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RESEARCH AND DEVELOPMENT IN THE PETROCHEMICAL INDUSTRY IN DEVELOPING COUNTRIES

Issue Paper*

Prepared by the
UNIDO Secretariat

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I. BACKGROUND

1. Research and development (R and D), although discussed in various contexts with other questions, has not been raised as a separate issue in previous Consultations on the petrochemical industry. It has been mentioned, inter alia, in the framework of long-term arrangements in the petrochemical industry [1/] when dealing with access to technology and to its improvements.

2. The joint OPEC/UNIDO/OPEC-Fund Seminar on Co-operation Among Developing Countries in Petrochemical Industries in March 1983, recommended that UNIDO should actively promote co-operation among the developing countries' R & D centres by facilitating their contacts and exchange of experience. It also considered that viable co-operation agreements could be based, inter alia, on obtaining regional skills to design and construct petrochemical plants which otherwise might not be forthcoming in view of prohibitive costs. At a second stage the objective would be to attain R & D capabilities to develop autonomous technology [2/].

3. The First Meeting of the Advisory Panel on Petrochemicals of October 1983 discussed briefly research and development in petrochemicals and concluded that this field represents an essentially uncharted territory for most developing countries. It also regretted that in-house R and D of purchased technology, including after sales services are often subject to secrecy clauses as part of the transfer agreements [3/].

4. The Second and Third Meetings of the Advisory Panel on Petrochemicals held in September 1984, and June 1985 respectively, generally examined this subject again. These meetings expressed concern at the inadequacies of applied research and development capabilities in developing countries without which the long-term operational viability of the petrochemical industries in these countries could not be ensured [4/].

1/ (ID.WG.336/7/Rev.1. Paras.40,43)
2/ Report on OPEC/UNIDO/OPEC-FUND Seminar on Co-operation Among Developing Countries in Petrochemical Industries
3/ UNIDO/PC. 82
4/ Reports on Second and Third Meeting of Advisory Panel on Petrochemicals

5) The Meeting on Co-operation among the developing countries of the Middle Eastern and North African Regions in the Petrochemical Industries held in Aliaga, Turkey, in October 1984, also discussed the R & D activities in some of the regional countries. It inter-alia recommended the holding of a special meeting of R and D in the petrochemical industry.[5/].

5/ Report on Meeting on Co-operation among the Developing Countries of the Middle Eastern and North African Region in the Petrochemical Industry, Aliaga, Turkey, October 1984.

II. INTRODUCTION

6. The value of world chemical consumption will approach 900,000 million US Dollars in 1985 with petrochemicals accounting for more than half of that figure [6/]. The petrochemical sector has persistently outperformed the aggregate rate of output of most national economies. For instance the industry's track-record of some 9% growth in 1984 and the continued expansion in the current year, expected to reach 4-5%, contrasts vividly with considerably weaker performance in the global economy in the same period.

7. More significantly, this achievement is set against a background of weighty forces which had detrimentally affected the industry's operational environment in the preceeding decade:

1) a six-fold escalation in the procurement costs of energy and feedstock for commodity chemical production
2) substantially higher pollution control expenditures as a result of environmental legislation which, in the case of the United States, for example, had doubled the costs in real terms
3) near-saturation of the dominant market segments of bulk chemicals and stagnating end-use demand for basic chemical products
4) maturing of the main process technologies

8. It is widely recognized that the key factor, responsible for the petrochemical industry's remarkable resilience and adaptability to changed circumstances is technology and its prerequisite research and development. R & D expenditures in the chemical industries of USA and FRG in relation to total capital outlays are given in table 1.

6/ Chemical Economy and Engineering Review, December 1984

Table 1

Expenditures in billion US $ (current)

	1975	1980	1981	1982	1983	1984	1985*
USA							
R and D expenditures	1.1	2.0	2.3	2.6	2.8	3.1	3.4
Capital expenditures	5.0	7.2	7.3	6.4	5.1	5.4	6.1
R and D/Capital (%)	22	28	32	41	55	57	56
FRD							
R and D expenditures	0.6	1.6	1.75	1.9	2.0	2.2	n.a.
Capital expenditures	1.8	2.2	2.35	2.3	2.3	2.3	n.a.
R&D/capital (%)	33	73	74	83	87	98	n.a.

* planned

Source: Chemical Week, June 1985,
Chemical and Engineering News, June 1985.

9. The massive R & D expenditures of recent years are coming increasingly into fruition. The resulting technological advances have already spearheaded the renewed vigour and restored the profitability of the petrochemical industry by enabling:

1) close control of costs, notably through energy savings;
2) innovation on conventional products and processes;
3) development of new product applications and
4) upgrading production efficiency and productivity

10. The shift from the high-volume primary petrochemicals, ethylene, propylene, aromatics and their first-line derivates, to higher value-added specialty and functional products is the direct expression of capitalizing on the technological edge enjoyed by research-based producers.

11. In a nutshell analysis the current technological transition is essentially characterized by two-pronged progress made in enhancing the capability of a given process in respect to technical product range and to the supply potential for various grades of products.

12. Interestingly the move to high technologies, and the resultant fragmentation and specialization, has also brought about a refocussing of many corporate strategies from the purely manufacturing to a growing service orientation. This stems from the "total product" concept where higher value-added components based on research and development potential are to augment the basic manufacturing in the form of broadly defined customer services. An inevitable consequence of the current search for enhanced commercialization of technology is causing a reduction in the traditional dominance of national or regional outlook in favour of a more global framework for strategic planning. In any event this process of geographic integration has already been set in motion by the concurrent quest for advantageously priced feedstocks together with immature and expanding markets.

III. ORGANIZATION OF RESEARCH AND DEVELOPMENT

13. The research and development efforts can be divided into four categories as defined below:

(1) basic research
(2) process know-how
(3) product know-how
(4) technical improvements.

14. Often, research which is applied to the equipment and other facilities or on product application or improvements after the technology has been deployed is called generically applied research. The research and development contains many components especially when specifics are discussed. For the above reasons, UNIDO Secretariat has intended to open an issue of a general nature, under an umbrella-definition, which should cover all future efforts in this field whatever forms they might take, rather than to take narrowly defined concepts and formulations.

15. Basic research which has often been called pure or fundamental research, studies mainly the nature of chemicals and their reactivity, the properties of elements, chemical processes and the hybrid compounds that can be induced. This research is usually carried out in universities and technical institutions or in specialized research laboratories. However larger chemical or oil companies can afford to maintain their own facilities.

16. Many companies do not consider it expedient to spend resources on pure research because of insecure or low returns on invested capital. Customarily the chemical companies spend relatively small portions of their overall R & D fundings on basic research and often sponsor and co-operate with academia and research institutions. However, recently it has become evident that the technologies used are in many instances outmoded, energy wasting, environmentally polluting and not sufficiently quality conscious. Principally, everything which was considered unalterable and inevitable in established technologies has become a candidate for major scrutiny and improvements, including equipment, utilities, catalysts, conventional reactions, materials etc. The results of this development are new processes, products and technologies. In fact, it has become a necessity, in global competition for market shares in the petrochemical industry, to create a R & D competitive edge in basic research to support other R & D functions.

17. Process research and development is a major R & D activity of chemical companies which concentrate their efforts on designing new and better processes with significantly lower costs and improved quality of products. A good example of this are the UNIPOL polyethylene and polypropylene processes based on fluidized-bed technology.

18. In many end product applications, the process itself does not necessarily play the most important role, but competitiveness depends rather on factors such as product formulation and product systems based on a particular technology or raw materials composition.

The objective is to build up a unique system incorporating innovative technologies to yield quality properties in response to very specific consumer requirements. A good example of such a product system is the creation of large high density polyethylene pipes which are extruded from high density polyethylene, freely available from different sources. The system embraces not only pipes, but also fittings, welding technology etc. Companies which utilize this type of R & D are often medium or small-sized. They therefore need back-up from specialized R & D institutions, government offices etc.

19. Technical improvements are widely used in the process industries as routine tools to improve the process, to make it safer, to control emissions, to reduce costs, to improve catalyst systems, separation facilities etc... All physical facilities and utility systems are involved in the effort to keep the products competitive in the market place. Traditionally stable and uneventful, this field has become dynamic since the seventies. Now, it often leads to the creation of patented innovations like HIGEE-destillation system, new separation processes as part of any commercial process plant. The number of unpatented improvements is unaccounted for, involving alterations to principally all equipment. The area of technical improvements can be considered as an important part of technology with immediate relevance to operating petrochemical complexes in the developing countries.

IV. OWNERSHIP-STRUCTURE AND DEVELOPMENT PATTERN OF PETROCHEMICAL TECHNOLOGY

20. The present stock of hydrocarbon technologies is concentrated in private, and to a lesser extent public, corporations of few industrialized market economies, notably United States, United Kingdom and Federal Republic of Germany with some inroads made recently by other countries. The technological orientation of the industry until the mid-seventies period was largely conditioned and influenced by:

1) availability of products of the petroleum refining and energy industries such as naphtha in Europe and natural gas in the United States;
2) penetration of rescurce-rich oil companies into first generation petrochemical derivatives, contrasted with little corresponding "backward integration" of chemical corporations;
3) technological diversification due to geographical variations in market forces and sectoral compositions;
4) large potential for substitution of traditional materials by thermoplastics, synthetic fibres and elastomers;
5) pre-dominance of engineering companies as technological innovators particularly in intermediates and upstream technologies;
6) geographic concentration of the industry in the immediate vicinity of main markets with a virtual absence of production sites at supply sources of raw materials; and
7) no significant dispersion in the established ownership pattern of the industry.

21. The quadrupling of oil prices in 1973/74 had far-reaching consequences on the conduct of business of the chemical corporations. The accompanied technological implications were further accentuated by the second upsurge in energy and feedstock costs in 1979. The necessary reassessment of corporate priorities to adapt to and survive in a changed environment have, inter-alia, contributed to:

1) increased efforts of chemical companies for up-stream integration through mergers and aquisitions, particularly in the United States;
2) search for alternative feedstocks technology such as heavy residue-derived syngas for chemicals and biomass technology;
3) greater built-in flexibility for feedstock variations;
4) enhanced participation o. the state directly or through the public sector in reshaping the industry, particularly in Europe and Japan;
5) further international diversification of production and marketing;
6) major additional R & D expenditures with a view to increasing energy and raw material efficiencies of conventional materials and processes;
7) rationalization in bulk commodities and incipient emergence of performance products in composites, engineering plastics, etc.;
8) a two-fold expansion of coporate basic R & D budgets leading to technological breakthroughs especially in surface chemistry and catalysts with high selectivity, which enable scaling down of plant size;
9) proliferation of multiple and competing technologies, particularly for the manufacture of intermediates;
10) emphasis on multi-disciplinary R & D with some bias towards physics and biology, rather than pure chemistry;
11) accelerated rate of technological obsolescence;
12) closer synchronization between market intelligence and technology response;
13) technological diversification through the dual approach of increased R&D fundings and technology aquisition; and
14) certain entrenchment against market penetration in commodities by new producers.

. REORIENTATION OF CORPORATE RESEARCH AND DEVELOPMENT STRATEGIES IN THE CHEMICAL INDUSTRY

22. R & D corporate strategy, although wide disparities between individual firms persist, is undergoing a significant transition. The centre piece of change, invariably, involves a closer integration between research, manufacturing and marketing functions of the company. In this context an obvious distinction should be made in the segmentation of R and D efforts in the petrochemical industry. The upstream-industries concentrate in process research which requires strong support from basic and fundamental knowledge in chemistry and engineering whereas downstream-operations rely heavily on applied research and technical services. The traditional approach of "product orientation" where first the creation of a product was initiated through R & D and subsequently attempts were made to market it, have all but been phased out. The new approach consists of developing product lines in response to well-identified and specific needs of the customer. Therefore in many petrochemical companies there has been an emerging shift of emphasis from "process R & D" to "product R & D" which, in turn, translates into larger expenditures on technical services. The nature of process R & D itself has undergone qualitative mutations to find simpler and cheaper routes with less resource consuming facilities. An important consequence of this reorientation in policy can be gauged from the corporate R & D budget distribution by product segment which clearly reflects the progressive move to higher value-added and technologically sophisticated products, particularly industrial specialities. R & D figures for a major chemical company, contained in table 2 clearly demonstrates the trend.

Table 2

R & D funds distribution within a typical chemical company
(per cent)

By product segment	1982	1983	1984
Industrial specialities	3i	33	40
Consumer specialities	32	34	33
Basic chemicals	23	29	18
Basic plastics	8	8	8
Other	6	5	1
By R & D category			
Product research	40	44	44
Process research	29	23	22
Technical service and development	31	33	34

Source: Chemical and Engineering News, March 1985.

23. The priority areas absorbing the bulk of current R & D fundings are molecular and biotechnology, composites, ceramics and spaciality resins.The trend towards new products would conceivably be even more pronounced but for some inertia of traditional business commitments of the major companies in process technologies and geographical expansion of their bulk operations.

24. The prerequisite for devising new application fields and products calls for detailed, comprehensive and essentially new breeds of market intelligence through modern techniques. The innovative technical sale and distribution networks are designed for providing total integrated services. The search for novel uses of existing products and the development of new ones is characteristically conducted through direct and close contact with the customer, which has necessicated a thorough revision of the training requirements and the technical skills of the marketing and sales force.

25. Another aspect of the diversification into new markets and products is manifest through agressive aquisition of technology, particularly, when synergistic with the ongoing operations of the company. The trend of technology purchase, as opposed to less certain and more time consuming R & D path, for strengthening competitive positions will further accelerate as resource-rich countries increase their penetration of commodity markets. This is quite consistant with emerging evidence of some decentralization of product adaptive R & D and a burgeoning interest for foreign scientific communities and establishments within the practical limits imposed on affiliate R & D by the exigencies of the critical mass or minimum efficient scale, inherent to the chemical industry. In the main industrialized countries a major share of the basic chemical research is performed at academic institutions. However, in recent years, the fluctuations in the level of public support and funding uncertainties have caused some discontinuity in institutional research programmes.

VI. THE RELEVANCE OF THIRD WORLD'S AUTONOMOUS TECHNOLOGY IN PETROCHEMICALS

26. The production possibilities of ethylene, the primary petrochemical building block, can illustrate the option of alternative technologies in response to feedstock availability and other technical factors. For example in the United States, ethylene is mainly produced from natural gas whereas in Europe it is mostly naphtha based. Furthermore, in spite of ethylene's gaseous nature, its suitability to maritime and pipeline transport has greatly improved recently due to technology. As a consequence, the bulk of international trade in this commodity is no longer confined to neighbouring countries as it was during the seventies. Nevertheless most producers of ethylene convert it into derivatives on site in preference to its shipment as a petrochemical intermediate.

27. The economies of scale, dictated by the conventional technologies in plant size also plays a critical role in the investment decision of new capacities. To construct an economically efficient ethylene process, must therefore take into account many considerations specific to the locational characteristics of raw material, infrastructure, marketing channels and so on.

28. World production of ethylene in 1984 was in the order of some 38 million tons with naphtha accounting for 54%, ethane for 22%, LPG for 15%, gasoil and others for 9% of the feedstock requirements. A structural shift in the international pattern of ethylene supplies is currently underway as a result of incipient exports of ethylene and its derivatives from the new petrochemical producing areas such as Saudi Arabia and Canada. Globally, the use of ethane as feedstock for ethylene manufacturing is expected to increase to around 30% over the next decade, a trend set essentially by economics. However, for countries possessing abundant fermentation materials but limited hydrocarbon resources such as Turkey, India, Pakistan and a number of Latin American countries, technologies using those alternative feedstocks have obvious economic and social significance. In 1975 Brazil embarked upon an ambitious R & D effort, in the framework of the "Proalcohol" programme, in both the utilization and production technologies of alcohol fuels and other alternative energy sources. It still constitutes the largest operational alternative fuels programme in the world. Currently some 130.000 b/d of ethanol are thus produced in the country. Based on the availability of this

ethanol, Petrobrás, the national oil company, has developed a process, at its research centre Cenpés, for the conversion of ethanol to ethylene. The adiabatic process, in contrast to the conventional isothermic units, has a high conversion rate of around 99%. More significantly, in view of the reduction in the number of reactor vessels to three (in comparison with the required eight in isothermal reaction system) the capital expenditure of a production facility amounts to a mere fraction of the conventional unit.

29. The Cenpés process, conveniently incorporates other advantageous features, apart from the crucially important capital costs and feedstock. Among these, simplicity and flexibility of operation, infrequent catalyst regeneration, greater purity and selectivity are particularly relevant to operational environment of the developing countries. The first operating plant, using this technology, is currently producing 90.000 metric ton annually of ethylene.

30. The Brazilian ethylene process is indicative of the feasibility of selective and rational technological response to the condition prevailing in the developing countries through R & D.

31. Expectedly this technology has provoked considerable interest outside Brazil, most notably among the developing countries, in view of its obvious merits. Negotiations are currently underway for the licensing of the technology to a number of developing countries among them Philippines, Indonesia, Peru, Kenya etc. India is reported to have already acquired the process know-how for a 5000 t/y preliminary project currently underway. Although the emergence of this particular technology will not affect the global picture of the ethylene business as described above to any significant extent, its repercussions on the viability of individual projects to manufacture ethylene dichloride and other derivatives with indigenous feedstocks in many developing countries could be decisive.

VII. PETROCHEMICAL TECHNOLOGIES IN USE IN DEVELOPING COUNTRIES AND THEIR DRAW-BACKS

32. The establishment of petrochemical complexes in the developing countries has customarily posed serious challenges. The various aspects of the obstacles at play, have been and continue to be closely investigated by industry analysts and international fora including UNIDO's System of Consultations. Problems associated with contextual definition of projects, infrastructural and resource limitations, transfer of technology, marketing and management, technical operation and maintenance, education and manpower training, international co-operation etc., have, rightfully, assumed wide-scale recognition and are subjected to expert scrutiny.

33. Nevertheless, it must be reemphasized that the spectacular growth of the petrochemical industry in the post-war period has been, to a large extent, due to technological breakthroughs in the production of synthetic materials. This was followed by the emergence of processing technologies for the transformation of those derivatives into a multitude of products, particularly for use in such sectors as agriculture, construction, textiles, industrial and, most importantly, consumer goods. These technologies were entirely developed in the industrialized countries through a concerted pattern of research and development strategy based, inter alia, on the resource and feedstock availabilities and prevalent market characteristics. A major illustrative example, in this context, was the access, in Europe during fifties and sixties, to competitively priced naphtha as a refinery by-product which prompted the emergence of technological innovations in synthetics. Similarly, in the wake of price escalations of feedstock and energy in the seventies, the bulk of recent technology advances have occured in reducing the hydrocarbon consumption, both as raw-material and fuel, in petrochemical processes.

34. The developing countries, as a rule, have depended mostly on foreign technology for the manufacture of petrochemical building blocks as well as conversion and down-stream facilities. However, this technology, conceived and implemented under alien conditions, and certainly not as a scape route from underdevelopment, does not necessarily correspond to the particular requirements and priorities of the developing countries. A fact which also renders its technical absorption and assimilation an onerous task. In some cases, the limitations on technological adaptability of these petrochemical processes, especially in the basics, are severe if at all existing. Furthermore the problem can be compounded by a lack of technical back-up from the licensors or contractors for the efficient, safe and on-spec. operation of the petrochemical plants under the general conditions of the developing countries. This also holds true even from the perspective of the construction, assembly and erection of the plants within battery limits, contributing to significantly higher capital expenditures in comparison with similar projects implemented in industrialized countries.

35. In the final analysis, construction cost escalations and operational inefficiencies are, inter alia, traceable to an absence of consideration, at R & D stage, of local parameters and their divergence from the industrial environment of the technology holder. The current low-level of technological capabilities of the developing countries greatly aggravate the encountered difficulties and perpetuates an unsatisfactory dependency on the industrial front in their economic development. The spin-off effects of petrochemical technology on other vital sectors of the economy such as agriculture, construction and, obviously, down-stream processing have been demonstrated to be substantial in the industrialized nations. In the developing countries, available evidence suggests that this multiplier effect can be even more powerful given the unrealized potential for absorption of petrochemical products in many sectors.

36. As argued previously, the bulk of available petrochemical technologies has been developed in a few industrialized countries by corporate entities in response to their policy assessment of a multitude of factors affecting the

industry. These factors, not all neccessarily economic, will continue to determire the future orientation of technological change in the industry. This process of change by gathering both speed and scope at present, will entail profound repercussions beyond the traditional confines of the petrochemical industry.

37. Viewed from the perspective of the developing countries the foreign technology on offer invariably embodies some inherent incongruities and outlandishness in respect to:

1) optimal utilization of indigenous raw-material and energy resources;
2) capital cost structure of technology;
3) operational, maintenance and technical back-up characteristics;
4) responsiveness to local market potential;
5) socio-cultural acceptability and adaptability;
6) chain of technological continuity;
7) industrial and infrastuctural realities;
8) sectoral integration in the overall economy;
9) limitations of a genuine transfer of the know-how imbedded in technology; and
10) requirement of and impact on man-power training and development.

38. Although obtaining foreign technology for setting up petrochemical complexes in the developing countries has so far been the routine practice, it nevertheless has, on occasions, created innumerable problems of "mismatch". Realistically, the aquisition and transfer of overseas technology, in spite of its imperfections, has traditionally represented, the only mechanism for implementing the industrial aspirations of the developing countries. The cost of this process has, however, been unduly inflated by the technological unpreparedness of the recepients to accomodate its exigencies.
The root-causes of this insufficiency in technological capabilities are undoubtedly diverse, being subjected to expert scrutinity elsewhere in the petrochemical Consultations. Certainly a major force at play, must be the inadequacies of support from and the interaction with indigenous research and development capacity in the absorption and adaptation of foreign technology. The required assimilation cannot effectively take place in the absence of sufficiently developed technological capacities based on home-grown R & D efforts.

VIII. PETROCHEMICAL R & D OPTIONS FOR THE DEVELOPING COUNTRIES

39. Although the issue of research and development is of fundamental importance, as it plays an indispensible part in the creation of a sound basis of the petrochemical industry in the developing countries, nevertheless, intense impediments have preluded the formation of adequate technological capabilities. Meaningful research and development at the national level, obviously, necessitates mobilization of considerable resources, both in man-power allocation and in capital commitments, in turn, effective only in conjunction with well-entrenched scientific infrastructure and technical organization. The required number of highly-qualified scientists, engineers and managerial talents, backed with adequate facilities and equipment, is certainly, beyond the means of all but very few developing countries. Another essential ingredient is the linkage and the existence of appropriate channels for a continuous and substantive feedback between the research community and the operating petrochemical industries. This co-operation has proven exceedingly difficult, even in the industrialized countries, in cases where harnessing of research functions, outside corporate confines, is attempted. With the exeption of a few developing countries public support for R & D in the petrochemicals has not been perceived as a high priority in industrial policies. Neither have technology adaptation concepts successfully counteracted the low levels of R & D productivity in these countries. In developing countries the role of government in the R & D sector is crucial, since many petrochemical companies simply cannot afford to possess state-of-the-art laboratories for analytical and technical services, pilot plants, testing etc.. In these cases the organization of back-up facilities and systems can only be state sponsored or even state-owned.

In order to gain a better appreciation of the magnitude of R & D efforts in a global context the indication of the following figures might be warranted.

For the first time spending for research and development in the United States will surpass 100 billion US $ in 1985, representing 2.7% of the expected gross national product, a raise of 11% over the previous year. The chemical and allied products industry will have a 12% share of all industrial R & D expenditures in that country. Similarly other industralizcd countries earmark a comparable portion of their aggregate income to R & D, whereas the corresponding budgets of most developing countries remain negligible not only in absolute terms but more adversely even in relation to the size of their national economies.

40) Aware of the pressing needs UNIDO has established a network of continuous petrochemical and polymer consultation-weeks in the field of R & D involving regional organizations and representatives of companies from developed countries to present papers on topical issues in that field. Such seminars have been held for example on man-made fibres in Bombay, India, in April 1982, for petrochemicals and polymers in Porto Alegre, Brazil, in May of the same year and for regional development of the petrochemical industry in Bahia Blanca, Argentina, in August, 1983, on plastic processing industries in Jubail, Saudi Arabia in October 1984 and one scheduled on synthetic fibres in China, for November 1985.

41. The recent advent of international long-term co-operation arrangements in the sector, notably petrochemical joint ventures, routinely incorporate provisions for research and development to be jointly undertaken by the partners. In actuality, however, the R & D work tends to be dictated by the foreign partners' own corporate strategies and conducted at his facilities with modest enhancement of the autonomous research capabilities of the host country's petrochemical entities. In view of these limitations inherent in a purely national approach to R & D in the petrochemical sector and the acknowledged shortcomings in the aquisition of foreign technology, common efforts on bilateral, regional or international basis represent a number of viable alternatives for the developing countries. The option of joint effort in research and development, hitherto largely untapped, can obviously assume a large spectrum of different modalities and operational mechanisms. These can range from co-sponsorship of specific technology ventures at established research facilities in the industrialized countries to the creation of regional technology clubs, co-ordinated technology import schemes, development consortia, consultative bodies or even "centres of excellence" with the participation of the world's leading technologists and scientists.

42. A prerequisite of this co-operation however, is a detailed assessment of the technological needs and priorities in the sector cast against a quantitative and qualitative analysis in respect to current involvement of the developing countries in petrochemical research and development work. Obviously, R & D initiatives at national level must reflect industry priorities with a view of translating them into a coherent and selective

framework. In view of the complexity of the subject and extremely high costs involved direct government subsidy and indirect schemes of fiscal and other incentives would be of particular importance for the success of such efforts.

43. The questions involved in formulating schemes for co-operation in this field are extremely varied, and so far little real attempt has been launched by the petrochemical fraternity or multilateral agencies to gain a better understanding of the complexities, prior to contemplating measures for partial solutions. Above all, the pooling of resources presupposes an in-depth understanding of R & D activities of the concerned countries in respect to manpower, facilities, equipment, programmes and projects. This could constitute a practical first step in the co-ordination effort, where UNIDO could conceivably play the pivotal role of a catalyst in this process of exchange of information and collective stock-taking. In the same context, a study could be launched to ascertain the scope and possible modalities of TCDC* in the field of petrochemical technology. The resource-rich developing countries, which have recently embarked upon large-scale petrochemical complexes with the accompanying massive transfer of know-how and technology are well-positioned to make substantive contributions to these efforts. It should be noted that a great deal of the R & D initiatives could be undertaken by the existing operational organizations through project co-ordination and particularly in many areas of down-stream product applications.

44. Likewise a number of Latin American and South-East Asian countries and a few others already possess considerable expertise in petrochemical technology enabling them to cater to many R & D needs of the less-exposed group among the developing countries. It is only through international co-operation that priorities in important areas of research and development in the petrochemical industry relevant to developing countries can be identified. At a second stage the experience so gained would then serve as a basis for concrete joint action to promote the development and diffusion of new petrochemical technologies among the developing countries.

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* Technical co-operation between developing countries

IX. THE ISSUES

This paper has attempted to demonstrate the crucially important role of R & D and the resultant new technologies in the petrochemical industry. The costs, gestation time, and organizational resources involved in this process are so vast and varied that effective R & D targets are rendered beyond the possibilities of most companies operating in the developing countries, indeed beyond the collective capabilities of the countries themselves. In spite of these constraints, however some notable instances of successful R & D in few developing countries have recently been recorded. Viewed against a background where the mainstream of current R & D is undertaken in and directed towards conditions and needs of the industrialized countries it becomes imperative that special efforts be made in the developing countries to upgrade their autonomous involvement in this vital field. It stands to reason that co-operation in organizing this activity would make it less prohibitive by spreading its heavy burden over a number of countries. As argued previously co-operation could assume many forms and levels and UNIDO could contribute, on its part, to the promotion of such co-operative action. It is proposed that the following activities be considered as possible issues for further discussions and closer investigation on the subject by the Consultation:

1) - Establishment of regional R & D networks with special emphasis on:

   a. Exchange of information and creation of joint R & D activities on product application;
   b. Exchange of information and undertaking of joint intiatives in process development and/or improvement
   c. Exchange of experience and undertaking of co-ordinated schemes with respect to technology imports and technology transfer negotiations

2) - Surveys to assess the technological needs and prioprities of developing countries in the petrochemical industry;

3) - Investigation into the feasibility of creating appropriate mechanisms such as regional technology clubs, development consortia, consultative bodies, centres of excellence etc.;

4) - Identification of opportunities for ECDC* in petrochemical technologies;

5) - The development of national policies, guidelines, blueprints for petrochemical research and development.

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* Economic co-operation among developing countries