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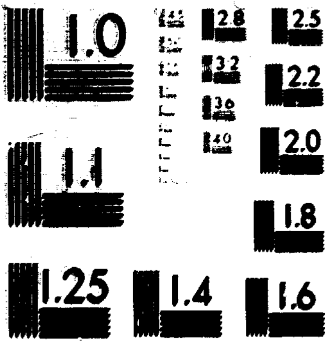

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

20 January 1982

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PERSPECTIVES, PARAMETERS AND OPTIONS IN EMERGENT PETROCHEMICALS TECHNOLOGY: IMPLICATIONS TO DEVELOPING COUNTRIES*

Draft Summary**

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** Summary of draft study commissioned by the Technology Programme of UNIDO.

DRAFT SUMMARY

STRUCTURAL ASPECTS OF INTERNATIONAL PETROCHEMICAL INDUSTRY

Because of its own and proximate resource positions, vast industrial infrastructure, technological prowess, financing capabilities, economic growth rate and enterprise, the US, the Survey finds, will emerge in the post-OPEC period as the largest petrochemicals market and production centre among the industrialised countries. According to a Shell Oil/SRI forecast (supported by responsible industrial opinion) the US is expected to consume ethylene - a fundamental and major building block of the petrochemical industry - at the level of 30 million tonnes in 2000. This is expected to exceed that of Western Europe, at that time, by 40% (reversing the larger role of Europe presently) and that of the LDCs by 80%. In reaching this position, the US will add new capacity representing a 65% addition to present levels.

Because of a series of developments in the international energy field, there is wide recognition that petroleum companies, very largely the 'oil majors', will be the principal entities creating the new capacity. It is also anticipated that oil companies will control much of overall ethylene capacity in the US, both through outright ownership and through participation in joint-ventures with chemical companies.

US leadership of the industry will be vastly enhanced by the large moves that US corporations, mostly the petroleum corporations, are making to manage international production of ethylene,such as Shell,Exxon, Occidental and Dow Chemicals' efforts to secure access to North Sea NGL supplies for Scotland-based ethylene production plants; Shell, Exxon and Dow Chemicals ventures in Saudi Arabia, in association with Saudi Arabian agencies; the maintenance and expansion, directly and through joint-venture, of oil company investments in Europe as those of Occidental-ENI, Gulf Oil, Exxon, Marathon and Caltex; of Mobil and Exxon interests in Australia; Exxon's proposed ethylene venture in Indonesia; the joint-ventures of the type established by DuPont, Union Carbide in Canada, etc. Since these investments and ventures are large, and will produce commodities as polyethylene and ethylene glycol far in excess of demand of the countries in which the investments are made, the markets for the commodities is expected to be a directionless 'world market'.

The commodity products, being based, in most of these locations, on raw materials whose alternative value is only as fuel, and even so difficult of transport, will be able to penetrate tariff barriers of most countries. Thus, American firms, besides a large home market can be expected to dominate world markets.

The Survey finds that while European chemical firms, through joint-venture association with oil majors and with national oil companies, will have feedstock security sufficient to maintain their commodity businesses (bulk plastics and chemicals) in their home markets, they are unlikely to deepen their positions or seek greater consolidation. It is anticipated that there will be a preferential move 'far downstream' into speciality and proprietary products, which have a low feedstock content and which can be advantageously marketed in their cultivated brandname-based distribution chains. At the same time, in recognition of the high cash flows that arise in tonnage products, as plastics, the European firms are expected to reinforce their existing manufacturing positions in North American markets in acknowledgement of its fast growth.

The Japanese appear as the most disadvantaged of the industrialised countries in the post-OPEC period in consequence of their very distant location from energy/

feedstock resources and because of their near total reliance on imports for meeting minimal energy needs. While, like the Europeans, the Japanese are not expected to disinvest in home-based commodities, they are, however, not expected to add to capacity at anywhere near the rates achieved in the post-War period. A broadening of production-mix, with concentration in fine and speciality chemicals, appears as an interim strategy precedent to a OPEC-driven restructuring of their chemical industry, requiring new feedstocks, or investment in international locations.

A survival option being exercised by the Japanese petrochemical corporations - individual corporate decisions rather than the effort of some planning superstructure - is a drive to internationalise investment. This finds expression in the association of Japanese companies with multi-partner energy/feedstock enterprises in hydrocarbon-rich countries, as in Indonesia for oil, in Australia for coal, in Canada and Alaska for natural gas, in the US for ethylene dichloride (indirect access to electric energy), in Saudi Arabia for crude entitlements, etc. While these projects give Japan an access to hydrocarbons (feedstocks and energy) to service home industries, there appears to be little motivation for the Japanese companies, at the present time, to see international locations as sources of petrochemical commodity supply for the home markets. Japanese overseas investments in commodities appear to relate to 'world markets', usually LDC markets.

The overseas thrust of the American corporations has a different basis to the Japanese in that the investments of the former arise from large, investible funds and as a means of spreading business risk. Individual Japanese corporations, on the other hand, do not have the financial resources of their US counterparts and thus invest with other like-minded corporations (chemical and non-chemical associates) to survive home market competition with peer groups.

The petrochemical industry of the three industrialised regions is faced with three common situations: (a) large dependence on the Middle East countries for crude supplies (b) the need to depend on sources of petroleum which are not controlled by them, and (c) competition in home markets arising from the sharing of naphtha between the petrochemical and gasoline users in a situation of tight supply. These give rise to problems, to the industry, in terms of the play of political forces in the case of the first situation, that of 'guaranteed access' - or feedstock security - in terms of the second, and price in the case of the third.

While the strategies adopted by the countries to solve these problems differ in many ways, there are two common approaches: (a) implement inter-fuel substitution so that petroleum can be made to maximally serve "unsubstitutable" usages - transportation and chemicals, and (b) reduce reliance on Middle East crude.

One of the basic features emerging from these strategies is a stress on locating, or developing, regional access (stable access) to hydrocarbons. This has been surprisingly aided by new resource developments or new resource discoveries. Thus, the USA sees Alaska, Canada and Mexico as proximate and new sources of hydrocarbons, which can supplement indigenous effort (itself propelled by graduated removal of government price and supply controls on natural gas and crude). European industry finds strategic significance in the discovery of North Sea oil and gas, while emerging political and economic equations with the USSR give it growing access to natural gas of which Siberia has plentiful (if still not exploitable) supply. The Japanese see in natural gas a means of obtaining a large measure of independence from cartelised supplies, obtaining natural gas from 'neighbourhood' sources as Indonesia, Bruenii, Thailand, Alaska and Canada. Thus, all three regions are strongly influenced by the geopolitics of new *hydrocarbon resources. That is, strategic access plays a far greater role than gross levels of availability or the costs and convenience of use.*

While Japan has little option, (even if the domestic political situation improved to admit wide employment of nuclear energy), most of the countries of Europe obtain a degree of flexibility through accent on the indigenous use of fuels: brown coal and lignite in FRG; nuclear energy in France; natural gas, from the Gronigen fields, in the case of the Netherlands; oil and gas from the North Sea for UK, etc. These supplies are then supplemented by access to 'regional sources' - as Soviet and Algerian gas - to give the countries, the assurance, from their political viewpoint, of reduced dependence on the Middle East. In effect, the European countries appear to be aiming at a level of insularity with respect to the Middle East.

In the USA, the dominance of the automobile industry in the national economy creates such a large demand on gasoline that, unless there were to be significant technological breakthroughs for obtaining alternate sources of gasoline, the country would not be able to reduce its dependence on the Middle East.

Interfuel substitution strategies, combined with access to regional hydrocarbon sources, have given the countries of Western Europe a means of temporary but stable adjustment to the supply crises induced by OPEC actions. However, their ability to maintain a modicum of growth hinges on the development of new technology. The reading of the Survey is that there being insufficient demand for such technology, supply would not be forthcoming. That is, in the laissez-faire economies of Western Europe, there needs to be corporate perception of demand before response can occur. Only the largest corporations of Europe - ICI, Bayer, Hoechst, BASF - have the prompting to undertake defensive research to maintain their distinctive corporate identities. Technological effort for the independent survival of competing units - a demand which spurred much of post-War research in Europe - has greatly lapsed in countries such as Italy and France.

The Survey finds European corporations otherwise preoccupied with structural change in the industry: (a) the penetration of oil companies, particularly oil majors, into European chemical commodity markets (b) the growing saturation of the European market in areas as fibers, synthetic rubbers, etc. which could well extend itself to the plastics (c) the high reflection of feedstock prices in product costs (d) the abandonment of the European chemical market by US chemical companies as Union Carbide, Monsanto and Gulf, by European companies as Rhone Poulenc and Napthachimie and the collapse of companies as S.I.R., Liquichimica and Rumianca, etc. (e) the giant moves being made by oil companies, on the periphery of Europe, to produce commodity chemicals with location advantages, and (f) the difficulty of raising financial resources of the order required to commercialise European coal as feedstock.

Thus, to the European companies, internationalisation of investment, to obtain growth markets, particularly in the US, appears as a viable solution, although it is a structural one.

It is only in the US that there is a definite corporate perception of technology demand. In acknowledging this it must be recognised that the chemical industry of the US, today, is an industry shared by both chemical and oil companies in keen competition with each other (as enterprises and as industries). Hence, perception has different bases.

To the oil companies coal (as a source of coal liquids or syngas) has emerged as a viable alternative to petroleum (seen as a source of gasoline) solely because the price gap between it and oil (real prices) is widening, favouring coal. With 70% of US coal in the hands of oil companies - as a result of acquisition policies adopted as early as 1964 - access does not create a structural problem.

For the chemical companies coal, 30% of which is with 'independents', appears as an alternative not only because of its price differential with respect to petroleum but a means of maintaining their traditional independence from the oil companies in respect of resources (i.e. as their present reliance on the natural gas-processing industry for ethane rather than on the oil industry for naphtha).

For both oil and chemical companies the forecasted size of the national incremental market for ethylene of 15 million tonnes by 2000, with large net additions to capacity - provides further incentive to develop coal since its conversion economics - whether to liquid or gaseous hydrocarbons - is highly scale-sensitive.

Prospects for the development of coal is further reinforced by the investment interests of German companies in US industry, particularly in terms of their long association with commercialised (wartime) coal technology. Even Japanese companies have waited years to participate in efforts to exploit low-cost Western US coal if American investor interest was forthcoming.

DIRECTIONS OF TECHNOLOGICAL EFFORT

In the contexts of post-OPEC energy prices, and decline in international 'R/P' ratios of gaseous and liquid hydrocarbons, the situation has arisen in which there is little economic incentive to use, as feedstock, one of these hydrocarbons in place of the other if both hydrocarbons have equal alternative energy/fuel markets. This is the environment in most industrialised countries, and particularly that of the market economy group. Consequently, the thrust of developmental effort in these countries - most evident in the USA - is the attempt to use hydrocarbons that are priced in bargaining counters far removed from those of oil and natural gas - namely, coal, shale oil, tar-sands, biomass, etc.: counters where the costs of extraction or conversion are likely to be major components of the market price. Thus, if capital and operating costs of using such hydrocarbons as sourcing materials for the manufacture of chemicals could be recovered at a price which reflects, say, a 12% DCF rate of return on investment, in a utility type of financing pattern, then a measure is obtained of the maximum price that can be afforded for the raw material.

Coal is today the most attractive of the alternate materials because: (a) it is in wider geographic dispersion than shale or tar sands and unlikely to result in resource monopolies (b) a well-developed infrastructure already exists for its exploitation and movement, and (c), its ecological and safety problems are well-known. Interest in US Western coals is keener than on other coals, national and international, because its infrastructure permits a low cost of extraction.

For the exploitation of coal there are three general lines of approach: (1) to covert it to liqui s which can be readily processed by means already well established for petroleum and serviced in an undistubed petroleum infrastructure - e.g. coal naphtha (2) to covert it into intermediary materials, or to final commodities, for which adequate infrastructures exist or can be developed at reasonable costs with known technology - e.g. synthesis gas or methanol and (3) new or unfamiliar materials whose prices can be expected to be low enough to override the cost element that will emerge from the need to create new infrastructures for their use - e.g. mixed lower alcohols for use as automobile fuel.

In coal technology concepts, infrastructural needs and costs play a very important part because coal can be efficiently used only when it can be processed on a large scale.

In this there are considerations of an 'upstream infrastructure' - which would bring coal to the processing point - and a 'down-stream structure' - which will take coal, in its converted form, to its first-level users. In the US, overland coal transport costs are so large in relationship to the 'pithead' cost of coal, particularly high-ash Western coals, that technological development has the premise that upstream infrastructure should present a very low cost burden: in other words, the coal processing point should be at the pithead.

A cost implication of the 'downstream infrastructure' is that market potential will have to be large enough to warrant that the product utilising the infrastructure will impose a base-load on it; that is, absorb infrastructure costs.

Since chemical feedstocks, for all their volume, are too small to load the large existing infrastructures for energy hydrocarbons (only 8% or so of all petroleum-based, or gas-field-based, hydrocarbons are used for chemicals), or to lead to economies in the mass processing of coal, the relevance of coal technology to chemicals arises only in that the energy industry can be its promoter.

While not all 'energy hydrocarbons' are usable as chemical raw materials, a maximum utilisation of the energy 'residing' in a raw hydrocarbon source, including coal, is achieved when low-level heat, rejected by efficient energy systems, can be employed in chemical systems. Thus, independent of whether the chemicals manufacturer or the energy producer (i.e. a secondary energy producer) deploys coal as a source of hydrocarbons, the dictate of thermal economy requires energy diversion to low-temperature chemical process (for chemical products).

This rather extended preface is necessary to focus on forthcoming technology which will produce hydrocarbons, with clear chemical labels, possessing the ambivalance that they can be employed in both the energy and chemical industries.

The most important implication of modern research to petrochemical feedstocks is the capability to convert synthesis gas and methanol, in independent frameworks, to ethylene and propylene.

The techno-economic significance of this capability is that the immediate upstream technologies that produce syngas and methanol, and downstream technology structures which will convert ethylene and propylene to petrochemical end-products would be left undisturbed, in both structural and technical terms. Thus, the new developments would be linkage technologies working within an existing industrial framework. Figure I (Methanol as a Petrochemicals Feedstock) identifies the position of the linkages looking at the industry from a conceptual point of view, and considering primarily the role of methanol.

That a capability prevails to convert methanol, and similar intermediates, to the industry's principal building blocks - ethylene and propylene - is exhibited by responsible industrial research. Whether or not it will eventually result in commercial technology hinges on the availability of methanol at a cost differential to existing feedstocks (principally naphtha) sufficient to (a) induce the development of a distribution infrastructure for methanol and (b) stimulate new investment in 'grassroots' facilities to convert methanol to ethylene.

The finding of the Survey is that American response to the opportunity - that is, the effort to develop capability to produce ethylene from methanol - will not be forthcoming unles [illegible]l, directly or indirectly, became an energy fuel, and in consequence led to the development of a self-servicing infrastructure. That is, for innovation to occur in the chemical industry structural and technical change would be necessary in the energy industry.

This is not so extreme a conjecture or association as it might appear at first sight. The European chemical industry, within a decade, shifted from its basic reliance on electric power based acetylene to naphtha-sourced ethylene, as feedstock, in sequel to a structural reform in the energy industry: as the latter changed from its dependence on coal to that on petroleum. The reform, indeed, founded a parallel infrastructure for the production and dispersal of naphtha.

The most important structural change that can be expected to occur in the US energy industry, in a foreseable time frame, is its shift to 'M' gasoline, a revolutionary way of obtaining conventional gasoline from methanol. The technology is based on Mobil Oil's patented developments in 'zeolite chemistry'; a technology first announced in 1973.

Unlike the status of methanol-to-ethylene technology, there has been significant industrial committment to that of gasoline, the best example being the decision of the New Zealand Government to fuel 30% of its automobiles with 'M' gasoline (incurred investment).

A feature which make 'M' gasoline a viable concept in the US is that a new infrastructure does not have to be created for its use or is there a requirement for modification of automobile engines. Furthermore, there is also no requirement that conventional gasoline be wholly replaced by the new gasoline for its suitability as a vehicle fuel. 'M' gasoline need only be a supplementing source, 'an additive'.

US corporate commitment to 'M' gasoline is impeded, in the Survey's findings, not by enterprise, technological or sociological uncertainities in the production and use of 'M' gasoline, the relativity of the price of coal to petroleum (which now significantly favours coal) and its trends, markets for gasoline or by facets in the pricing of methanol. The basic impediment arises from the scale of investment involved in the production of methanol from coal and following from it, socio-economic implications. Even the largest petroleum companies assess that they will not be able to generate, as individual companies, required investible funds - of the order of $ 3-6 billion for economic sized units; that for 'coalplexes' to fructify, investment/production consortiums will need to be formed.

The association of oil majors or oil/chemical majors to fund investment is expected to be resisted under the anti-trust legislation of the US. The alternative association of oil majors with utility companies (power, natural gas, etc), which is less likely to face anti-trust action, would *require that the coalplexes produce synthetic natural gas (SNG) to satisfy utility company investors. The present level of SNG technology does not give the assurance of competitive cost.*

The use of coal for methanol in FRG, the only other location in the industrialised countries where a coal option can be exercised consistent with energy strategies, is again inhibited by investable resources of individual corporate organisations, anti-trust factors, high cost of exploiting hard coals (the most expensive in the world), and the pre-emption of softer coals for electric power generation.

Although investment levels would still be in the billion dollar range, there are fewer institutional limitations on the production of syngas from coal. However, as with methanol, its availability to the chemical industry would be dependent on its co-exploitation for energy.

The factors limiting the use of syngas for energy are basically: (a) the need for a distribution infrastructure (pipeline system) should the alternative of employing it for pithead electric power generation be infeasible on some economic grounds, and (b) technological uncertainities in inter-coal substitutabilities (a problem of coal grades), necessitating,at the minimum, prototype evaluation for each major variation of grade.

As for the utilisation of syngas for chemical intermediates - particularly ethylene - a viable technological route does not, at present, exist. However, there is no theoretical or conceptual impediment to its generation. In fact, the earliest of coal technologies - the Fischer Tropsch process - currently used in the three large Sasol complexes of South Africa does produce ethylene as a coproduct with energy hydrocarbons. Thus, technological development for chemicals usage is a process involving the improvement of catalyst selectivity to ethylene. The soundness of theoretical approaches to ethylene from syngas has lead Shell Oil to forecast that,at the very least, 8% of the world's ethylene in 2000 will be Syngas-derived.

A basic issue that the above discussion leaves out is the technological relevance of obtaining ethylene from methanol, with methanol based on hydrocarbons other than coal. A discussion of this is summarised in the following section because of its tremendous importance to the LDCs.

IMPLICATIONS OF NEW TECHNOLOGY TO LDCs

While its eventual crystallisation as a mature, cost relevant and transferrable technology cannot be assessed a certainty, a Mobil Oil route to ethylene and propylene promises to be a most important technological development which can have far-reaching contributive implications for LDCs - to those who are self-sufficient in any or a combination of hydrocarbon resources - petroleum, natural gas, coal or biomass. The significance of ethylene and propylene, in themselves, is that they are crucial building blocks for the plastics - vital and strategic in the materials-mix of nations - and for a whole host of petrochemicals.

In the present state of development of the technology, methanol intervenes (see Figure I) between the source hydrocarbon - petroleum, biomass, etc - and the 'building blocks'. Conceptual and 'bench-scale' research indicates, however, that a more direct linkage to the hydrocarbon source - a shortening of the production chain - is possible. This alternative involves the use of synthesis gas (syngas a mixture of carbon monoxide and hydrogen) as the linking agent between the source hydrocarbon and the building-blocks.

This direct alternative is favoured by the American corporations on the grounds that: (a) syngas production is more scale-responding than the production of methanol (b) the forecasted US incremental market is large enough to warrant scale-relevant production and (c) the need of a methanol infrastructure, or the use of it, is obviated.

In Europe and Japan, while there is interest in both the methanol and syngas routes, the size of their future incremental markets is not large enough to warrant a pervasive corporate commitment to new sources of ethylene. Energy strategies of the countries, and growing regional access to new resources of traditional hydrocarbons, together with other factors, permit or require them to postpone technological change. Furthermore, European hydrocarbon availabilities are such that they would have to depend on imported methanol, an unattractive indulgence.

For the LDCs, on the other hand, the methanol route can have very large attractions: (a) methanol is a commodity (world production 12 million tonnes) in widespread international trade (b) as a commodity, and unlike syngas, it can be readily stored, transported and serviced by the existing petroleum infrastructure (c) it can be imported from a plurality of competitive resources, with excellent scope of regional access, (d) it would permit scales of production which are efficient to service LDC-level ethylene markets (e) it can be indigenously produced from a variety of hydrocarbon sources and (f) where strategic, a petroleum-independent route to petrochemicals can be achieved.

There are large indications that relevant technology will emerge for methanol-based production of the olefins (ethylene and propylene). These are: (1) the technological pathway that leads to the production of 'M' gasoline in Mobil's 'M' gasoline process (from methanol) involves 'in-prodess' creation of the olefins which are then transformed, in-situ, to 'gasoline molecules' (2) Mobil's patents, public presentations and comments made during the Survey clearly and unequivocally claim that the process of olefins conversion to the gasoline molecules can be arrested and diverted to the production of the olefins (3) independent research, as by the US Bureau of Mines, on zeolites - catalyst-carriers and 'regulators of molecular traffic' in the Mobil 'M' process - confirm catalyst chemistry can be adjusted to maximise the production of the olefins (4) there is widespread and responsible industrial appraisal that methanol is a workable source of ethylene (5) European firms as BASF and Bayer have committed funds for pilot plant investigation of the process (6) African Explosives and Chemicals, a South African firm with 40% ICI equity, has a large joint programme with Mobil Oil to specifically explore olefins production from methanol (7) energy-promoted large-scale production of methanol carries the promise of reducing methanol production and infrastructure costs to levels where it will attract serious chemical interest as an independent feedstock (8) firms as DuPont and Celanese, in apparent acknowledgement, have vastly expanded their methanol production capacities (and in international sites) and finally (9), fully commercialised methanol-to-petrochemical technologies - as those of acetic acid and acetic anhydride - have evolved (Monsanto, Eastman Kodak) which have penetrated conventional production.

The impact of olefins from methanol on general petrochemistry is illustrated in Figures II to IV, with Figure II showing present commercial positions of naphtha and other conventional feedstocks in relation to the rather narrow role of methanol.

Figure III, on the other hand, shows the replacement role that methanol can play as a straight-forward source of olefins for LDCs (and others). Its ability to cater to the most volume-intensive segment of the petrochemical industry - the thermoplastics - is a critical contribution of this figure.

Figure IV shows competitive non-conventional routes to the 'petrochemicals'. Here new approaches, as chemicals sourcing from the petroleum refinery, together with new technological developments (which the Survey shows as having practical near-term significance to LDCs and others) is presented. In order to avoid duplication, new applications of methanol, as described by FigureIII are ommitted in Figure IV, . Thus, Figures III and IV - in total summarise the technical findings of the Study.

LDC SPUR TO TECHNOLOGICAL DEVELOPMENT

There is no demand in the industrialised countries, outside that of the US, for the creation of a pervasive non-petroleum structure for 'petrochemicals'. On the other hand, there is expressed need for an alternative to petroleum within the LDCs. Since, in the foreseeable time span, capability in the LDCs is unlikely to provide an effective technical response to such need, some form of a 'technological mechanism' must be devised so that LDC requirements can be met through developed country action. That is, LDCs must intervene in the process of international technological development so that emerging incipient research - as that of methanol to ethylene - monitored as organic to LDCs can be reinforced. Intervention has to be more robust than catalytic.

Despite the critical impact of imported petroleum on the economy of most industrialised countries, adequate demand for the use of substitutes as methanol and syngas are resisted. The primary reason for this situation, the Survey finds, is that existing infrastructure - the physical structure of the petroleum distribution system of pipelines, loading and reception terminals, tankage and underground storage - built in an era of low-cost energy subsidiees the usage of petroleum and natural gas. Today, in North Eastern Europe, and on the

US Gulf Coast, such concentrations of industry and infrastructure exist that grided ethylene distribution systems, in these regions, have all the characteristics of utility distribution (like electric power) - conferring on ethylene indeed the status of a utility.

Thus, infrastructure acts as a giant flywheel to resist the dynamics of change. Inducing new technology in such a framework is a struggle to penetrate the infrastructure.

Yet historically, as noted earlier with respect to carbide-based acetylene and naphtha-based ethylene, vital new technology has demonstrated the power of penetration. Provided in the extant aase of methanol-to-ethylene, methanol prices at points of import, through some collective action of LDCs, can be subsidised to overcome the subsidy otherwise provided by infrastructure, a stimulus is provided for the precipitation of new technology. It can be noted, for example, that Rotterdam or Antwerp have the required logistical features for methanol import, its conversion to ethylene, and its transmission by the European distribution system. Methanol's penetration into naphtha's strongholds, it must be recognised, will be the reverse of a process by which low-priced naphtha penetrated a previous carbide-acetylene infrastructure.

Methanol is produced at the lowest cost, and with reasonable levels of fixed investment, when its raw material source is *natural gas. Indeed, this is presently methanol's most important source. If one looks at natural gas as the backing resource, it emerges that LDC's have, collectively, 39% of the world's reserves (OPEC-25%)distributed over some 65 countries in wide geographic dispersion. Much of LDC gas presently goes to serve developed country demand (Europe mainly) for heat (indirectly subsidising the generation of electric power). Thus, creating a situation by which natural gas will function as a 'carbon carrier' in turn to initiate the development of technology of value to LDC$ appears a viable strategy.*

Fostering a mechanism which will make coal an attractive technological medium for methanol (or other chemicals) has a lower implication in that LDC ownership of world coal is only about 21% (with practically very little in the OPEC countries) - thus lacking the potential for collective LDC action. Consequently, reinforcing the otherwise effective technology demand for coal-based chemistry in the USA would not be relevant LDC action.

The above emphasis on methanol-based ethylene arises because of its great potential contribution to virtually all LDCs. However, there are several options - pathways - by which LDCs can effectuate technological mechanisms for this and other technologies.

The Survey finds that purchase of technology options through sponsorship of developed country research programmes - through membership in development consortiums - could be an important mechanism (research options operate on the principle that the sponsoring group obtains, for a pre-settled fee, the option to commercially employ generated technology. The option fee is separate to risk funds otherwise provided to the project). A more viable approach, the Survey finds, would be for LDCs to stimulate development at locales which have responsive environments. It is also a finding of the Survey that the 'entry fee' LDCs would have to pay for the use of new technology, which they have not supported, would perforce be very high.

Development consortiums, in the medium term, must be seen as technological mechanisms which will create future chemistry for LDC needs in a continuum having bearing on their commercial usage in developed countries.

The Survey, on the basis of various studies presented in the body of this Report, projects 'first commercialisation' of emergent technologies as given in Table I.

That change can occur this quickly is a projection, on the other hand, of historical trends in the industry. As seen in Table II naphtha-based technology overrode that carbide-based in a time span of less than 20 years with very small beginnings.

In conclusion, and to summarise the above discussion, for LDCs to achieve their needs in the medium-term, they must through various mechanisms impose a research contract on the 'developed country industrial system'. If developed countries *wish to exist in a world in which they have predominantly consumed and consume the world's most facile feedstocks, it should be made incumbent on them to develop new resources in replacement.*

TABLE I

TIME-FRAME FOR EARLIEST COMMERCIAL UTILISATION OF EMERGENT TECHNOLOGIES

O = Industrialised countries

X = LDCs

	1980	1985	1990	
I. SYNGAS				
1. From conventional resources				
A. Natural gas to syngas (for chemicals other than methanol)	O	X		
B. Petroleum residues to syngas for chemicals	O	X		
C. Direct routes to products				
(i) acetic acid(HA) acetic anhydride (AA) vinyl acetate, MMA, ethylene glycol (EG)		O(HA) O(AA) O(EG)	X(HA)	X(EG)
(ii) ethylene/propylene (thus to virtually all thermoplastics and chemicals)			O	X
2. From non-conventional resources				
A. Coal to syngas (for chemicals)*		O	X	
B. Biomass to syngas		X		O

*Excluding South Africa.

TABLE I (continued)

	1980	1985	1990	
II. METHANOL				
1. Direct routes to products				
(i) acetic acid(HA)	O(HA)	X(HA)		
vinyl acetate(VAM)		O(EG)	X(EG)	
ethylene glycol(EG)		O(VAM)	X(VAM)	
styrene (S)			O(S) O(E)	
ethanol(E)				
(ii) ethylene/propylene (thus to virtually all thermoplastics and chemicals)			O X	
2. Methanol to gasoline (G)/Aromatics(A)		O(G)	X(G)	X(A)
III. PETROLEUM & FRACTIONS				
1. Fluid Catalytic Cracking (FCC) to chemicals	O	X		
2. Naphtha's from hydrocrackers - for use in conventional steam-cracking.	O		X	
3. Direct cracking of crude to ethylene				O
IV. PSEUDO-PETROLEUM FEEDSTOCKS				
1. Coal liquids(used for chemicals)			O	
2. Shale (SH) and tar-sand (TS) distillates (used for chemicals)	O(TS)		X(SH)	O(SH)

TABLE II

EVOLUTION OF TYPICAL SIZES OF PRODUCTION UNITS FROM 1955 TO 1976 FOR SOME SIGNIFICANT PRODUCTS (thousands tonnes/year)

	1955	1960	1965	1970	1976
Basic products					
Ethylene	20	50	150	300	450
Ammonia	50	85	150	350	350
Intermediate products					
Acetaldehyde	10	20	30	100	135
Acrylonitrile	10	15	30	60	180
Caprolactam	10	20	40	60	70
Phenol	10	25	45	70	90
Styrene	10	30	50	150	450
Vinyl chloride	30	50	100	150	270
Ethylene oxide	5	10	20	70	135
Final products					
Low density polyethylene	10	30	50	100	100
High density polyethylene	5	10	20	60	90

Source: ECMRA Conference "European Chemicals in the 1980's: problems and possibilities". Venice, 1978.

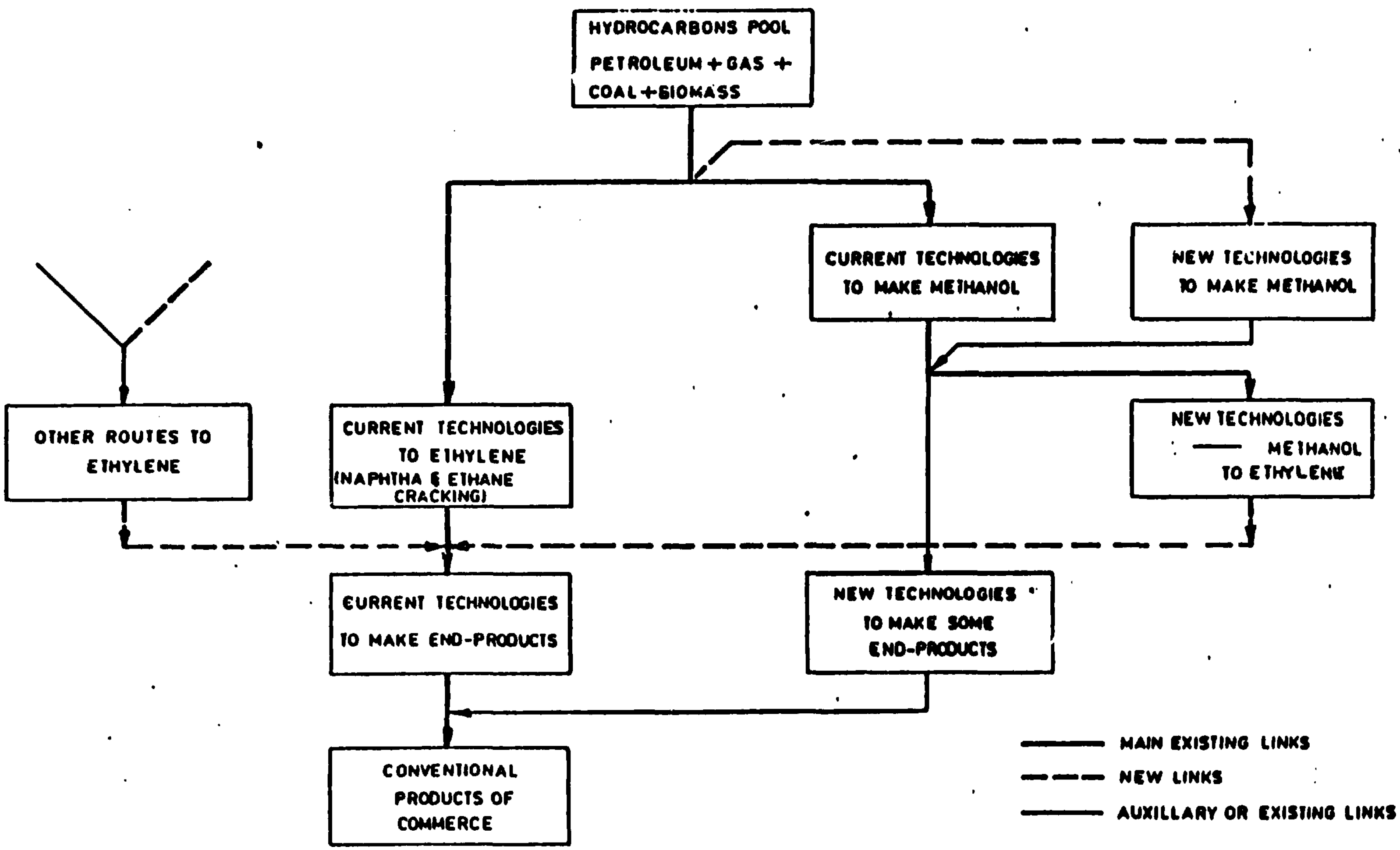

FIGURE I. METHANOL AS PETROCHEMICAL FEEDSTOCK

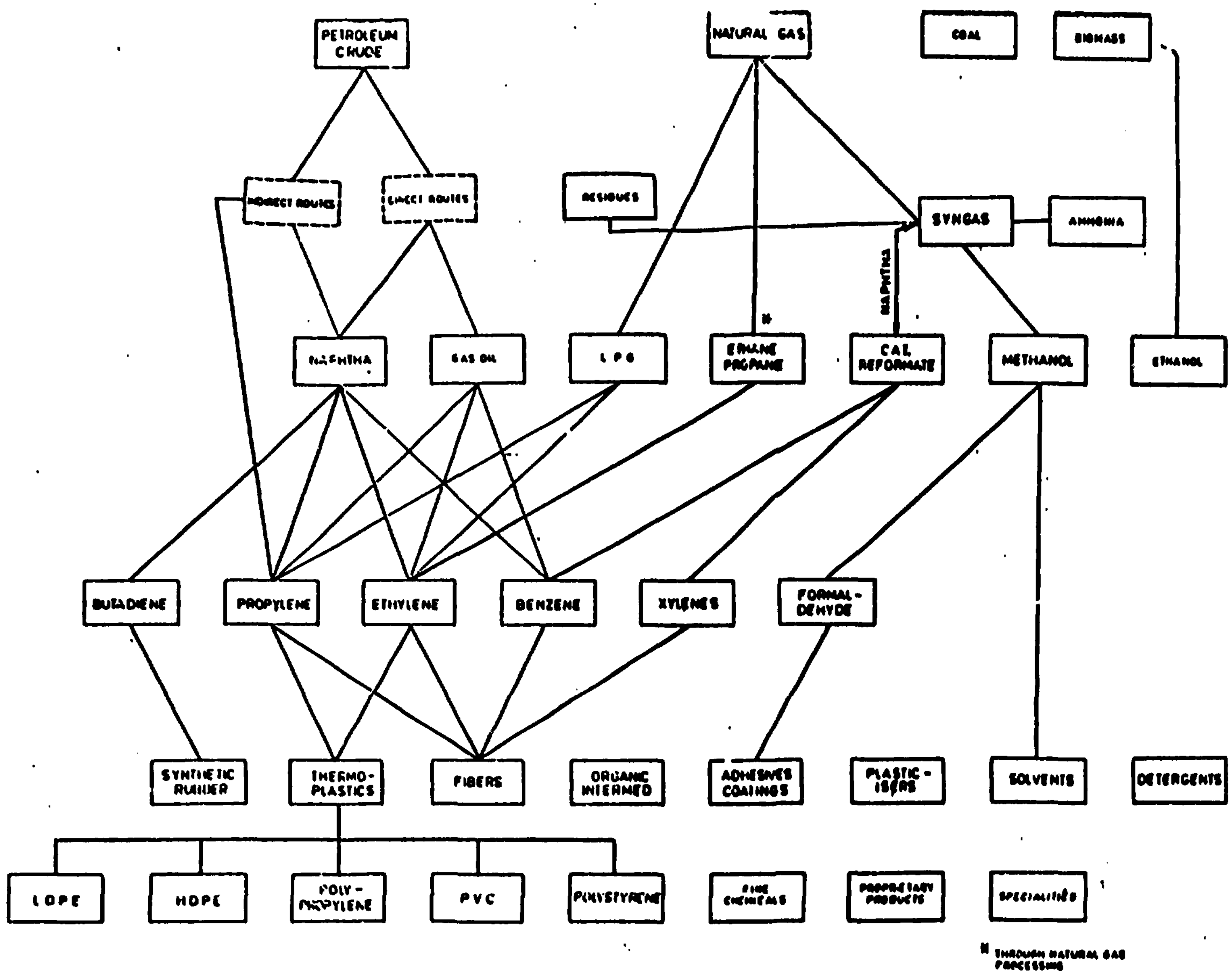

FIGURE II. FEEDSTOCK LINKAGES TO MAIN ORGANIC CHEMICALS AND POLYMERS (1981)

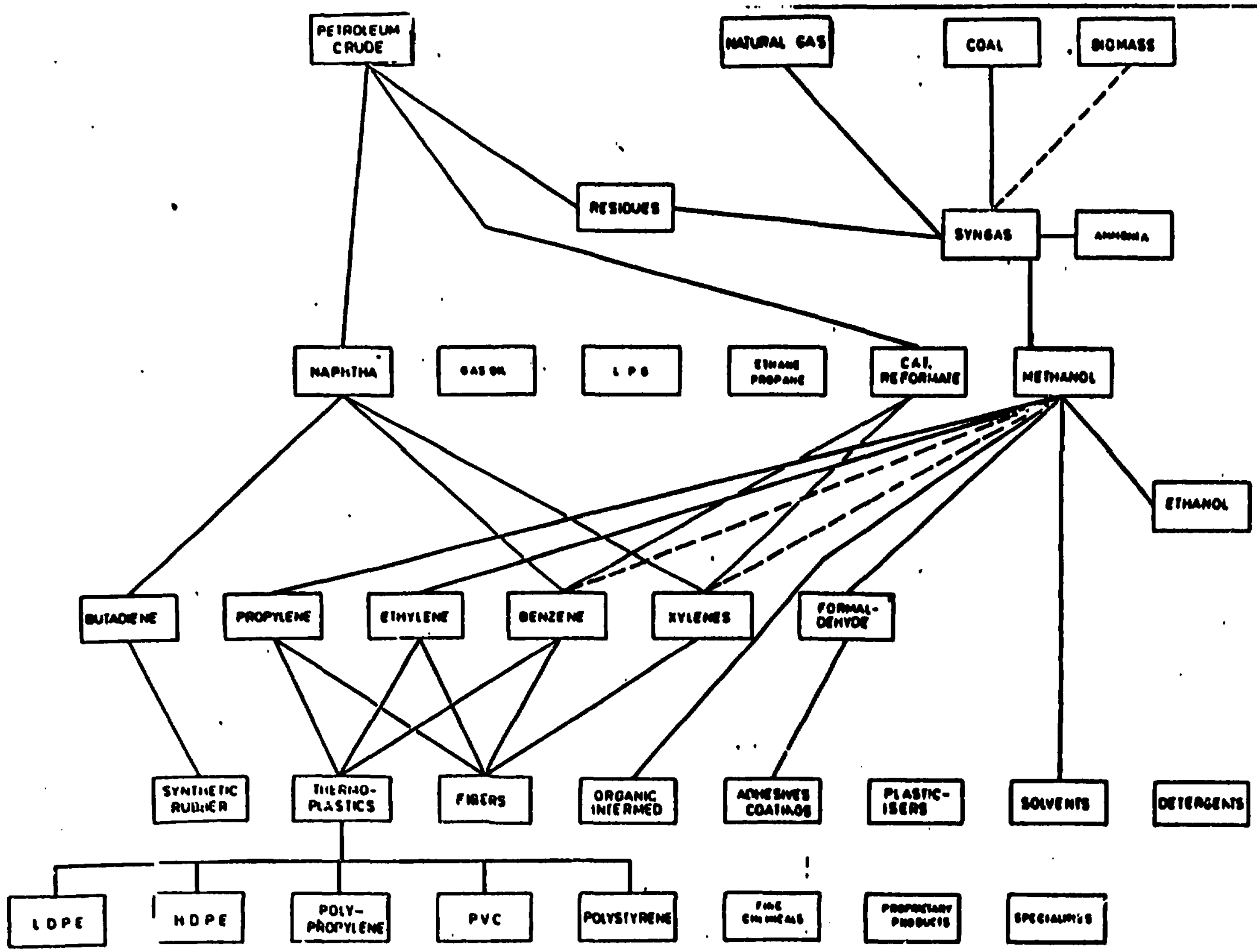

FIGURE III. METHANOL AS A MAJOR FEEDSTOCK SUBSTITUTE TO NAPHTHA

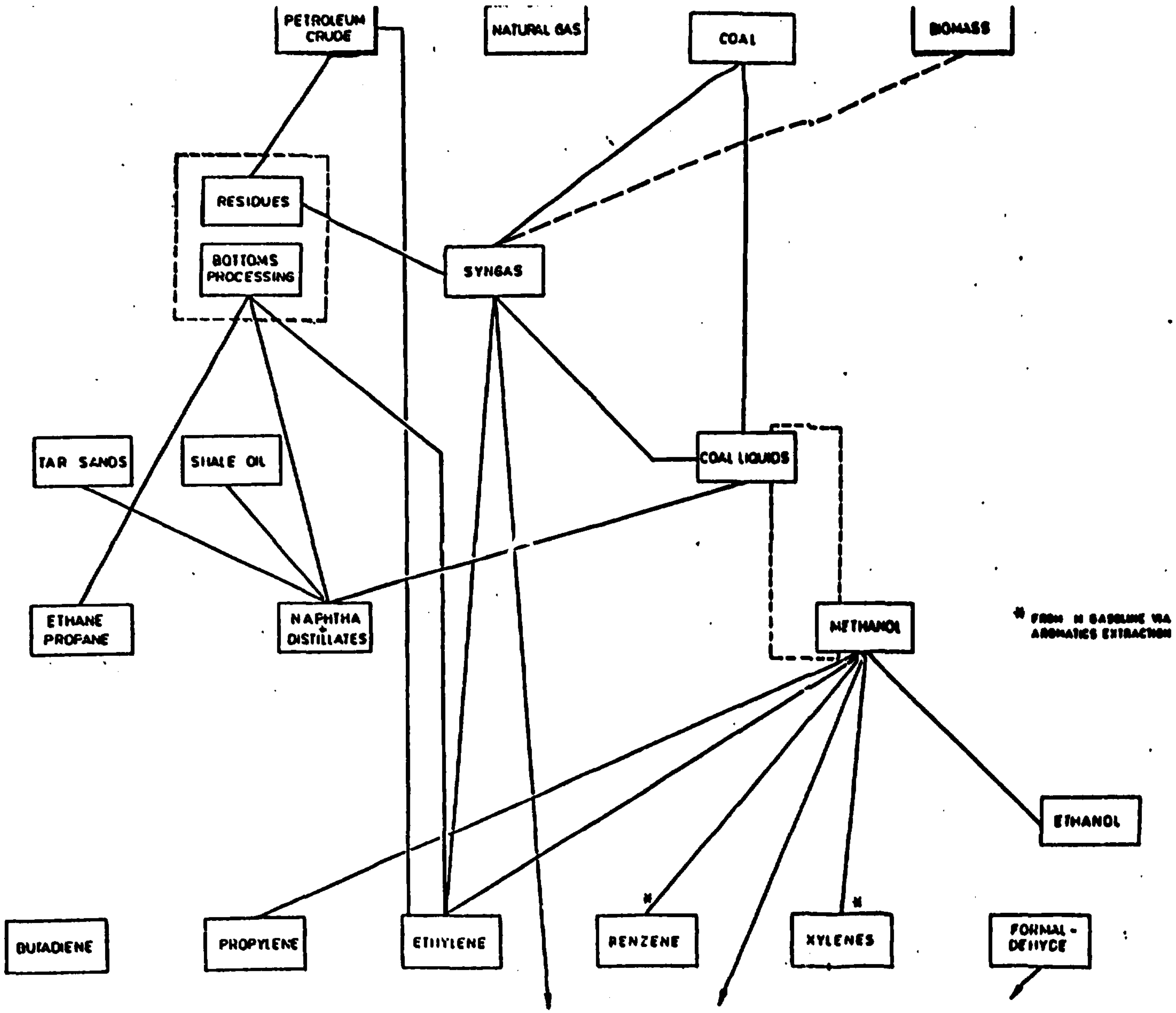

FIGURE IV. NON-CONVENTIONAL ROUTES TO PETROCHEMICALS