketing personnel	Total manpower	World total (percentage)
Western Europe	283.3	28.3	14.2	325.8	24.4
Eastern Europe	160.5	16.0	8.0	184.5	13.8
North America	326.4	31.6	16.3	374.3	28.1
Latin America	85.3	8.5	4.3	98.1	7.4
Africa	23.8	2.4	1.2	27.4	2.1
Asia:					
Middle East	26.9	2.7	1.3	30.9	2.3
East Asia	52.1	5.2	2.6	59.9	4.5
Japan	124.2	12.4	6.2	142.8	10.7
South Asia	59.6	6.0	3.0	68.6	5.2
Pacific area	17.5	1.8	0.9	20.2	1.5
World total	1,159.6	114.9	58.0	1,332.5	100

Annex 19 - Estimated petrochemical price trends
(based on current prices)

	Share of present price expected to vary with crude oil price %	Share of present price expected to vary with overall inflation %
Ethylene	50	50
Propylene	50	50
Butadiene	50	50
Benzene	50	50
Oxylene	50	50
P. Xylene	50	50
Styrene	40	60
D M T	30	70
Acrylonitrile	33	67
Ld Polyethylene	29	71
Polystyrene	28	72
Polyester fibres	17	83
Acrylic fibres	16	84

Annex 20(a) - Main GDP growth hypotheses, 1985-2000
(percentage per year)

Region	Hypothesis A	Hypothesis B	Hypothesis C
Western Europe	2.9	4.5	3.4
Eastern Europe	2.9	4.5	4.2
North America	2.9	4.5	3.4
Latin America	6.3	5.4	5.1
Africa	6.8	5.9	5.2
Asia:			
Middle East	7.8	6.8	5.9
East Asia	6.9	5.9	5.2
China	6.9	5.9	5.2
Japan	2.9	4.5	3.4
South Asia	6.8	5.9	5.2
Pacific area	2.9	4.5	3.4
Total world	4.0	4.8	4.0

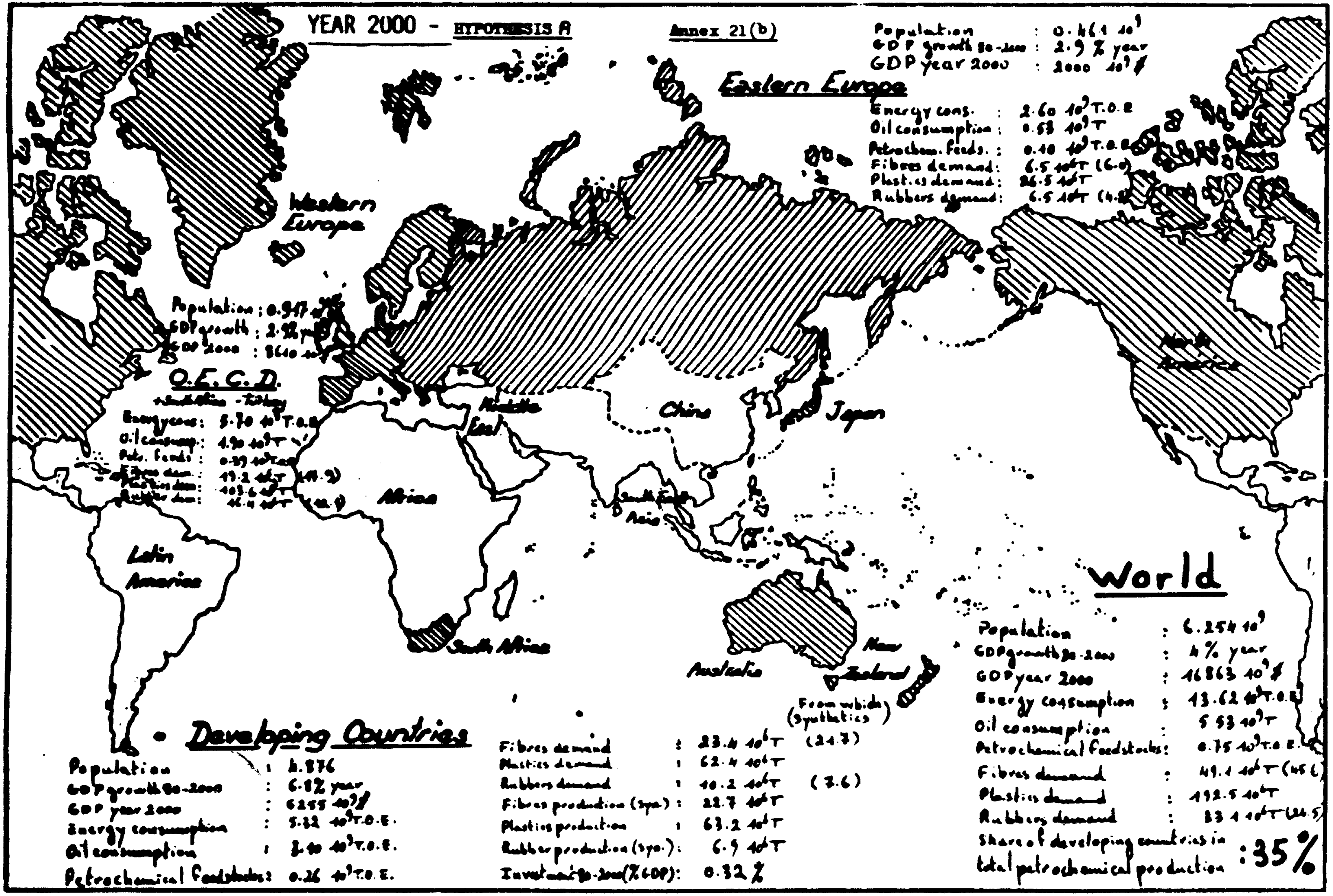
Annex 20(b) - Set of consistent assumptions
(percentage)

	Inter-regional co-operation among developing countries	Internal market opening of the developed countries to imports	Minimum economic capacity
Hypothesis A	90	10	High
Hypothesis B	20	2	Low
Hypothesis C	60	2	High

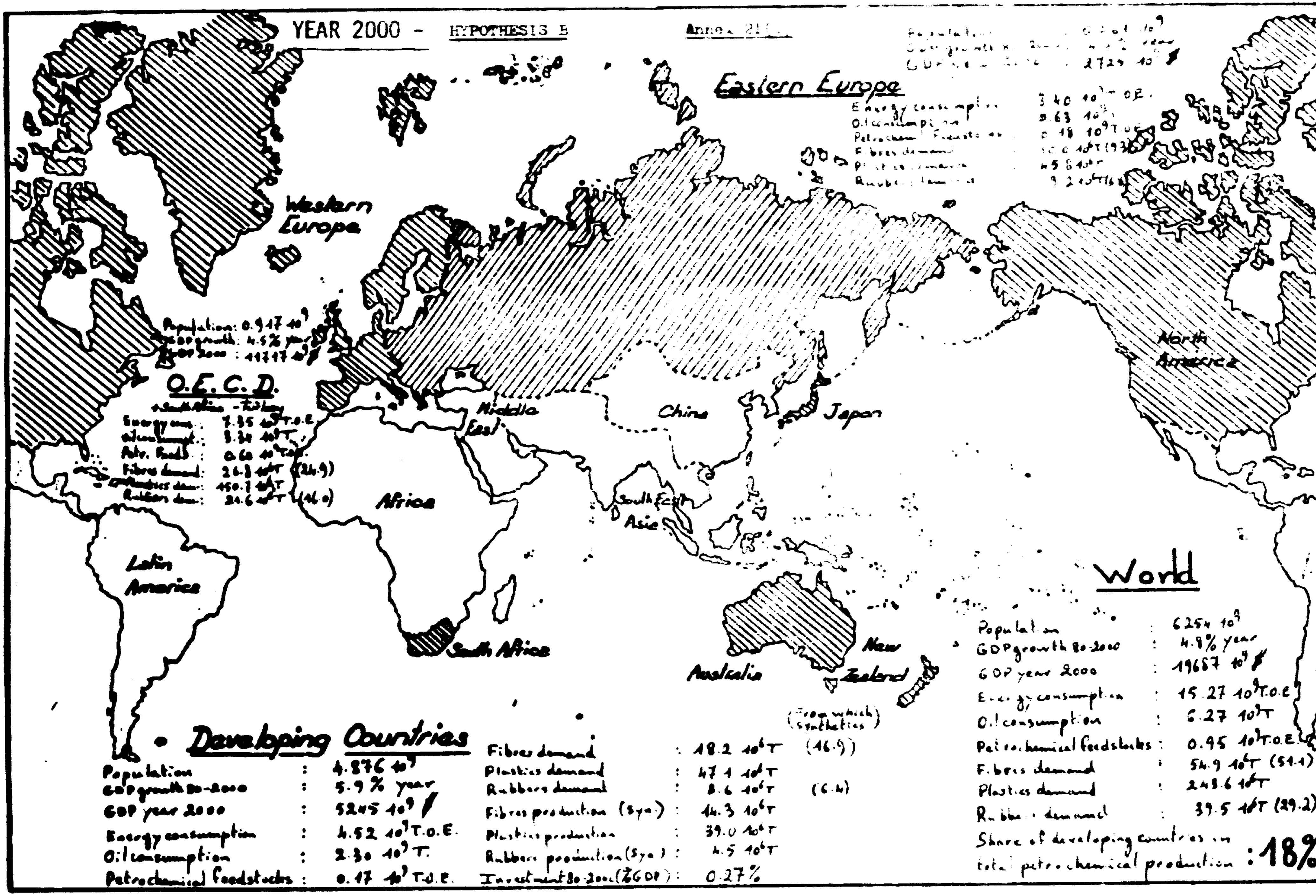
Annex 21(a) - Compared pictures of the year 2000

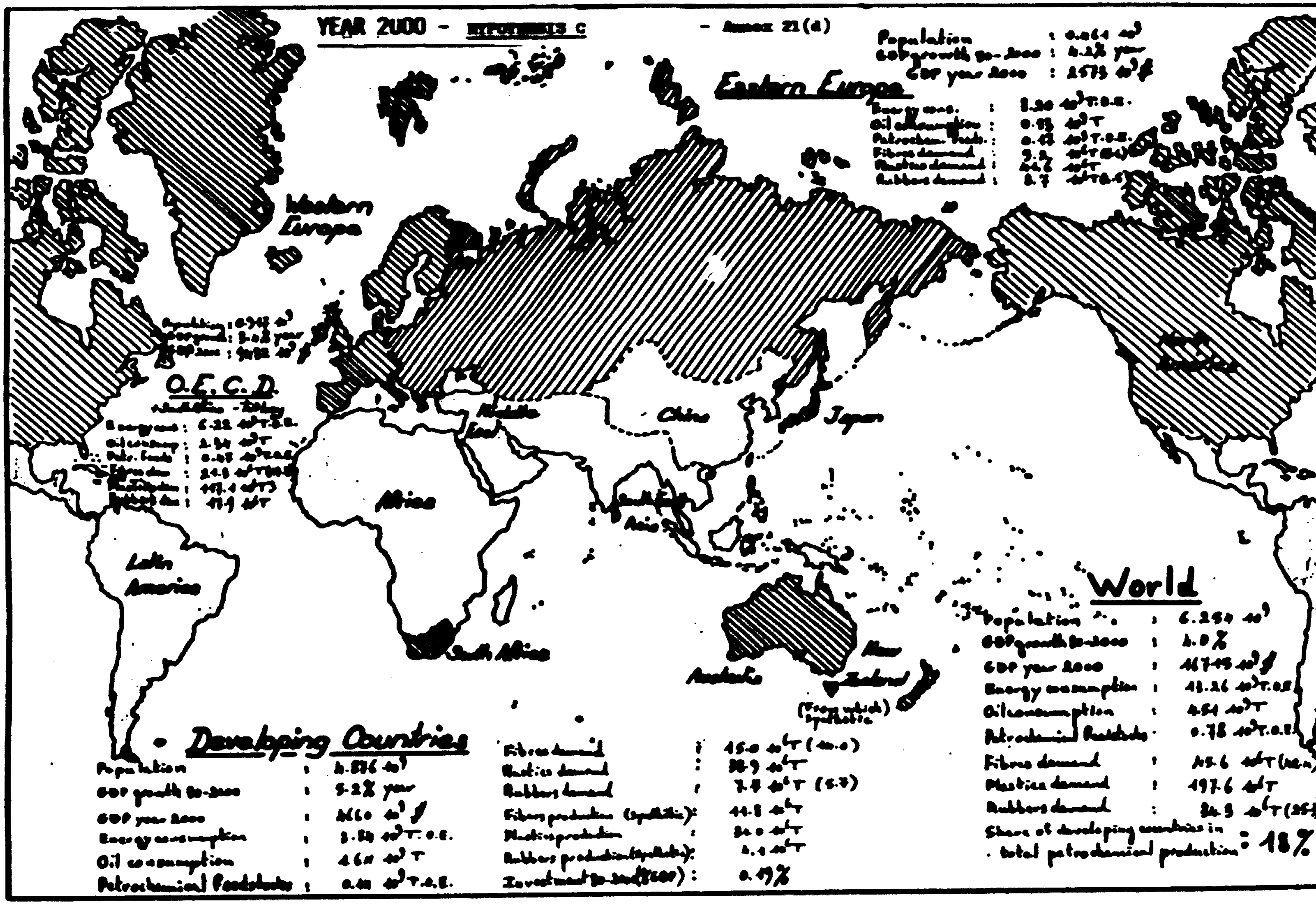
SCENARIO	DEVELOPED COUNTRIES			DEVELOPING COUNTRIES			WORLD		
	Hypothesis A	Hypothesis B	Hypothesis C	Hypothesis A	Hypothesis B	Hypothesis C	Hypothesis A	Hypothesis B	Hypothesis C
Population 10^9 inhabitants	1379	1379	1379	4876	4876	4876	6254	6254	6254
GDP growth % year	2.9	4.5	3.5	6.8	5.9	5.2	4.0	4.8	4.0
GDP 2000 $10^9$$ (1977 $)	10608	14443	12055	6255	5245	4660	16863	19687	16715
Energy consumption 10^9TOE	8.3	10.75	9.42	5.32	4.52	3.84	13.62	15.27	13.26
Oil consumption 10^9T	2.43	3.97	2.87	3.10	2.30	1.64	5.53	6.27	4.51
Petrochemical feedstocks** 10^9TOE	0.49	0.78	0.64	0.26	0.17	0.14	0.75	0.95	0.78
Fibres* demand 10^6T	23.9	34.2	28.4	21.7	16.9	14.0	45.6	51.1	42.4
Plastics* demand 10^6T	130.1	196.5	158.7	62.4	47.1	38.9	192.5	243.6	197.6
Rubber* demand 10^6T	16.9	22.8	19.7	7.6	6.4	5.7	24.5	29.2	25.4
Fibres* production 10^6T	22.9	36.8	30.6	22.7	14.3	11.8	45.6	51.1	42.4
Plastics production 10^6T	129.3	204.6	166.6	63.2	39.0	31.0	102.5	243.6	197.6
Rubber* production 10^6T	17.6	24.7	21.2	6.9	4.5	4.1	24.5	29.2	25.3
Ethylene production 10^6T	68.8	111.5	91.4	38.6	25.2	20.0	107.4	136.7	111.4
Share of rpoduction of petrochemical products %	65	82	82	35	18	18	100	100	100
Investment for petrochemical industry $10^9$$	310.9	499.4	411.8	248.6	189.1	122.6	559.5	688.5	534.4
Share of GDP for investment in petrochemical industry %	0.18	0.24	0.22	0.32	0.27	0.19	0.22	0.25	0.21
Manpower 10^6workers	1.86	2.98	2.48	1.44	0.98	0.71	3.30	3.94	3.19

* *Synthetic* or thermoplastics
** *Including fuel requirements*



YEAR 2000 - HYPOTHESIS A
Annex 21(b)
Western Europe
O.E.C.D.
Population
GDP growth
Energy cons.
Oil consump.
Latin America
Africa
South Africa
Middle East
China
Japan
South East Asia
Australia
New Zealand
North America
Eastern Europe
Population : 0.464 10⁹
GDP growth 80-2000 : 2.9 % year
GDP year 2000 : 2000 10⁹ $
Energy cons. : 2.60 10⁹ T.O.E
Oil consumption : 0.58 10⁹ T
Petrochem. feeds. : 0.10 10⁹ T.O.E
Fibres demand : 6.5 10⁶ T
Plastics demand : 26.5 10⁶ T
Rubbers demand : 6.5 10⁶ T
Developing Countries
Population : 4.876
GDP growth 80-2000 : 6.8% year
GDP year 2000 : 6255 10⁹ $
Energy consumption : 5.32 10⁹ T.O.E.
Oil consumption : 2.40 10⁹ T.O.E.
Petrochemical Feedstocks : 0.26 10⁹ T.O.E.
Fibres demand : 23.4 10⁶ T
Plastics demand : 62.4 10⁶ T
Rubbers demand : 10.2 10⁶ T
Fibres production (syn.) : 22.7 10⁶ T
Plastics production : 63.2 10⁶ T
Rubber production (syn.) : 6.9 10⁶ T
Investment 80-2000 (% GDP) : 0.32 %
From which (Synthetics)
(24.7)
(7.6)
World
Population : 6.254 10⁹
GDP growth 80-2000 : 4% year
GDP year 2000 : 16863 10⁹ $
Energy consumption : 13.62 10⁹ T.O.E.
Oil consumption : 5.53 10⁹ T
Petrochemical Feedstocks : 0.75 10⁹ T.O.E.
Fibres demand : 49.1 10⁶ T
Plastics demand : 192.5 10⁶ T
Rubbers demand : 33.4 10⁶ T
Share of developing countries in total petrochemical production : 35%


YEAR 2000 - HYPOTHESIS B
Annex 21
Western Europe
Eastern Europe
Energy consumption
Oil consumption
Petrochem. Feedstocks
Fibres demand
Plastics demand
Rubbers demand
2729 10⁹ $
3.40 10⁹ T.O.E.
Population: 0.917 10⁹
GDP growth: 4.5% year
GDP 2000: 11717 10⁹ $
O.E.C.D.
+ South Africa - Turkey
Energy cons.: 7.35 10⁹ T.O.E.
Oil consumpt.: 3.34 10⁹ T.
Petr. Feeds: 0.60 10⁹ T.O.E.
Fibres demand: 26.3 10⁶ T (24.9)
Plastics dem.: 150.7 10⁶ T
Rubbers dem.: 24.6 10⁶ T (16.0)
Middle East
China
Japan
North America
Africa
South East Asia
Latin America
South Africa
Australia
New Zealand
World
Population : 6254 10⁶
GDP growth 80-2000 : 4.8% year
GDP year 2000 : 19657 10⁹ $
Energy consumption : 15.27 10⁹ T.O.E.
Oil consumption : 6.27 10⁹ T
Petrochemical feedstocks : 0.95 10⁹ T.O.E.
Fibres demand : 54.9 10⁶ T (51.1)
Plastics demand : 243.6 10⁶ T
Rubbers demand : 39.5 10⁶ T (29.2)
Share of developing countries in total petrochemical production : 18%
Developing Countries
Population : 4.876 10⁹
GDP growth 80-2000 : 5.9% year
GDP year 2000 : 5245 10⁹ $
Energy consumption : 4.52 10⁹ T.O.E.
Oil consumption : 2.30 10⁹ T.
Petrochemical feedstocks : 0.17 10⁹ T.O.E.
Fibres demand : 18.2 10⁶ T
Plastics demand : 47.4 10⁶ T
Rubbers demand : 8.6 10⁶ T
Fibres production (Syn.) : 14.3 10⁶ T
Plastics production : 39.0 10⁶ T
Rubbers production (Syn.) : 4.5 10⁶ T
Investment 80-2000 (%GDP) : 0.27%
(from which synthetics)
(16.9)
(6.4)


YEAR 2000 - HYPOTHESIS C
- Annex 21(d)
Eastern Europe
Population : 0.464 10^9
GDP year 2000 : 2573 10^9 $
Energy cons. : 3.30 10^9 T.O.E.
Western Europe
O.E.C.D.
Energy cons. : 6.22
China
Japan
Middle East
Africa
South East Asia
Latin America
South Africa
Australia
New Zealand
Developing Countries
Population : 4.876 10^9
GDP growth 80-2000 : 5.2% year
GDP year 2000
Energy consumption : 3.84 10^9 T.O.E.
Oil consumption : 4.6 10^9 T
Petrochemical Feedstocks : 10^9 T.O.E.
Fibres demand : 45.0 10^6 T (40.0)
Plastics demand : 38.9 10^6 T
Rubbers demand : 10^6 T
Fibres production (synthetic)
Plastics production : 10^6 T
Rubbers production (synthetic)
Investment 80-2000 (GDP) : 0.49%
World
Population : 6.254 10^9
GDP growth 80-2000
GDP year 2000
Energy consumption : 43.26 10^9 T.O.E.
Oil consumption : 10^9 T
Petrochemical Feedstocks : 0.78 10^9 T.O.E.
Fibres demand
Plastics demand : 197.6 10^6 T
Rubbers demand
Share of developing countries in total petrochemical production : 18%

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