



**TOGETHER**  
*for a sustainable future*

## OCCASION

This publication has been made available to the public on the occasion of the 50<sup>th</sup> anniversary of the United Nations Industrial Development Organisation.



**TOGETHER**  
*for a sustainable future*

## DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

## FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

## CONTACT

Please contact [publications@unido.org](mailto:publications@unido.org) for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at [www.unido.org](http://www.unido.org)

D00345

UNIDO

Distribution:  
UNIDOC

ID/CG.34/16.Rev.1  
12 February 1970

Unit: \_\_\_\_\_ Organization: \_\_\_\_\_

ORIGINAL: ENGLISH

\_\_\_\_\_ on the  
\_\_\_\_\_ Industries in  
\_\_\_\_\_

FRF.343.3/1

\_\_\_\_\_ 1959

RECENT DEVELOPMENT IN THE FIELD OF BASIC PETROCHEMICALS

AND THEIR SPECIAL INTEREST FOR DEVELOPING COUNTRIES<sup>1/</sup>

by

P. Leprince  
C. Mercier  
M. Grimaud

Institut Français du Pétrole (IFP)  
Rueil-Malmaison France

1/ The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

**TABLE OF CONTENTS**

	<b>Page</b>
<b>A - MARKET FOR MAIN BASIC PRODUCTS</b>	<b>4</b>
<b>I - ETHYLENE</b>	<b>4</b>
The production of ethylene - General features	4
The major ethylene consumption areas	8
Meeting the demand for ethylene	12
<b>II - PROPYLENE</b>	<b>14</b>
The production of propylene - General features	14
The major propylene consumption areas	16
Meeting the demand for propylene	19
<b>III - BUTADIENE</b>	<b>21</b>
The production of butadiene - General features	21
The major butadiene consumption areas	24
Meeting the demand for butadiene	27
<b>IV - BENZENE</b>	<b>29</b>
The production of benzene - General features	29
The major benzene consumption areas	32
Meeting the demand for benzene	35
<b>V - XYLENES</b>	<b>37</b>
The production of xylenes - General features	37
Principal areas of ortho-xylene and para-xylene	39
Meeting the demand for ortho-xylene and para-xylene	40

II - ECONOMICS OF FARM PRODUCTION PROCESSES

41

I - EFFICIENCY OF FARM PRODUCTION

41

1. Influence of size of unit on price of output

43

2. Influence of capacity of the unit on price of output

46

II - EFFECTS OF PRODUCTION OF PRODUCTS

49

1. Influence of the market and of the prices of products

50

2. Influence of production of animal products on...

51

A - MARKET FOR MAIN BASIC PRODUCTS

1 - ETHYLENE

THE PRODUCTION OF ETHYLENE - GENERAL FEATURES

1. Raw material

The raw materials available to the petroleum product market (natural gas, condensate, crude oil) as well as the structure of the market and the factors determining the quantity and nature of raw material depend in the production of ethylene.

United States: the substantial resources of ethane and propane in natural gas, as well as the existence of a high refining capacity (including cracking plants), are the reasons for the production structure shown in the following table.

TABLE 1  
PRODUCTION OF ETHYLENE IN THE UNITED STATES - 1965

Raw material	% of production
Ethane and propane from natural gas	62
Ethane and propane from refineries	15
Residual gas from refineries	10
Liquid feedstocks (naphtha, gas oil, condensates, etc.)	13

Western Europe: the preponderant feedstock used in naphtha.

Table 2 illustrates, as an example, the production structure of West Germany.

T A B L E 2

PREMIUMS ON EXPORTS OF WESTERN CEMENTS, 1969

Country	% of production
Japan	7
France	6
Germany	12
Italy	1

The effect of market conditions (availability) in the United States and Europe is provided by the average price of bags

per ton: \$28 to \$35 in the United States  
 \$18 to \$22 in Europe.

The case of ammonia is a good example of a meritably low level of protection. The Japanese government has, since 1965, arranged to buy 100,000 metric tons of ammonia from the United States each year at a price of 100 cents per metric ton. In addition, it has entered into a long-term contract with the United States for the purchase of 100,000 metric tons of ammonia each year at a price of 100 cents per metric ton.

Under these circumstances, it is believed that the United States is able to export its ammonia to Japan at a price which is relatively low.

Japan's high level of protection for ammonia is a result of its high level of consumption. The government has a long history of providing subsidies to the ammonia industry as the price of ammonia in Japan is one of the highest in the world. This has led to a high level of production in Japan and to the need for Japan to import ammonia from other countries. However, it is necessary for Japan to import ammonia from other countries because it does not have enough of its own ammonia to meet its demand. This is why it is necessary for Japan to import ammonia from other countries, despite high duties.

## 2. Sizes of production units

The size of profit making steam-cracking units is continually increasing, with a corresponding increase in the average unit capacity.

United States: in 1964, there were 33 steam-cracking units with an average ethylene capacity of 120,000 tons per year each.

This capacity had risen to 180,000 tons a year by 1966, with 35 units.

Europe: the average ethylene capacity of steam-cracking units operating in 1965 was 50,000 to 60,000 tons a year in the various countries. By 1970, the average capacity will be about 150,000 to 180,000 tons a year, and a relatively large number of units will have been constructed during this five-year period (one or two additional plants per country).

The increase in the profitable size of steam-cracking plants is leading to ever greater investment.

In addition, the concentration around the steam-cracking unit of production using ethylene as a raw material leads to the creation of large petrochemical complexes; in turn, these require substantial capital resources (in general, the ethylene consumers take shares in the company owning the steam-cracking plant, not vice-versa).

It is true that a discordant factor in the trend towards concentration has now arisen, with the prospect of transporting ethylene by pipeline (Rhône-Alpes in France, Esso and ICI in the United Kingdom, for example).

Finally, there are production risks arising from the small number of ethylene producing units, and thus risks of discontinuous supply.

## 3. Product quality

To separate ethylene from the other derivatives of the steam-cracking process, distillation is required, resulting in an extremely pure product - 99.7 per cent (in weight) ethylene, suitable for polymerisation.



#### 4. Ethylene versus acetylene

ethylene is increasingly taking the place of acetylene in the production of many non-halogenated polymers. The use of the well-known ethylene monomer, as well as the more

recently developed ethylene copolymers, has been increasing rapidly. The use of ethylene in the production of polyethylene is well known. The use of ethylene in the production of other polymers, such as polyethylene glycol, is also increasing. The use of ethylene in the production of other polymers, such as polyethylene glycol, is also increasing. The use of ethylene in the production of other polymers, such as polyethylene glycol, is also increasing.

The use of ethylene in the production of other polymers, such as polyethylene glycol, is also increasing. The use of ethylene in the production of other polymers, such as polyethylene glycol, is also increasing. The use of ethylene in the production of other polymers, such as polyethylene glycol, is also increasing.

### ETHYLENE POLYMERIZATION AREAS

A characteristic feature of the ethylene market is that to a great extent it is a spot market. This has arisen from the nature of the product, which requires complex and large storage installations, and from the fact that it is produced as it is required. The ethylene market is, therefore, closely linked with that of its derivatives. For example, for a given quantity of the producers manufacture to a given consumer, two out of ten produce on an average, and about 10 per cent of the quantity produced is consumed in the form of ethylene.

The average annual consumption for the five-year period 1965-1970 is 10.7 million metric tons in the United States (1.7 per cent), high in Western Europe (10.7 million metric tons) and higher in Japan (23.6 per cent). The consumption level in the basic consumption level in these areas is:

- United States 1.7 per cent
- Western Europe 10.7 per cent
- Japan 23.6 per cent

The growth rates for ethylene are about the same as those of its derivatives, polyethylene.

The ethylene consumption structure shows a general predominance of propylene, representing about 45 per cent of the outlets of ethylene in the United States in 1965, 60 per cent in Western Europe.

This predominance has increased still further by 1970: 60 per cent in the United States and 75 per cent in Western Europe.

There is a marked variation in the ethylene consumption structure of different countries. However, in the United States there is a high proportion of ethylene glycol (20 per cent of ethylene is used for the production of ethylene oxide) and a relatively low proportion is reserved for polyethylene - 13.5 per cent in 1965.

In the United States, as in the rest of the world, there is a shift away from the traditional uses of ethylene, butadiene, and styrene, and more emphasis is being placed on new uses, such as with the production of thermoplastic olefin copolymers, diene copolymers, etc.

The ethylene market in the United States will remain relatively stable in the near future, but the market is expected to expand in the long run.

In the United States, the ethylene market is expected to expand in the near future, but the market is expected to expand in the long run.

In China, the ethylene market is expected to expand in the near future, but the market is expected to expand in the long run.

In Japan, the ethylene market is expected to expand in the near future, but the market is expected to expand in the long run.

The ethylene market in the United States is expected to expand in the near future, but the market is expected to expand in the long run.

T A B L E 1

	1955	1970
United States	4,250,000	6,000,000
Japan	740,000	2,150,000
India, New Zealand	590,000	1,400,000
France	225,000	600,000
Italy	400,000	750,000
Netherlands	120,000	570,000
Taiwan	30,000	280,000
	1,485,000	3,600,000
United Kingdom	530,000	1,000,000
Other Western European countries	160,000	300,000
	2,035,000	5,000,000
USSR	250,000	1,000,000
		(1,200,000)
Latin America, North Africa		
Canada, Brazil	10,000	120,000
India, Pakistan	20,000	120,000

TABLE 4  
ETHYLENE CONSUMPTION STRUCTURE IN THE  
UNITED STATES, JAPAN AND S.E.A. (1)  
(1000 metric tons)

Commodity	United States		Japan		S.E.A.	
	1965	1970	1965	1970	1965	1970
Polyethylene	33.5	42.5	51	50	36	43
Mylar	9	3.5	3	7	3	12
Other plastics	3.5	10	5	10	10	10
Other chemicals	4	14.5	11	11.5	17	14
Etanol	17	15	17	16		
Waxes	9	12	-	4.5	10	16
Total consumption	4,554	6,900	740	7,180	1,465	3,600

MEETING THE DEMAND FOR ETHYLENE

The more highly industrialized Western European nations - the EEC countries plus the United Kingdom - will multiply their production capacity by 2.7 between 1965 and 1970, whereas their consumption will have been multiplied only by 1.5.

In 1965, the operating ratio of ethylene producing units was 84 per cent of the capacity in this area. If this ratio is maintained and overall capacity increases accordingly, by 1970 there will be a surplus of 1,000,000 tons of ethylene capacity with the requirements of the internal market, representing an overproduction capacity of about 20 per cent. If, on the other hand, the 1970 production figure is adjusted to the level of internal market consumption, the operating ratio of plants would fall to 65 per cent of capacity.

The production capacity of Western European countries outside the Common Market and United Kingdom is expected to rise from 170,000 to 200,000 metric tons between 1965 and 1970.

If this happens, the operating ratio would fall from 59 per cent to 40 per cent (if the extension of Svenska Lasse installations to a capacity of 300,000 tons were only partly completed by 1970, the ratio of the units in this group of countries will be close to that of the other Western European nations).

The situation in the COMECON countries is more difficult to evaluate, since the location of plants producing ethylene from petrochemicals is unknown. If all such plants produce this type of ethylene (the proportion of ethylene derived from the carbide industry is very probably decreasing steadily), it appears that this area will have to meet its overall needs by maintaining the operating ratio of its units at 80 or 90 per cent of capacity.

T A B L E 5  
ETHYLENE PRODUCTION CAPACITY  
(metric tons)

	1975	1976
France (incl. Germany)	115,000	1,320,000
Belgium	30,000	420,000
France	277,000	1,130,000
Italy	580,000	735,000
Netherlands	10,000	20,000
Germany (incl. France)	1,000,000	3,035,000
Eastern European	60,000	230,000
Other EEC countries	50,000	80,000
Germany (incl. France)	10,000	100,000
Other Western European countries	10,000	210,000
Central and Western Europe	2,597,000	7,035,000
Western Hemisphere	40,000	100,000
Latin Am.	-	60,000
Canada	-	40,000
Poland	23,000	40,000
North America	20,000	100,000
Other Hemisphere	-	40,000
World (incl. USSR) less USSR	2,657,000	7,275,000
India	83,000	173,000
Iran	-	32,000
China	-	20,000
USSR	15,000	20,000
Thailand	-	30,000
U.A.R.	-	20,000
Latin America	58,500	620,000

## III - PROPYLENE

### THE PRODUCTION OF PROPYLENE -- GENERAL FEATURES

#### 1. The raw material

Like ethylene, propylene is derived either from refinery gases (basically, gases obtained by catalytic cracking operations) or from the steam-cracking of gaseous mixtures, such as ethane, propane or LPG's or liquid mixtures (particularly naphtha). The availability of one particular type of feedstock rather than another will, therefore, influence the overall economics of propylene production. Its particular product market structure will, as in the case of ethylene, depend on the nature and quantities of the raw material used for the production of propylene.

United States: The theoretical propylene production potential in 1965 was 21 per cent from refinery gases and 17 per cent from steam-cracking effluent.

Catalytic cracking plant capacities should increase very slightly in the future, and the use of new types of catalysts (zeolite) will also minimize gas production.

The propylene yield to naphtha steam-cracking (50 per cent of the production of ethylene, compared with 33 per cent in the steam-cracking of propane) is an inducement to adopt this type of production more widely over the next few years.

The problem of the potential supply of naphtha, therefore, will be crucial in the United States. Unless naphtha imports (quota policy) are authorized, certain producers fear that there will be substantial propylene deficits in the coming years.



Europe: the potential propylene production capacity is divided equally between refinery gases and steam-cracking effluents. In the future, there will be an increasing tendency to produce propylene by the steam-cracking route in later years. The possibility of adjusting output to a certain extent to market demands by varying the severity of the process (and in some cases the quality of the feed) provides a certain degree of flexibility.

The amount of capacity available, therefore, will be the most important factor in the economics of production in the future. The influence of the process structure on the overall plant cost has been mentioned in the literature of ethylene. No problems are expected with regard to naphtha availability for certain lump capacity in the next few years.

As regards the situation in Asia, see the chapter on ethylene.

### 2. Sizes of production units

The production of propylene is linked with that of ethylene, and in the case of the present cracking plants the capacity of the two is inter-related. The feed for the propylene plant is the C<sub>3</sub> fraction resulting from the cracking of the feed.

The production of the concentrate of an olefin associated with steam-cracking depends on the size of the steam-cracking furnace (producers of large capacity, 100,000 t/a, and smaller units).

In 1965 in Europe the average maximum propylene production capacity of steam-cracking plants fluctuated between 30,000 and 65,000 t/a per year. In the future, in order to meet the demand, the maximum unit capacity will be between 35,000 and 100,000 tons a year.

### 3. Product quality

Propylene 90 - 95 per cent pure, for "chemical use", can be obtained directly from steam-cracking (C<sub>3</sub> fraction).

Additional distillation is required to produce the 99.5 per cent pure propylene "polymerisation grade".

On the other hand, C<sub>3</sub> fractions produced by catalytic cracking contain only 40 per cent. to 60 per cent propylene and the propane must be separated in all cases.

MAJOR PROPYLENE CONSUMPTION AREAS

In the United States, the average annual growth rate during the five year period, 1965-1970, will be slightly higher than that of ethylene, at 10.8 per cent compared with 9.7 per cent. Propylene consumption in the U.S. consisting of the U.S.A. countries and the United Kingdom will rise on average 10.3 per cent per year, similar to the predicted growth rate for ethylene over the same period.

The increase in consumption in Japan, which is roughly the same as in U.S.C. countries, will, however, be considerably lower than the growth rate of the consumption of ethylene, which is exceptionally high (15.8 per cent).

Per capita consumption - now about 4.5 kg in the more industrialized nations of Western Europe and in Japan - will rise to about 10 kg by 1970 (see Table 6).

TABLE 6

CONSUMPTION OF PROPYLENE (metric tons)

Country	1965	1970	Annual Growth Rate (%)	Per capita consumption (kg)	
				1965	1970
U.S.A.	3,335,000	3,100,000	10.7	12	19
E. E.C.	630,000	1,640,000	14.5	4.6	9.1
U.K.	245,000	590,000	15.7	4.5	10.5
Japan	457,000	1,029,000	15	4.7	10

Consumption structure

Propylene is used mainly in two fields: oil products and petrochemicals. In the United States in 1965, 40 to 70 per cent of the propylene produced was used for the octane number of petrol, by manufacturers of polymers and alcohols in particular. The amount of propylene in the petrochemical industry is expected to rise to 90 per cent by 1975.

In view of the octane number of petrol in Japan, it is the proportion of petrol from cracking towers, the production of polymers; the relative quantity of propylene used in the petrochemical industry is, therefore, markedly higher.

There is little variation in the consumption structure in different countries, with the following points of interest:

- 1. the high proportion of propylene used in the manufacture of petrol in Japan, which is 45 per cent in 1965 and 49.5 per cent in 1970;
- 2. the high proportion of propylene used for the production of polymers in the United States. This proportion was 40 per cent in 1965 and 37 per cent in 1970, the polymer share of the market being 45 per cent and 50 per cent respectively.

**TABLE 7**  
**PROPYLENE USED IN THE CHEMICAL INDUSTRY - CONSUMPTION**  
**STRUCTURE IN THE U.S., JAPAN AND E.E.C. (%)**

	United States		Japan		E. E.C.	
	1965	1970	1965	1970	1965	1970
Propyl alcohol	25.3	20.6	11.5	12	21.5	16
Acetone					23.5	14.5
Propylene oxide	10.7	11.1	9.5	7.5	12	9.5
Other olefins and olefins	32	24.5	14.5	9.5	25	- *)
Polypropylene	0.5	15.9	17	27	6	8.5
Acrylonitrile	10.5	12.3	32	35	5.5	20.5
Others	12.9	15.6	9.5	9	6.5	31 *)
Total (metric tons)	2,312,000	3,200,000	457,000	1,030,000	530,000	1,640,000

\*) Inclusive of olefins, ethylene, alcohols

in the United States, manufacture of major products (polypropylene and acrylonitrile) with the basic growth prospects already accounts for 19.1 per cent of propylene consumed by the petrochemical industry, and by 1970 will account for 28.2 per cent.

in Japan, 55 per cent of propylene produced is used for these processes, and this proportion will increase to 62 per cent by 1970.

## MEETING THE DEMAND FOR PROPYLENE

The propylene production capacities shown in Table 2 do not include any supplier that may be available from refineries (the figures may of course vary depending on the severity of the steam cracking process).

Estimates have been made of the capacity in Western European countries, COMECON countries (except the U.S.S.R.), African and Middle East nations as well as Latin America.

In Western Europe, the production rate of propylene supplier units was 100 per cent in 1965, and it is expected to be approximately 70 per cent in 1970.

Very little refinery propylene was used in 1965<sup>\*)</sup> however, the latter source will probably gain in favour by 1970 because of the existence of substantial supplies of propylene from steam cracking operations.

\*) In France, Elf and BPSO used refinery propylene for paraffin oils.

T A B L E 8

PROPYLENE PRODUCTION CAPACITIES (metric tons)

	1965	1970
West Germany	549,000	914,000
Belgium	26,000	110,000
France	222,000	774,000
Italy	228,000	268,000
Netherlands	115,000	229,000
<b>E. W. G. TOTAL</b>	<b>1,200,000</b>	<b>2,353,000</b>
United Kingdom	468,000	830,000
Other E.P.T.A. countries	78,000	138,000
<b>E.P.T.A. TOTAL</b>	<b>546,000</b>	<b>968,000</b>
Other Western European countries	35,000	62,000
<b>TOTAL FOR WESTERN EUROPE</b>	<b>1,781,000</b>	<b>3,389,000</b>
West Germany		10,000
Belgium		10,000
France		existing production
Italy		40,000
Netherlands		25,000
Finland		35,000
<b>TOTAL COMMONWEALTH minus U.S.A., R.</b>		<b>167,000</b>
China	--	3,600
Japan	6,000	10,000
India	--	-- (foregoing production)
U.S.A.	--	20,000
Latin America	90,000	227,000

### III - BUTADIENE

#### THE PRODUCTION OF BUTADIENE - GENERAL FEATURES

##### 1. Raw materials - processes

Butenes produced ethylenically and propylene, the products for which there are normally a considerable number of existing plants, may also occur in appreciable amounts in bitumens, either directly or in the price form of asphalt that is subsequently being cracked.

The butadiene/ethylene ratio in steam cracking effluent is more or less constant whatever cracking process is used and whatever kind of naphtha is produced.

Ethylene	21 - 23 per cent of the feed
Propylene	14 - 17 per cent
Butenes	6 - 7 per cent
Butadiene	3,5 - 4 per cent

Butadiene is extracted or isolated operationally economic, in other words, there is sufficient quantity of it to produce butadiene as a competitive commodity. This is the reason why both in the U.S.A. and in Europe, steam cracking plants, such as the Shell's extraction unit,

Many butadiene production processes involve dehydrogenation of butane or butenes:

- HOUBBY process: butane is dehydrogenated directly in butadiene.
- The IDAS (SHELL) process: this is beginning to be used in Europe. Butane (or other C<sub>4</sub> to C<sub>6</sub> feedstocks) is dehydrogenated.
- Dehydrogenation of butenes: steam cracking effluent is first subjected to extractive distillation to isolate them.

in the United States

The proportionate use of these processes for the manufacture of butadiene was as follows (1965 - 1966):

- butane dehydrogenation	36 per cent
- butane dehydrogenation (Houdry)	27 per cent
- Houdry and steam cracking on the same site	21.5 per cent
- Steam cracking	<u>15.5 per cent</u>
	100.0 per cent

Compared with the last three previous years, the percentage quantity of butadiene produced by dehydrogenation of butane increased markedly, not least because they are in short supply as they were being used for the production of alkylates, an additive for high octane motor petrol. On the other hand, the proportion of butadiene from steam cracking now corresponds

In the main, steam cracking operations will account for future growth in the American production of butadiene. However, the abundant supplies of cheap butane (12 cents per lb) as well as recent improvements in the HOUDRY process may also encourage more widespread adoption of this process.

in Europe

The situation is different from that in the United States: the greater part of butadiene production is extracted from steam cracking effluent.

Butane and butene dehydrogenation takes place in some of the larger plants, for example a SHELL plant at REPERE in France (SHELL-UMC process), a LICHTEN plant in Denmark (HOUDRY process), and a ICI plant at the Billingham refinery in Great Britain (butane dehydrogenation).

The predominance of butadiene from steam-cracking will not be challenged over the next few years. For example, in France more than three quarters of the 1970 production of butadiene will come from fraction units associated with steam cracking plants.



In countries other than France, there are still some doubts about the construction of it, if not about the size, of some of these extraction units, especially in Germany.

Presently, the availability of the supply of raw materials for butadiene production is not a major problem for the production of butadiene:

- the availability of DCO's and  $C_2$  fractions from catalytic cracking conditions and the production of steam cracking feedstocks in the United States

- the availability of mobile fuel to supply of steam cracking processes in Europe.

## 2. Size of plants

As in the case of other olefins, on the average, capacity of butadiene production units is higher in the United States than in Europe. In order to be precise on this respect, the average capacity of American plants for the extraction of butadiene for 1965 - 1966:

- butadiene hydrochloride	110,000 tons
- butadiene dihydrochloride (Germany)	30,000 tons
- steam cracking	over 40,000 tons.

In Europe, the capacity of butadiene extraction units in 1965 ranged from 10,000 to 75,000 tons. An average can be stated.

By 1966, the average capacity of these units should be close to the estimated 1965 figures in the United States, i.e. 40-45,000 tons in Germany and the Netherlands, 30,000 tons in France.

## 3. Product quality

Butadiene as separated by extractive distillation; an extremely pure product is obtained, better than 99 per cent, and this is suitable for polymerization.



The latter is manufactured from butadiene by DU PONT (103,000 metric tons in 1966, 60,000 in 1964) for the production of 6.6 nylon.

T A B L E 9  
USES OF BUTADIENE IN U.S., 1966

SBR	60%
Polybutadiene	14%
Adispenitrile	7%
Nitrile rubber	4%
SB and ABS resins	<u>15%</u>
	100% (1,450,000 m.t.).

In Europe, (E.E.C. + U.K.), almost all of the butadiene production is at the present used in the manufacture of synthetic rubber - 94% in 1965. The situation will change very little over the next few years, as the percentage will still be as high as 91% in 1970.

Within the group consisting of synthetic rubber derived from butadiene, production is expected to increase considerably between 1965 and 1970: production will double in the case of nitrile rubber, more than double in the case of polybutadiene.

Despite the high rate of development, resins derived from butadiene (ABS, etc.) will still account for a small part of the market in 1970 because of the present low production level.

T A B L E 10  
CONSUMPTION IN E.E.C. 1965/1970 ( $10^3$  metric tons)

	1965	1970
SBR	246	395
Polybutadiene	70	135
Nitrile rubber	25.5	37
Others	<u>23.5</u>	<u>53</u>
	365.0	620

In Japan, where the demand for butadiene has increased at rates as high as 35 % (1966 compared with 1965) expansion is expected to be much less rapid - about 10% per year as in Europe - as soon as per capita consumption reaches the level attained in Europe in 1965; this predicted for 1968 or 1969.

TABLE 11  
CONSUMPTION OF BUTADIENE - JAPAN (10<sup>3</sup> metric tons)

	1965	1970
SBR	81.4	139.5
Nitrile rubber	3.9	8.5
Polybutadiene	15.8	68.5
ABS resins	3.4	14.5
Others	4.9	-
TOTAL	109.4	231.0

COMECON -- The butadiene situation is difficult to ascertain, but, based on the capacity of plants manufacturing synthetic rubber in 1970, butadiene consumption is probably about:

300,000 m. tons in the U.S.S.R.

200,000-250,000 m. tons in other Eastern European countries.

The total is 500-550,000 metric tons, a quantity only slightly lower than the consumption of the whole of the E.E.C.



In Europe (E.E.C. + U.K.), the present situation is somewhat similar to that in the United States. Plants are in many cases operating at almost maximum capacity, and prices are at a slightly lower level than in the United States, but somewhat above (import price). The developing demand for butadiene is such that it is possible for production facilities to be increased on a fairly large scale.

Despite the construction of extraction units linked with larger steam cracking plants, there will probably still be a butadiene deficit in Europe in 1950.

CONCLUSION. According to our current information on the scale of existing and future steam cracking plants, butadiene can probably not be extracted economically. Butadiene is obtained solely from dehydrogenation processes.



## U.S.A., 1965

- Reforming	58%
- Distillation of toluene	27%
- Steam-cracking	5%
- Light oils	13%
- Road's tar	2%

It has been observed that even in the most industrialized European countries, the development of petrochemistry in the production of benzene is still relatively small.

The example of France illustrates this observation, since out of some fifteen catalytic reforming units now in use only three are extracting benzene.

### 2. Size of Investment

Production capacities for benzene are essentially linked to those for reforming, and in particular to those for catalytic reforming. To obtain a definite quantity of benzene starting with reformates the minimum size of plant is, therefore, fairly large. The units which are in operation in France are fractionation plants - three, dimethyl sulphoxide, sulphuric acid and other separation of the various aromatics to produce amounts ranging from 30,000 tons of benzene a year to more than 100,000 tons. In the countries of high production of petrochemicals, benzene appears to be one of the most important chemical products. For example, the benzene production capacity of the plant with naphthenols at Puerto Rico is 350,000 tons a year and that planned by ICI at Milton, when set up for benzene (after hydrodemethylation of other aromatics), should reach 265,000 tons a year.



Because of the large scales, the capital investments are comparable to those for refinery units. For example, the installed cost of an extraction, hydrodesulfurization and aromatic separation unit leading to the recovery of benzene, toluene, and the separated  $C_8$  aromatics - can be put at about \$100 million for a capacity of 60,000 tons for a production of 10,000 tons of aromatic feed of which 60,000 tons will be produced.

There is little industrial integration of this kind petrochemical production, which is the only one of its kind in the world. From new units, capacity production units will be started in both Europe and the U.S. to the detriment of existing extraction units regarded as less desirable, and with the direct change of the production of considerable quantities of petroleum oil derivatives.

In conclusion, it can be said that the main features of aromatics - and particularly of benzene - inside of the chemical industry is that their production is almost entirely based on that of naphthalene, obtained in the form of several  $C_{10}$  compounds in 1960, in Germany, one half of this production was used with naphthalene and benzene from oil refinery.

### 3. Quality of product

The degree of purity required varies with the use to which the product is put.

Purity is characterized mainly by crystallizing point and by sulfur content.

The specific case regarding the crystallizing point of benzene intended for electrical synthetic (60/60) is easily satisfied by all petrochemical production.

The maximum acceptable sulfur content (2 ppm in the case of hydrogenation or oxidation) now requires only prolonged pre-treatment of the feed by hydrogenation.

## THE SEVERAL BENZENE CONSUMPTION AREAS

In the case of benzene, there are to be found most of the common points encountered in the course of the comparative study of demand for the main hydrocarbons in the principal fields of consumption, viz.

- a very great increase in the U.S.A.: 20% (between 1965 and 1970), or an average annual growth of 4.9%
- higher growth in Europe: 20% between 1965 and 1970, or an average annual growth of 4.6%
- still higher growth in Japan: doubling between 1965 and 1970, or an average annual growth of more than 15%.

The consumption levels per capita achieved in the various countries explain these differences in the rate of increase in demand.

TABLE 12  
DEVELOPMENT OF PER CAPITA CONSUMPTION OF BENZENE  
(kg/cap)

kg/cap	1960	1965	1970	1975
U.S.A.	5.6	11.8	17.5	23
Europe	2.7	5.2	8.5	11.2
E.E.C.	3.55	6.4	10.5	
Japan		4.2	8.5	12.7

The foregoing data still for some elements:

- In the time place, the increase in the absolute tonnage of benzene consumed, between 1965 and 1970 for example, is of the same order of magnitude in the U.S.A. as in Europe, viz; 1 million tons and 1.2-1.3 million tons respectively;

- on the other hand, account should be taken of the fact that part of the benzene consumed in the U.S.A. is actually exported in the form of benzene derivatives (mainly styrene and cyclohexane), this remark likewise applying to the export of benzene through the opposite direction of consideration of the balance of differences in consumption of benzene derivatives, as indicated by the foregoing table.

Structure of benzene derivatives

Three benzene derivatives - styrene, phenol and cyclohexane - provide by themselves with the greater part of the total benzene compound.

In the U.S.A., in 1970, in 1965 and 1960, these three derivatives represented 40% of the consumption of benzene in the industrialized countries of Europe, the Americas, Australasia and Africa. At present, consumption has declined.

TABLE 13  
COMPOSITION OF BENZENE CONSUMPTION

By product	1960	1965	1970
Styrene	31.5	35	37
Phenol	21.5	20.5	20
Cyclohexane	22	21	22
Other	24.5	23.5	21
Total	1,552,000	1,700,000	1,600,000

T A B L E 14  
CONSUMPTION OF BENZENE - JAPAN  
Thousand metric tons

	1960	1965	1970	%
Synthetic	1.5	310	36.5	
Phenol	84	90	10.5	
Polynorbornene	56.5	305	36	
Other	100	145	17	
Total	387	850	100	

T A B L E 15  
CONSUMPTION OF BENZENE - COMMON MARKET  
Thousand metric tons

	1960	1965	1970
Federal Germany	310	453	630
Belgium	15	25	120
France	155	307	450
Italy	110	263	450
Netherlands	12	85	210
Total E.E.C.	602	1,123	1,910

## MEETING THE DEMAND FOR ENERGY

### Production capacities

The quantities of the units is difficult to evaluate because their capacity may vary between fairly wide limits (more or less complete utilization).

Nevertheless it is thought that this level is near 80% in the U.S.A. and that it remains on the high figure because of the gross state of the market - an exceptional high, much higher than that experienced during the preceding year (near 60% in 1968).

The utilization of the production capacities has increased on several recent occasions, but the effect of this increase is limited by the fact that if the production capacities are increased, their production capacity will all together (including the units), the capacity of the units would increase by about 50% (from 1.75 and 1.75 to 2.6 million tons).

In 1968, the production capacity was 2.0 million tons and the production was 1.65 million tons, which has not been since 1.65 million tons.

Actually, the production was as much higher than that (66%) implied by the capacity of the two plants.

### In fact:

- Some of the gas turbines operating at a higher rate, while others are at the limit of output
- Many units are still under repair or have recently been put into production, and their productive capacity is, therefore, less than their full capacity.
- The gas turbines are still greatly underutilized in 1970 (60% of capacity). Taking into account the anticipated consumption, the operation ratio would have to be higher than 80% if it was to provide self-sufficiency, and this appears to be highly improbable.

In the COMECON countries, it appears that the development of demand for benzene derivatives (3 kg/cap) has not yet reached a level at which the whole production of benzene can be absorbed locally. Up till now, benzene production has remained essentially based on coal tar (1965 production was of the order of 1 million tons) and the increase in capacity for petrochemicals remains still rather low in the future.

In the developing countries, one region already in production - Latin America - will meet a large part of its 1970 needs from the installation of production capacity in Argentina, Brazil, Colombia and Mexico: the total demand for benzene will be about 250,000 tons against an installed capacity of 185,000 tons. Another producer, India, where demand for benzene will reach 60,000 tons in 1970, will have an installed capacity of 80,000 tons.

## V - XYLENES

### THE PRODUCTION OF XYLENES - GENERAL FEATURES

#### 1. Raw materials and processes

In the petrochemical industry, the origin of xylenes is essentially that of benzene, viz:

- Catalytic reforming followed by extraction of aromatics,
- in which case, in the case of benzene, is distilled as motor spirit, which contains very little of the mixture of xylenes.

Methods of separating and purifying both of these mixtures are of recent origin; formerly, by condensation, the two mixtures used as a mixture in solvents and above all to produce the extreme number of products.

Utilization for polyester - filled gives an important boost to paraxylene, generated by slight reaction with the other isomers. The very low solubility and high melting point of the latter is a better solvent than the other isomers. In certain cases, ortho-xylene can be separated from this mixture by distillation to give a high percentage of phthalic anhydride. In the case of the other isomers, para-xylene, the other isomers were either converted to paraxylene and recycled to the crystallization process.

The total market for xylenes in the U.S.A. in 1965 (production of 275,000 tons of xylenes) can be broken down as follows:

motor spirit and solvents	61%
ortho-xylene	12%
meta-xylene	12%
para-xylene	14.5%
ethylbenzene	1%

2. Sizes of Investment

Production of xylenes, like that of benzene, comes from the same extraction and fractionation capabilities. If one considers the usual separation of the various xylenes, however, the tonnages produced are similar to those of benzene. Most installations for para-xylene or for m-xylene had capacities of 10,000 - 40,000 tons a year in the past, but today, they are of at least 50,000 tons and are reaching higher levels of capacities of 80,000 - 100,000 tons a year.

Having regard to the tonnages, the investments needed for the separation of an individual xylene are high because of the necessary recovery and several fractional distillation processes. For example, for a significant recovery unit using 100,000 tons of xylenes, comprising fractionation of meta-xylene and the crystallization of 50,000 tons of para-xylene, the installed cost can be estimated at 6 million dollars including off-sites.

3. Quality of Products

Since a specification is necessary for mixtures of xylenes when used as solvents or as fuel additives, only the purest uses of para-xylene and of m-xylene need be considered. For the production of benzothiazole derivatives or phenolic derivatives, the same equipments are as follows, which are typical of those currently obtained at the end of the distillation process:

Para-xylene (by volume)		Ortho-xylene (by volume)	
Acidity	0.1%	Acidity	negligible
Sulphur compounds	negligible	H <sub>2</sub> S and SO <sub>2</sub>	negligible
Iodine index	0.03	Olefins + saturated compounds (by volume)	0.03



### PRINCIPAL AREAS OF ORTHO-XYLENE AND META-XYLENE CONSUMPTION

#### 1. Ortho-xylene

In the U.S.A. the rate of growth in production of ortho-xylene was 19% a year from 1968 to 1969. The greater part was exported to Western Europe and elsewhere, but domestic demand grew by 14% a year.

There is no production of ortho-xylene in the U.S.A., consumption in Western Europe and elsewhere being 100%.

TABLE 1  
ORTH-XYLENE  
(Million tonnes per year)

	1960	1965	1970
Production in U.S.A.	60	80	100
Consumption in U.S.A.		50	200
Consumption in Western Europe		140	190

The growth of ortho-xylene in the U.S.A. is significant and this is reflected in the rapid increase in its consumption in 1970. The total production of ortho-xylene in the U.S.A. in 1970 was 100 million tonnes, which is a 67% increase on the production of 60 million tonnes in 1960. In Europe in 1965, the total production of ortho-xylene was 140 million tonnes, which is a 100% increase on the production of 70 million tonnes in 1960. The total demand for ortho-xylene in the U.S.A. and Western Europe in 1970 was 290 million tonnes, which is a 100% increase on the demand of 140 million tonnes in 1965.

#### 2. Para-xylene

Para-xylene is used in the production of polyester fibres and films, through the intermediates of terephthalic acid or of its dimethyl (DMT) terephthalate.

Demand rose at a very rapid rate of 20% a year in the U.S.A. between 1960 and 1969 - and the established growth in polyesters further accelerated this trend.

Table 2 shows production and consumption in the U.S.A., consumption in Western Europe and elsewhere for 1970.

TABLE 17  
PARA-XYLENE  
(thousands of metric tons)

	1960	1965	1970
Production in U.S.A.	95	133	700
Consumption in U.S.A.		150	500
Consumption in Western Europe		130	400

#### MEETING THE DEMAND FOR ORTHO-XYLENE AND PARA-XYLENE

##### 1. Ortho-xylene

Production capacity in 1965 was 153,000 tons in the U.S.A. and 170,000 tons in Western Europe. While considerable increase in capacity has taken place in the U.S.A. (600,000 tons a year expected in 1970) total capacity in Western Europe is making little progress.

There is considerable trade between Europe, which is short, and the U.S.A. which has a surplus. Of 160,000 tons produced in 1965, the U.S.A. exported 60,000 tons to Europe and 30,000 tons to Japan, keeping only about 30,000 tons for domestic consumption. At the present time, more than half of the U.S. production is exported, largely to Western Europe.

Latin America, where Brazil and to a greater extent Mexico (9,700 tons capacity) produce xylene, has a small consumption of phthalic anhydride and, therefore, of ortho-xylene, supplied in practice from local production. A project for 22,000 tons a year of ortho-xylene in India will satisfy local needs until 1970.

2. Para-xylene.

Production capacities, which are already large in relation to the production of other xylenes, are being considerably increased in U.S.A. and in Western Europe by the availability of xylene isomerisation units.

In the U.S.A., the 1960 capacity of 200,000 tons will rise to about 250,000 tons in 1961. Western Europe and other production capacities will rise from 200,000 tons in 1960 to more than 400,000 tons in 1961, a great part of which will be located in Britain. Considerable quantities of xylene isomerisation units will put this capacity into operation in 1961, and it is probable that a quarter of the output will still be in Britain.

In the U.S.A., the large quantities of xylene (25,200 tons a year) will be almost sufficient to meet the needs of that region, but a shortage will be occurring before the end of the period. A program of xylene isomerisation in the U.S.A. will meet a considerable part of local needs after 1960.

B - ECONOMICS OF XYLENE PRODUCTION PROPOSALS

I - ECONOMICS OF STYRENE-MAKING

In the production of plastic materials (polyethylene and PVC) as in that of synthetic rubber, acrylonitrile, dodecylamine, etc., the costs of the monomers (ethylene, propylene, butadiene) and their derivatives are of the order of 1.000 can be sold at the present prices, or the order of 1.000/lb., only because of the selling price of styrene which varies between 3 and 4 c/lb.

More and more, in industrialized countries, one witnesses the installation of steam-cracking plants of greater size (300,000 tons a year of ethylene or more) and of increasing complexity (utilization of butadiene and so forth). In developing countries, for reasons connected with the nature and conditions with the availability of foreign exchange, steam-cracking plants now being installed have capacities of 40,000 - 100,000 tons a year of ethylene. Even in the industrialized countries (except in the U.S.A. for reasons of availability) steam-cracking plants operated on a regular, or decreasing, basis are still in some cases being installed in the same or other capacities. The unit investment is greater in the case, but a plant of 100,000 tons presents lower investment per ton of capacity (40,000 - 100,000 tons a year of ethylene) in which only 20% of the capacity is utilized as a rule, the cost of building per ton of ethylene ranging from 6 to 8 dollars. In developing regions, however, the investment cost is high.

The program of ethylene in its making stage since at the present time for the purpose of the environment and in some of the U.S.A. with a view to the availability of the group of steam-cracking plants and the operation of the same. However, it is clear that the cost of ethylene is still high, and it is not yet possible to steam-cracking operations in industrialized countries to compete with other producers. However, it is expected that the cost of construction will continue to be reduced in some parts, in spite of the high ethylene prices which result from the installation of small steam-cracking plants.

### 1. Influence of size of unit on price of ethylene

In general, developing countries build steam-cracking plants with capacities ranging from 40,000 to 200,000 tons a year. In the majority of cases, the plants are inadequate to insure foreign exchange balance. Within the framework of competition at the local level, or even in export demand, price competition arises in petrochemical sub-products - polyethylene and PVC for example. It is of interest, however, to note the differences in the selling price of ethylene which can be obtained in steam-cracking plants reaching the size of units built in industrialized countries. Profitability calculations (table 13, capital costs, table 14) estimates of operating costs) made under European conditions, with prices of by-products shown in table 15 (benzene and butadiene not yet priced) show ethylene selling prices ranging from about 4.75 c/lb. to 3.5 c/lb. for plant sizes from 100,000 tons a year to 400,000 tons a year, on the basis of a 5 year pay-out.

T A B L E 13  
SELLING PRICE OF ETHYLENE  
WITH A FIVE-YEAR PAY-OUT

Capacity in terms of ethylene	100,000t/yr	200,000t/yr	400,000t/yr
Actual profitability: 20% of capital investment	3,200,000	4,000,000	7,600,000
Provision for depreciation over 10 years	1,600,000	2,800,000	3,800,000
Profits after taxes	1,600,000	2,400,000	3,800,000
Profits before taxes (taken as 30%)	3,200,000	4,000,000	7,600,000
Operating costs	11,900,000	22,000,000	42,050,000
Total sales	15,100,000	26,300,000	49,650,000
Sales of by-products	4,570,000	9,140,000	18,280,000
Sales of ethylene	10,530,000	17,660,000	31,370,000
Selling price of ethylene t/ton c/lb.	105.3 4.75	88.3 4	78.4 3.55

T A B L E 19

STEAM-CRACKING OF NAPHTHA

(ESTIMATE OF CAPITAL COSTS (in dollars))

Capacity in thousands of metric tons/yr	100,000t/yr	200,000t/yr	400,000t/yr
Plant and installation	8,500,000	11,000,000	21,000,000
Working capital	7,500,000	11,000,000	17,000,000
<b>Total</b>	<b>16,000,000</b>	<b>22,000,000</b>	<b>38,000,000</b>

Capital costs US\$ x 10<sup>6</sup>

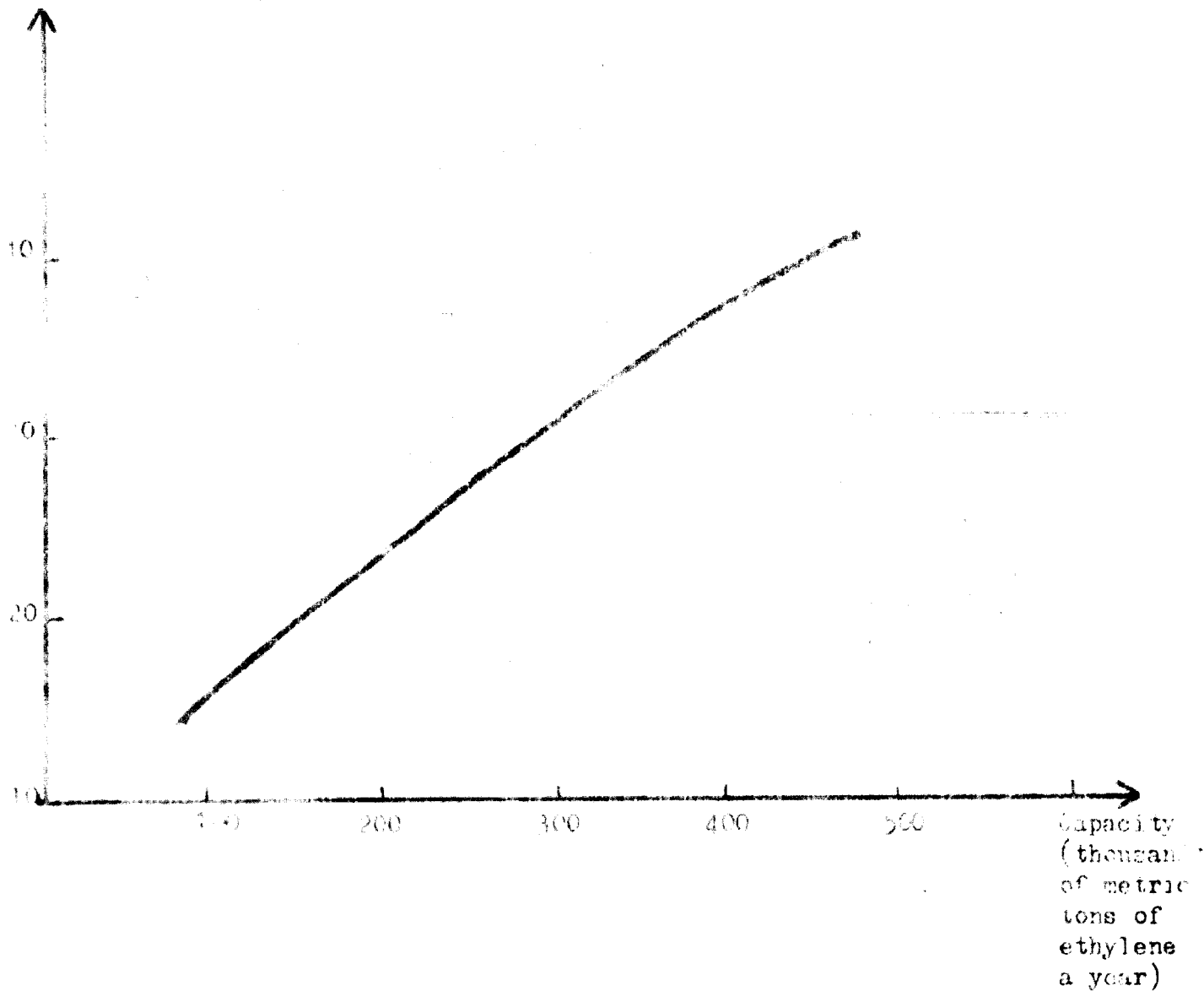


TABLE 20  
STEM CRACKING OF NAPHTHA  
ESTIMATE OF OPERATING COSTS (in \$)

Capacity in terms of ethylene	100,000 t/yr	200,000 t/yr	400,000 t/yr
<u>Fixed costs</u>			
(Depreciation, interest, maintenance, overheads, taxes and insurance)	3,000,000	4,500,000	7,450,000
<u>Variable costs</u>			
Raw material (including at \$20/t)	6,650,000	13,300,000	26,600,000
Utilities, overheads and chemical labour	2,200,000	4,200,000	8,000,000
<u>Operating costs</u>	11,900,000	22,000,000	42,050,000

TABLE 21  
SALES OF BY-PRODUCTS (in \$)

Capacity in terms of ethylene	100,000 t/yr	200,000 t/yr	400,000 t/yr
Fuel gas at \$13/t	700,000	1,400,000	2,800,000
Fuel oil at \$12/t	100,000	200,000	400,000
C <sub>3</sub> Fraction at \$24/t	1,400,000	2,800,000	5,600,000
C <sub>4</sub> Fraction at \$24/t	780,000	1,560,000	3,120,000
Petrol at \$20/t	1,540,000	3,080,000	6,160,000
Total	4,540,000	9,120,000	18,280,000

2. Influence of complexity of the unit on price of ethylene

While steam-cracking plants installed in developing countries, because of their small size, valorize only ethylene, and sometimes propylene, steam-cracking plants installed in industrialized countries and having capacities in excess of 1,000,000 or 300,000 tons a year of ethylene offer more conditions of valorization centered on the petrol. Profitability conditions (Table 2) capital costs; table 2a estimates of operating costs) show for a 500,000 ton a year steam-cracking plant installed under European conditions, with the sales of by-product (propylene and gasoline) priced at 20 and 25 \$/ton, ethylene selling prices ranging from 1.5 \$/lb. to 2.7 \$/lb., on the basis of a 5-year pay out, and if the conditions of the production and the outlet are valorized, for example, a developing country with conditions, with valorization program, ethylene at 6-8 \$/lb. will not be handicapped in the sales of its various products by comparison with industrialized countries in which ethylene currently averages selling at 1.5 - 3 \$/lb.

TABLE 2  
SELLING PRICE OF ETHYLENE IN A FIVE YEAR PAY OUT

	Case 1	Case 2	Case 3
Annual profitability: 20% of capital investment	6,300,000	6,440,000	7,540,000
Provision for depreciation (over 10 years)	3,150,000	3,220,000	3,770,000
Profits after taxes	3,150,000	3,220,000	3,770,000
Profit before taxes (taxes at 50%)	6,300,000	6,440,000	7,540,000
Operating costs	32,340,000	32,930,000	35,320,000
Total sales	38,640,000	39,420,000	42,320,000
Sales of by-products	13,710,000	18,000,000	23,460,000
Sales of ethylene	24,930,000	21,420,000	19,360,000
Selling price of ethylene: \$/ton	83.1	71.4	64.5
\$/lb.	3.75	3.2	2.9





T A B L E 24

STEAM-CHALKING OF NAPHTHA (300,000 t/yr Naphtha)

ESTIMATE OF OPERATING COSTS (in dollars)

	Case 1	Case 2	Case 3
<u>Fixed costs</u>			
(Depreciation, interest, maintenance, overheads, taxes and insurance)	6,140,000	6,280,000	7,320,000
<u>Depreciation</u>			
Plant and equipment (as detailed in Table 23)	20,000,000	20,000,000	20,000,000
Utilities - electricity and chemicals - 180,000	6,200,000	6,700,000	6,000,000
Operating costs	32,340,000	32,980,000	35,320,000

T A B L E 25

VALUES OF BY-PRODUCTS (in dollars)

	Case 1	Case 2	Case 3
Diene at 115/t	2,110,000	2,110,000	2,110,000
Diene at 122/t	530,000	530,000	530,000
Diene at 124/t	4,700,000	4,700,000	4,700,000
Paraffins at 150/t		2,250,000	2,250,000
Diene at 124/t	2,350,000	2,350,000	1,510,000
Bitumens at 110/t			6,300,000
Petrol at 120/t	4,520,000	4,520,000	4,520,000
Total	13,710,000	13,000,000	24,460,000

## II - ECONOMICS OF THE PRODUCTION OF AROMATICS

In industrialized countries and, even more, in developing countries, extraction of aromatics from the products of steam-cracking, does not satisfy requirements. In general, after steam-cracking, the maximum of benzene is extracted (after dealkylation of toluene) and only more rarely the xylenes in separated form since the amounts are too small for decarboxylation of the C<sub>6</sub> aromatics and for the crystallization of para-xylene. The traditional petrochemical source of aromatics (extraction of aromatic products coming from the catalytic reformers of naphthenes) continues to supply an important part of the aromatic requirements, especially the para-xylene.

The economic size of extraction of aromatics corresponds in fact to the technical minima of plant size for crystallization of para-xylene and for decarboxylation of the C<sub>6</sub> aromatics, and to a secondary extent (depending on the price of toluene) to the economic size of dealkylation of toluene. A refinery producing 10,000,000 barrels of aromatic products per year and having a capacity of around 400,000 barrels per year, will not be able to adapt its aromatic production extraction of aromatics. The transport of aromatic materials presents no practical difficulties, whether they are liquid or solid, but the cost of transportation, due to the structure of the industry and to the integration between the refinery and the petrochemical unit (in particular, the mixtures of products) extraction is limited to the capacity of the corresponding refinery or steam-cracking unit.

Contrary to the case in steam-cracking, where limitations of size or complexity are the important factors, constraints of the market and of pricing of products play a decisive part in the setting up of aromatics production.

11. Volume of the market and of the prices of products

If the mixtures of  $C_6$ ,  $C_7$ , and of aromatics, are used after the valorization of benzene and toluene alone, which are obtained in notable quantity and without the need for high capital investments, the extraction process is especially profitable and the product is recovered after being reformed. This results from the size and magnitude of the organic molecules. For the extraction of aromatics, as for the high prices of aromatics in general and of benzene in particular, at the present time benzene prices vary between 110 and 125/1 (5.25e/100 gallon).

The needs of the market has, in fact, been the determining factor for the development of the extraction of aromatics. Thus, the demand for the demethylation of toluene and the isomerization of toluene products for which the market has developed most favorably, i.e. benzene, ortho-xylene and above all para-xylene, have been the subject of greater extraction capacities, with a consequent production and demand for the products have been higher than the others. Thus, demand in France in 1975 is estimated at 1.4 million tons of benzene, 200/250,000 tons of ortho-xylene and 6-10 million tons of para-xylene, whereas these figures are compared with demand for benzene and other xylenes, of the order of some hundreds of thousands of tons, and for the demethylation of toluene and for the isomerization of the  $C^7$ s appear insignificant.

In developing countries where demand for subproducts based on aromatics (nylons, polyester, styrene derivatives), though growing fast, has not yet reached a sufficiently high level, on a country by country basis, extraction capacities will most often be limited to the maximum production of benzene and more rarely (Mexico, India, etc.) to the production of ortho- and para-xylene.

Corresponding to any size of resource utilization, the capital cost is recovered in less than 5 years. This is partly due to the relatively low cost of investment of equipment, fixtures, tools and other attributes with a significant number of units due to the high prices of the processing plant.

1. Investment in plant and equipment  
2. Investment in fixtures, tools and other attributes  
3. Investment in labor

The investment in the processing plant is subject to legal taxation for up to 10% of the total investment, which is subject to a 20% rubber tax. Subject to the same tax, the investment in the processing plant is subject to a 20% rubber tax. The investment in the processing plant is subject to a 20% rubber tax. In the case of steel processing, investment in equipment is satisfied only if it exceeds a certain sufficiently large volume with the utilization of all the products.

2. Example of investment of operation from results

The following table indicates the following assumptions of profitability (investment in the processing plant, total investment costs, total investment costs, etc.) which are shown in the table and show an estimate of the investment, with a detailed list of investment of plant and equipment, etc. For example, an investment of 100,000 tons of benzene) investment could be recovered in less than 3 years.

PROFITABILITY OF INVESTMENT IN THE PROCESSING PLANT

Total sales	11,250,000
Operative costs	10,000,000
Profit before tax	1,250,000
Profit after tax (at 50%)	625,000
Provision for depreciation (over 15 years)	1,200,000
Annual profit	425,000
Payback time	3.0 years

T A B L E 27  
PRODUCTION OF AROMATICS - MATERIAL BALANCE

Charge	Products
Asphaltum	Diene 80,000 tons
100,000 tons	Ortho-xylene 40,000 tons
	Para-xylene 30,000 tons
	Refined extraction products 90,000 tons
	C <sub>7</sub> and C <sub>8</sub> aromatics 60,000 tons
	High-boiling aromatics 20,000 tons

T A B L E 28  
ESTIMATE OF CAPITAL COSTS (in Dollars (INCLUDING WORKING CAPITAL))

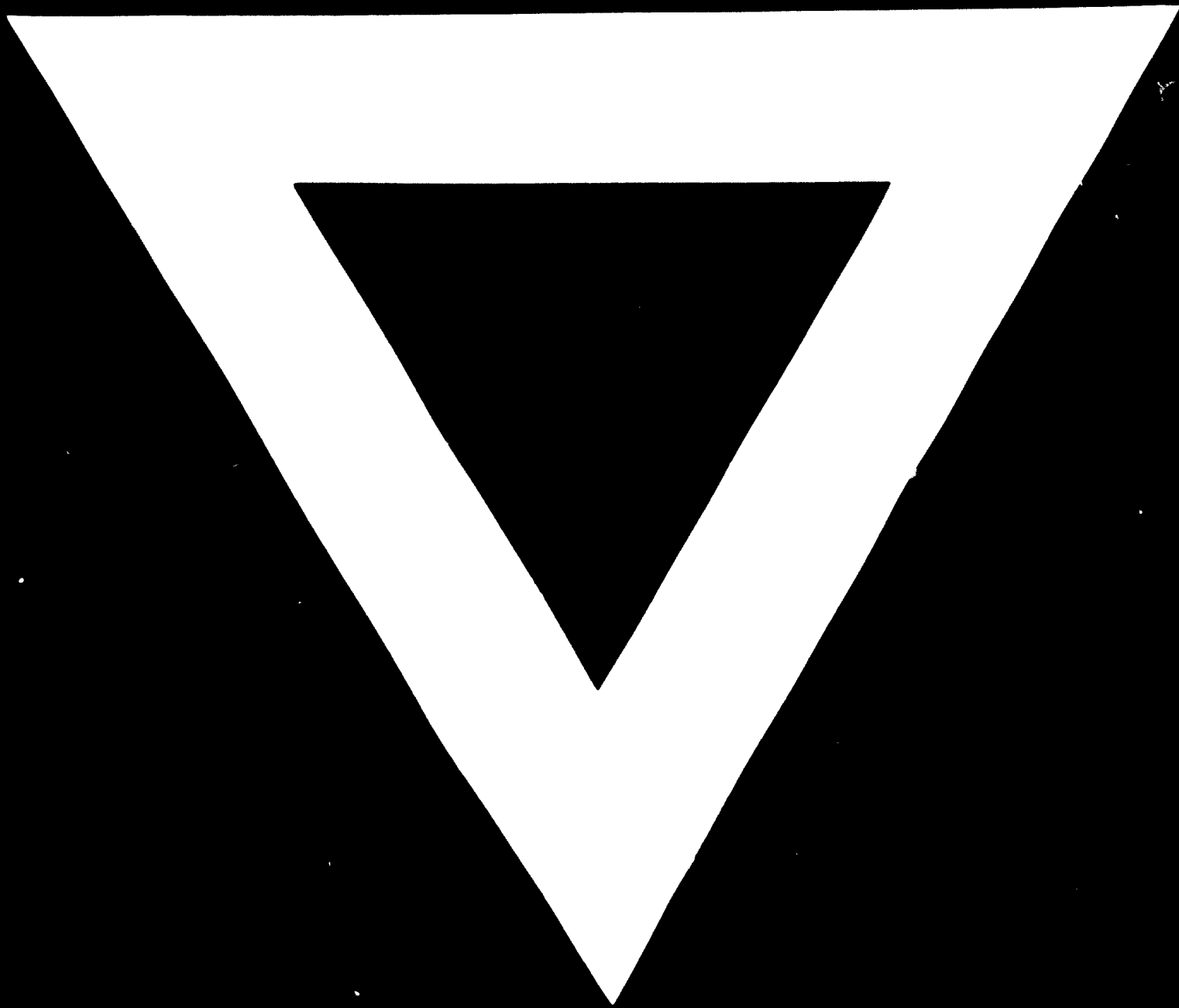
Plant Unit	Estimated Cost
Extraction of dienes	4,500,000
Hydrodealkylation of diene to benzene	1,000,000
Fractional separation of ortho-xylene	1,400,000
Crystallization of para-xylene	5,000,000
Isomerization of aromatics into C <sub>7</sub>	3,300,000
Total	15,200,000

T A B L E 29  
 PRODUCTION OF AROMATICS - ESTIMATE OF OPERATING COSTS

<u>Fixed costs</u>	
(Depreciation, interest, maintenance, overhead, taxes and insurances)	3,180,000
<u>Variable costs</u>	
Rotamats at 22¢/t	8,970,000
Utilities - coal, gases and chemicals, etc.	50,000
<u>Operating costs</u>	13,000,000

T A B L E 30  
 SALES OF PRODUCTS (in dollars)

Benzene	at \$70/t	5,600,000
Ortho-xylene	at \$75/t	3,000,000
Para-xylene	at \$100/t	5,400,000
C <sub>9+</sub> and aromatics	at \$45/t	2,700,000
Refined extraction product	at \$15/t	1,380,000
Fuel gas and hydrogen	at \$10/t	200,000
Total		18,280,000



**24 . 1 . 72**