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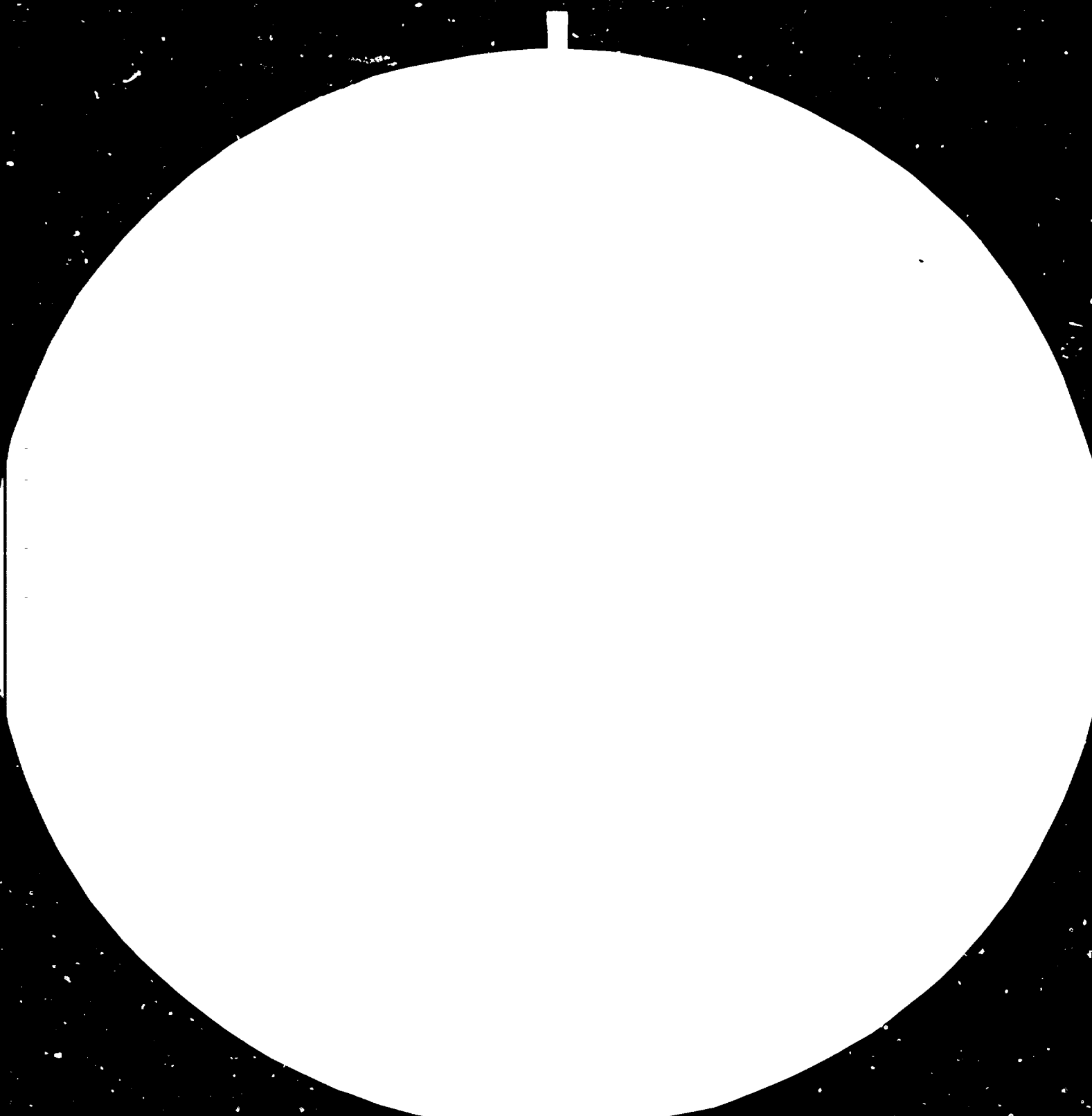

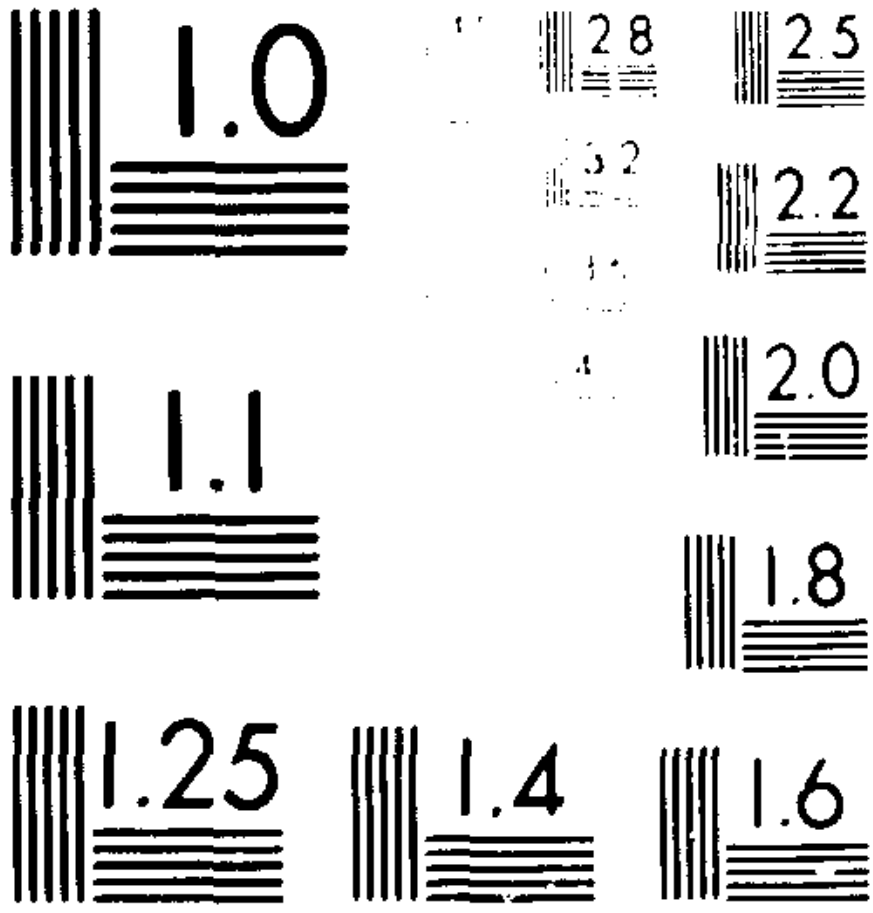
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UNITED NATIONS INDUSTRIAL
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Conference on the Future Role of
Natural Gas in meeting Energy Needs

Bahrain, 14 - 15 November 1981*

PETROCHEMICAL AND OTHER INDUSTRIAL USES OF NATURAL GAS**

by the

United Nations Industrial Development Organization

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* Organized by the Bahrain Society of Engineers in co-operation with the Bahrain National Oil Company.

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INTRODUCTION

1. Natural gas is the preferred fuel for many industries and a feedstock for the petrochemical industry. Both uses of natural gas can be expected to increase in the 1980s and 1990s, provided natural gas is made available for industrial uses at an attractive price.

2. The present paper summarizes the results of a Study of the Industrial Uses of Associated Gas[1/], which UNIDO completed in April 1981 for presentation to the Second Consultation on the Petrochemical Industry convened in Istanbul, Turkey in June 1981. The Study was prepared in co-operation with the Gulf Organization for Industrial Consulting (GOIC). UNIDO was also assisted by OAPEC in the initial stages.

3. The Study was prepared in response to a recommendation of the First UNIDO Consultation on the Petrochemical Industry convened in Mexico City in March 1979 that:

> " UNIDO should make a detailed study of the associated gas that is presently flared in oil-producing developing countries in order to give a clear picture of the advantages of setting up economic projects to use these wasted resources."

4. The UNIDO Study examines the projects which 18 developing countries[2/] have established to collect and utilize their associated gas and concludes that the world should maker greater use of the associated gas available in these developing countries to establish petrochemical plants and energy-intensive industries such as aluminium and steel (by direct reduction). In 1978, these industries used about 5 per cent of the associated gas available in the 18 developing countries, whilst almost 50 per cent was flared. The proportion of gas flared is lower today (1981) and will be further reduced by 1985.

1/ The Industrial Uses of Associated Gas; a joint study by UNIDO in co-operation with GOIC, 30 April 1981; Document UNIDO/PC.11.

2/ The 18 countries are: Algeria, Bahrain, Brunei, Indonesia, Iran, Iraq, Kuwait, Libyan Arab Jamahiriya, Malaysia, Mexico, Nigeria, Oman, Qatar, Saudi Arabia, Syrian Arab Repuolic, Trinidad and Tobago, United Arab Emirates and Venezuela.

I. PETROCHEMICAL USES OF NATURAL GAS

Components of Associated Gas

5. Associated gas can be distinguished from non-associated gas (almost 100 per cent methane) by the significant quantities of ethane, propane and butane which it contains. The associated gas in the Gulf appears to be richer in these components than the associated gas available in other countries (see Table I).

Table 1: Composition of Associated Gas in Selected Countries

(Average Volume, per cent)

Country	Qatar	Saudi Arabia	United Arab Emirates	Indonesia	Mexico
Methane	55.5	51.0	55.7	71.9	82.0
Ethane	13.3	18.5	16.6	5.6	10.0
Propane	9.7	11.5	11.7	2.6	2.5
Butanes	5.6	4.4	5.4	n/a	3.5

SOURCE: Information provided to UNIDO

6. The propane and butane fractions have a significant value in alternative uses either as bottled gas for use by households or for export LPG. The UNIDO Study therefore concentrated on examining some of the petrochemical uses of methane and ethane. For a more complete list of petrochemical products that could be made from one of the C_1, C_2, C_3 and C_4 fractions of associated gas the reader is referred to the Chart on page 12.

Petrochemicals from Methane

7. Production of nitrogenous chemical fertilizers is probably the largest industrial use of natural gas. Ammonia is produced at lowest capital cost and most efficiently from methane. The 18 developing countries covered by UNIDO's Study plan to have constructed plants with a capacity of 17 million tons per annum, or 15 per cent of total world capacity by 1985. (See Table II).

8. Methanol is the only other major chemical product produced from methane. The 18 developing countries plan to have constructed plants with a capacity of 4.5 million tons per annum by 1985 or 18 per cent of world capacity. (See Table II). At present, almost all of the methanol produced is for chemical uses but from 1985 onwards the methanol may be used on a growing scale for blending with gasoline and as a fuel; for these uses new production units will be constructed with specific customers in mind.

9. Natural gas supplies provide the basis for a competitive advantage (See Table III) because feedstocks and energy account for 80 per cent of the manufacturing cost of ammonia and methanol. Furthermore, chemical fertilizers, ammonia and methanol can be transported in bulk to most markets of the world. They are easy to market because they do not require supplier technical services to support sales.

10. Methane can be converted to synthesis gas (mixtures of carbon monoxide and hydrogen) which is seen as a new route to various chemical products as well as gasoline and the middle distillates. Although a plant to produce gasoline from methanol based on natural gas is under construction in New Zealand and methane has been converted to ethylene in pilot plants, these new processes are not yet commercially proven.[3/]

3/ Synthesis gas derived from coal was used for the production of gasoline products in World II (Fischer-Tropsch processes). A commercial scale plant, mainly for making gasoline (C_6-C_8) exists in South Africa (SASOL process). It is claimed that by the use of modified catalysts, a whole range of products with different numbers of carbon atoms can be produced.

Petrochemicals from Ethane

11. Ethylene has become the most important basic petrochemical. It can be produced most efficiently and at lowest capital cost from ethane. The 18 developing countries covered by UNIDO's Study plan to have capacity to produce almost 6 million tons of ethylene by 1985 or 9 per cent of total world capacity (See Table II).

12. Although ethylene has been shipped across oceans, the preferred approach is to convert it on-the-spot to derivatives which are transported more easily such as glycol and plastic resins or their intermediates. The 18 developing countries covered by the UNIDO Study plan to establish capacities as shown in Table II. For LDPE their planned share of world production is about 11 per cent, but for HDPE it is about 6 per cent and for PVC about 2.5 per cent.

13. Low cost ethylene produced from ethane provides the basis for a competitive advantage in the production of ethylene derivatives. Since an expensive feedstock such as naphtha accounts for 60 per cent of the manufacturing cost of ethylene in an industrialized country, some existing ethylene plants in industrialized countries are being modified to accept NGL.[4/] But as ethane has no real alternative uses, the competitive position of ethylene plants based on ethane is likely to be maintained (See Table III).

14. Ethylene derivatives, particularly plastics, are less easy to market than methanol or ammonia because they require technical services to support sales and market development. New production units aimed at export markets are therefore likely to be established when such marketing arrangements have been assured.

4/ One forecast is that at least 75 per cent of Western European ethylene demand will still be derived from naphtha in 1990 compared to 88 per cent in 1980. In the United States in 1980, 60 per cent of ethylene was derived from NGL and the remainder primarily from gas oil and a little from naphtha. After decontrol of gas prices in the United States (not later than 1985), the price of ethylene in the United States is expected to be 2.9 times the price of light Arabian Crude compared to 3.0 to 3.1 times in Western Europe and Japan. See SRI International Chemical Industries Division Newsletter September 1981.

Petrochemicals from Propane and Butane 5/

15. The ethylene yields are less than if ethane is used as feedstock, but propane and butane can also be cracked to produce ethylene; propylene is produced as a by-product. The economics of the process depend on alternative uses for the liquids.

16. Only one of the 18 developing countries (Mexico) covered by the UNIDO Study had plans to produce propylene in this way. This route to propylene may be used by other countries in the future who wish to produce a broader range of petrochemical products (see Chart). The main use of propylene are in gasoline, polypropylene, acrylonitrile, propylene oxide and isopropyl-alcohol.

17. Butadiene can be produced from n-butane. The main market for butadiene is synthetic rubbers (mainly SBR and polybutadiene) used in the tyre industry. Another use is in polymers like ABS resins. Butadiene is transported across oceans, but greater value can be obtained by further processing on-the-spot.

5/ The opportunity to produce this range of petrochemicals is not considered in the Joint UNIDO/GOIC Study. The opportunity was considered in the Industrial Uses of Associated Gas: Progress Report on a Joint Study, UNIDO 31 May 1980.

II. SOME OTHER INDUSTRIAL USES OF NATURAL GAS

Aluminium from Alumina

18. Energy costs in Europe and North America account for about 30 per cent of the cost of manufacturing aluminium from alumina. If the cost of the alumina is excluded, energy account for almost 50 per cent of the value added in the manufacturing process. Thus low cost natural gas can provide a basis for competing in world markets.

19. Consumption of aluminium in the world was about 20 million tons in 1979. Consumption is expected to reach 25 million tons in 1985 and 32 million tons in 1990. The developing countries' share of total world consumption is expected to rise from 11.5 per cent in 1979 to 14 per cent in 1990.

20. For a long time the world market has been dominated by six transnational producers who produce 56 per cent of the world's alumina and 41 per cent of the world's primary aluminium. Some producers sign long-term supply contracts with one of the big six producers; another way it to sign such a long-term contract with a country which is a large importer such as Japan. For independent producers primary aluminium ingot is traded on the London Metal Exchange. Prices, as with other commodities, fluctuate.

21. At present, demand for primary aluminium is depressed and free market prices are low. Transnational producers are reconsidering the timing of construction of new smelters; in particular, plans for some of the six smelters based on low-cost energy supplies in Australia are likely to be postponed.

Sponge Iron and Steel

22. Natural gas can be used for the direct reduction of iron ore to manufacture sponge iron which can then be converted to steel in an electric arc furnace or used as a substitute for scrap in a traditional steel-making process.

23. World demand for steel was 720 million tons in 1978 and is expected to reach 960 million tons in 1985 and 1200 million tons in 1990.

24. The world market for steel is most buoyant in developing countries who imported 35 million tons of steel in 1977. Plans have been made to substantially increase capacity and many of these plans are based on the direct reduction process.

25. The market for steel in industrialized countries is depressed and capacity is being closed down in Western Europe in order to bring it in line with demand. UNIDO is preparing forecasts of the future demand in industrialized countries as well as in developing countries for consideration by the Third Consultation on the Iron and Steel Industry in 1982.

26. Energy accounts for about 10 per cent of the cost of manufacturing sponge iron or about 20 per cent of the value added to the iron ore in the manufacturing process. Countries with low-cost natural gas supplies therefore have a cost advantage, but this is not as large as for aluminium. It is only a little higher than for an industry like cement where about 10 per cent of the manufacturing cost is for energy supplies.[6/]

6/ The opportunity to produce cement or cement clinker in large plants using natural gas as a fuel were considered in the Industrial Uses of Associated Gas: Progress Report on a Joint Study, UNIDO 31 May 1980.

III. THE PROSPECTS FOR PETROCHEMICAL AND OTHER INDUSTRIES BASED ON NATURAL GAS

27. Prospects for selling ammonia and/or nitrogenous fertilizers are certain because the world's growing population needs more food. World demand for nitrogenous fertilizers is expected to increase by between 2.0 and 2.5 million tons each year in the 1980s, rising from 57 million tons in 1979 to 70 million tons in 1984 and 85 million tons in 1988. Demand in developing countries will increase from 22.5 million tons in 1979 to almost 38 million tons in 1990.7/

28. Prospects for selling methanol are less certain. Enough capacity to supply demand for chemical uses up to 1985 has been planned. But after 1985, demand for fuel and blending with gasoline are likely to become increasingly important. No one is sure how fast demand for these uses will grow and how much of it will be supplied by local plants producing methanol from coal instead of imports.

29. Prospects for selling ethylene-based derivatives and petrochemicals in general in industrialized countries depends on a resumption of economic growth. There is large excess capacity in Western Europe at present and some ethylene plants are likely to close down. The market in developing countries is expected to grow much faster and the overall world market growth is forecast in the UNIDO Study as follows.

World Demand for Selected Petrochemicals, 1979, 1984 and 1990

(million metric tons)

	1979	1984	1990
Ethylene	37.2	47.8	65.9
LDPE	12.1	15.6	21.9
HDPE	5.6	7.6	10.5
PVC	12.4	16.6	23.1
Ethylene glycol	4.3	6.0	..

7/ All measurements in terms of tons of the nutrient nitrogen.

30. The prospects for selling aluminium are good after 1985. There is likely to be sufficient capacity to supply world requirements of aluminium up to 1985 but between 1985 and 1995 at least 60 smelters of capacity 150,000 t/a are likely to be needed. Some of these plants could use electric power generated by gas turbines.

31. The prospects for selling sponge iron on world markets are less certain. In the industrialized countries the state of the steel industry and the growth of production using electric furnaces determine the level of demand for steel scrap or sponge iron. The energy content of steel production is not very high. The UNIDO Study therefore suggests that countries consider production of steel for local consumption and for the faster growing markets of developing countries.

Gas-based production of petrochemic
in 18 developing countries

	Ethylene	Low-density Polyethylene	High-density Polyethylene	EDC/VCM or PVC
Algeria	140 000	48 000	-	35 000
Bahrain	-	-	-	-
Brunei	-	-	-	-
Indonesia	300 000[a]	185 000[a]	60 000[a]	110 000
Iran	325 000[b]	100 000	60 000	40 000
Iraq	130 000[a]	60 000[a]	30 000[a]	60 000[a]
Kuwait	350 000[a]	130 000[a]	-	-
Libya	-	-	-	-
Malaysia	1 945 000[b/c]	-	-	-
Mexico	300 000[a]	499 000[b]	200 000[b]	570 000[b/d]
Nigeria	-	120 000[a]	60 000[a]	120 000[a]
Oman	-	-	-	-
Qatar	280 000	140 000	70 000	-
Saudi Arabia	1 606 000	640 000	171 000	454 000[e]
Syria	-	-	-	-
Trinidad and Tobago	-	-	-	-
UAE	-	-	-	-
Venezuela	150 000	50 000	60 000	54 000
Total	5 914 000	1 705 000	642 000	1 443 000

a/ UNIDO estimate of proposed new unit
b/ UNIDO estimate of proposed expansion
c/ Includes some naphtha-fed, older units
d/ As VCM, some of which may be exported
e/ As EDC
f/ For 40,000 t/a SDR unit
g/ OOIC estimate

TABLE II

cals, fertilizers and selected industrial products
(existing plants plus planned new capacities)
ton/year

Styrene	Ammonia	Urea	Methanol[a]	Aluminium	Sponge iron
-	991 000	278 000	100 000	127 000[b]	800 000[a]
-	660 000[a]	-	350 000	120 000	400 000
-	-	-	-	-	-
-	2 173 000	3 954 000[b]	400 000	225 000[a]	2 200 000[b]
30 000[f]	1 106 000[a]	1 180 000[a]	-	110 000	6 130 000[a]
-	994 000	1 535 000	135 000[a]	120 000[a]	1 935 000[a]
320 000[a]	994 000[b]	1 360 000	-	120 000[a]	-
-	663 000[b]	900 000	330 000	60 000[a]	1 000 000[a]
-	380 000[a]	328 000[a]	550 000	100 000[a]	800 000[a]
333 000[b]	4 796 000[b]	1 691 000[a]	1 007 000	120 000	4 540 000[a]
-	330 000[a]	496 000[a]	-	-	-
-	-	-	-	-	400 000[a]
-	595 000[b]	991 000[b]	-	-	800 000[b]
295 000[a]	528 000[a]	500 000[b]	1 320 000	-	800 000[a]
-	300 000	346 000	-	-	1 000 000[a]
-	1 280 000[b]	70 000[a]	435 000	180 000[a]	840 000[b]
-	330 000[a]	-	-	135 000	800 000[a]
-	792 000[b]	661 000	-	-	5 120 000[b]
978 000	16 992 000	14 790 000	4 627 000	1 417 000	27 565 000

Table III: THE IMPORTANCE OF VARIABLE AND FIXED COSTS IN THE ESTIMATED MANUFACTURING COST OF SELECTED PETROCHEMICALS

(1980 United States $ per ton of product)

Final Product	Feedstock	Feedstock Cost ($ per ton of feedstock)			Variable Cost			Fixed Cost			Final Product Cost		
		United States Gulf Coast	Federal Republic Germany	Arabian Gulf	United States Gulf Coast	Federal Republic Germany	Arabian Gulf	United States Gulf Coast	Federal Republic Germany	Arabian Gulf	United States Gulf Coast	Federal Republic Germany	Arabian Gulf
Ammonia	methane	228	-	17	165	-	34	53	-	61	219	-	95
"	naphtha	-	326	-		171		-	62	-	-	233	-
Urea	ammonia	219	233	95	149	160	63	20	23	20	169	183	86
Methanol	methane	228	-	17	175	-	27	39	-	43	213	-	70
"	naphtha	-	326	-	-	184	-	-	44	-	-	228	-
Ethylene	ethane	215	-	25	310	-	57	112	-	127	422	-	184
"	naphtha	-	326	-	-	434	-	-	192	-	-	627	-
Ethylene Glycol	ethylene	422	627	184	490	698	382	44	55	52	534	753	381
LDPE	ethylene	422	627	184	492	700	231	132	154	151	624	854	382
HDPE	ethylene	422	627	184	552	773	294	127	146	145	679	920	439

SOURCE: UNIDO/GOIC Industrial Uses of Associated Gas Table 35 and Annex V. Based on information provided by SRI International and GOIC.

CHART

SOME PETROCHEMICAL PRODUCTS THAT CAN BE PRODUCED FROM ASSOCIATED GAS