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in the
Second United Nations Development Decade

THE PETROCHEMICAL INDUSTRY

Corrigendum

Page 66, third paragraph

The first sentence *should read*

With a reserve of slightly more than 2 billion tons and an annual output of about 190 million tons of crude, Venezuela ranks as one of the top oil producers of the world.

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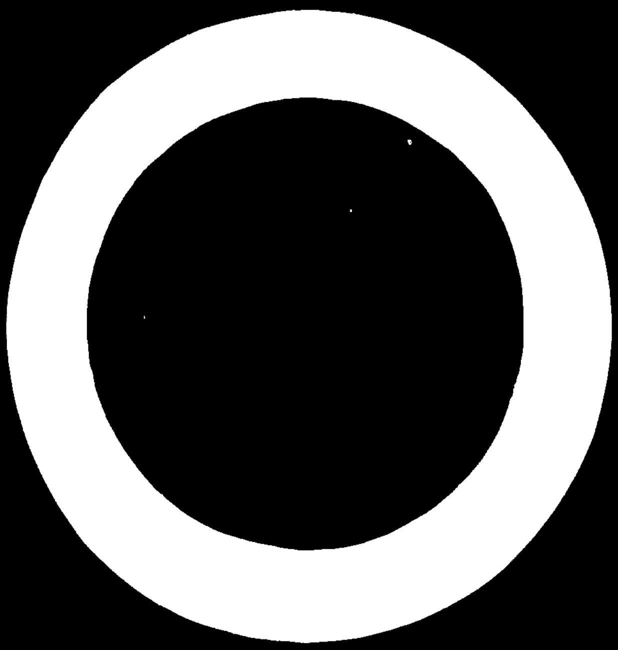
THE PETROCHEMICAL INDUSTRY



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

PERSPECTIVES FOR INDUSTRIAL DEVELOPMENT IN THE SECOND UNITED NATIONS DEVELOPMENT DECADE

THE PETROCHEMICAL INDUSTRY

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PREFACE

In the first years of the Second United Nations Development Decade, the United Nations Industrial Development Organization (UNIDO) will devote increasing attention to those problems of industrial development for which the planning time-span is some five years or more. Such problems are often among the most difficult to solve; the research necessary just to devise appropriate measures may take considerable time, apart from the lengthy period required for the measures themselves to produce their full effects.

Most projects for technical assistance to a developing country are of much shorter duration than five years, and while they are being devised and implemented there is some risk of putting insufficient emphasis on long-term measures. It is not intended that UNIDO should interrupt the rhythm of its established technical assistance activities to give more intensive study to the problems of longer-term planning. On the contrary, an important part of the new activity will consist of taking stock of past experience to see what lessons can be drawn for the benefit of future work programmes. It is particularly important to identify the common factors that affect the operation of projects and to evaluate their influence. It is through such factors that projects can interact, even if they are in different branches of industry.

As an essential part of its Second Development Decade activities, UNIDO is publishing a series of papers on the prospects for the development of some of the main branches of industry in the developing countries during the 1970s. These papers are intended to serve as preparatory material for workshops and seminars, where the proposals will be debated, and for regional meetings, where they will be made more precise. The papers will normally include forecasts of consumption and production up to 1980. Obviously, accurate predictions cannot be made for ten years ahead. Nevertheless, quantitative forecasts help to illustrate and orient the text. No attempt will be made to impose a uniform methodology or set of assumptions on the consultants who collaborate in preparing these forecasts.

According to the International Development Strategy for the Second United Nations Development Decade,[1] manufacturing output in the developing countries should be increased by an average of 8 per cent yearly. To achieve this target, some complex problems must be resolved in the fields of planning, finance, management and implementation. In particular, it is essential to take full account of factors whose effects are felt only in the long term.[2] It is hoped that the papers in the new UNIDO series will make a contribution to the long-range industrial development strategy of Governments and to the work of UNIDO and of other United Nations bodies concerned.

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[1] General Assembly resolution 2626 (XXV).

[2] See "A study of the capacity of the United Nations development system" (DP/5), chap. five.

The petrochemical industry, the subject of this third paper in the series, represents a tantalizing prospect for the developing countries: It is based on raw materials that many of them have in abundance. Its products are diverse and promise an easier way of life for many. But it requires two other resources, capital and technical personnel, that are scarce in most developing countries.

Thus, the current pattern of petrochemical production is heavily weighted in favour of the developed countries: Western Europe, Japan, the United States of America and the Union of Soviet Socialist Republics account for approximately 85 per cent of the world production. Nevertheless, there can be no doubt that the developing countries will play a greater role in the future. The United States, the originator of petrochemical industry, has been accounting for a declining share of world production, and this trend will probably continue. Although Western European production has been increasing rapidly, the rate of expansion has been greater elsewhere, where, however, the base has been hitherto fairly narrow compared with that in the United States and Western Europe. If the developing countries are willing to co-operate with one another in the formation of larger markets, the outlook for production of petrochemicals in them would seem fairly bright. It is the purpose of this study to estimate just how bright it can be.

This study is based on a paper prepared by K. H. Rönitz of Farbwerke Hoechst AG, Federal Republic of Germany. The UNIDO secretariat first prepared a draft working paper and submitted excerpts of it to certain of the developing countries included in the study, with a request for comments. On the basis of the response, extensive revisions were made in the paper to bring it to its present form.

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EXPLANATORY NOTES

The following definitions are used:

"Billion" means thousand million.
"Dollar" ($) means the United States dollar.
"Ton" (t) means metric ton.

In tables, a dash (–) indicates that the amount is nil or negligible, three dots (. . .) that data are not available, and a blank that the item is not applicable. Most numbers have been rounded. When numbers rounded to different extents are added, the sum is rounded to the same extent as the least precise addend. For example, a tenths digit will not appear in a number representing the sum of integers and decimal fractions.

The following abbreviations are used:

ABS	acrylonitrile-butadiene-styrene
BHC	benzene hexachloride
BR	polybutadiene (butadiene rubber)
BTX	benzene-toluene-xylene
DDT	dichlorodiphenyltrichloroethane
DMT	dimethyl terephthalate
HP	high-pressure
IPA	isopropyl alcohol
LP	low-pressure
PF	phenol-formaldehyde
PVC	polyvinyl chloride
SBR	styrene-butadiene rubber
UF	urea-formaldehyde

Chapter 1

GENERAL CONSIDERATIONS

Petrochemicals is a generic term for the diverse chemical products derived from petroleum and natural gas. Since the Second World War, few industries have developed so rapidly or produced so many new products as the petrochemical industry. The two main reasons for this are that petrochemistry makes possible efficient use of otherwise useless by-products of oil and gas refining, and petrochemicals can generally be obtained in greater quantity and better quality than chemicals from sources such as coal, coal tar and agricultural feedstocks.

Some statistics will set the perspective. In recent years, chemical production has been growing faster than over-all industrial production. In the period 1950–1956 industrial production tripled, but chemical production quadrupled. In the period 1955–1969 world manufacturing output increased at an average annual rate of 6.6 per cent; chemical production, 9.4 per cent.[1] Within the chemicals sector, the fastest growth has been in petrochemicals: in 1925 world production of petrochemicals was 75 tons, but today the United States of America alone produces over 70 million tons annually. In the world today, only 3 per cent of the oil and 6 per cent of the natural gas produced are used to make petrochemicals. By the year 2000, these fractions will increase to 20–30 per cent.

This fantastic growth is a good example of supply creating its own demand. At one time, many of the petroleum fractions and refinery gases obtained as by-products of oil refining had no obvious uses. Their abundance stimulated a search for ways to use them, and it was soon discovered that they were excellent sources of chemicals. The development of techniques for transforming these new source materials into chemicals led to an ever-increasing number of new products. These products–plastics, synthetic rubber, synthetic fibres, detergents, dyestuffs, fertilizers, pharmaceuticals–in turn created new markets that were easy to exploit because the starting materials were plentiful and inexpensive.

The growth was also enhanced by the characteristics of the raw materials themselves. Not only do petroleum fractions and gas constituents yield products of higher purity than those obtainable from carbochemistry, but they also enable an increased production of some chemicals whose supply would otherwise be restricted. Glycerine is a case in point. The development of an economic process for the synthesis of glycerine must be counted as one of the major achievements of petrochemistry. Further, petrochemistry has created routes to certain substances that are otherwise difficult to make, the xylenes for example.

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[1] *The Growth of World Industry* (United Nations publication, Sales No. 71.XVII.6). "World manufacturing output" excludes the output of Albania, China, the Democratic People's Republic of Korea, the Democratic Republic of Viet-Nam, and Mongolia. "Chemical production" includes a small proportion of coal and rubber products.

Choice of starting material

Many routes lead from the basic raw materials, petroleum and natural gas, to the secondary raw materials (primary products), the most important of which are ethylene, propylene, butylene, butadiene, n-paraffins and aromatics such as benzene, toluene and xylene. With the addition of inorganic feedstocks like oxygen, chlorine and hydrogen, over three thousand petrochemicals are produced from this small number of primary products.

The primary products are not produced in the same proportion from the two basics. Take, for example, the case of ethylene and propylene. The following comparison shows the yield of propylene relative to the ethylene yield for gas and oil sources.

Source	*Propylene-ethylene ratio (Percentage)*
Gas constitutents:	
Ethane	3.8
Propane	38.4
Petroleum fractions:	
Full-range naphtha	52.1
Light heating oil	51.7
Heavy heating oil	61.4

In the establishment of a new petrochemical industry, therefore, the choice of starting material will depend in the first place on which of the basic raw materials is more readily available. Countries with substantial supplies of natural gas or refinery gas will more naturally start with ethylene. However, since there are now processes that make propylene a valuable primary product for the manufacture of polypropylene, acrylonitrile, oxo alcohols and cumene, it is often advantageous even in these countries to operate crackers on low-boiling petroleum fractions to meet the demand for propylene and C_4 fractions.

Another important factor that will influence the choice of starting material is the wide difference in the investment costs for different processes; this is discussed briefly in the next section.

Petrochemical economics

In theory, there is virtually no organic chemical that cannot be produced by a petrochemical route. Nevertheless, the petrochemical route may not always be the most practical one and certainly will not be exploited if it is not economical, no matter how abundant the raw materials are. In analysing any proposed petrochemical route for feasibility there are many other factors to be considered.

Assuming that a steady supply of the required feedstock is available and that it is suitable for the specific circumstances of the plant where it is to be used, its cost is of prime importance. The cost, in turn, depends on the transportation charges, the organization of the market and the applicable taxes and tariffs.

Another important factor is the range of products to be manufactured. When there is a choice among different routes, the need to sell products at competitive prices will point to the route with the lowest operating costs.

The petrochemical industry is extremely capital intensive. Investment per unit of output is very high, and the capital-labour ratio, which ranges from $20,000 to $100,000 for each new job created, is one of the highest in industry.[2] Both the initial investment costs and the operating costs of plants using different processes to make the same chemical differ significantly. For example, table 1 compares the approximate costs of obtaining the same annual production of ethylene from different starting materials.

TABLE 1. COST OF PRODUCING ETHYLENE FROM DIFFERENT STARTING MATERIALS (DESIGNED CAPACITY: 450,000 TONS PER YEAR)

	Ethane	*Propane*	*Full-range naphtha*	*Light fuel oil*	*Heavy fuel oil*
Investment cost (million dollars)	31	33	36	42	44
Production cost (dollars per ton)	61	54	44	78	47

The investment cost will, of course, depend on the size of the plant, i.e., on its designed capacity. But it may not be realized how strongly the production costs depend on how fully this capacity is utilized. This dependence is shown, again for ethylene, in table 2.

TABLE 2. EFFECT OF UNDERUTILIZATION OF ETHYLENE PLANT CAPACITY ON PRODUCTION COST

Capacity utilization (percentage)	*Relative production cost (index number)*	
	Plant capacity 400,000 tons per year	*Plant capacity 70,000 tons per year*
100	100	100
75	115	125
50	145	160

The cost of energy may well be the largest component in the production costs. It, too, depends strongly on the process. Thus, the energy costs for PVC and polyethylene are 35–50 per cent of the total production cost; for ethylene oxide and acetaldehyde, 45–75 per cent. These high ratios are due primarily to the energy cost of oxygen and chlorine, the latter having an electricity requirement of about 3,300 kWh/ton. Styrene, on the other hand, has a very high steam requirement, approximately 8 tons per ton of styrene.

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[2] C. Mercier, *The Petrochemical Industry and the Possibilities of its Establishment in the Developing Countries* (Paris, Editions Technip, 1966).

Petrochemical plants are generally large and elaborate; they use sophisticated, automated equipment. A fairly large scale of operation is usually necessary to make such plants economically advantageous. The question of the most efficient plant size therefore occupies a central place in any consideration of petrochemical development. In industrially advanced countries, the need to reduce production costs is leading to increasingly larger manufacturing units that have annual outputs far beyond the requirements of most developing countries. The trend for ethylene is shown in table 3. The tremendous increase in plant size seen here is a result of

TABLE 3. GROWTH IN CAPACITY OF ETHYLENE PLANTS IN WESTERN EUROPE, 1950–1970

Period	*Average ethylene capacity (thousand tons per year)*
1950	15
1958	50
1963–1965	100
1967–1968	100–450[a]
1969–1970	150–500[a]

[a]Capacity range of new plants commissioned during period.

technological advances that have made large-scale plants more and more efficient; at the moment, a capacity of 400,000–500,000 tons per year is considered best. A comparison of production costs for ethylene plants of different sizes in Europe reveals the following:[3]

Plant size (tons per year)	130,000	350,000	450,000
Production cost (per ton)	$69	$46	$42

(In calculating these costs, it was assumed that the price of naphtha was $20 per ton and that the by-products could be sold at normal market prices.) Production costs can be reduced, although not so dramatically as in this comparison, by linking several smaller plants in series. However, the gain is significant only for plants producing ethylene by-products; the reductions obtained in series production of ethylene itself are quite small.

In spite of the general rise in the prices of capital goods, the investment involved in ethylene production has dropped from $220 per ton in plants with a designed capacity of 50,000 tons per year to about $90 per ton in plants with a capacity of 450,000 tons per year.

The data on which this discussion of petrochemical economics was based have perforce come from the developed countries. They show in which directions the industry is moving and indicate the production costs attainable—in those countries. It will be appreciated that the circumstances of developing countries are different; they cannot follow blindly in the same path. This point will be discussed further in the last chapter.

[3]Figures derived from: V. T. Besson, "New developments in ethylene production", *Chemical Economy and Engineering Review* (October 1971).

Chapter 2

ASSUMPTIONS AND METHODOLOGY

The central problem of this study, perhaps the first of its kind, is to predict, in quantitative terms, what the petrochemical industry will be like in the developing countries in 1980, the final year of the United Nations Second Development Decade. It is clearly impossible to do this to the last detail for such a dynamic and varied industry. Some worthwhile predictions of a more general nature can be made, however, if we are content to limit the number of products considered to those which are the most basic and important. In addition, to make proposals for the development of petrochemical industry in individual developing countries, many assumptions must be made on how these products are made and consumed. This chapter sets forth these limitations and assumptions and explains how they are combined with available data to formulate the proposals that constitute the bulk of what follows.

A word about these proposals: they should not be considered as blueprints for development. The intention is to suggest production units that are judged, at this time, to merit further study. Only detailed marketing and feasibility studies can show whether these units are actually justified in particular circumstances and what their exact cost will be. Nevertheless, this study can be quite helpful both to those responsible for specific petrochemical projects and to those concerned with formulation of general policies, provided they are aware of the problems and limitations discussed below.

Consideration of products

Products included in the study

Attention has already been drawn to the great diversity of products derived from petroleum and natural gas. Fortunately, it is neither necessary nor desirable to treat each product individually, since they are not equally important. They can be divided into three main categories according to their respective position in the chain that starts from the petrochemical feedstock and ends in the final product, namely the conventional categories of primary, intermediate and end products. Table 4 shows the routes that interrelate the products in each category that have been given the greatest attention in this study.

The primary products include ethylene, propylene, butadiene, benzene, *o*-xylene and *p*-xylene. Chemical conversion of primary products results in products that are intermediates or end products, depending on the use that is made of them; e.g.,

TABLE 4. PETROCHEMICAL ROUTES

Primary products		Intermediate products			End products	
Ethylene →		→			Polyethylene	PLASTICS
	+ chlorine →	Vinyl chloride →			Polyvinyl chloride (PVC)	PLASTICS
	+ acetic acid →	Vinyl acetate →			Polyvinyl acetate	PLASTICS
	+ oxygen →	Acetaldehyde →	acetic acid			
	+ oxygen →	Ethylene oxide →	ethylene glycol			
	+ benzene →	Styrene →			Polystyrene	PLASTICS
Propylene →		→			Polypropylene	PLASTICS
	+ benzene →	Cumene →	phenol, acetone			
	+ ammonia →	Acrylonitrile →			Acrylic	FIBRES
Benzene	+ hydrogen →	Cyclohexane →	caprolactam, adipic acid →		Polyamide	FIBRES
p-Xylene	+ methanol →	Dimethyl terephthalate (DMT) →	(+ ethylene glycol) →		Polyester	FIBRES
Butadiene →		→			Polybutadiene (BR)	ELASTOMERS
	+ styrene →	→			Styrene-butadiene rubber (SBR)	ELASTOMERS
o-Xylene	+ propylene →	Phthalic anhydride →	(+ alcohols) →	phthalate plasticizers		
Sulphur →		Sulphuric acid				
Methanol						
Ammonia						

ethylene oxide, ethylene glycol, vinyl acetate, acetic acid, phthalic anhydride, phenol, acetone. In view of the countless petrochemical end products, the scope of this study has been confined to those whose development has been made possible largely because cheap intermediates were available in bulk. The petrochemical end products that meet this requirement are the plastics, elastomers and synthetic fibres listed in table 4. The plastics chosen, for example, account for nearly 60 per cent of world plastics production. The primary products and intermediates to be considered were in fact determined by this choice of end products. Certain other products not appearing in table 4 have also been considered, for example, thermosetting resins.

Assumptions about the products included

Many plastic technologists believe that low-pressure (LP) polyethylene is probably the most useful polyolefin. This belief, coupled with the substitution possibilities among different thermoplastics, underlies the recommendation made here for the erection of an LP polyethylene plant to satisfy the major part of the thermoplastic polymer requirements of many of the smaller countries. In these countries it may also be desirable, as a matter of trade policy, to limit the availability of other thermoplastics to those applications for which LP polyethylene is not suitable. In other countries, a high-pressure (HP) polyethylene plant has been recommended. In the elaboration of these proposals, it is taken into account that a suitably designed LP polyethylene plant can also make polypropylene.

The assumption relating to polystyrene is that the entire production is in the form of crystal. The over-all demand in most countries is not sufficient to justify the production of the high-impact grade, which normally involves polymerization of the styrene in the presence of a substantial proportion of synthetic rubber followed by a special working-up process. Copolymers such as styrene-acrylonitrile polymers also require special working-up processes. However, the terpolymer, acrylonitrile-butadiene-styrene (ABS), is showing signs of developing into an important, if not a major, thermoplastic in developed countries. This will probably not exert much influence on the petrochemical industry in the developing countries during the 1970s.

It is assumed that vinyl chloride is made from ethylene by the oxychlorination route, with the result that the quantity of chlorine used is the net quantity after oxidation of the hydrogen chloride.

The chemical industry makes wide use of phenol and acetone. It has therefore been considered advisable to propose a plant for the production of phenol and acetone from propylene by the cumene process where conditions in a country warrant it. Excess propylene can also be used in the production of isopropyl alcohol and acetone, and such use has been envisaged in certain countries where these chemicals are not obtainable by fermentation.

The end consumption of synthetic fibres has been insignificant, both relatively and absolutely, in most developing countries. Only a few countries, those that are net exporters of woven and knitted fabrics and ready-made textiles, consume these fibres in substantial quantities. Industrial consumption is high in Hong Kong and the Republic of Korea, both of which have highly developed textile and clothing industries. For these countries, therefore, it did not appear realistic to limit the forecasts to end consumption, and their probable industrial consumption of synthetic fibres has also been taken into account.

The consumption of methyl alcohol in the production of DMT is given in gros quantities. Although it can be recovered during the next stage in the production o polyester chips, such an operation is hardly worthwhile.

Regarding the production of polyamide chips and fibres, experts say tha nylon 6 (from caprolactam) is marginally cheaper to produce and is more suitable fo small plants than nylon 66 (from adipic acid). It has therefore been assumed that al polyamide production will be in the form of nylon 6. No such assumption has bee made where capacity for the production of nylon 66 has already been installed.

Of the various synthetic rubbers only general-purpose ones will be considerec here. Only countries having a large stock of motor vehicles should contemplate synthetic rubber production. For every million motor vehicles, an annual productior capacity of 16,000 tons of styrene-butadiene rubber (SBR) and 8,000 tons o polybutadiene (BR), together with smaller quantities of special types of synthetic and natural rubber, is normally sufficient to cover domestic requirements, although it should be noted that the demand for vehicle tires will also differ even between countries that have the same number of vehicles because of other factors such as quality of roads and driving habits. Plants are available that will make either SBR or BR, and this availability is taken into account in the proposals formulated in this study.

Plasticizers are blended with PVC polymers to make flexible materials. The blending proportions vary, but, after taking into account both the breakdown of end uses in the industrialized countries and the consumption of rigid (i.e. unplasticized) material, it appears reasonable to assume that 500 tons of plasticizers are required for every 1,000 tons of PVC polymers. Most plasticizers are esters made from higher alcohols and phthalic anhydride. The phthalic anhydride can be made by the oxidation of either naphthalene, which is a coal-tar product, or the *o*-xylene that is separated from *p*-xylene in the production of polyesters. Comparatively small plants are economically viable, and some developing countries already have one or more on stream. Phthalic anhydride has several other uses in, for example, the manufacture of paint, resins and unsaturated polyesters. However, since these products are only partly of petrochemical origin, they are only touched upon here.

Thermosetting resins have been produced for around fifty years. These products find numerous uses in moulding, paints, chipboard, laminated plastics, insulating foam and reinforced plastics. Production of the principal resins such as phenol-formaldehyde (PF), urea-formaldehyde (UF), unsaturated polyesters and polyurethane foams, is particularly suitable in many developing countries. Production is relatively labour intensive and the cost of equipment is low. All these resins, with the exception of polyurethanes, can be made in a multipurpose plant; small quantities of any of them can be made in simple and inexpensive plants.

The developed countries are encountering waste-disposal problems caused by detergents that are not bio-degradable. It is precisely this type of detergent that is simplest to make by polymerizing propylene to the tetramer and then treating the tetramer with benzene in the presence of aluminium chloride catalyst. Techniques for manufacturing bio-degradable detergents are being sought. If it is willing to tolerate the use of non-biodegradable detergents for the time being, a developing country with a major oil refinery might reasonably consider manufacturing detergent alkylate from cracker raffinate. The proposals advanced here have been limited to propylene tetramer plants in those countries where there is either excess propylene or benzene.

Products omitted from the study

The only important thermoplastic omitted is polymethyl methacrylate, which has been manufactured for nearly forty years. The demand for it, however, has been moving slowly compared, for example, with the rapid increase in the market for PVC. It is doubtful whether its production in the developing countries would be justified, except in a few countries with a sizable plastics industry.

Ethyl alcohol can be produced readily by the fermentation of agricultural products; this is by far the simplest method of manufacture in countries having adequate supplies of these raw materials. With the exception of a few desert countries, the erection of an ethylene cracker just to make ethyl alcohol would scarcely be justified. Similar considerations apply to the chemicals made from ethyl alcohol and to the derivation from propylene of isopropyl alcohol, whose main uses, other than the production of acetone, largely duplicate those of ethyl alcohol. Acetone itself can be produced more suitably in most developing countries by the cumene process, which also gives phenol.

Chlorinated solvents have not been included, although they are widely used in dry cleaning and their consumption tends to rise as the standard of living rises. While there are routes for their derivation from ethylene, acetylene is a preferable starting material, and a small carbide plant will generally satisfy the requirements of a developing country in which the production of chlorinated solvents appears justified.

Although ammonia and nitrogen fertilizers rank among the most important petrochemical derivatives and can make a signal contribution to agriculture in the developing countries, they have not been considered in this study. Indeed, most countries have given priority to fertilizer production, but in most cases it has been assumed that there is sufficient ammonia available for the production of polyamide and acrylic fibres. A similar assumption has been made with respect to urea for the production of UF resins.

Insecticides and pesticides are often partly of petrochemical origin. The aldrin-dieldrin range of insecticides, for example, is made from cyclopentadiene, which is obtained as a by-product in a naphtha steam cracker operating under certain conditions. Benzene is required for BHC, lindane, DDT and many weedkillers. Attention that has long been focused on the beneficial effects of these chemicals has recently been shifted to their deleterious effects on the environment. The long-term prospects for any of the products in this category are therefore highly uncertain, and they are not included in this study.

Carbon black is an important petrochemical product whose main use is in rubber compounding. However, since other fillers are also used for this purpose it was not considered practical to arrive at consumption estimates for carbon black via consumption forecasts for natural and synthetic rubber. Another reason why it is excluded from this study is that carbon black is usually made from higher-boiling fractions of oil and does not fit in with the other petrochemicals discussed here.

Petrochemicals provide starting materials for other branches of the chemical industry and for other industrial sectors as well. Such varied products as dyestuffs, paints, varnishes, explosives and textiles use petrochemical inputs, but they are too diverse to be included in the present study. Many developing countries, however, are interested in manufacturing these products, and such manufacture would provide additional outlets for the petrochemicals discussed in the following pages.

Methodology

The projection period is the United Nations Second Development Decade, with 1980 as the horizon. When work was started on the projections comprising the bulk of this study, 1967–1968 was the latest period for which reasonably full data were available. The projections presented here are based on the consumption figures for this period.

Estimating consumption in the base period

There are two practical problems in determining the actual consumption of petrochemicals in the developing countries. The first is getting information; since there are few petrochemical industries in the developing world now, there are few sources of data. The second is deciding what the term "petrochemicals consumption" should mean. A developing country may import a petrochemical material in any of several forms: as a raw material for processing locally, or as a semi-finished or finished product. The figure given for consumption will obviously depend on where in this chain the material is deemed to be "consumed". In this study consumption is defined as the use of the material in its various marketed forms at the processing level. The semi-finished and finished products are not considered to be petrochemical products but products of the processing industry that makes them. For example, if a country imports a ton of polystyrene pellets and makes castings from them, it consumes a ton of polystyrene plastic, but if it merely imports the castings, it consumes none.

Figures on the apparent consumption of plastics in individual developing countries were obtained primarily from data on their imports from the main suppliers, Australia, Belgium, Canada, the Federal Republic of Germany, France, Italy, Japan, the Netherlands, the United Kingdom of Great Britain and Northern Ireland, and the United States of America. Domestic production, if any, was added to the import figures, and the totals were recorded in tabular form as first indicators. These indicators were then compared with other available data and modified as required, the remaining gaps being filled by estimates. Since the consumption of plastics in most developing countries is very small, imports of polyethylene film, PVC film and PVC floorings were also taken into account in calculating the consumption of plastics to provide a more realistic view. The same procedure was followed in the case of synthetic fibres and elastomers.

Estimating future consumption

The next step was to forecast the consumption trends giving due consideration to such factors as the rate of population growth and the expected increase in gross national product (GNP). Details of the population and GNP forecasts used can be found in the companion study on the motor vehicle industry.[4] For simplicity, only the first set of forecasts presented there were used here. Account was also taken of the probable changes in consumer preferences in the utilization of plastics, synthetic fibres and synthetic rubbers.

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[4] *The Motor Vehicle Industry* (United Nations publication, Sales No. 72.II.B.17).

Estimates of the future consumption of textile fibres had previously been made in connexion with another study in this series.[5] These were revised and updated. Since there was not enough data from which to estimate 1980 consumption of most developing countries, an indirect course was therefore adopted via forecasts for total textile fibre consumption at the stage of final consumption. The consumption of man-made fibres, divided into the broad categories of artificial and synthetic fibres, were estimated at the same time. In 1980, world consumption of synthetics will be about 11 million tons, out of which the developing countries will account for 1.42 million tons, or nearly 13 per cent.

The future demand for synthetic rubber was estimated on the basis of the vehicle park forecasts worked out in connexion with the study on the motor vehicle industry. Again, only the first set of forecasts were used. No estimates of future demand for synthetic rubber were made for countries in which the vehicle park is not expected to exceed 1 million vehicles in 1980.

Table 5 summarizes the forecasts of consumption of the major plastics and synthetic fibres in the developing countries in 1980 by broad geographical area. These forecasts are discussed in detail in the following chapters.

TABLE 5. FORECASTS OF PETROCHEMICAL CONSUMPTION IN THE DEVELOPING COUNTRIES IN 1980 – SUMMARY BY REGION
(Thousand tons)

	Plastics				*Fibres*		
Region	*Poly-ethylene*	*PVC*	*Poly-styrene*	*Poly-propylene*	*Acrylic*	*Polyamide*	*Polyester*
Africa	200	187	55	–	16.8	36.2	67
Asia and the Far East	774	637	244	151	76	292	253
Latin America	1,004	826	286	172	55.6	200	174.1
Middle East	152	156	59	–	22	57	69
Total	2,130	1,806	644	323	170	585	563

Estimating plant capacities

The estimates of the demand for the petrochemical end products covered gave some indication of the possible level of petrochemical production that could be envisaged in these countries. They were used as preliminary indicators in determining the plant capacities that could be installed.

The next step involved the determination of the type and quantity of feedstock available, either from domestic sources or from external suppliers. This in turn facilitated the determination of the most likely primary and intermediate raw materials and processes for the production of end products. The backward integration approach was then used to estimate expected requirements in terms of intermediate and primary products.

[5] *The Textile Industry* (United Nations publication, Sales No. 71.II.B.14).

Advantage was taken of the technological possibility of varying the output of ethylene and its by-products by variations in operating conditions and the quantity of naphtha used, to slant the output towards ethylene, olefins or benzene depending on the requirements of the particular country. The relative and absolute yields of these products therefore differ appreciably from plant to plant. While attempts were made to make use of all the main coproducts, this was not always possible, particularly in plants for the developing countries. The alternatives in such cases are to use surplus propylene as fuel, to burn surplus butadiene and to leave benzene in the pyrolysis gasolene to serve as an anti-knock agent.

The feedstock requirements were calculated on the basis of the conversion factors given in table 6. These conversion factors have not been rigidly applied, however; a safety margin has sometimes been allowed and figures have been rounded. It will be appreciated that no particular conversion factor can be regarded as the correct one, since even in the industrialized countries plants making the same product operate with different efficiencies.

TABLE 6. PETROCHEMICAL PRODUCTION: CONVERSION FACTORS AND CAPITAL COSTS

Product	*Conversion factor (tons of starting material per ton of product)*	*Capacity (thousand tons per year)*	*Capital cost (million dollars)*		
			Battery limits	*Energy supply installations*	*Sum*
PRIMARY					
Ethylene (by steam cracking)	4 naphtha	50			14.5[a]
		100			20
Coproducts: 50% propylene, 15% butadiene		150			26
		200			32.5
Aromatics:					
benzene, *o*-xylene, *p*-xylene	+ 1.88 platformate + 0.77 pyrolysis gasolene with dealkylation	102, 18, 30			21[a]
benzene, toluene, ethyl benzene, *o*-xylene, *m*-xylene, *p*-xylene	+ 1.30 platformate + 0.56 pyrolysis gasolene without dealkylation	34, 12, 14, 14, 27, 14	8	2	10[b]
Methanol	0.7 natural gas	30	3	1.5	5
Chlorine	1.75 rock salt	3.5	1.1	0.5	1.6
Coproduct: 113% caustic soda	(+ 3350 kWh electricity + 2.1 kg graphite electrodes)	17.5	3.5	1	5
Oxygen		16	1.6	0.6	2.2

Product	*Conversion factor (tons of starting material per ton of product)*	*Capacity (thousand tons per year)*	*Capital cost (million dollars)*		
			Battery limits	*Energy supply installations*	*Sum*
INTERMEDIATE					
Acetylene	4.3 methane + 4.9 oxygen	33	8.5	1.5	10.0
Styrene	1.00 benzene + 0.36 ethylene	24 100	5 11.5	1 2.9	6 14.4
Vinyl chloride	0.50 ethylene + 0.61 chlorine	24 100	4 9.5	1 2.4	5 11.9
Vinyl chloride	+ 0.60 acetylene 0.43 hydrogen chloride	20	3	1	4
Vinyl acetate	0.39 ethylene + 0.33 oxygen + 0.72 acetic acid	12 50	3 7.5	1 1.9	4 9.4
Ethylene glycol	0.70 ethylene + 0.95 oxygen	40	3	1	4
Acrylonitrile	1.40 propylene + 0.43 ammonia	10 45	3.5 8	2.4 6	5.9 14
Phenol/acetone 1.00/0.65 (cumene process)	1.0 benzene + 0.6 propylene	25/15	6	2	8
DMT	0.7 *p*-xylene + 0.5 methanol	30	10	0.6	11
Cyclohexane[c]	0.94 benzene + 0.08 hydrogen	30	0.5	–	0.5
Caprolactam[d] Coproduct: 45% ammonium sulphate	1.0 cyclohexane + 1.5 ammonia + 1.4 sulphuric acid + 0.7 sulphur	20	14	5	19
Phthalic anhydride	0.97 *o*-xylene + 0.92 naphthalene	50	10.5	3.1	13.6
2-Ethyl hexanol Coproducts: 16% isobutanol 30% isobutyr-aldehyde 2.7% isooctanol	1.147 propylene + 0.996 water gas + 0.038 hydrogen	10	16	4	20

TABLE 6. *(cont'd)*

Product	*Conversion factor (tons of starting material per ton of product)*	*Capacity (thousand tons per year)*	*Capital cost (million dollars)*		
			Battery limits	*Energy supply installations*	*Sum*
INTERMEDIATE *(cont'd)*					
Dioctyl phthalate	0.7 2-ethyl hexanol (or isooctanol) + 0.4 phthalic anhydride	10	1.0	0.1	1.1
END					
Plastics					
Polyethylene, HP	1.05 ethylene	40	17	7	24
Polyethylene, LP or Polypropylene (LP polymerization)	1.05 ethylene or 1.07 propylene	20 or 14	10	4	14
PVC	1.06 vinyl chloride	6 26	2.0 6	0.5 2	2.5 8
Polystyrene	1 styrene	6 24	1.5 4.0	0.4 1.0	1.9 5.0
Fibres					
Acrylic fibre	1.06 acrylonitrile	4 30	6.5 20	1.5 2.5	8.0 22
Polyamide (nylon 6) chips	1.10 caprolactam	3	1.5	0.3	1.8
Polyamide (nylon 6) fibre	1.08 nylon 6 chips	3	8	1	9
Polyester chips	1.05 DMT + 0.4 ethylene glycol	10	4.5	0.5	5.0
Polyester fibre	1.05 polyester chips	4 10	3 6.5	0.7 1.0	4 7.5
Elastomers					
BR	1.04 butadiene	8	8.5	3.4	11.9
SBR	0.78 butadiene + 0.33 styrene	16			

Product	*Conversion factor (tons of starting material per ton of product)*	*Capacity (thousand tons per year)*	*Capital cost (million dollars)* Battery limits	Energy supply installations	Sum
END *(cont'd)*					
Others					
Thermosetting plastics	0.72 PF resin or 0.72 UF resin or 1.60 unsaturated polyester resin	2.5	1.2	0.3	1.5
Detergent alkylate	0.83 propylene + 0.34 benzene	13	2.5	0.5	3.0
Detergent alkylate, sulphonated		13	5.0	0.8	5.8

[a] These represent total investment costs for the steam-cracking and aromatic extraction plants shown; the costs of the refinery supplying the naphtha inputs are not included.

[b] This capital cost does not include the cost of the reformer. An allowance has therefore been made for this in computing the cost of specific plants.

[c] The profitability of this operation depends on the availability of cheap hydrogen.

[d] The profitability of this process is greatly affected by the price at which the ammonium sulphate can be sold.

In the case of synthetic fibres, the situation was slightly more complicated. The method utilized in estimating the future consumption did not contain any individual forecasts for the main chemical groups, polyacrylic, polyamide and polyester. Such a division is necessary, however, for the determination of future requirements for the starting materials, namely, acrylonitrile, caprolactam and DMT. Appropriate estimates were therefore made on the basis of the probable distribution of the demand over the three groups.

Estimating capital costs

The last problem was to determine the capital costs of the units that appeared justified. Experience shows that these costs are generally higher in the developing countries than in the industrialized countries.[6] Capital goods have to be transported over long distances by ship, and frequently over land as well. Insurance costs must be

[6] *Studies in Petrochemicals*, vol. I, (United Nations publication, Sales No. 67.II.B.2), p.38.

added to the cost of this transportation. Construction and engineering costs are often much higher because technical personnel have to be drawn from overseas and the construction period is generally longer than in the industrialized countries.

The data from which the investment requirements were calculated are given in table 6, which indicates capital cost as a function of plant capacity. Particulars are also given of plants for the manufacture of auxiliary products. In some instances, two figures are given under plant capacity: the first is the minimum capacity that is technically efficient; the second is the minimum capacity that is economically efficient. The investment costs are broken down into battery limits and the costs for energy supply installations. Battery limits include the basic production plant with assembly and engineering but exclude licence fees and energy supply installations. The additional costs for energy installations vary from zero to a significant percentage of the battery limits.

The cost of building a plant is not directly proportional to its capacity but to the capacity taken to the power 0.6. That is, if capacity of a plant A is twice the capacity of another plant B using the same process, the investment necessary for plant A is not twice but $2^{0.6} = 1.5$ times that for plant B. The rule does not normally apply to the case of synthetic fibre plants, which are usually based on a number of small units linked in series.

Other factors

It was necessary to take into consideration many other factors before formulating proposals for the growth of the petrochemical industry in the developing countries: the geographical situation of the particular country and its general infrastructure; the country's current trade policy and its potential for exporting petrochemicals; the possibilities for co-operation with neighbouring countries; and the nature and number of petrochemical plants now on stream, under construction or at an advanced planning stage.

It was further assumed that most developing countries will not entertain any illusions about breaking into the world market for petrochemical products. The chapters that follow will make clear that a rising level of domestic consumption provides a sounder foundation for the development of this industry. Therefore, unless explicitly mentioned, export possibilities have generally been ignored.

Chapter 3

AFRICA

Many international oil companies, sometimes in combination with national companies, are actively exploring a large part of Africa, the coastal areas in particular. Discoveries and increased yields are frequently in the news. This activity and the known reserves are good indicators of the availability of hydrocarbon raw materials.

Total African reserves of crude oil at the beginning of 1967 were 32,356 million barrels, as against 389,050 million for the whole world.[7] Comparison with the 1958 reserves of 4,119 million barrels shows that in nine years African reserves increased eightfold, representing an average annual rate of increase of about 26 per cent. The African share of world reserves increased from 1.5 per cent in 1958 to 4.6 in 1963 and 8.3 in 1967. The future relative importance of African hydrocarbon reserves may be gauged by prospects in other countries, the United States of America for example. At the 1967 consumption rate, known reserves of crude oil and natural gas liquids in the United States will be exhausted in 9 years and natural gas in 16 years.[8] In contrast, African crude oil will last for over 30 years at the 1967 rate of output.

The exploitation of these reserves has grown apace. Production of crude oil shot up from 23.5 million tons in 1961 to 144 million in 1967, an average annual rate of increase of more than 35 per cent. Thus, Africa has become a significant contributor to world output of crude oil (1.3 per cent in 1960, 7.4 in 1965 and 8.3 in 1967).

The situation regarding natural gas is equally impressive. The 1965 African reserves of natural gas have been estimated at 2,200 billion cubic metres.[9] This works out at 8.5 per cent of world reserves, slightly higher than the 1967 crude oil share. Production is relatively small in comparison with reserves (4.5 billion cubic metres in 1965) and with world output (0.3 per cent).[10]

Tar sands and oil shales are other future sources of hydrocarbon materials. Africa can obtain 15 billion tons of oil from such sources.

Despite these resources, there is little probability that major petrochemical activity will take place in Africa during the 1970s. In 1970 few petrochemical production facilities existed, and most African countries were not in a good position

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[7] *Europe–France Outremer*, No. 456 (January 1968).
[8] *Chemical and Engineering News* (April 1968).
[9] *World Petroleum Report* (1967).
[10] *"Electric Energy Survey for Africa"* (E/CN.14/EP/36).

to set up a petrochemical industry. Most of the countries are small, and the effective demand for petrochemical products is very limited because of the generally low *per capita* incomes. Moreover, the hydrocarbon resources of the continent are concentrated in the Libyan Arab Republic, Algeria, Nigeria, Egypt, Angola, Gabon, Tunisia, the Congo and Morocco (descending order of importance).

In view of the vast size of the region and the large number of countries, these have been grouped into three geographical areas: North Africa, East Africa, and West and Central Africa. It should be borne in mind, however, that such a subregional classification is artificial to a certain extent, since it conceals the substantial differences existing among countries within each area. In discussing the probable development of petrochemical consumption and production, it may occasionally be desirable to group some countries together on the basis of their economic and other affinities and the possibility of their co-operating in the field of petrochemicals.

Thus, Algeria, Morocco and Tunisia form a compact group with many obvious affinities. In the northeast, Egypt, Ethiopia, Somalia and the Sudan constitute another such group, although Egypt might just as readily be considered along with the countries in the Middle East (see chapter VI). In East Africa, Kenya, Uganda and the United Republic of Tanzania have fairly close ties, and both Malawi and Zambia could be grouped with them. In West Africa, Nigeria is by far the largest state. With its oil production and refinery capacity, it could easily form the centre for petrochemical development to supply the needs of the smaller neighbouring countries.

Table 7 presents forecasts of consumption of the major petrochemical products in the main countries of Africa in 1980. It is apparent that the forecast of demand in the North African subregion is substantially higher than in the other subregions, even though the North African area includes only six countries while each of the other two subregions have three times that many. Indeed, for some products, the forecast for North African demand is higher than the combined forecasts for the other two subregions. This is not surprising, since North Africa includes three of the five countries in the African region that are expected to increase their consumption of petrochemical products substantially by the end of the decade: Algeria, Egypt and Morocco. The other two are Mozambique in East Africa and Nigeria in West and Central Africa. With the exception of Algeria, Egypt and Nigeria, no countries in the region are expected to reach the range of minimum economic capacities for the manufacture of primary petrochemicals by 1980.

The general basis for petrochemical development in the African region has been taken to be the erection of a naphtha steam cracker in countries where, in view of existing refinery capacity and basic infrastructural facilities, such an operation is deemed feasible. Some of the major products could be made on the same site and supplied to neighbouring countries for working into finished products.

The facilities for petrochemical production that may be established during this period are presented in summary form in table 8. The table shows a small amount of production of PVC and synthetic fibres forecast for some countries in this region. In view of the long distances from major suppliers and other similar cost-raising factors, small units for the manufacture of PVC may prove economic in some African countries, and they have accordingly been included among the production possibilities meriting further study. Petrochemical complexes appear to be feasible in Algeria, Egypt and Nigeria, while substantial production facilities can be established in Ghana and Tunisia.

TABLE 7. AFRICA: FORECASTS OF PETROCHEMICAL CONSUMPTION IN 1980
(Thousand tons)

	Plastics			Fibres		
	Polyethylene	*PVC*	*Polystyrene*	*Acrylic*	*Polyamide*	*Polyester*
East Africa[a]						
Angola	5	4	0.8	*b*	0.2	1.4
Ethiopia	4	6	4	*b*	0.3	2.0
Kenya	5	4.5	1	0.4	0.6	2.5
Mozambique	12	10	4.5	0.8	1.4	2.0
Uganda	3	1.2	4.5	*b*	0.4	0.6
United Republic of Tanzania	4	4.5	–	0.5	1.6	1.8
Other[c]	10	7	2.5	*b*	3.0	4.0
Subtotal	43	37	17	1.7	7.5	14.3
North Africa						
Algeria	20	22	7	2.2	5.8	4
Egypt	45	40	6	2	0.4	25
Libyan Arab Republic	4	4.5	–	0.8	1.5	1
Morocco	15	17	6	5.4	8.4	7
Sudan	4	4	3	*b*	0.2	1
Tunisia	8	8	1.5	0.8	2.1	1.4
Subtotal	96	95	24	11.2	18.4	39
West and Central Africa						
Ghana	7	6	1.8	1.1	1.4	3.0
Guinea	4	2	–	*b*	0.3	0.5
Ivory Coast	7	8	1.0	0.8	1.2	1.0
Nigeria	22	20	7	1.4	3.0	4.0
Senegal	6	5	0.4	0.6	1.0	1.3
Sierra Leone	2	1.5	–	*b*	0.4	0.2
Other[d]	13	12	4	*b*	3.0	4.0
Subtotal	61	55	14	3.9	10.3	14.0
Total	200	187	55	16.8	36.2	67

[a] Angola has been included in East Africa for convenience.
[b] Included with polyamide fibres.
[c] The countries included are Botswana, Burundi, Comoro Islands, Lesotho, Madagascar, Malawi, Mauritius, Réunion, Rwanda, Seychelles, Somalia, Swaziland and Zambia.
[d] Countries included are Cameroon, Central African Republic, Chad, Congo, Dahomey, Gabon, Gambia, Liberia, Mali, Mauritania, Niger, Togo, Upper Volta and Zaire.

TABLE 8. AFRICA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980–SUMMARY BY SUBREGION

	Production (thousand tons per year)							Total investment[a]	
	Ethylene	*Benzene*	*Poly-ethylene*	*PVC*	*Poly-styrene*	*Polyamide fibres*	*Polyester fibres*	*Amount (million dollars)*	*Fraction of total (percentage)*
East Africa[b]									
Angola	–	–	–	6	–	–	–	1.5	–
Ethiopia	–	–	–	6	–	–	3.5	4.5	1
Kenya	–	–	–	6	–	–	3.5	4.5	1
Mozambique	–	–	–	12	6	–	3.5	7.5	1
United Republic of Tanzania	–	–	–	6	–	3	–	12	2
Subtotal	–	–	–	36	6	3	10.5	30	6
North Africa									
Algeria	100	18	45	35	18	6	4	119	23
Egypt	80	–	40	40	6	–	25	134.5	26

Libyan Arab Republic	–	–	–	6	–	–	–	1.5	–
Morocco	–	–	–	18	12	9	10	79	15
Sudan	–	–	–	6	–	–	–	1.5	–
Tunisia	–	–	–	6	–	–	–	16.5	3
Subtotal	180	18	85	111	36	15	39	352	67
West and Central Africa									
Ghana	–	–	17	6	–	–	3.5	22.5	4
Ivory Coast	–	–	–	20	–	–	–	5.5	1
Nigeria	100	18	70	24	9	3	3.5	115	22
Senegal	–	–	–	6	–	–	–	1.5	–
Subtotal	100	18	87	56	9	3	7	144.5	27
Total	280	36	172	203	51	21	56.5	526.5	100

[a]These amounts include investments in production of other petrochemicals besides the ones in this table. See individual subregion tables.

[b]Angola has been included in East Africa for convenience.

East Africa

As defined for the purposes of this study, this subregion contains no less than 19 countries. Individual consumption forecasts have been worked out for only half a dozen of these, since insufficient data were available for the others. The consumption forecasts that are given for these countries should be treated with great caution, since they are very rough estimates. The total consumption that may be expected in this subregion for the various petrochemical products is in most cases less than the consumption forecast for Egypt alone and approximately half the consumption forecast for Hong Kong.

Mozambique is expected to become the largest single consumer in this area, although the level of consumption will be low. Oil prospecting is actively pursued and there is substantial refinery capacity. Angola has extensive oil reserves, and the production, refining and distribution of oil constitute its second most important economic activity. The greatest impetus to expansion is the Cabinda offshore finds of 1966; reserves of crude oil are estimated at a minimum of 300 million tons. The opportunities for co-operation between Angola and Mozambique appear to be good. However, their combined demand does not alter the picture significantly as far as production prospects are concerned.

TABLE 9. EAST AFRICA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Angola[a]		
PVC	6	1.5
Ethiopia		
PVC	6	1.5
Polyester fibres	3.5	3
Kenya		
PVC	6	1.5
Polyester fibres	3.5	3
Mozambique		
PVC	12	3
Polystyrene	6	1.5
Polyester fibres	3.5	3
United Republic of Tanzania		
PVC	6	1.5
Polyamide chips and fibres	3 fibres	10.5
	Total	30

[a]Angola has been included in East Africa for convenience.

Kenya, Uganda, the United Republic of Tanzania and Zambia form a fairly homogeneous group with a modest living standard, and three of them have made considerable progress in the establishment of a subregional common market. They do not, however, have any crude oil resources or gas fields within their frontiers, although Kenya has substantial refinery capacity handling 2.5 million tons of crude annually. Rwanda, on the other hand, has about two fifths of the Lake Kivu gas, or about 23 million cubic metres in terms of pure methane.

Although there is no petrochemical industry in the subregion and no petrochemical projects are now under serious study, some small-scale production facilities could be established in a few of these countries. Angola, Kenya, Mozambique and the United Republic of Tanzania could establish small units for the production of PVC. Kenya and Mozambique could also embark on the production of polyester fibres, while the manufacture of polystyrene may be feasible in Mozambique. The United Republic of Tanzania could consider the production of polyamides, both fibres and chips. Table 9 summarizes the production facilities that can be justified by the end of the decade and their capital costs. On the basis of these forecasts, this subregion can absorb only $30 million for the development of its petrochemical production.

The demand forecast for the subregion as a whole would support an LP polyethylene plant to supply a wide range of plastic requirements within the area. However, in view of the large number of countries constituting the market, the long distances over which the ethylene raw material and the polyethylene would have to be transported and the small size of the plant, such a proposal would scarcely prove attractive.

North Africa

Of the six countries in this subregion, Algeria, Egypt and Morocco are likely to emerge as major consumers of petrochemical end products by 1980. Egypt is expected to be the largest single consumer of petrochemical products, accounting for nearly half the expected demand for high-tonnage plastics in the area, while Tunisia also can expect a fairly substantial domestic demand for these products. In addition, the demand for SBR may reach 35,000 tons. Available data for other countries indicate that the consumption of polypropylene is normally about the same as that of polystyrene and thus the area may also expect a demand of 20,000–25,000 tons of polypropylene in 1980.

This subregion is generously endowed with resources and would therefore be in a good position to embark on the production of petrochemicals. Algeria has ample supplies of crude oil and natural gas, while Tunisia's reserves of these are modest. A field of natural gas has recently been discovered in Morocco, but the oil reserves there are meagre. With an oil reserve of 7.6 billion tons in 1969, the Libyan Arab Republic is one of the major oil-producing countries of the world and the foremost oil exporter of Africa. Its natural gas reserves are expected to reach 620 billion cubic metres by 1975. Sudan does not have any petrochemical feedstocks of its own, while Egypt has become an oil-producing country of some importance.

It is convenient to treat some of these countries together in discussing the possible evolution of petrochemical production. Algeria, Morocco and Tunisia have many features in common, while Egypt and Sudan may be discussed together, along with some countries in the horn of Africa, namely, Ethiopia and Somalia. The Libyan Arab Republic is in many respects different from these other countries–it has a much higher GNP, for example–and deserves separate treatment.

There are no petrochemical plants in Algeria, Morocco and Tunisia, although all three have transformation industries utilizing imported intermediate petrochemical products. Their combined demand in 1980 is forecast as follows (thousand tons): polyethylene, 43; PVC, 47, polystyrene, 14.5, acrylic fibres, 8.4; polyamide fibres, 16.3; polyester fibres, 12.4; SBR, 31; and corresponding amounts of the relevant intermediate and primary products. Their combined demand is, therefore, fairly high and justifies the production of a wide range of petrochemicals. One possible arrangement would be for Algeria to erect a large, economic ethylene cracker that could supply the primary products to the other two countries for further processing. Success would, of course, depend on a substantial degree of harmonization of petrochemical development among these countries. Assuming this, the production would be as given in table 10, which also gives the attendant capital costs.

Plans are being made to speed the implantation of a petrochemical industry in this area, especially in Algeria, where the Government is eager to develop this industry and is attempting to do so "through the establishment of projects for the production of the essential and intermediate petrochemical materials".[11] Consideration is being given to projects involving the annual production of 120,000 tons of ethylene, 40,000 tons of polyethylene, and 35,000 tons of PVC. A project for the production of aromatics is also reported. Algeria is negotiating the construction of a polyester fibre plant with a final daily capacity of 30 tons. This would be based on *p*-xylene from the second Algerian refinery, now under construction. Since polyester capacity will exceed Algerian demand, agreements will have to be reached with Morocco and Tunisia, as well as with other prospective customers for the surplus production. Tunisia is interested in establishing facilities for producing annually 20,000 tons of HP polyethylene, 20,000 tons of PVC and 50,000 tons of ethylene, these capacities being based on the possibility of exporting a large part of the production.

Although the Libyan Arab Republic has experienced an eightfold increase in *per capita* national income over the last decade, the market for petrochemicals in that country is very restricted, largely because of its small population. Besides the forecast consumption shown in table 7, the annual demand for synthetic rubber may reach 3,000 tons by 1980. The domestic demand will not, therefore, be sufficient to justify any production of petrochemicals, with the possible exception of a small PVC unit. Had it not been for the long distances involved and had its immediate neighbours not had their own sources, the Libyan Arab Republic might well have become the supplier of bulk intermediates to its neighbours.

In the Libyan Arab Republic, a second refinery is being built and a third is expected by 1975. This extension of refinery capacity could make available many grades of naphtha that would in turn make possible some petrochemical production for export markets. A large reformer could be erected to produce aromatics, particularly benzene and *p*-xylene. Both these products are readily transportable, and benzene, in particular, can be sent to any part of the world where there is a demand. The investment required for the reformer and working-up plant alone would be

[11] "A study on the status of the petrochemical industry in the Arab countries," unpublished document (Industrial Development Centre of the Arab States, 1970).

TABLE 10. ALGERIA, MOROCCO AND TUNISIA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*		*Investment (million dollars)*
Algeria			
Naphtha steam cracker	100 ethylene 60 propylene 15 butadiene 18 benzene		20
Vinyl chloride	60		9
Oxo alcohols	18		25
HP polyethylene	45		25
PVC	35		9
Polystyrene	18		6
Polyamide chips and fibres	6 fibres		21
Polyester fibres	4		4
		Subtotal	119
Morocco			
PVC	18		7
Polystyrene	12		5
Polypropylene	20		18
Acrylic fibres	4		6.5
Polyamide chips and fibres	9 fibres		31.5
Polyester chips and fibres	10 fibres		11
		Subtotal	79
Tunisia			
PVC	6		1.5
Synthetic rubber	28		11
Detergent alkylate	20		4
		Subtotal	16.5
		Total	214.5

about $50 million to $60 million for a viable capacity of around 300,000 tons of benzene per year. The availability of cheap raw materials is an *a priori* justification for such a plant, but since this plant would cater to export markets, a detailed analysis is obviously required before the economics of such a proposal can be properly evaluated.

It is reported that the Libyan Government is not at present planning to establish a basic petrochemical industry. It is, however, considering projects for the production of 22,000 tons of carbon black and 300,000 tons of methanol per year. As mentioned earlier, the only production facility that would be justified by the consumption forecasts presented here would be a small unit for the manufacture of 6,000 tons of PVC per year. The investment costs for this capacity would be about $1.5 million.

TABLE 11. EGYPT, LIBYAN ARAB REPUBLIC AND SUDAN: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Egypt		
Naphtha steam cracker (in two stages)	80 ethylene 40 propylene	22
	28 *p*-xylene 10 *o*-xylene	20
Vinyl chloride	48	8
DMT	30	10
HP polyethylene	40	17
PVC	40	10
Polystyrene	6	1.5
Acrylic fibres	4	6.5
Polyester chips and fibres	25 fibres	26
Synthetic rubber	24	8.5
Thermosetting resins	12	5
	Subtotal	134.5
Libyan Arab Republic		
PVC	6	1.5
Sudan		
PVC	6	1.5
	Total	137.5

The remaining two countries in the subregion, Egypt and the Sudan, can conveniently be considered together with one East African country, Ethiopia. Since Egypt is the only one that has petrochemical feedstocks of its own, petrochemical development in this part of Africa hinges largely on what Egypt does; if Egypt participates with the countries of the Middle East in a major petrochemical complex, the petrochemical development of Ethiopia and the Sudan will be less likely. Although the expected demand for petrochemical products in 1980 in Ethiopia and the Sudan is very low, it does slightly widen the market opportunities available to Egypt. The total demand forecasts for these countries in 1980 is (thousand tons): polyethylene, 53; PVC, 50; polystyrene, 13; acrylic and polyamide fibres, 2.9; polyester fibres, 28; synthetic rubber, 6; thermosetting resins, 11.

This level of consumption in Ethiopia and the Sudan would not support any domestic petrochemical production, with the exception of small plants with an annual capacity of 6,000 tons of PVC in each and possibly also a small plant for the production of synthetic fibres in Ethiopia. Although Egypt is the country most likely to establish petrochemical production in this area, any viable development will depend on a certain measure of export orientation. The probable markets would have to be surveyed before any serious proposals could be formulated. Table 11 summarizes the production capacities that could be envisaged in these countries, with the exception of Ethiopia, for which details have been given in table 9.

The total investment requirements for the establishment of the petrochemical production facilities mentioned would be about $140 million, of which Egypt would account for $134 million. It is reported that Egypt is studying projects for plants that will produce (thousand tons per year): ethylene, 80; polyethylene, 40; PVC, 33; polybutadiene, 20; polyesters, 10. Unless domestic consumption develops at a rate much faster than can reasonably be expected at present, however, a sizable proportion of the output will have to be exported.

West and Central Africa

Like East Africa, this subregion also includes a large number of countries whose domestic markets, with a few notable exceptions, are limited. Data on actual consumption of petrochemical products are not readily available for many of these countries, so that the figures given for their probable consumption in 1980 should again be treated as very rough estimates. Individual forecasts have been made for six of the largest countries in this area. Of these, Nigeria is expected to achieve a level of petrochemical consumption that may rank among the highest for the continent, while Ghana, the Ivory Coast and Senegal may reach levels that would be quite substantial by African standards, but far too low to justify setting up even the smallest possible units.

There are substantial hydrocarbon resources in this subregion. With 200 million cubic metres of crude oil and 280 billion cubic metres of natural gas, Nigeria possesses significant reserves of hydrocarbons; it also has substantial refinery capacity. Hydrocarbon resources are becoming less significant in the Congo, where the reserves are not so great. An offshore oil find in Dahomey has resulted in flow rates as high as 1,440 barrels a day. There are indications of oil and gas deposits in Western Cameroon, and the prospects of the oil industry in that country are said to be good. Traces of oil have been discovered in the Volta Region in Ghana. Zaire has oil deposits adjacent to the Cabinda finds and three fifths of the Lake Kivu gas, about 34 million cubic metres, expressed as pure methane. Gabon was one of the first African countries to produce oil, and, because of its earnings from petroleum exports, it is the richest African country in the French community.

The development of petrochemical production in this subregion will therefore not be hindered by a lack of raw materials. The most serious obstacle to such development lies in the insufficiency of demand in most of these countries. Market-sharing arrangements would be a way out of this impasse, but it would be foolish to base the growth of a petrochemical sector on the strength of the total demand forecast for the entire subregion, in view of the multitude of countries, the long distances involved and the poor communications network. However, some countries in the area have economic co-operation agreements and are actively seeking ways and means of integrating their industrial development.

It would therefore not be unrealistic to expect some co-operation among countries in this subregion. Unfortunately, even a pooling of markets does not improve the demand position significantly unless a potential major consumer is included among the participating countries. A high degree of export orientation would thus appear to be a necessary condition for the development of the petrochemical industry in this area. The export prospects must be assessed carefully before ventures in petrochemical production are undertaken.

Nigeria would in many respects seem the ideal location for a major petrochemical industry in this subregion. Neighbouring countries could also be supplied from Nigeria. A naphtha steam cracker with an annual output of 100,000 tons of ethylene and the corresponding co-products together with extraction of benzene from the pyrolysis gasolene could be considered in Nigeria. Other products that could be made are polyethylene, polypropylene, styrene, polystyrene, synthetic rubber and some synthetic fibres. No estimates of the consumption of polypropylene have been made, but the experience of other countries indicates that a moderate demand for this product develops with the expansion of the plastics market. Nigeria would produce only HP polyethylene and draw its requirements of LP polyethylene from Ghana. Table 12 gives details of the production facilities that could be established.

In addition to the consumption of the products included in the table, there is likely to be considerable demand for detergents in Nigeria and its neighbouring countries. This is estimated at about 75,000 tons in 1980 and would entail the production of 15,000 tons per year of detergent alkylate. In the scheme proposed, provision has been made for the production of propylene tetramer, but it is possible that by 1980 the use of biologically soft alkylates will be considered essential in Nigeria, with its relatively dense population, and in some parts of Ghana. Nigeria would probably be the best location for the plant; an alternative would be Ghana. A detergent alkylate plant has been included among the plants that may be considered in Ghana by the end of the decade. Other facilities that may also be justified in Ghana are a small unit for the production of PVC (although it may be more economical for Ghana to import PVC from Nigeria) and a small plant for the manufacture of polyester fibres from imported chips with an annual capacity of 3,500 tons.

The French-speaking countries in this subregion may find it easier to co-operate in the field of petrochemicals. The Ivory Coast and Senegal may face domestic demand levels that would justify the establishment of small units with a capacity of

TABLE 12. WEST AND CENTRAL AFRICA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*		*Investment (million dollars)*
Ghana			
Polyethylene	17		14
PVC	6		1.5
Polyester fibres	3.5		3
Detergent alkylate	20		4
		Subtotal	22.5
Ivory Coast			
PVC	20		5.5
Nigeria			
Naphtha steam cracker	100 ethylene 60 propylene 18 benzene 15 butadiene etc.		20
Styrene	15		5
Vinyl chloride	48		8
HP polyethylene	70		31
PVC	24		5.5
Polystyrene	9		4
Polypropylene	18		18
Polyamide chips and fibres	3		10.5
Polyester fibres	3.5		3
SBR	19		10
		Subtotal	115
Senegal			
PVC	6		1.5
		Total	144.5

6,000 tons of PVC per year by 1980. In view of the potential for co-operation among these countries, however, it should be possible to establish a PVC plant with a capacity as high as 20,000 tons per year. The Ivory Coast, since it has somewhat higher consumption estimates than Senegal, would seem a reasonable location. The capacity of the plant in the Ivory Coast suggested above would depend on agreements with other countries to spread the application of PVC wherever possible.

For several countries no individual forecasts have been made. Gabon has an adequate hydrocarbon base but a small domestic market, which makes the production of petrochemicals in this country unlikely before the end of this decade. In view of the Government's interest in optimizing the use of the resources, the possibility of export production cannot be discounted. Zaire is considering a PVC project, presumably geared to production for exports, with a capacity of 25,000 tons per year. Malawi and Zambia in the East African subregion may represent possible outlets but cannot be expected to absorb more than a tiny fraction of this production.

Chapter 4

ASIA AND THE FAR EAST

This chapter discusses the petrochemical industry in Asia and the Far East, with the exception of the developed country in the region, Japan, and the centrally planned economies for which data are scarce, namely China, the Democratic People's Republic of Korea and the Democratic Republic of Viet-Nam. This region has sizable resources of crude oil and natural gas. Indonesia and Iran abound in these resources; Burma and India have a substantial production of oil and natural gas. In these countries there appears to be some scope for the development of facilities for the production of petrochemicals on the basis of feedstocks domestically available.

The current demand for petrochemicals in most developing countries of the region is quite low but is expected to increase considerably during the decade. Few of the countries in this region have a developed petrochemical industry. They rely on imports for the bulk of their petrochemical requirements, which represents a serious burden on their foreign exchange. For example, the Republic of Korea spent an estimated $80 million on petrochemical imports in 1970. Table 13 gives the expected consumption of the major petrochemical end products in 1980.

The production of petrochemicals that appears necessary to satisfy these levels of demand is summarized by product and by country in table 14. The investment costs for establishing this capacity are estimated to be just over $3 billion. The Indian subcontinent is likely to account for a large part of the probable investment in the petrochemical sector.

The prospects for the production of petrochemicals in the region would naturally be greatly improved if the countries in the region could have access to neighbouring markets and thereby reap the advantages of large-scale production, which are quite substantial in the case of some products. Some production-sharing plans have been already negotiated between some of the countries in this region for the production of caprolactam and DMT.

Bangladesh

There are large reserves of natural gas in Bangladesh, but no oil. A complex based on natural gas to produce 15,000 tons per year of PVC resins and polyvinyl alcohol fibre is at the planning stage.

The production that could be achieved in Bangladesh by 1980 is detailed in table 15. (See the footnote to table 13.)

TABLE 13. ASIA AND THE FAR EAST: FORECASTS OF PETROCHEMICAL CONSUMPTION IN 1980

(Thousand tons)

	Plastics				*Fibres*				
	Poly-ethylene	*PVC*	*Poly-styrene*	*Poly-propylene*	*Acrylic*	*Polyamide*	*Polyester*	*Thermosetting resins*	*Synthetic rubber*
Afghanistan	3.5	5	...	...	0.2	3	3	...	...
Bangladesh[a]	...	...	...	...	...	...	...	...	...
Burma	10	10	1.5	...	0.5	1.2	0.8	....	...
Hong Kong	90	72	68	19	10	35	40	...	...
India	200	175	60	35	20	70	75	...	45
Indonesia	25	16	8	7	5	15	18	12	...
Iran	80	80	23	14	8	45	20	50	14
Khmer Republic	5.5	4	...	...	0.5	1	4	...	...
Malaysia	6	7	1	...	1.5	2	2	...	...
Pakistan[a]	40	36	14	10	4	25	10		
Philippines	90	70	25	16	3	30	15	50	25
Republic of Korea	83	65	15	18	20	48	45	50	...
Singapore	35	22	8	8	2.5	5	4	...	...
Sri Lanka	6	5	1	...	0.5	2	2.5	13	...
Thailand	100	70	20	24	1	10	14	60	...
Total	774	637	244	151	76	292	253	235	84

[a]The basic work on this study was completed before East Pakistan became the independent country of Bangladesh. The comments made in the text regarding the difficulty of making demand forecasts for Pakistan on the basis of 1967–1968 data apply *a fortiori* to Bangladesh, for which no comparable data are available. The forecasts shown for Pakistan, the proposals based on them and all statements made about the petrochemical sector in both Bangladesh and Pakistan relate to the situation prevailing before Bangladesh became independent.

TABLE 14. ASIA AND THE FAR EAST: PROPOSED PETROCHEMICAL PRODUCTION BY 1980 – SUMMARY BY COUNTRY

	Production (thousand tons per year)							Total investment[a]	
	Ethylene	Benzene	Polyethylene	PVC	Polystyrene	Polyamide fibres	Polyester fibres	Amount (million dollars)	Fraction of total (percentage)
Bangladesh	–	–	–	39	–	–	–	151	5
Burma	–	–	–	15	–	–	–	6	–
India	350	260	150	190	65	70	70	831	27
Indonesia	50	–	40	16	–	10	10	104	3
Iran	150	–	100	80	25	50	20	363	12
Pakistan	60	–	50	15	–	25	10	162	15
Philippines	150	–	140	70	25	30	15	342	11
Republic of Korea	180	–	110	65	15	50	45	500	16
Singapore	–	–	40	25	–	5	5	60	2
Sri Lanka	–	–	–	10	–	–	3[b]	8	–
Thailand	170	–	120	80	25	10	15	223	8
Other countries[c]	250	102	120	72	72	39	47	339	11
Total		362	1,020	677	227	289	240	3,089	100

[a]These amounts include investments in production of other petrochemicals besides those listed in this table. See individual country tables.

[b]Including polyamide fibres.

[c]Hong Kong has by far the largest share of the total investment: $325 million.

TABLE 15. BANGLADESH: PROPOSED PETROCHEMICAL PRODUCTION BY 1980[a]

Product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Acetylene from natural gas	36	100 (including oxygen facilities)
Vinyl chloride (from acetylene)	41	8
Acrylonitrile (from acetylene)	18	10
Hydrogen cyanide	10	8
PVC	39	10
Acrylic fibres	16	15
	Total	151

[a]See the footnote to table 13.

Burma

Burma has modest resources of crude oil; additional prospecting is going on under the aegis of the state-owned People's Oil Industry. Naphtha is available from the existing oil refineries; an additional refinery to be finished in 1972 will provide more. Current petrochemical production is restricted to fertilizers and is based on natural gas, which was discovered in 1960. Additional gas strikes have since been made, and there is much interest in establishing or extending industries based on natural gas.

The demand for petrochemicals in the past few years has been fluctuating; it has also been limited. The importation of synthetic plastics and resins has averaged about 2,000 tons per year recently, but this demand is expected to reach 30,000 tons per year by 1980, of which polyethylene and PVC will each account for about 10,000 tons per year. Since cotton is produced in substantial quantity, it is doubtful whether the production of synthetic fibres can be undertaken during the decade. Similar considerations apply to synthetic rubber, since Burma has some production of natural rubber for export.

Even though Burma is expected to have as much as 100,000 tons per year of naphtha in the early years of the decade, market considerations appear to rule out the possibility of having cracking facilities. The establishment of PVC production based on imported vinyl chloride (from Bangladesh, for example) is possible. A capacity of 15,000 tons per year appears justified. This would, however, have to be accompanied by restrictive measures on the import of thermoplastic and plastic goods to ensure the maximum utilization of PVC. The capital cost of this particular plant would be about $6 million. Finally, the production of thermosetting resins and aromatic-based petrochemicals is possible, but this would require access to export markets.

India

India's reserves of crude oil have recently been estimated at about 140 million tons. There is substantial refinery capacity and naphtha is in reasonably good supply. Gas resources are estimated at 69 billion cubic metres.

There has been considerable development of the production of petrochemicals since the state-appointed Petrochemicals Committee drew up a development programme in the early 1960s. The Oil and Natural Gas Commission further elaborated this programme and, as a consquence, many units have already come into operation. The present capacity is shown in the following list.

	(Thousand tons per year)
Ethylene	75
Propylene	40
Butadiene	7
Benzene	18
Phenol	10–15
Acetone	6– 9
Ethylene oxide	12
Isopropyl alcohol	13
LP polyethylene	20
HP polyethylene	10
PVC	20
Polystyrene	12

The polystyrene is made from imported styrene. In addition to the above, oxo alcohols, ethylene dichloride (for PVC) and small quantities of synthetic fibres are produced.

The demand for petrochemicals was depressed for a long time owing to a severe restriction on imported products and to the limited domestic production. However, with the production of a number of petrochemicals in the country and the development of the processing capacity for a number of end products, the domestic demand is developing rapidly. The domestic demand for the main petrochemical end products will reach fairly high levels by 1980, when India may expect an annual internal consumption of high-tonnage plastics of over 400,000 tons per year, over 150,000 tons per year of synthetic fibres, and 45,000 tons per year of synthetic rubber (table 13).

The availability of coal has led to a considerable production of chemicals based on this raw material, while the availability of agricultural raw materials has likewise encouraged the production of chemicals by fermentation processes. Thus, the production of ethyl alcohol by fermentation is nearly 300,000 tons per year; ethyl alcohol thus produced is the present source of acetic acid, acetic anhydride, butadiene, acetone and acetic esters. Ethylene is made by the dehydration of ethyl alcohol, while styrene is made from this ethylene and coal-tar benzene. Hence, there are polyethylene and SBR plants based on raw materials of non-petrochemical origin. It appears likely that India will repeat the experience of other countries and gradually switch over to a petrochemical base for its chemical and allied industries, although the transition process may be lengthy because of the lack of capital resources and the protective barrier erected to encourage the use of domestic raw materials.

On the basis of the assumption that fermentation processes will be changed over to petrochemical processes wherever practicable by the end of the decade, the capacity expansions or new capacities that could be established by 1980 are summarized in table 16. It is assumed that acetic acid will be available from fermentation processes and that coal-tar processing will yield the additional quantities of benzene and phenol that will be required. Since the ethylene cracking operations will not produce sufficient butadiene for the synthetic-rubber plant, the difference may have to be imported or produced from fermentation ethyl alcohol.

TABLE 16. INDIA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*		*Investment (million dollars)*
	Increase required	*Attained by 1980*	
Naphtha steam cracker	275	350 ethylene 180 propylene 60 butadiene	50
Cracking of ethane etc. from natural gas		100 ethylene 5 propylene	15
Catalytic reforming of naphtha and pyrolysis gasolene from the naphtha steam crackers, including dealkylation		260 benzene 40 toluene 180 mixed xylenes	55
Isomerization and extraction		60 *p*-xylene	10
Methanol		75	9
Formaldehyde		30	2
Oxygen		70	50
Styrene		110	15
Vinyl chloride (oxy-chlorination route)	175	200	22
Vinyl acetate (ethylene route)		30	7
Ethylene oxide/glycol	45/0	25/35	5
Phenol/acetone (cumene process)	45/0	60/39	11
DMT		85	20
Cyclohexane		90	2

Plant or product	Capacity (thousand tons per year) Increase required	Attained by 1980	Investment (million dollars)
Caprolactam (from cyclohexane via the oxime route)		85	52
Isopropyl alcohol/acetone	50/0	30/35	15
Oxo alcohols	70	85 2-ethyl hexanol 12 *n*-butanol	40
LP polymerization	130 polyethylene or 80 polypropylene	150 polyethylene, or 20 polyethylene and 80 polypropylene	70
PVC	170	190	35
Polystyrene	55	65	9
Polyamide chips and fibres		70 fibres	240
Polyester chips and fibres		70 fibres	75
BR/SBR		15/35	18
Detergent alkylate (soft)		30	4
		Total	831

Indonesia

Indonesia is a major producer of both oil and gas. The country produces 23 to 25 million tons per year of crude oil and 1.6 billion cubic metres per year of natural gas. Estimates put reserves at 50 to 60 times the annual production.

The only facilities for petrochemical production now in operation are a nitrogenous-fertilizer plant with a capacity of 70,000 tons per year of ammonia and 50,000 tons per year of urea, as well as a detergent plant with a capacity of 6,000 tons per year. A 2,000-ton-per-year carbon-black plant is expected on stream shortly. On stream is a plant for making vinyl-acetate copolymer as a raw material for the manufacture of shoe soles and synthetic leather.

The current demand for petrochemicals is rather limited, considering the country's population and income. Imports of thermoplastic raw materials were 11,000 tons in 1968, having risen from 8,500 tons in 1963. There were virtually no imports of synthetic fibres, but some 6,000 tons of textiles made from synthetic fibres were imported that year. The demand estimates for 1980 are in table 13.

A 20,000-ton-per-year polypropylene plant using propylene from refinery gases is reported on stream. In formulating proposals in table 17 to meet the demand expected by 1980, the suggestion is made that Indonesia consider the possibility of establishing a fairly large plant that could make either polyethylene or polypropylene according to demand. The whole of the investment costs associated with this plant has been included, no allowance being made for any existing plant. It is assumed that DMT, ethylene glycol, caprolactam and some of the constitutents for the thermosetting resins will be imported; no allowance is made for their domestic production.

TABLE 17. INDONESIA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Ethane-propane cracker	50 ethylene and/or propylene	20
Chlorine	15	4
Vinyl chloride (from ethylene)	18	6
LP polymerization	40 polyethylene or 28 polypropylene	16
PVC	16	7
Polyamide chips and fibres (all plants operating)	10 fibres	36
Polyester chips and fibres	10 fibres	11
Thermosetting resins (all plants operating)	12	4
	Total	104

Iran

With an estimated reserve of 5,200 million tons and an annual production of 144 million tons, Iran is one of the largest producers of oil in the world. The associated-gas availability is also very high. Refinery gases containing propane, ethane and ethylene are also available in large quantities. Iran is thus generously endowed with sources of raw materials for the petrochemical industry.

The National Petroleum Company has embarked on an extensive programme for the development of petrochemicals production. There already exist large-scale complexes for the production of ammonia, sulphur, fertilizers and liquid gases geared to export production. Other plants, such as PVC and dodecyl-benzene plants, are aimed at meeting the domestic demand. There are also facilities for the production of synthetic fibres. The country's first nylon plant started operating in 1969 with a capacity of 3,000 tons per year of mono-filament; its capacity will be increased to 6,000 and later to 10,000 tons per year. The consumption of petrochemicals has been increasing rapidly in recent years; if this rate of growth is maintained, the consumption of several of these products will be sufficient to warrant their economic production in Iran. The estimated consumption in 1980 is given in table 13. The demand for synthetic rubber shown there is much higher than it was in 1968. This level of demand could justify the establishment of synthetic rubber plants, but the availability of natural rubber in the region may preclude this.

A major petrochemical complex would be required to satisfy the expected demand for all products. There will, however, be a considerable excess of propylene and, for this reason, it is proposed that an isopropyl-alcohol/acetone plant might be included to provide raw materials, solvents etc. to other branches of the petrochemical industry. Many of the raw materials, e.g. benzene and phenol, may have to be imported since it may not be economic to produce them domestically.

The petrochemical production facilities that could be established by the end of the decade, together with their estimated capital costs, are given in table 18.

TABLE 18. IRAN: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Naphtha steam cracker	150 ethylene 75 propylene	26
Styrene	30	8
Vinyl chloride (ethylene route; hydrogen chloride produced could be partly consumed by older acetylene plant)	85 (increase of 65)	8
Caprolactam (by oxime route)	60	39
Isopropyl alcohol/acetone	10/20	10
HP polyethylene	60	30
LP polyethylene or Propylene	40 or 28	23
PVC	80 (increase of 60)	15
Polystyrene	25	6
Polyamide chips	55	17
Polyamide fibres	50	145
Polyester chips and fibres	20 fibres	22
Thermosetting resins	50	14
	Total	363

Malaysia

Malaysia has no oil or gas resources. The existing refineries provide naphtha, which is used for the production of fertilizers and detergents. No naphtha is available for further petrochemical development. Imports of plastic raw materials were 18,000 tons in 1968; there were also some imports of synthetic fibres and yarns. The fairly substantial imports of plastics were due to the previous association with Singapore, which has well developed end-uses. By 1980 the total demand for plastics is not expected to be much higher than 15,000 tons per year. The demand for PVC in 1980 is expected to be about 7,000 tons and that of polyethylene about 6,000 tons. The total consumption of synthetic fibres is expected to reach 5,000 tons in 1980.

A polyethylene plant could be established, but it would not only have to rely on imported ethylene, possible from Singapore, but also have to direct the bulk of its output to export markets. There would not therefore seem to be much scope for the production of plastics raw materials or synthetic fibres based on petrochemicals during the decade.

Pakistan

Both oil and natural gas are available in Pakistan, and there are refineries there. Despite the availability of raw materials, the petrochemical industry has not been able to make much headway owing to the limited development of end-use industries (e.g. the plastics industry), the heavy investment required, and controversies over the selection of products to be produced. The consumption estimates for 1980 (table 13) are very approximate since on the basis of recent statistics it is not possible to establish a definite trend in the demand for plastic products or synthetic fibres in view of restrictions on imports, licensing controls and other measures that impinge on the demand for petrochemicals.

A contract has recently been awarded for the design, supply and construction of five interrelated chemical plants. The units will produce chlorine and caustic soda, vinyl chloride, 22,000 tons per year of PVC, 16,000 of polyethylene and 10,000 of polypropylene. These units are part of a major petrochemical complex to be built around a cracker with a capacity of 60,000 tons per year of ethylene. The investment in this complex will be about $77 million.

Together with Iran and Turkey, Pakistan is planning a polyester fibre plant with a capacity of 7,000 tons per year of chips and 5,000 of fibre. There are also plans for the production of BR and for the extension of detergent capacity. A BTX (benzene-toluene-xylene) unit is being built to meet the domestic demand for toluene and xylene and part of the demand for benzene.

The projects that can be envisaged by the end of the decade and their attendant investment costs are shown in table 19.

TABLE 19. PAKISTAN: PROPOSED PETROCHEMICAL PRODUCTION BY 1980[a]

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Naphtha steam cracker	60 ethylene 27 propylene	17
Vinyl chloride (from ethylene)	17	5
HP polyethylene	50 (increase of 45)	25
PVC	15	6
Polypropylene	10	12
Polyamide fibres	25	75
Polyester chips and fibres	10 fibres	11
Synthetic rubber	24	8.5
Detergent alkylate	10	3
	Total	162

[a]See the footnote to table 13.

Philippines

There is a small oil field in the Philippines awaiting exploitation; meanwhile, four refineries with a total capacity of 10 million tons per year are using imported crudes. The availability of natural gas is limited.

Current petrochemical production is rather limited (thousand tons per year): PVC resin from carbide, 6; carbon black, 8; detergents, 37; UF resins, 40.

Imports of plastic raw materials have doubled between 1961 and 1968, when they reached 35,000 tons.[12] The imports of synthetic fibres in 1968 were about 5,000 tons and of synthetic rubber 8,000 tons. The domestic consumption of the principal petrochemical end products is expected to increase substantially by the end of this decade (table 13). It should be sufficient to support a full-scale petrochemical complex. Indeed, the country has been considering building up its own petrochemical industry. Plants with these capacities are being planned (thousand tons per year): ethylene, 250; low-density polyethylene, 135; high-density polyethylene, 55; vinyl chloride, 104; PVC, 57; polypropylene, 29. Some of the proposed capacities are quite generous in the light of the forecasts in table 13, and the full utilization of these capacities may require export outlets. The capacities that could meet the expected domestic demand, together with their attendant capital costs and their raw-material requirements, are summarized in table 20.

[12] Government news release quoted by *Search*, Plastics and Resins Division, vol. 8 (September 1971).

TABLE 20. PHILIPPINES: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Naphtha steam cracker	150 ethylene 90 propylene 25 butadiene 25 benzene	28
Methanol	36 (in two stages)	5
Formaldehyde	33 (in two stages)	
Styrene	35	8
Vinyl chloride (from ethylene)	75	13
Phenol/acetone (cumene process)	30/20	10
Caprolactam (flexible process to use either phenol or cyclohexane, then via traditional oxime route)	35	30
HP polyethylene	90	40
LP polyethylene or Polypropylene	50 or 32	30
PVC	70	16
Polystyrene	25	5
Polyamide chips and fibres	30 fibres	110
Polyester chips and fibres	15 fibres	16
SBR	24	8.5
PF resin	10	15
Expansion of UF-resin plant	60	
Unsaturated polyester	10	
Detergent alkylate (via propylene tetramer)	20	4
	Total	342

Republic of Korea

Although the Republic of Korea has no crude oil or natural gas of its own, it does produce naphtha. The refining capacity is being increased, and the crude through-put is expected to reach 3.8 million tons per year. Benzene, phenol and other chemicals are derived from coal, large amounts of which are carbonized yearly. The petrochemical industry has been developing rapidly to meet the increasing domestic and export demands.

The country's first petrochemical complex, expected to start operating soon, will be based on a naphtha steam cracker with an ethylene capacity of 150,000 tons per year and will have eight downstream facilities, including a 50,000-ton-per-year polyethylene plant, a 60,000-ton-per-year vinyl chloride plant and a 30,000-ton-per-year capacity for polypropylene production, with corresponding capacities of other coproducts.[13]

The production facilities currently in operation include plants utilizing imported vinyl chloride to produce:

	(Thousand tons per year)	
PVC	50	using imported vinyl chloride
Polystyrene	8	using imported styrene
UF resins	25	
Acrylic fibres	4.7	
Polyamide fibres	7.2	
Polyester fibres	2.0	

In 1980 the domestic demand for PVC is expected to reach 65,000 tons per year as against the demand of 38,000 tons in 1970. Polyethylene demand is expected to rise from 30,000 tons in 1970 to 83,000 tons in 1980. The domestic demand for polypropylene, which was approximately 9,000 tons in 1970, is expected to double while polystyrene demand is expected to reach about 15,000 tons per year by the end of the decade. As regards synthetic fibres, the demand levels in 1980 are expected to be 20,000 tons for acrylic fibres, 48,000 tons for polyamide fibres and 45,000 tons for polyester fibres. In addition, domestic consumption of thermosetting resins may reach 50,000 tons per year by 1980.

Although the Republic of Korea imports the bulk of its petrochemical requirements, it has been diverting its surplus production of PVC into exports to South-East Asia and even Japan. This export experience may well widen the possibilities of petrochemical production in the country. Bearing in mind the expected demand, the existing capacity and the possibility of exports, the plants that could exist in 1980 are those listed in table 21.

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[13] *Modern Plastics International* (February 1971).

TABLE 21. REPUBLIC OF KOREA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Naphtha steam cracker	180 ethylene 95 propylene 35 butadiene	30
Reforming of naphtha, extraction of production and pyrolysis gasolene from naphtha cracker (dealkylation included)	100 benzene 20 toluene 60 mixed xylenes	25
p-Xylene	30	6
Methanol	45	6
Styrene	22	6
Vinyl chloride (for existing PVC plants)	70	12
Ethylene glycol	50	67
Acrylonitrile	25	9
Cyclohexane	65	2
Caprolactam (capacity of 33,000 t/yr under construction)	60	38
HP polyethylene	60	29
LP polyethylene or Polypropylene	50 or 36	25
Polystyrene	15 (increase of 7)	4
Acrylic fibres	20 (increase of 7)	11
Polyamide chips and fibres	50	156
Polyester chips, and fibres including production of DMT	45 fibres	56
BR/SBR	8/16	8.5
Thermosetting resins	50	10
	Total	500

Singapore

Singapore does not produce any oil or natural gas. However, its already substantial refinery capacity is expected to rise to over 35 million tons in the next few years, so that refinery gas will be available as a feedstock, although it may be expensive. As a major commercial port, Singapore supplies large quantities of bunker oil to ships, which implies the presence of an excellent source of naphtha to use for feedstock. This refining potential offers a basis for the development of the country's own petrochemical industry. The existing petrochemical production is limited to 4,800 tons per year of UF resins, 1,200 tons per year of PF resins and some 6,000 tons per year of detergents. A PVC plant with a capacity of 3,000 tons per year using imported raw materials is being planned.

The demand for polyethylene expected in 1980 (see table 13) could be met by a plant producing 40,000 tons per year of HP polyethylene from imported ethylene (cost: $24 million). Another possibility would be an LP polymerization plant using imported ethane/propane cracked to a mixture of ethylene and propylene to produce polyethylene or poly-propylene according to the demand requirements and the supplies of raw material inputs. A plant for producing 42,000 tons per year of polyethylene by the low pressure process or 25,000 tons per year of polypropylene would cost $25 million and the ethane/propane cracker another $10 million. The PVC plant that is being planned could be expanded to 25,000 tons per year by 1980 at a cost of $8 million. The annual production of polyester fibres and polyamide chips and fibres can be envisaged on a small scale of 4,000–5,000 tons each, at a cost of $25 million. The total investment required for the development of petrochemical production would be $57 million to $60 million.

Sri Lanka

Sri Lanka has no resources of crude oil or natural gas, so that feedstocks for petrochemical production would have to be imported. Since Sri Lanka is a major producer of natural rubber, it is unlikely that plastics will be used in those applications where rubber is suitable.

In view of the low demand expected (see table 13) and the lack of petrochemical feedstocks, it appears unlikely that any other production may be envisaged apart from a small PF or UF resin unit or some small fibre units. The only thermoplastic unit that can be envisaged is a 10,000-ton-per-year PVC plant based on imported vinyl chloride, with supporting measures similar to those mentioned in the case of Burma. The possible petrochemical-production facilities and their capital cost implications are summarized in table 22. A plant to polymerize caprolactum and spin the product (nylon 6) is under construction. The projected production capacity is 2,000 tons per year of nylon 6. The polymer will also be used for products other than fibres.

TABLE 22. SRI LANKA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
PVC	10	3
Polyamide and polyester fibres	3	4
PF and UF resins	2	1
Total		8

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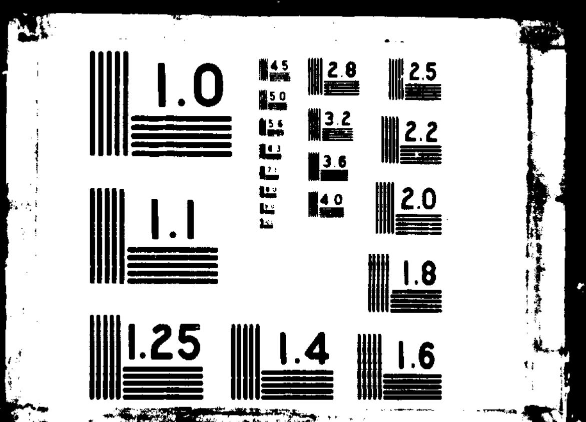

Thailand

There is no natural gas in Thailand other than that associated with the limited supplies of crude oil. The existing refinery capacity is about 3 million tons a year, but it is not likely that the source will yield sufficient naphtha to meet the raw-material requirements of a petrochemical complex. In the absence of restrictions on imports, the demand for petrochemical products has been moving briskly. In 1968 the country imported 4,000 tons of thermosetting resins, 50,000 tons of thermoplastic resins, including compounds, 3,000 tons of synthetic fibres and 1,200 tons of synthetic rubber.

The domestic demand is expected to grow substantially over the decade and may reach levels that would warrant a full-scale petrochemical complex by the end of the decade (table 13). Since Thailand is a major producer of natural rubber, the possibility of its producing synthetic rubber can be disregarded. The plants that may be envisaged on the basis of the domestic market are a steam cracker to produce ethylene and propylene from imported naphtha, an HP polyethylene plant and a polypropylene plant. Production of PVC using vinyl chloride made from ethylene can also be considered. Ethylene could be used with imported benzene to produce styrene for the manufacture of polystyrene. The substantial demand for synthetic fibres appears to justify both polyamide and polyester fibre plants using imported chips. The production of thermosetting resins is also a good possibility. Excess propylene could be combined with imported benzene to produce phenol and acetone via the cumene route. The production of methanol and formaldehyde could be based on refinery gases. Estimates of the production of petrochemicals in Thailand in 1980 are shown in table 23.

TABLE 23. THAILAND: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Naphtha steam cracker	170 ethylene 85 propylene	28
Methanol	60	8
Formaldehyde	50	3
Styrene	27	7
Vinyl chloride (from ethylene)	85	10
Phenol/acetone	25/15	8
HP polyethylene (in two stages)	100	45

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
LP polyethylene or Polypropylene	20 or 45	35
PVC	80	18
Polystyrene	25	5
Polyamide fibres (small plants in stages)	10 total	30
Polyester fibres (small plants in stages)	15 total	13
Thermosetting resins	60	10
Detergent alkylate (from benzene and propylene tetramer)	10	3
	Total	223

Other countries

Forecasts of demand were also calculated for Afghanistan, Hong Kong and the Khmer Republic (table 13). Since the economy of Hong Kong differs markedly from that of most developing countries in its high degree of export orientation and *entrepôt* trade, the forecasts of probable consumption should be treated with considerable caution. Hong Kong already has some production facilities for some petrochemical products, notably synthetic fibres; it is not unrealistic to expect some progress in the production of petrochemicals during the decade.

Since the domestic market is expected to remain small in both Afghanistan and the Khmer Republic, there is not much scope for petrochemical development in these countries, except in synthetic fibres. The demand levels expected in Hong Kong are much higher and would justify the establishment of a full-scale petrochemical complex. The plants that could make up such a complex and details of their capital costs and production capacities are given in table 24. The total investment requirements for the three countries would therefore amount to $339 million, of which Hong Kong would account for $325 million. However, the cost of establishing synthetic fibre production in Afghanistan and the Khmer Republic may in fact be significantly higher than the figures given, because of the relative inaccessibility of these countries.

TABLE 24. OTHER ASIAN COUNTRIES: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Afghanistan		
Polyamide fibres	3	8
Polyester fibres	3.5	3
	Subtotal	11
Hong Kong		
Naphtha steam cracker (in three stages)	250	54.5
Aromatics	102 benzene 30 *p*-xylene 18 *o*-xylene	21
Styrene	96	20
Vinyl chloride	96	16
DMT	30	9.5
Cyclohexane	30	0.5
Caprolactam	40	14
HP polyethylene	80	32
LP polyethylene or Polypropylene	40 or 28	20
PVC	72	16.5
Polystyrene	72	12
Acrylic fibres	8	6
Polyamide chips and fibres	36 fibres	63
Polyester chips and fibres	40 fibres	40
	Subtotal	325
Khmer Republic		
Polyester fibres	3.5	3
	Total	339

Chapter 5

LATIN AMERICA

Latin America possesses vast resources of petroleum and natural gas that have been exploited in the petroleum industry since the 1940s, at least in the relatively more developed countries of the region. In those early years the first projects for the establishment of petrochemical plants were also prepared, but few materialized; those that did were mostly in countries with state petroleum enterprises, such as Argentina, Mexico and Venezuela.

The Second World War gave rise to a world-wide demand for more basic organic chemicals, and this opened up markets for petroleum products, to the detriment of by-products from coal and the fermentation of agricultural residues. Latin America, with its petroleum and natural-gas resources, began then to emerge as one of the regions with the brightest prospects in this field.

It was only in the second half of the 1950s, however, that the construction of petrochemical plants was initiated, in Argentina, Brazil, Colombia, Mexico and Venezuela. The plants were small, since they were intended to supply only small domestic markets, and were protected by high customs tariffs. Most of them were designed and built by well-known international firms and belonged to large-scale international chemical enterprises, except in Mexico, where the state company, Petróleos Mexicanos (PEMEX), held the monopoly on production of all basic petrochemicals and some intermediate products.

This new construction was not an isolated venture; it formed part of the process of industrialization. At that time, industrial-development laws were approved in several Latin American countries; they established priorities for industrial-development plans, including those for the petrochemical industry, on the basis of the import substitution to be achieved through the processing of their abundant natural resources of petroleum and natural gas using up-to-date techniques.

In the case of the petrochemical industry, this development legislation had serious flaws, since it ignored important intersectoral conditions. Thus, no account was taken of certain intermediate and finished products of the chemical industry that accelerate the growth of demand for basic petrochemical products. Moreover, because of the technical and economic interdependence of the petroleum and petrochemical industries, the institutional system for petroleum development in each country affected the institutional structure and development of its petrochemical industry.

In countries which follow the system of granting long-term oil concessions to private enterprises (for example, Colombia, Peru and Venezuela), the possibility of utilizing natural gas as a raw material for petrochemicals depends on whether the companies holding the concessions intend to expand their activities and increase their investment in the country. Since the concessionaires are generally international companies operating petrochemical plants predominantly for export, their interest in developing the petrochemical industry in Latin America has not gone beyond the exploratory stage, mainly because of the small domestic markets and the dim prospects for interregional trade, certainly not because of any lack of know-how or money, both of which these companies have in abundance.

Where the petroleum industry is in the hands of the State, on the other hand, the financial resources required for the development of the petroleum industry are so great that very little is left to promote petrochemical projects. Moreover, the negotiations undertaken by national institutions to obtain external loans for investment in the petrochemical industry scarcely ever yield satisfactory results unless they are backed by prior agreements on the use of patents and the provision of technical assistance.

The consumption of some petrochemical end products has made significant headway in Latin America; it has reached particularly high levels in Argentina, Brazil and Mexico. During the decade Latin America will increase its petrochemical consumption substantially and will become the largest of the consuming regions in the developing world, including as it does Brazil and Mexico, which are expected to be the two largest individual consumers of petrochemicals among the developing countries in 1980. Forecasts of consumption of the major end products are given in table 25. For the Caribbean countries, estimates of individual consumption for 1980 are given only for the Dominican Republic, Jamaica and Trinidad and Tobago, since it did not prove practicable to make these estimates for the others. Estimates of the

TABLE 25. LATIN AMERICA: FORECASTS OF PETROCHEMICAL CONSUMPTION IN 1980

(Thousand tons)

	Plastics				*Fibres*		
	Poly-ethylene	*PVC*	*Poly-styrene*	*Polypro-pylene*	*Acrylic*	*Poly-amide*	*Poly-ester*
Middle America							
Costa Rica	10	6	1.5	–	*a*	1.5	1.1
Dominican Republic	7	5	0.6	–	0.5	1.8	1.6
El Salvador	10	8	2.0	–	*a*	1.9	1.5
Guatemala	8	5	0.8	–	0.5	3.0	3.4
Honduras	7	5	0.8	–	*a*	1.7	2.2
Jamaica	5	4	0.5	–	*a*	1.1	1.2
Mexico	250	200	70	50	8.0	22.0	20.0
Nicaragua	8	5	0.8	–	*a*	1.1	1.0
Panama	6	3	0.5	–	*a*	1.4	1.5
Trinidad and Tobago	5	5	0.5	–	*a*	1.2	1.4
Other countries[b]	4	4	0.6	–	1.4	1.8	2.0
Subtotal	320	250	79	50	10.4	38.5	36.9

	Plastics				Fibres		
	Polyethylene	PVC	Polystyrene	Polypropylene	Acrylic	Polyamide	Polyester
South America							
Argentina	140	120	60	26	9.2	30	24.0
Bolivia	5	4	0.5	–	[a]	1.2	0.8
Brazil	275	240	80	50	20.0	80	60.0
Chile	50	35	12	10	1.0	8.5	12.0
Colombia	60	50	17	12	4.0	12.0	13.5
Ecuador	10	7	1.5	–	2.8	5.0	5.0
Paraguay	5	4	0.4	–	[a]	0.6	0.9
Peru	60	50	17	12	3.0	8.5	4.5
Uruguay	10	7	1	–	0.7	1.8	2.5
Venezuela	60	50	17	12	4.5	10.0	9.0
Other countries[c]	9	9	1	–	[a]	4.5	5.0
Subtotal	684	576	207	122	45.2	162	137.2
Total	1,004	826	286	172	55.6	200	174.1

[a]Included with polyamide fibres.

[b]Includes the Bahamas, Barbados, Bermuda, British Honduras, Guadeloupe, Martinique and the Netherlands Antilles. (Bermuda is included for convenience; it is not, strictly speaking, in Middle America.)

[c]Includes Guyana, French Guiana and Surinam.

total consumption in Latin America in 1980 are 2.3 million tons for the high-tonnage plastics and 405,000 tons for synthetic fibres of which South America will account for nearly 70 and 80 per cent, respectively. In Middle America, a single country, Mexico, will account for 82 per cent of the total consumption of high-tonnage plastics and 58 per cent of fibres, while in South America, Argentina and Brazil, together will account for 62 and 70 per cent of the consumption of the same products.

Table 26 gives in summary form the facilities for the production of petrochemicals that can be envisaged in 1980 in each country. A rough indication of the attendant costs is also given.

With the wealth of petrochemical raw materials and a lively interest in their optimum utilization, the prospects for the petrochemical industry in Latin America are quite encouraging. Broadly speaking, the main features of Latin American petrochemical production in the next ten years will be the establishment of some big industrial plants comparable in size to those elsewhere in the world, marked diversification of production, a drop in the currently high domestic prices and some increase in interregional trade. There is also a possibility that its products will gain a foothold on world markets.

TABLE 26. LATIN AMERICA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980 – SUMMARY BY SUBREGION

	Production (thousand tons per year)							*Total investment*[a]	
	Ethylene	*Benzene*	*Poly-ethylene*	*PVC*	*Poly-styrene*	*Polyamide fibres*	*Polyester fibres*	*Amount (million dollars)*	*Fraction of total (percentage)*
Middle America									
Central America	100	–	60	20	–	3	4	91	4
Mexico	210	60	270	200	72	22	12	339	15
West Indies	(1,100)	(530)	(125)	–	–	–	–	*b*	
Subtotal	310	60	330	220	72	25	16	430	19
South America									
Argentina	319	133	140	120	60	30	24	306	13
Brazil	485	208	234	150	80	80	60	680	30
Chile	110	–	50	35	14	8	14	159	7
Columbia	150	150	65	50	20	–	–	179	8
Ecuador	–	–	20	–	–	12	12	69	3
Peru	120	–	86	50	18	20	5	216	10
Uruguay	–	–	15	–	–	–	3	15	–
Venezuela	150	–	75	50	20	10	10	205	9
Subtotal	1,334	491	685	455	212	160	128	1,829	81
Total	1,644	551	1,015	675	284	185	144	2,259	100

[a] These amounts include investments in production of other petrochemicals besides the ones in this table. See individual country tables.

[b] For the West Indies, it was not realistic to project the development of petrochemical production on the basis of internal demand; the figures given are those of the 1969 capacity and have not been included in the product totals.

Middle America

Central America

The six Central American countries included here are fairly small. None of them have any resources of crude oil or natural gas, with the exception of Nicaragua, which has discovered some indications of oil off its Atlantic coast. In Costa Rica extensive petroleum exploration has been under way for some time but no traces of oil have been reported. This relative lack of petrochemical raw materials accounts for the difficulty of starting any petrochemical production.

The forecasts of the consumption in 1980 are shown in table 25. El Salvador may expect a marginally higher demand for high-tonnage plastics, while the demand in Panama in 1980 will be marginally lower than the average for all the six countries. The level of consumption expected in 1980 is not sufficient to justify any significant development of petrochemical production in any of these countries on an individual basis, unless there is some possibility of export. However, given some active interest in mutual co-operation, the combined demand of these countries would justify a medium-size naphtha steam cracker, along with the ancillary chemical and plastics plants.

Nicaragua already has some facilities for the production of petrochemicals. There is a PVC plant with a capacity of 10,000 tons per year utilizing imported vinyl chloride. The facilities proposed for Nicaragua in table 27 are actually in the planning

TABLE 27. CENTRAL AMERICA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Guatemala		
Polyamide chips and fibres	3	10.5
Polyester fibres	3.5	3.0
	Subtotal	13.5
Nicaragua		
Naphtha steam cracker	100 ethylene	19
Vinyl chloride	20	4.5
HP polyethylene (in two stages)	30 first stage	20
	30 second stage	17
PVC	20 (increase of 10)	5
Polypropylene	10	12
	Subtotal	77
	Total	91

stage now. The development of the production of petrochemicals in Nicaragua does not rely on the local market but is oriented towards exporting. The Nicaraguan complex would rule out the possibility of any additional petrochemical production in the subregion, for Nicaragua could easily supply the requirements of the other Central American countries. The only other justifiable possibility would be for Guatemala to establish small units as indicated in table 27 for the manufacture of polyester fibres from imported chips, and polyamide chips and fibres from imported caprolactam. Under the circumstances it is not realistic to formulate any proposals for the development of the petrochemical production in any of the other countries of this subregion.

Mexico

The position of Mexico is, in many respects, substantially different from that of the other countries in Middle America. With an annual production of 24 million tons of crude oil and 15 billion cubic metres of natural gas, Mexico has a wide base for petrochemical development. Indeed, considerable development has already taken place; the Mexican petrochemical industry is one of the most advanced among the developing countries. While private investment is encouraged in the production of intermediate and end products, the production of primary products is in the hands of a state organization, Petróleos Mexicanos (PEMEX). PEMEX has an investment of more than $250 million in petrochemicals, and its plants produced over 800,000 tons of petrochemicals in 1967.

The production facilities currently available or being built cover a wide range of products and processes. Besides those shown in table 28, there are (thousand tons per year): toluene, 100; cyclohexane, 85; detergent alkylate, 46; *o*-xylene, 15; and *m*- and *p*-xylenes, 38.

By 1980 Mexico is expected to be the second largest consumer of petrochemical products among the developing countries (table 25). A substantial demand is also expected for some other end products not included in table 25. For these and for certain intermediates, the demand levels expected in 1980 are (thousand tons per year): ethylene oxide, 80; ethylene glycol, 25; vinyl acetate, 30; acetic acid, 55; phthalic anhydride, 55; phenol, 30; acetone, 16; 2-ethyl-hexanol, 35; SBR, 172; and BR, 80.

The demand forecast for 1980 is quite impressive and would justify a substantial increase in the scale of petrochemical production in the country. The production capacity required to meet the expected demand is set against the available capacity in table 28 to arrive at the additional capacity required.

As shown in table 28, the expansion of the current petrochemical capacity to meet the domestic demand in 1980 will require an investment of $399 million. Mexico may be in a position to export petrochemicals to other countries in the area. In 1970, for example, 29,000 tons of benzene out of a total domestic production of 77,000 tons were exported. If export prospects were taken into account, the projected petrochemical development would be even more substantial.

TABLE 28. MEXICO: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Product	*Capacity (thousand tons per year)* Existing in 1970	Planned or being built	Proposed for 1980	*Investment needed for increase*[a] *(million dollars)*
Ethylene (and coproducts)	60	180	180	30
Propylene	117	110	110[b]	
Butadiene	–	55	145[c]	8
Benzene	110	43	60	22
Acetic acid	42	–	25	3
Styrene	30	–	85	13
Vinyl chloride	20	70	180	24
Ethylene oxide/glycol	–/9	28/–	50/17	12
Phenol/acetone	0.5/–	–	25/16	7
Caprolactam	–	40	20	14
2-Ethyl hexanol	. . .	–	30	13
HP polyethylene	75	50	120	58
LP polyethylene or Polypropylene	– / –	40 / –	150 or 100	60
PVC	30	–	170	25
Polystyrene	16	–	60	10
Acrylic fibres	16	9	–	–
Polyester fibres	9	–	12	14
BR, SBR	70	–	70	26
			Total	339

[a]The investment costs given are for the increases in capacity required by 1980 and are not related to the capacities being built or planned.

[b]The figure given is the new capacity at the engineering stage, which can be satisfied from ethylene production; thus no additional investment has been included.

[c]Total butadiene required is 200,000 tons. Since the ethylene plants would produce a maximum of 75,000 tons per year, other routes would be required for the production of the balance, e.g. dehydrogenation of butane.

West Indies

Trinidad and Tobago is the only country in the West Indies with significant petroleum resources. Cuba and the Dominican Republic also have some production, apparently.[14] The Caribbean area offers important advantages to refineries located there: the supply of crudes in impressive quantity from Venezuela and, to a lesser extent, from Trinidad; the convenience of shipping export products both to the Americas and to Western Europe. Petroleum products are produced in Jamaica from imported crudes for both the domestic and export markets. The three sites having refinery operations for the longest time–Aruba, Curaçao, and Trinidad–have plants that are among the largest in the world. Both Aruba and Curaçao, enjoying the favourable treatment accorded to the overseas territories of the Netherlands, have tariff advantages with the European Economic Community (EEC). Trinidad and Tobago have similar advantages when exporting to the United Kingdom and to other Commonwealth countries. Similarly, there are no trade barriers between Puerto Rico and the United States. Other islands in the area have certain advantages in their trade with various European countries to which they are or have been connected.

One feature the West Indian countries have in common is their narrow domestic market for petrochemicals (see table 26). The forecasts of probable consumption in 1980 show that the Dominican Republic, Jamaica and Trinidad and Tobago can expect a very modest domestic demand. The demand expected in the other countries in the subregion is still lower.

The existing petrochemical capacity is quite large in relation to the size of the domestic market expected in 1980. In addition to the capacities noted in parentheses in table 26 the area also has facilities for the production of (thousand tons per year): ammonia, 820; urea, 150; oxo alcohols, 215; phthalic anhydride, 85; styrene, 200; ethyl alcohol, 450; cyclohexanol, 75; xylenes, 370.

It seems that the Netherlands Antilles, Puerto Rico and Trinidad and Tobago are best placed for further petrochemical development. It is not, however, possible to forecast the growth of petrochemical production in these countries without undertaking detailed forecasts and marketing studies for the developed countries to which they have easy access.

South America

Most countries in South America have oil and gas reserves to dispose of, and a few have already developed the production of petrochemicals on a substantial scale. Petroleum and natural gas are found in considerable quantities in Argentina. Substantial reserves of natural gas exist in Bolivia, and petroleum has been found in large quantities there in a broad area east of the Andes. In fact, this area is potentially the largest oil field in South America, and oil may soon surpass tin as Bolivia's largest export item. Bolivia has recently entered into a 20-year agreement to supply natural gas to Argentina. Brazil also has great petroleum reserves but does not make full use of them. Colombia is the fourth biggest producer of petroleum in Latin America after Venezuela, Mexico and Argentina. Ecuador has large petroleum

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[14] *World Petroleum Report* (1969).

resources. Oil constitutes Peru's most valuable non-metallic product, while Venezuela is the world's third largest oil producer and disposes of large quantities of natural gas. Explorations have been under way in Guyana and Uruguay, but no important petroleum deposits have been reported.

Argentina

The development of petrochemical activity in Argentina goes back to 1944 when plans were set in motion for the establishment of isopropanol facilities.[15] Since Argentina annually processes about 20 million tons of crude oil and produces over 7 billion cubic metres of natural gas, further development of the petrochemical industry has a promising base to build upon.

The current production of organic chemicals includes a wide range of products, many of which are made from petrochemical raw materials. There are some 3,600 plants engaged in chemical production[15] but most of these are small scale and can operate profitably only behind protective barriers. The liberalization of import policy has exposed them to world competition so that now there is new interest in the development of a viable petrochemical industry. As shown in table 25, the level of demand expected in 1980 is certainly high enough to justify a vigorous development of this sector. In fact, Argentina will have the third highest consumption in the region after Brazil and Mexico. Besides the plastics and fibres in the table, the demand in 1980 will include (thousand tons per year): ethylene glycol, 15; ethylene oxide, 30; acetic acid, 45; phthalic anhydride, 40; phenol, 20; acetone, 14; and 2-ethyl-hexanol, 25. Since there is no production of natural rubber, a demand for synthetic rubber of about 80,000 tons per year could also be expected by the end of the decade.

Table 29 summarizes the production prospects for petrochemicals in Argentina during the 1970s.

It is planned to obtain much of the ethylene from C_2 and other sources in natural gas. This is an encouraging sign since the ethylene/propylene ratio of the expected demand is unusually high. Much of the present output of propylene for the current production of isopropyl alcohol, acetone and various solvents, is derived from the C_3 stream in the gases from the refinery crackers. The extra requirement can readily be obtained from a naphtha steam cracker supplying part of the ethylene; the capital costs are included under the costs of the facilities for ethylene production.

In the existing plant, phenol is made by the chlorination of benzene. It is probably best to use the same route in the new facilities; otherwise, the acetone available would be out of balance.

The situation of synthetic chips and fibres is slightly complicated—both nylon 6 and nylon 66 are being produced. However, the fact that a caprolactam plant is under study indicates that current thinking tends towards nylon 6.

Argentina would appear to offer plenty of scope for petrochemical development. The tentative suggestions given in table 29 involve an investment of over $300 million by the end of the decade.

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[15] C. Zarate and others, "Industria Química Argentina, Año 1967", presented to the IVth Inter-American Congress of Chemical Engineering, Buenos Aires, 1969.

TABLE 29. ARGENTINA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Product	Capacity (thousand tons per year)			Investment needed for increase (million dollars)
	Existing in 1970	*Planned or being built*[a]	*Proposed for 1980 (total)*	
Ethylene	42	153 (75)	319	48
Propylene	...	...	51	*b*
Butadiene	30	35	60	–
Benzene	98	52	133	20
Methanol	28.5	–	–	
Formaldehyde	32.5	–	–	
Acetaldehyde	–	40	–	
Styrene	16	2	83	10
Vinyl chloride	32	54.5 (50)	130	11.5
Vinyl acetate	20.4	–	–	
Ethylene oxide/glycol	–	15/20	–	
Propylene oxide/glycol	–	10/10	–	
Acrylonitrile	–	(5)	–	
Phenol	8.5	–	20	15
Acetone	22	–	–	
Chlorinated solvents	11.1	68	–	
Cyclohexane	–	28	38	1
Caprolactam	–	(35)	35	28
Phthalic anhydride	10.7	–	–	
Isopropyl alcohol	24	–	14	
Polyethylene	25	60	140	43
Polypropylene	1	(7)	26	22
PVC	46	41	120	14
Polystyrene	13.2	5.8	60	8
Acrylic fibres	–	3.6	–	
Polyamide chips	4.8	8	33	55
Polyamide fibres	13	–	30	*c*
Polyester chips and fibres	7.7	14	24	15
BR/SBR	–/37	(10)/–	–/33	15
Detergent alkylate	–	15	–	
			Total	306

[a]The figures in parentheses refer to projects that are only at the study stage.
[b]Capital costs are included with those for ethylene.
[c]Capital costs are included with those for polyamide chips.

Bolivia

Bolivia has modest resources of crude oil but quite substantial reserves of natural gas. Along with the development of the petroleum industry in the 1960s, the Government has continuously paid attention to petrochemicals. Following the practice that has proved quite successful in other South American countries, for example, Brazil and Mexico, the Government placed the development of petrochemicals in the hands of the State Oil Company. Looking at the domestic market, however, the outlook for petrochemicals is not very bright, for only a fertilizer project seems justified. By 1980 the country can expect only a fairly small consumption of petrochemicals (table 25), insufficient to justify any petrochemical production. One possibility would be polymer production with a small PVC plant based on imported vinyl chloride. In view, however, of the topography and the difficulty of communications, such a project would hardly prove attractive.

The regional petrochemical agreement signed by the Andean countries (Bolivia, Chile, Colombia, Ecuador and Peru) is intended to promote the balanced development of the petrochemical industry, the installation of plants of optimum size to take advantage of economies of scale, and the attainment of levels of efficiency and productivity that will lead to competitive products at competitive prices in world markets; it opens up some new possibilities for the entrance of Bolivia into the field of petrochemicals. It is reported that agreement has been reached among the Andean countries with respect to the production of specific petrochemicals; this augurs well for the development of petrochemical production in all the participating countries.

Brazil

Like Argentina and Mexico, Brazil has an output of petrochemicals that meets a high proportion of the domestic demand for basic chemical products.[16] Brazil, however, differs from Argentina in that its petrochemical development is mainly state controlled. PETROBRAS (Petróleo Brasileiro S.A.) is the state organization responsible for the production, refining and supply of petroleum products and natural gas; the petrochemical development itself is encouraged by another state organization known as GEQUIM (Executive Group of the Chemical Industry), although a substantial part of the petrochemical industry is in the hands of the private sector.

Crude oil is produced mostly in the State of Bahia. The total refinery capacity in Brazil, 9 million tons per year, is sufficient to refine not only this but also some imported crude. The production of natural gas is slightly over 12 million cubic metres per year. A large number of petrochemical plants are in operation, producing a wide range of products. Many other plants are under construction with the approval of GEQUIM; still others await approval. As shown in table 25, Brazil is expected to be the largest consumer of petrochemicals in Latin America in 1980; the expected domestic demand alone would justify a marked development of this sector.

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[16] Although Trinidad and Tobago could be included in this group, it is in a different and almost unique position in the region, since its petrochemical industry produces mainly for export, and its chemical industry still manufactures intermediate products on a very small scale.

Table 30 summarizes the petrochemical situation of Brazil with respect to actual production capacity; planned capacity increase; capacity that will be required to satisfy the level of demand expected in 1980; and estimates of the investment costs that will be required for the installation of additional capacity. The proposals advanced in the table have been limited to the most important petrochemicals and entail a capital cost of $680 million. Depending on the possibility of developing petrochemical exports on the one hand, and of manufacturing other products for home use on the other, the total investment requirements during this period could be substantially higher.

TABLE 30. BRAZIL: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

	Capacity (thousand tons per year)				
Product	*Existing in 1970*	*Planned*	*Proposed for 1980 (total)*	*Increase required*	*Investment required (million dollars)*
Ethylene and coproducts	30	370	485	455	70 (Ethylene, Propylene, Butadiene)
Propylene	...	...	121	[a]	
Butadiene	...	...	150	[a]	
Aromatics		40			
Benzene	30		208	178	30 (Benzene, o-Xylene, p-Xylene)
o-Xylene	40		60	20[b]	
p-Xylene	–		45	45	
Methanol	–	77	40	77	9[c]
Styrene	16	90	115	99	20
Vinyl chloride	–	–	150	150	14
Ethylene oxide	–	40	70	70	14
Acrylonitrile	–	15	25	25	10
Phenol	8	–	54	46	14
Cyclohexane	–	–	75	75	1
Caprolactam	–	–	70	70	60
Phthalic anhydride	5	10	60	55	15
HP polyethylene	20	152	184	164	57
LP polyethylene or Polypropylene	– / –	32 or 15	50	50	33
PVC	44.5	–	150	106	18
Polystyrene	30	30	80	50	9
Polyamide (nylon 6) chips and fibres	–	–	60	60	190

Product	Capacity (thousand tons per year) Existing in 1970	Planned	Proposed for 1980 (total)	Increase required	Investment required (million dollars)
Polyamide (nylon 66)	20	–	20	–	...
Polyester chips and fibres	–	–	60	60	65
BR	...	–	56	est. 50	38 (BR and SBR)
SBR	...	–	112	est. 100	
Thermosetting resins	...	–	80	est. 40	13
				Total	680

[a]Included with ethylene. By normal cracking the butadiene would not be sufficient; however, there is already a plant for dehydrogenation of butane.

[b]This is insufficient for the proposed phthalic anhydride production. Some o-xylene may have to be imported or some phthalic anhydride made from naphthalene.

[c]The investment shown is for the capacity at the planning stage.

Chile

The supplies of crude oil and natural gas in Chile are in the south, both on the mainland and on the island of Tierra del Fuego. Prospecting for additional hydrocarbon resources is under way in other parts of the country. The existing refinery capacity of 4–5 million tons per year is quite adequate for supplying raw materials for the petrochemical industry. Chile is signatory to the regional petrochemical agreement mentioned above in the section on Bolivia.

The petrochemical installations in Chile in the mid-1960s made end products: chemical solvents, resins, polystyrene, synthetic detergents etc. In that period the Production Development Corporation (CORFO) began to study a possible development programme for the Chilean petrochemical industry. CORFO, in association with the National Petroleum Enterprise (ENAP), an agency entrusted with prospecting for and exploitation of the petroleum resources of Chile, created an affiliate, Petroquímica Chilena, with the object of ensuring the development of the petrochemical industry. At the end of 1970 Chile had recorded substantial progress in this direction. Installed capacities included (thousand tons per year): ethylene, 60; polyethylene, 20; PVC, 15; polystyrene, 35; thermosetting resins, 10; polyester fibres, 4; polyamide fibres, 5; polyamide chips, 6; and various amounts of some other products, such as chlorine, vinyl chloride, phthalic esters and mixed xylenes.

Petroquímica Chilena is currently implementing a modest but comprehensive development programme for the petrochemical industry. The plants and processes included in this programme constitute only the basis for what the Chilean petrochemical industry is expected to be in a few years. Table 31 gives in summary form petrochemical plants and capacities figuring in the current plan and sets them against the estimated consumption for 1980 of the relevant petrochemicals to determine the additional production facilities required by the end of the decade.

TABLE 31. CHILE: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)* *Existing or planned*	*Increase required*	*Investment (million dollars)*
Naphtha steam cracker	60 ethylene 40 propylene	50 12	30
Formaldehyde from imported methanol	25	–	2
Chlorine/caustic soda	33/37	–	5
Vinyl chloride from ethylene	18	25	10
Vinyl acetate from ethylene	20	–	5
Oxo process from propylene	17 2-ethyl hexanol 2.5 *n*-butanol 7 isobutanol		15
Polyethylene	20	30	35
Polypropylene	–	10	12
PVC	15	20	12
Polystyrene	3.5	10	3
Polyamide chips and fibres	5 fibres	3	10.5
Polyester chips and fibres	4 fibres	10	11
Thermosetting resins	10	est. 10	6
			159

No additional chlorine capacity has been allowed for, since that already planned is sufficient for the expansion of the vinyl chloride plant, provided the oxy-chlorination route is used. Similar considerations apply to the plants planned for vinyl acetate, oxo alcohols, detergent alkylate and formaldehyde. If the 2-ethyl hexanol is produced at the rated capacity of the oxo alcohol plant, there will be enough of it to make the plasticizer for all the PVC needed in 1980.

Colombia

With an annual production of 10 million tons of crude oil and 1.4 billion cubic metres of natural gas, Colombia has ample supplies of raw materials for a substantial petrochemical industry. The production facilities for petrochemical products include (thousand tons per year): PVC, 13; vinyl chloride, 8; PF, 4; polystyrene, 3; nylon 6, 5.4; polyester, 8.5; acrylics, 2.8.

Colombia is a party to the agreement reached among the Andean countries for close co-operation in the development of petrochemical production. Its immediate neighbours to the south, Ecuador and Peru, have substantial oil reserves and are also eager to develop petrochemicals. It would be possible for Colombia to set up a main cracking plant and sell early-stage intermediates to Ecuador, and perhaps Chile, for processing into finished products. A naphtha cracker producing 150,000 tons per year of ethylene will be feasible in Colombia by 1980 provided certain products are diverted to the neighbouring countries.

A plant for the production of benzene could also be set up by the end of the decade. The estimated requirement for benzene in the Andean countries in 1980 is 135,000 tons, i.e. 5,000 tons in Chile, 60,000 tons in Colombia and 70,000 tons in Peru. Allowing for some increase in demand in the other countries and for uses not taken into account in the above estimates, a reformer with an annual capacity of 150,000 tons of benzene is indicated. This reformer could be sited in Colombia, perhaps near one of the refineries, since a special fraction would be needed to give the best yield of benzene without at the same time producing too much toluene and xylene, for which there would be no ready outlets in the subregion. Colombia already has a project for the production of 40,000 tons of benzene.

Many other petrochemical projects are either being planned or built. Table 32 summarizes data relating to the possibilities of the production of petrochemicals in

TABLE 32. COLOMBIA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Naphtha steam cracker	150 ethylene (increase of 134) 90 propylene 30 butadiene	24
Naphtha reformer with dealkylation	150 benzene 20 toluene	35
Styrene	50	10
Vinyl chloride	70	9
Vinyl acetate	20	6
Ethylene glycol	20	43
HP polyethylene	40 (increase of 22)	16
LP polyethylene or Polypropylene	25 or 14	15
PVC	50	11
Polystyrene	20	4
Detergent alkylate	30	6
	Total	179

Colombia and gives estimates of the additional investment required for the plants that may be justified if part of their production can be exported to the neighbouring countries.

No facilities for the production of synthetic fibres have been included in the table, the rationale being that it may be in the country's interest to import its requirements of fibres from larger plants located in the subregion (possibly in Ecuador), as a *quid pro quo* for supplying other countries with the products it will be manufacturing itself in larger quantities.

Ecuador

Ecuador has an annual production of 200,000 300,000 tons of crude oil and is very interested in developing a petrochemical industry. The low level of expected demand (table 25) would not on its own justify much development of the petrochemical industry, but the prospects for the industry appear in a different light when seen in the perspective of the Andean petrochemical agreement and the market pooling it entails. Within the context of this agreement, Ecuador proposes to erect diverse facilities for the production of petrochemicals within its own borders. The establishment of an LP polyethylene plant with a capacity of 20,000 tons per year may be envisaged by the end of the decade. The ethylene input could be obtained from Colombia or Peru and the plant could be supported by policy measures designed to stimulate the use of LP polyethylene. Indeed, some of the output could be exported to any Andean country that does not have similar production facilities.

The production of synthetic fibres based on imported raw materials can also be envisaged, again with part of the output being diverted to neighbouring markets. Both polyester and polyamide could be produced by the end of the decade. The petrochemical projects that appear feasible in Ecuador, their capacity and the investment costs they would entail are summarized in table 33.

TABLE 33. ECUADOR AND PERU: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*		*Investment (million dollars)*
Ecuador			
LP polyethylene	20		15
Polyamide chips and fibres	12 fibres (in four units)		40
Polyester chips and fibres	12 fibres (in three units)		14
		Total	69
Peru			
Naphtha steam cracker	120 ethylene 60 propylene 20 butadiene		22
Styrene	25		7

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Vinyl chloride	55	9
Phenol/acetone	20/13	6
Caprolactam	25	22
HP polyethylene	50	27
LP polyethylene or Polypropylene	36 or 25	22
PVC	50	11
Polystyrene	18	5
Polyamide chips and fibres	20 fibres	65
Polyester chips and fibres	5 fibres	8
BR/SBR	8/16	12
	Total	216

Peru

Peru produces some 3.5 million tons of crude oil annually but has only limited gas associated with the crude. With its long coastline and its population of over 11 million, it is in a much better position for the production of petrochemicals than many of the other small countries in the region.

Excluding ammonia, of which there is a substantial production, Peru has no facilities for the production of petrochemicals. The demand forecast for 1980 is quite substantial for a country the size of Peru and may justify sizable production facilities on the basis of the country's internal market alone (table 25).

As a party to the Andean agreement, Peru is co-operating with its neighbours in the development of petrochemical production in the subregion. It can expect to derive substantial benefits from the enlarged market available to it as a result of this arrangement. A cracker to produce ethylene and other petrochemicals would seem justified by 1980. Table 33 gives details regarding the output and capital costs of these projects. Other production possibilities may also merit close consideration, especially if output levels in excess of local demand are planned, the assumption being that part of the output will be diverted to the other Andean countries. It is further assumed that some petrochemical products will move in the opposite direction; thus, Peru could obtain its requirements of benzene and other aromatics, DMT, ethylene, glycol, acrylic fibres and thermosetting resins from other countries in the Andean subregion.

Uruguay

Uruguay has no production of oil or natural gas; this lack of primary raw materials dims the prospects for petrochemical production in the near future.

Uruguay does have a modest capacity for the production of polyamide fibres (nylon 6 and nylon 66), however. Furthermore, the development of the petrochemical industry is considered necessary, since full advantage is already being taken of the possibilities of expansion in other fields, and imports of petrochemical products have an appreciable effect on the national economy. Although situated between two countries with relatively large markets, Argentina and Brazil, Uruguay has limited possibilities of penetrating these markets because of its tendency towards vertical integration of production and consequently towards self-sufficiency. Separated geographically from the Andean Group, Uruguay cannot expect to benefit from their market integration, either, and, at any rate, has limited opportunities for success in these markets in view of the transportation costs involved. If, however, the evolution of regional integration towards the establishment of a common market takes into account the need for balanced industrial development, Uruguay may hope to see a petrochemical project established within its borders. The possibilities outlined below are based on the assumption that Uruguay will probably not have access to other markets in the subregion and may have to rely on its domestic market.

The manufacture of PVC on a small scale of perhaps 6,000 tons per year may be considered, but it would probably be cheaper to import this product. A plant for the production of LP polyethylene might become viable if it is supported by policy measures designed to attract some users of PVC to domestically produced polyethylene. Although it is sometimes possible to substitute LP polyethylene for PVC in some applications, the difficulty of achieving such a substitution should not be overlooked in such a relatively sophisticated economy as that of Uruguay. Nevertheless, a plant for the manufacture of 15,000 tons per year of LP polyethylene can be envisaged. The capital costs of the plant would be about $12 million and the output could, if desired, be changed to polypropylene at 9,000 tons per year. Another possibility would be the local production of a small quantity of polyester fibres from imported chips; the investment requirements for a capacity of 3,500 tons per year would be $3 million.

Venezuela

With an annual output of about 2 billion tons of crude, Venezuela ranks as one of the top oil producers in the world. The production of natural gas is about 8 billion cubic metres. Venezuela has large refineries and ample sources of naphtha. There is thus a solid base for the development of the petrochemical industry in the country. Considerable petrochemical production facilities already do exist in the country.

The development of the petrochemical industry is the responsibility of the Instituto Venezuelano de Petroquímica (IVP). The existing petrochemical production covers a wide range of products. In addition to explosives and fertilizers, there are plants for the production of dodecyl benzene, phthalic anhydride, polyethylene, vinyl chloride, PVC, polystyrene etc. Many other plants are at various stages of planning or construction. When these are completed, the capacity will be (thousand tons per year): ethylene, 150; propylene, 90; vinyl chloride, 50; PVC, 25; polystyrene, 10; detergent alkylate, 15; phthalic anhydride, 5.

The above capacity appears sufficient to satisfy the volume of demand expected in 1980, when the consumption of the major petrochemicals will reach the levels shown in table 25. In addition to these, Venezuela may also expect a demand for synthetic rubber of about 30,000 tons per year by 1980.

The development of the petrochemical industry will probably be limited to relieving the shortfall in capacity: the PVC capacity could be doubled; the bottleneck in which the vinyl chloride plant would be caught could be overcome; polystyrene capacity could be doubled. In the current plans, no mention is made of a styrene plant, the idea probably being to import styrene. However, in view of the ethylene availability and the low cost of importing benzene, a styrene plant could be envisaged by the end of the decade. A plant for the production of LP polyethylene can also be recommended. Venezuela is the only developing country known to be planning a polyisoprene plant. Although there is no mention of an isoprene plant, Venezuela, with such good sources of oil fractions, should not have to import isoprene. Isoprene could in fact be obtained from the surplus propylene by dimerization, isomerization and selective cracking. The naphtha cracker being planned will produce some 25,000 tons per year of butadiene. A BR/SBR plant of similar capacity can therefore be envisaged. Such a plant would provide an additional load, although a small one, for the styrene plant. The expected demand does not warrant the production of raw materials for synthetic fibres, but the production of these fibres from imported starting materials can be justified.

Table 34 summarizes the proposed petrochemical production in Venezuela by 1980.

TABLE 34. VENEZUELA: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Naphtha steam cracker	150 ethylene 90 propylene 25 butadiene	26
Styrene	28	7
Vinyl chloride	55	8
Isoprene	65	30
Polyisoprene	60	20
HP polyethylene	50	27
LP polyethylene or Polypropylene	25 or 15	15
PVC	50	11
Polystyrene	20	4
Polyamide chips and fibres	10	30
Polyester fibres	10	12
BR SBR	28	12
Detergent alkylate	15	3
	Total	205

Other countries

In addition to the countries already discussed, demand forecasts were also made for some smaller countries in the South American subregion, namely Paraguay and French Guiana, Guyana and Surinam, the last three taken as a unit. The actual consumption of petrochemical products is small and the estimated demand for 1980 does not indicate much change (table 25). The demand expected in any individual country is far below the minimum required to justify the establishment of the smallest viable units. Besides, none of these countries have any resources of crude oil or natural gas, although exploration work is actively pursued in, for example, Guyana. The prospects for the development of any petrochemical production in these countries during this decade do not seem very bright.

Chapter 6

MIDDLE EAST

The Middle East produces more crude oil than any other region of the world. Its reserves of crude oil, approximately 32 billion tons, constitute 60 per cent of the proven world oil reserves. In addition, it is estimated that more than one third of the proven world natural gas reserves are located in the Middle East.[17]

The utilization of this enormous wealth is, at present, confined almost exclusively to extraction and shipping. Whatever chemical conversion is done is restricted to the oil refining and fertilizer industries. Petrochemical industries have not as yet been developed, but some are being planned. In evaluating these plans, it is important to review the present stage of development of the relevant infrastructure in the region, including pipelines, refineries, and gas-processing, fertilizer and power plants.

The refining capacity available in this region amounts to less than 5 per cent of the world's refining capacity. A number of the existing refineries cannot, however, be regarded as petrochemical plants at present.[18] The gas-processing plants exist mainly to purify the gas for use as a source of energy or as a raw material for fertilizer production. Plans exist, however, for the establishment of facilities for supplying liquefied gas to regions of the world where it can be used in this form.

If during the 1970s at least twenty different intermediate and end products could be developed, a Middle East common market in petrochemicals (like the one in iron and steel achieved twenty years ago in Europe) might emerge.

The actual market for petrochemicals in the Arab countries included in this region is at present estimated at 60,000 tons per year, approximately 0.24 per cent of the total world production. Assuming a population of approximately 30 million, this means a consumption of 2 kilogrammes *per capita*. The 1980 consumption estimates for the larger petrochemical markets in the region are summarized in table 35.

The table shows that the Arab countries in the region can look forward to a fairly substantial demand for petrochemicals. At least two alternatives present themselves to these countries so far as the future development of petrochemical industry is concerned. If there is a high degree of co-operation and co-ordination, the total demand position in the area would justify the erection of a petrochemical complex in a favourable location with regard to both the supply of inputs and the

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[17] The Middle Eastern countries covered in this study are Iraq, Israel, Jordan, Kuwait, Lebanon, Saudi Arabia, the Syrian Arab Republic and Turkey.

[18] *Annual Statistical Bulletin* (Vienna, Austria, Organization of Petroleum Exporting Countries, 1967), p. 49.

TABLE 35. MIDDLE EAST: FORECASTS OF PETROCHEMICAL CONSUMPTION IN 1980

(Thousand tons)

	Plastics			*Fibres*		
	Poly-ethylene	*PVC*	*Poly-styrene*	*Acrylic*	*Polyamide*	*Polyester*
Arab countries						
Iraq	10	10	4	1.0	3	3
Jordan	3	6	1.0	0.3	0.8	1.0
Kuwait	1	1.5	1.4		1.2[a]	
Lebanon	15	20	7	0.4	8.6	9
Saudi Arabia	5	5	1.0	0.2	0.9	1.0
Syrian Arab Republic	8	8	1.2	0.2	5.5	6
Subtotal	42	51	16	2	20	20
Variant I[b]	87	91	22	4	20	45
Others						
Israel	45	45	18	3	11	16
Turkey	65	60	25	17	26	33
Subtotal	110	105	43	20	37	49
Total	152	156	59	22	57	69

[a] Includes acrylic and polyester fibres.

[b] Variant I = the Arab countries listed plus Egypt.

access to surrounding markets. The intermediates costing the least to transport could be made at the complex and transported to other countries in the region for polymerization, conversion to fibres or transformation into other chemical products. Alternatively, each country with a fairly sizable market could proceed independently with the manufacture of one selected thermoplastic raw material or synthetic fibre. In view of the technical possibilities for substitution among both thermoplastics and synthetic fibres in many of their usual applications, this selection will normally be based on economic considerations.

A joint approach would be the more desirable alternative because of the greater economies and the better utilization of by-products that could be achieved in an integrated complex. The countries concerned are well aware of the possible benefits from such co-operation and have already expressed the need for the development of a petrochemical policy.[19, 20] The guidelines that have been established for the future development of petrochemicals in Iraq attest to the interest there in co-operative development. These include *(a)* the erection of plants capable of satisfying not only the home market but also the markets of all the neighbouring Arab countries; *(b)* the production of only those intermediates that are cheapest to transport; and *(c)* the encouragement of joint ventures and public ownership, with a view to building economic links between the Arab countries.

In making proposals for future petrochemical production, two variants are put forward here: Variant I, based on the assumption that there will be regional co-operation in the establishment of a petrochemical complex; and Variant II, based on the assumption that individual countries will develop their petrochemical production independently. Table 36 summarizes the production proposed for 1980.

Variant I includes Egypt in the development of the complex. Although normally classified with the African region, Egypt has many affinities with the Middle Eastern countries and could be considered together with these as well as with its less-developed neighbours on the African continent.

If the consumption estimates for Egypt are taken into account, the total demand for the petrochemical complex of Variant I would be significantly increased. The joint annual demand would then be about (thousand tons per year): polyethylene, 87; PVC, 91; polystyrene, 22; polyamide fibres, 20; polyester fibres, 45; acrylic fibres, 4; thermosetting resins, 30; synthetic rubber, 25. The demand for polypropylene is negligible for individual countries, but might well develop to 10,000 tons per year for the whole group. The consumption of other countries in the area has not been included in these estimates. These countries may well provide additional markets so that the quantities given above may be treated as minimum volumes and plans could be made for a slightly larger production.

The plants that could make up this complex, their output and their capital cost requirements are summarized in table 37. The figure given there for the cost of the Variant I complex, $474 million, does not include the cost of supply installations and supporting infrastructure.

In Variant II only three countries are considered, Iraq, Lebanon, and the Syrian Arab Republic. For Iraq, production of polyethylene from its own ethylene and of synthetic fibres from imported raw materials is feasible. Lebanon, with no oil of its own, is a pipeline terminal and has easy access to it. The existing refineries could stimulate the development of the basic petrochemical industry. Lebanon has the added advantage of having a relatively high degree of technical competence. In the Syrian Arab Republic, ethylene production could be developed out of local gas sources. Part of the output would have to be diverted to neighbouring countries, e.g. Lebanon. Production of PVC and polyamides could also be expected by the end of the decade. Latest reports indicate that the Syrian Arab Republic is considering petrochemical projects for the production of (thousand tons per year): ethylene, 40; polyethylene, 25; PVC, 25; and acrylonitrile, 10. The feasibility of these projects is yet to be determined.

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[19] *Report of the Symposium on Industrial Development in Arab Countries*, Kuwait, 1-10 March 1966 (ID/CONF.1/R.R./4).

[20] Organization of the Petroleum Exporting Countries, "Petrochemical industries development in the OPEC and other Arab countries", background paper submitted to the symposium referred to in footnote 19 above (CIDAC.KUW/II/OPEC-29).

TABLE 36. MIDDLE EAST: PROPOSED PETROCHEMICAL PRODUCTION BY 1980—SUMMARY BY SUBREGION

	Production (thousand tons per year)							
	Ethylene	*Benzene*	*Poly-ethylene*	*PVC*	*Poly-styrene*	*Polyamide fibres*	*Polyester fibres*	*Total Investment (million dollars)*
Arab countries								
Variant I[a]	170	120	90	70	15	30	45	474
Variant II[b]	80	–	57	44	–	18	19	252
Iraq	15	–	14	10	–	3	3	75
Lebanon	40	–	20	24	–	9	10	82
Syrian Arab Republic	25	–	23	10	–	6	6	95
Others								
Israel	200	–	80	78	24	12	17.5	199
Turkey	180	–	110	80	30	30	35	397
Subtotal	380		190	158	54	42	53	596
Total with Variant I	550	120	280	228	69	72	98	1,070
Total with Variant II	460	–	247	202	54	60	72	848

[a]Variant I = the Arab countries listed in table 35 plus Egypt.

[b]Variant II = the three Arab countries listed here.

TABLE 37. ARAB COUNTRIES (VARIANT I): PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons per year)*	*Investment (million dollars)*
Naphtha steam cracker	170 ethylene 100 propylene 40 butadiene	28
Reforming of naphtha and extraction of pyrolysis gasolene, with dealkylation	120 benzene 15 toluene 70 mixed xylenes	28
p-Xylene	40	15
Methanol	50	6
Chlorine/caustic soda	50/60	8
Oxygen	40	5.5
Ammonia	100	15
Styrene	25	6
Vinyl chloride from ethylene	75	10
Ethylene oxide/glycol	10/20	44
Acrylonitrile	30	12
Phenol/acetone	20/13	7
Cyclohexane	45	1
Caprolactam (oxime route)	40	30
HP polyethylene	50	30
LP polyethylene or Polypropylene	40 or 28	22
PVC	70	14
Polystyrene	15	5
Polyamide chips and fibres	30 fibres	100
Polyester chips and fibres, including DMT	45 fibres	70
BR/SBR	10/20	13
Detergent Alkylate	20	4
	Total	474

Kuwait and Saudi Arabia could also embark on some modest petrochemical projects by the end of the decade if they can find a ready export market. Kuwait is seriously considering a project for the production of ethylene (400,000 tons per year) for export markets, while Saudi Arabia is studying the feasibility of a plant with production of 60,000 tons per year of PVC.

The two remaining countries in this region for which consumption forecasts have been given in table 35, Israel and Turkey, clearly stand out as potential major producers of petrochemical products on the basis of their internal demand alone. Turkey produces some 4 million tons of crude oil per year; there is substantial oil refining in both Israel and Turkey. There are plans for petrochemical complexes; some plants already exist while others are in the course of erection or expected to come on stream shortly.

Israel has the facilities for the production of formaldehyde, paraformaldehyde and synthetic fibres. A methanol plant with a capacity of 50,000 tons per year utilizing naphtha as raw material is under consideration. It would use the ICI (Imperial Chemical Industries, Ltd.) low-pressure process, which is supposed to produce methanol in a medium-size plant at a price competitive with that of methanol produced in a large-scale plant. Since the designed capacity is five times the 1969 demand of methanol, a large part of the production will have to be diverted into exports.

The forecast domestic demand is sufficient to justify the establishment in Israel of substantial production capacity of other petrochemicals by the end of the decade. The plants that could be included in such a production complex are presented in table 38. Table 39 summarizes the same information for Turkey. Many of these plants could be erected in two or more stages. Rather liberal allowances have therefore been made in the investment calculations for the larger plants.

TABLE 38. ISRAEL: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	*Capacity (thousand tons)*	*Investment (million dollars)*
Naphtha steam cracker in two stages	200 ethylene	40
Styrene	48	10
Vinyl chloride	96	16
DMT	30	9.5
HP polyethylene	60	30
LP polyethylene or Polypropylene	20 or 14	20
PVC	78	16.5
Polystyrene	24	4
Polyamide chips and fibres	12 fibres	21
Polyester chips and fibres	17.5 fibres	24
BR/SBR	8/16	8.5
	Total	199

TABLE 39. TURKEY: PROPOSED PETROCHEMICAL PRODUCTION BY 1980

Plant or product	Capacity (thousand tons per year) Existing	Proposed for 1980	Increase required	Investment (million dollars)
Naphtha steam cracker	30	180 ethylene etc.	150	33
Reformer for aromatics		60 benzene 10 toluene 60 mixed xylenes	130	30
Styrene		40	40	9
Vinyl chloride	27	85	58	8
Acrylonitrile		25	25	10
Caprolactam		30	30	25
HP polyethylene		60	60	30
LP polyethylene or Polypropylene		50 or 35	50 or 35	40
PVC	26	80	54	14
Polystyrene		30	30	8
Acrylic chips and fibres		20	20	30
Polyamide chips and fibres		30	30	105
Polyester chips and fibres		35	35	38
BR/SBR		30/15	30/15	17
			Total	397

In view of the restricted size of the domestic markets a full-scale petrochemical development may not be justified in most of the countries in the Middle East by the end of the decade. For the Arab countries to make any significant progress in this direction, a substantial degree of co-operation is essential. As shown in table 36, the development of the petrochemical industry in the Middle East may in this case absorb over $1 billion in investment costs, 47% of which would be spent in the Arab countries. Without such co-operation, however, the total investment requirements for the establishment of petrochemical production facilities would be almost $225 million less, the decrease being due exclusively to the reduced possibilities for local production in the Arab countries on the basis of their individual domestic markets. The Arab countries would in this case account for only 30 per cent of the total investment in the petrochemical sector in the region.

Chapter 7

TOWARDS A DEVELOPMENT STRATEGY

The preceding chapters have been concerned with the details of establishing viable petrochemical industries in specific countries. This study will now conclude with a look at some of the problems of petrochemical development that all of these countries have in common and at some suggestions for their solution.

The first, and basic, problem is that of demand. Although *per capita* consumption of petrochemicals in these countries is lower than in the developed countries and is not expected to change much in the Second United Nations Development Decade, the total consumption is quite high because the populations are large. Unfortunately, this demand is fragmented over a multitude of markets. Such fragmentation is an obstacle to the rapid development of the petrochemical industry of any one country since it results in a reduction of the exploitable market available to that country.

To increase *per capita* consumption, new outlets for petrochemical products must be created. At the macro-economic level, planning might emphasize the development of manufacturing industries that require petrochemical inputs. At a lower level, efforts might be made to modify consumer habits, for example by campaigns to encourage consumers to buy items made of plastics and synthetic fibre. Indeed, such items are usually cheaper than the same items made of traditional materials, a matter of some importance when purchasing power is low. However, it should be realized that changes in consumer preference, by themselves, can play only a limited role here. Basically, the stimulation of a local demand for petrochemicals must come from general economic development.

As demand grows, a reorganization of the existing retail and wholesale outlets may be necessary. In most developing countries these outlets depend largely on imports, so that the emphasis has to be changed to include more and more of the domestic petrochemical output. The goal is to establish a commercial network that will effectively channel petrochemical products to consumers. Sometimes, of course, the total output of a given plant goes to one or a few large consumers, but in most cases, especially if highly finished goods are involved, a product is sold in many different formulations to a large number of small consumers. At an early stage, therefore, consideration must be given to the development of an adequate sales and distribution network.

Within the network, technical specifications for and performance testing of products soon become indispensable. Standards for these must be established by some national or international authority. Petrochemicals can be divided into two broadly overlapping categories. The first includes those materials whose chemical and physical properties are well defined and whose finished-product specifications are established by some international standard. Most of the primary and intermediate products fall in this group. The second category includes more complex materials whose chemical properties are well defined, but whose physical properties and finished-product specifications are determined by the intended use, e.g., the sort of polyethylene that can be made into films, the sort of nylon needed to weave a particular fabric. The standard specifications of products in the first category are there to be followed, but those for products in the second must usually be established in large testing laboratories; it may be neither practical nor desirable for a developing country to provide such facilities. It is therefore wise to obtain outside technical assistance before starting to produce products of this kind.

The most discouraging aspect of petrochemical industry is probably its capital-intensive nature. (See chapter I, section entitled "Petrochemical economics".) As technology advances, the industry demands even more capital and even more technically skilled labour. These are just the resources the developing countries have the least of. Should developing countries adopt an intermediate technology that perhaps does not require so much of these scarce resources? On the face of it, this could be justified by the economic principle of optimization of resource utilization. However, it is not known whether an intermediate technology can actually be realized. And even if it can, it would probably be unable to compete in export markets. The issue is complicated and should be investigated further, preferably on an international or regional basis.

The developing countries are not compelled, of course, to follow the pattern of petrochemical development shown by the industrially advanced countries, either with respect to process or plant capacity. Thus, a relatively small plant that would be regarded as uneconomical in the industrialized countries may satisfy the needs of a developing country that wants, for example, to substitute domestic production for imports that incur high freight charges. But if the developing country also desires to earn foreign exchange by exporting its petrochemical products, the need to be competitive will dictate the building of efficient, i.e. large-capacity, plants. But large capacities can be justified only if the markets are large, and the developing country bent on this course will have to find ways to create larger markets at home as well as abroad.

In evolving a strategy for petrochemical development, great caution should be exercised in approving projects that depend heavily on exports for their viability. Whatever the export prospects may be, the establishment of large-scale plants for export production is out of the question for most developing countries. To meet the keen competition in the export market, it is imperative to manufacture products of high quality and to have an established selling organization that can sell them at a profit. Lack of success may mean having to operate plants at less than full capacity. The consequent higher production costs would probably be passed on to the domestic industries that have to obtain their inputs from the same plants. The preferred strategy for these countries is, therefore, to develop petrochemical production on the basis of the domestic market, step by step if the market is too small to support a fully integrated petrochemical complex from the start. Some protection from foreign competition may be necessary in the early stages, but this should be progressively relaxed to enable the infant industry to grow up. The absence of competition partially destroys any incentive to apply efficient techniques and processes.

The recommendations for establishing or extending petrochemical capacity made in the preceding chapters have in many instances been based on the assumption of close co-ordination between countries. Such co-ordinated development, already under consideration in some areas (e.g. in the Andean and Arab countries), requires agreement about the legal provisions, technical specifications and commercial policies that affect petrochemical products. All potential partners in petrochemical development should analyse the full impact of such agreements on their economies before committing themselves to a particular petrochemical policy.

There are a host of questions about manufacturing, licensing, research and financing that are beyond the scope of this study to discuss. But one comment can be made about financing: the development of petrochemical production in developing countries will require a great deal of money during this decade, much of which will obviously have to be obtained from outside sources. International and national agencies can help obtain it by mobilizing resources, screening proposals and promoting investment in this industrial sector. In this connexion, UNIDO could play an important advisory role.

If any factor can be singled out for special emphasis, it is multi-country co-operation, either on a regional or a subregional basis. This, more than anything else, is likely to exert a determining effect on the future of petrochemical production in developing countries. Any possibility for such co-operation should be carefully investigated.

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