CHAPTER 5

Petrochemical Technology Transfers

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CHAPTER 5

Petrochemical Technology Transfers

INTRODUCTION

Petrochemical technology transfer to the Middle East is of interest for several reasons. First, petrochemical manufacture involves complex technologies that are often difficult to master, heightening the importance of training programs for indigenous personnel. Because petrochemical products are sold in a world marketplace, efficient operation and quality control are critical. Second, petrochemical production is a very capital-intensive, feedstock-dependent industry where plants with a small number of highly trained personnel and inexpensive energy supplies can be cost competitive, even in remote locations. Several Middle Eastern countries are in this situation. With their small populations, substantial oil income that permits operation at world scale-capacity, using state-of-the-art technology and formerly wasted (flared) natural gas resources, downstream operations such as petrochemicals may be the most appropriate technology for such countries. Third, actual construction, licensing, and operation of petrochemical plants and marketing of the products is a lucrative business for foreign suppliers. Finally, the huge plants presently under construction or planned in the Middle East could cause severe dislocations in world commodity petrochemical markets once they come onstream. If more capacity is brought online in a slack world petrochemical market, this may quicken the pace of industry restructuring, particularly in Western Europe and Japan.

This chapter assesses the present status of Middle Eastern petrochemical production, perspectives of recipient and supplier countries and firms, and long-term developments. Finally, it addresses U.S. policy options, which are fairly limited.

One major theme is that, despite limited absorption of petrochemical technology by indigenous workers, Middle Eastern petrochemical facilities can be expected to operate efficiently and contribute significantly to their export revenues. Another major theme is the potential for negative effects on manufacturers in industrial countries, possibly leading to trade disputes, as these plants come onstream.

PETROCHEMICAL PRODUCTION IN THE MIDDLE EAST

Production of petrochemicals is an extremely complex industry wherein scores of international firms produce and trade many different feedstocks, intermediates, and product chemicals.[1] Central to the process is the conversion of feedstocks, such as natural gas or byproducts from the oil refining process, into basic petrochemicals such as ethylene, methanol, ammonia, and a limited range of simple derivatives such as low-density polyethylene and polyvinylchloride (PVC) (see app. 5A). Technical expertise is required in selecting appropriate feedstocks, products, and processes to produce those products; constructing, operating, and maintaining the plants; and marketing and distributing the products.

[1] Feedstocks are used in the first step of petrochemicals production and include natural gas, natural gas liquids, and crude oil, Intermediates such as butylenes arise during the course of steps leading toward production of desired petrochemical products and are generally not used by themselves as finished chemicals. Product chemicals. such as methanol and ammonia, can be used independently or further processed.

PRESENT AND NEAR-TERM STATUS OF PETROCHEMICALS IN THE MIDDLE EAST

Several countries in the Middle East currently plan or have petrochemical construction projects underway: Saudi Arabia, Kuwait, Algeria, Qatar, Bahrain, Iran, Iraq, Abu Dhabi (UAE), Egypt, and Libya. Each country's specific needs in developing its petrochemical sector, as embodied in invitations to bid and contract negotiations, vary and are a function of the following factors: 1) technological requirements, including type of process and products sought and the planned scale of production: 2) local administrative and operational capabilities; 3) the financial resources of the purchasing country or enterprise: and 4) political and cultural considerations.

To take advantage of economies of scale, Middle Eastern petrochemical plants are planned to very large; the number of projects is relativey few. Petrochemical plants are complex installations that are usually custom designed. Proven technology for petrochemical processes and products is widely available from suppliers in the United States, Japan, and Western Europe. Technological competition among these suppliers has centered on marginal differences in product yield, energy use, and product mix. Often the contractors must have a track record on work of a similar scale and have proven logistics capabilities. Suppliers usually have entered into either joint ventures or the construction of turnkey plants for national companies or state-owned industrial enterprises. Even more than is the case for some of the other technology sectors analyzed in this assessment (telecommunications and commercial aircraft support), no commodity trade classifications adequately capture imports of equipment for these plants.[2]

[2]No Standard lnternational Trade Clssification (SITC) product analysis is thus attempted, since equipment used in petrochemical production is included under a number of classifications, including Revised SITC 7148 (gas turbines); 742 (liquid pumps); 7431 (gas pumps): 7284 {special industrial machinery; and control instruments). It is impossible to disaggregate the imports under these categories destined specifically for petrochemical projects.

THE MIDDLE EASTERN PETROCHEMICAL INDUSTRY IN GLOBAL CONTEXT

To put the petrochemical situation in the Middle East and North Africa in perspective, tables 33 through 40 list the region's 1981 and projected future capacities for ethylene,[3] low-density polyethylene (LDPE)/linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE), ethylene glycol, styrene, methanol, and ammonia. These are all "primary or "commodity' chemicals: they are produced in large volume, by many companies, to standard specifications, and traded internationally, with price being a critical factor in trade.[4] Uses for these products in downstream operations are indicated later in table 43. Since various petrochemical projects have been announced and then postponed, the announced dates are subject to considerable change and are not included. Projects listed are expected by OTA to come onstream.[5]

As indicated in table 33, the most significant expected development in the Middle East is the rapid increase in ethylene capacity, expected to increase nearly sixfold in 1985 to 1990, with more than half of this increase reflecting the completion of Saudi Arabian projects. An additional 15 percent of new capacity could be added if Iraqi and Iranian projects are resumed. Considering that the bulk of this ethylene volume will be ethylene derivatives for export, the impact of these projects will be significant.

[3]Olefins (e.g., ethylene, propylene, or hut adiene) are considered to be primary chemicals, or building blocks which can be used to produce a range of derivative products.

[4]Chemical intermediates {sometimes referred to as "secondL ier chemicals) are produced from other chemicals. For example, the intermediate chemical polyvinylchloride (PVC) is itself produced from ethylene and chlorine, both commodity chemicals. "Specialty chemicals, unlike commodity chemicals, are relatively low-~' olume, high value-added products which are often produced by one or only a few companies. They are often specifically formulated for a particular customer for uses such as water treatment chemicals, lubricating additives, special adhesives, or electronic chemicals.

[5]The cost of canceling a project is often not large if done sufficiently early. In the case of the canceled project of Dow Chemical in Saudi Arabia, approximately 1.5 years after the project was announced, the company reportedly wrote-off only $26 million: the total value of the project is $1.5 billion.

Table 33.—Middle East and North African Ethylene Capacity, 1981 (thousand metric tons per year)

Country/company	Location	1981 capacity	Feedstock	Expansions (year)
Middle East:				
Kuwait:				
PIC	Shuaiba	—	Ethane	+350(1988-90)
Saudi Arabia:				
SABIC/Shell	Al-Jubail	—	Ethane	+650(1985-86)
SABIC/(Dow)/Mitsubishi	Al-Jubail	—	Ethane	+500(1986)
SABIC/Mobil	Yanbu	—	Ethane	+450(1985)
Iraq:				
Ministry of Industry	Basra	(130)a	Ethane	+130 (Restart 1985-90)
Iran:				
Abadan Petrochemical	Abadan	(25)[a]	Naphtha	Closed
Iran-Japan	Bandar Khomeini	—	Naphtha	+300(1990-95)
Turkey:				
Petkim	Yarimca	55	Naphtha	
Petkim	Aliaga	—	Naphtha	+300(1984-85)
Qatar				
QAPCO	Umm Said	280	Ethane	—
Other	—	130	—	+70(1989)
North Africa:				
Algeria:				
Sonatrach	Skikda	120	Ethane	—
Libya:				
Ras Lanuf Oil & Gas Processing	Ras Lanuf	—	Naphtha	+300(1984-85)
Total		585		3,050

[a]Capacity installd but facility not operational as of 1984

SOURCE Office of Technology Assessment

Table 34. —Middle East and North African LDPE and LLDPE Capacity, 1981 (thousand metric tons per year)

Country/company	Location	1981 capacity	Product	Expansions (year)
Middle East				
Kuwait:				
PIC	Shuaiba	—	LLDPE	+165(1988-90)
Saudi Arabia:				
SABIC/Exxon	Al-Jubail	—	LLDPE	+260(1985)
SABIC/(Dow)/Mitsubishi	Al-Jubad	— —	LLDPE LOPE	+120(1986) +130(1986)
SABIC/Mobil	Yanbu	—	LLDPE	+200(1985)
Iraq:				
Ministry of Industry	Basra	(60)[b]	LOPE	Restart (1985-90)
Iran:				
Iran-Japan	Bandar Khomeini	—	LDPE	+100(1990-95)
Turkey				
Petkim	Yarimca	24	LOPE	
Petkim	Aliaga	—	LOPE	+150(1984-85)
Qatar				
QAPCO	Umm Said	140	LDPE	—
Other	—	96	LDPE	—
North Africa:				
Algeria:				
Sonatrach	Skikda	48	LDPE	—
Libya:				
Ras Lanuf Oil & Gas Processing	Ras Lanuf	— —	LDPE LLDPE	+50(1 987) +80(1 987)
Egypt:[a]				
EGPC	Alexandria	—	LOPE	+90(1 990)
Total		308		1.405

[a]Based on imported ethylene
b Not operational as of 1984

SOURCE Office of Technology Assessment

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Table 35.–Middle East and North African HDPE Capacity, 1981
(thousand metric tons per year)

Country/company	Location	1981 capacity	Expansions (year)
Middle East:			
Kuwait:			
PIC	Shuaiba	—	—
Saudi Arabia:			
SABIC/(Dow)/Mitsubishi	Al-Jubail	—	80(1986)
SABIC/Mobil	Yanbu	—	100(1985)
Iraq:			
Ministry of Industry	Basra	—	30(1985-90)
Iran:			
Iran-Japan,	Bandar Khomeini	—	60(1990-95)
Turkey:			
Petkim	Yarimca	—	
Petkim	Aliaga	—	40(1984-85)
Qatar:			
QAPCO	Umm Said	—	70(1986-87)”
North Africa:			
Libya:			
LNOC	–	—	50 (Planned)
Egypt:[a]			
EGPC	Alexandria	—	40(1990)
Total		—	470

a Ultimately it may be a conversion and expansion of its LDPE facility to LLDPE. An LLDPE facility could be used to produce a range of products from LLDPE to HDPE

SOURCE Office of Technology Assessment

Table 36.–Middle East and North African Ethylene Glycol Capacity, 1981
(thousand metric tons per year)

Country/company	Location	1981 capacity	Expansions (year)
Middle East:			
Kuwait:			
PIC	Shuaiba	—	+ 135 (1 988-90)
Saudi Arabia:			
SABIC/(Dow)/Mitsubishi	Al-Jubail	—	+ 300 (1 986)
SABIC/Mobil	Yanbu	—	+ 200 (1985)
Turkey:			
Petkim	Aliaga	—	+68 (1 984-85)
North Africa:			
Libya:			
Ras Lanuf Oil & Gas Processing	Tobruk	—	+50 (1987)
Total		—	753

SOURCE Office of Technology Assessment

Tables 34 through 37 indicate the types of derivative capacity expected onstream in the Middle East region during the 1980’s. As shown in these tables, polyethylene—especially in the form of LDPE and LLDPE–will predominate over other forms of ethylene derivatives. Most of this material will be exported to Asia, Africa, and Europe. Similar distribution patterns are expected for other olefin-derivative exports.

Tables 38 through 40 for methanol and ammonia include export projects under development in the Middle East and North Africa. A

Table 37.— Middle East and North African Styrene Capacity, 1981
(thousand metric tons per year)

Country/company	Location	1981 capacity	Expansions (year)
Middle East:			
Kuwait:			
PIC	Shuaiba	—	+340(1988-90)
Saudi Arabia:			
SABIC/Sheil	Al-Jubail	—	+300 (1985-86)
Iran:			
Iran-Japan	Bandar Khomeini	—	+20(1990-95)
Turkey:			
Petkim	Yarimca	20	—
North Africa:		—	—
Total		20	660

SOURCE Office of Technology Assessment

Table 38.—Middle East and North African Methanol Capacity, 1981 (thousand metric tons per year)

Country	Company	Location	Feedstock[a]	Capacity	Expansions (year)
Middle East					
Egypt	Egyptian Petroleum	Alexandria	NG	10	—
Saudi Arabia	SABIC/Mitsubishi Gas Chemical	Al-Jubail	NG	—	600 (1 983)
	SABIC/Celanese/Texas Eastern	Al-Jubail	NG	—	650 (1985)
Bahrain	SABIC/PIC/BANOCO	Sitra Island	NG	70	360 (1984-85)
Other	...		NG	60	
North ***Africa:***					
Algeria	Almer	Arzew	NG	110	—
Libya	Libyan Methanol	Marsa El Brega	NG	330	330 (1985)
Total Middle East and North Africa				580	

[a]Natural gas
SOURCE Office of Technology Assessment

significant number of the ammonia projects in this region are dedicated to domestic fertilizer consumption.

For purposes of comparison, table 41 shows petrochemical production outside the Middle East in 1982 for the same eight commodity chemicals covered in tables 33-40. Middle East production—particularly of ethylene, LDPE and LLDPE-is significant when compared with non-U. S. producers (Western Europe, Japan, Canada, Mexico). U.S. production figures dwarf those of all other countries, including those in the Middle East, reflecting the large domestic U.S. market. It should be remembered that, because a large part of Middle East output is targeted to export markets, these plants will have a large impact on world trade in these chemicals. As indicated in table 41, production declined in many cases in recent years. This foreshadows significant restructuring ahead as the large Middle Eastern plants come onstream during the next few years.

PERSPECTIVES OF RECIPIENT COUNTRIES AND FIRMS

To understand how petrochemical technology is transferred to the Middle East and the implications of this transfer, OTA assessed projects in Saudi Arabia, Kuwait, Bahrain, Qatar, and Algeria. Because Iranian, Iraqi, and Egyptian projects will have minimal im-

Table 39.—Middle Eastern Ammonia Capacity, 1981 (thousand metric tons per year)

Country/company	Location	Capacity	Feedstock[a]	Expansions (year)
Bahrain;				
Gulf Petrochemical	Sitra	—	NG	270(1984-85)
Iran:				
Iran Fertilizer	Shiraz	28	NG	320(1982-83)
NPC	Bandar Khomeini	540	NG	Damaged due to war
Iraq:				
Ministry of Industry	Basra	272	NG	Damaged due to war
	Urn Qassr	272	NG	544 (Planned)
	Al-Kain	—	NG	41 (1984-85)
Kuwait:				
PIC	Shuaiba	330	NG	
	Shuaiba	220	NG	270(1983-84)
Qatar:				
QAPCO	Um Said	480	NG	
Saudi Arabia:				
Safco	Damman	160	NG	
SAMAD	Al-Jubail	—	NG	270(1983-84)
Turkey:				
IGSAS	Ismit	270	N	
	Kirklareli		NG	270(1983-84)
Azot Sanayii	Kutahya	124	N	
	Silifke		N	270(1983)
United Arab Emirates:				
ADNOC	Ruwais		NG	270(1984)
	Ruwais		NG	270(1985)
Other		80	N	270(1985-90)
Total Middle East		3,086		

[a] Feedstocks: NG = natural gas, N = naphtha

SOURCE Office of Technology Assessment

Table 40.—North African Ammonia Capacity, 1981 (thousand metric tons per year)

Country/company	Location	Capacity	Feedstock[a]	Expansions (year)
Algeria:				
Sonatrach	Arzew	—	NG	270(1980-81)
	Arzew	—	NG	270(1980)
	Annaba	—	NG	270(1983-84)
	Skikda	—	NG	270 (Planned)
Egypt:				
Nasr	Helwan	49	COG	
Kima	Aswan	119	N	
El Nasr d'Engrais et Ind Chimiques	Suez	48	N	
	Talkha	98	N	325(1980-81)
State	Abu Qir	—	NG	326(1979-80)
Libya:				
LNOC	Marsa El Brega	270	NG	270(1984-85)
Morocco:				
OCP	Jorf Lasfar	—	N	270 (Planned)
Nitromar	Mohammadia	—	N	90 (Planned)
Sudan:				
State	Port Sudan	—	N	50(1983) 50(1985)
Tunisia:				
Groupe Chimique	Gabes	—	NG	270(1985)
Total		584		

[a] Feedstocks: NG - natural gas: COG = coke oven gas; N = naphtha

SOURCE Office of Technology Assessment

Table 4˙.—Petrochemical Production Outside of the Middle East Region, 1982
(thousand metric tons produced/average annual growth, 198˙-82, %

	United States	France	Italy	United Kingdom	West Germany	Japan	Canada	Mexico
Ethylene	11218.2/ – 16.2	1868.2/1.0	909.1/0.0	1081.8/ – 13.0	2636.4/ – 9.0	3590.0/ – 2.0	1010.0/ – 24.0	400.0/5.0
Low-density polyethylene / Linear low-density polyethylene	3409.1/ – 2.0	881.8/0.0	509.1/ – 5.0	418.2/ – 8.0	1122.7/ – 6.0	1670.0/0.0	570.0/ – 10.0	90.0/2.0
High-density polyethylene	2240.9/5.0							80.0/0.0
Ethylene glycol	1954.6/3.7				181.8/ – 17.0	390.0/ – 6.0		
Styrene	2695.5/ – 11.3	309.1/18	309.1/6.0	136.4/ – 6.0		1090.0/ – 1.0		30.0/12.0
Methanol	3300.0/ – 15.5	340.9/ – 2.0			709.1/2.0	630.0/ – 15.0		190.0/6.0
Ammonia	14081.8/ – 18.6	1900.0/ – 16.0	1259.1/ – 15.0		1568.2/ – 20.0		2510.0/ 5.0	2470.0/13.0

SOURCE: "Facts and Figures for the Chemical Industry," *Chemical and ing News*, June 13, 1983, pp. 26ff.

pacts on world petrochemical markets, they are only briefly reviewed.

GOALS AND OBJECTIVES

While their priorities may be different, the goals and objectives of the Middle Eastern countries are similar. Simply stated, their objective in petrochemical development is to move away from overdependence on oil toward a profitable manufacturing area that involves use of natural resources (natural gas) that have been wasted (flared) in the past. The development, via technology transfer, of a petrochemical industry is also a matter of national pride. They expect their petrochemical development efforts to result in:

- Revenues or profits to support future economic growth.
- Human resource development—A dynamic industrial environment that would create employment, stimulate training with clear objectives, support industries giving an outlet to the local entrepreneurs, and foster a group of technocrats to support future national growth.
- The basis for future downstream industries.

The goals and objectives of these countries differ little from those typical of developing countries. Some of the more fundamental questions have been how to finance technology without incurring inordinate amounts of debt, where to gain access to low-cost raw materials, the degree of capital intensity or sophistication of the technology, the availability of trained manpower, structuring relationships with multinational corporations, and the implications of modern or Western technology on local culture.

The Middle East, with its unique combination of purchasing power and comparatively low level of industrialization, provides a challenging area for petrochemical development. Raw materials for petrochemicals are plentiful in this region and, in the case of the Gulf States, can be considered "free" because they are derived in association with crude oil production. This utilization of abundant natural resources helps mitigate the increased costs of building and operating petrochemical plants in the Middle East. Moreover, the initial capital for petrochemical projects and the hiring and training of local and foreign manpower can be financed through use of energy-derived funds and anticipated future project returns for collateral. In this environment debt, a typical constraint on many less developed countries (LDCs), has not been as important a consideration. This has made it possible to acquire the best technology available.

Middle Eastern countries have faced potential problems in a number of ways. By requiring competitive bids on all aspects of a project, potential overpayment is reduced, and through joint venture and other arrangements with foreign firms, marketing of products is planned. Cultural values are protected by citizenship restrictions and by limiting the incentives for foreign workers to go beyond their own enclaves or work camps. While a potential brain drain is an issue in these countries, professional opportunities and financial well-being should preclude a significant exodus of the educated in the more financially secure Gulf States.

PETROCHEMICAL PROJECTS

Petrochemical projects in the Middle East have been promoted by governments acting through oil ministries, state oil companies, or specialized agencies and government-controlled companies. Because local abilities of private or governmental entities to evaluate, design, engineer, construct, and operate the plants are generally inadequate to carry out these tasks independently, Middle Eastern countries have attempted to improve indigenous capabilities in these areas through participation with other countries in petrochemical projects. They also recognize a need for some level of foreign assistance from the beginning of a project through plant operation, a period generally spanning several years. Thus, through arrangements with joint venture partners, licensers, and contractors these countries expect to expedite their development process via the absorption of state-of-the-art technologies, the development of managerial, marketing, and organizational skills, as well as import substitution and local and international market development. International marketing abilities are important because, in order to achieve the level of economic scale prevalent internationally, a major portion of the output from these petrochemical projects must be exported. Since local demand will only account for approximately 10 percent of Saudi Arabia's eventual petrochemical production, the Saudi Arabian Basic Industries Corp. (SABIC) actively sought joint venture partners—Shell, Exxon, Mobil, Dow Chemical, Celanese/Texas Eastern, Mitsubishi Gas Chemical, and Taiwan Fertilizer—capable of marketing any surplus beyond the joint venture's own needs.

The development of large petrochemical projects and related infrastructure provides the opportunity for local entrepreneurs to develop supportive industries while enhancing business skills and judgment. The modernization process entailed in these projects will create a more technical and highly educated population. Hence, even trainees in petrochemical projects who leave that industry will take with them special skills and analytical tools that they and their local society might not otherwise have. These skills can be as simple as welding or as sophisticated as the management of large productive assets.

On the other hand, there are some potential disadvantages to host societies participating with foreign multinational corporations in these petrochemical projects. These perceived problems include excessive foreign profits. Multinational corporations are believed to sometimes skew their costs to the disadvantage of the host countries, drawing inordinately high returns back to their parent company while reinvesting very little, if any, funds in the host country for future development. Another type of problem involves inappropriate and inadequate training programs. All of SABIC's projects will train a large number of people, approximately 7,000 to 10,000 by 1985-86. However, this is a relatively small number in light of Saudi Arabia's total manpower development requirements. Furthermore, large capital-intensive projects do very little for the large number of underemployed in Algeria. There is also concern that research and development (R&D) efforts will never be based in the Middle East, and as a consequence, that true technology transfer will never occur. Others fear that indigenous business development will be preempted by these projects. Subsidizing wholly or even partially foreign-owned facilities, in their view, may prevent the development of similar facilities by local business and result in continuing dependence on foreign corporations. Finally, even those who do not believe that multinational corporations are necessarily exploitive still worry about potential corruption of cultural and religious value systems in their countries.

PROJECT PROFILES

The major petrochemical projects now under way in the Middle East include three large projects in Saudi Arabia (the Mobil/Saudi joint venture at Yanbu producing polyethylene and ethylene glycol; the Exxon/Saudi joint venture at Al-Jubail, producing polyethylene; and the Mitsubishi/Saudi joint venture at Al-Jubail, producing methanol). Other major projects are in Kuwait (PIC project, producing polyethylene, ethylene glycol, and styrene which is apparently on hold), in Algeria (a Sonatrach project, producing ammonia; another Sonatrach project producing liquefied natural gas—LNG), in Qatar (the QAPCO/CdF Chimie joint venture, producing polyethylene), and Bahrain (the PIC/SABIC/BANOCO joint venture, producing methanol and ammonia).* In Iran and Iraq, war has postponed petrochemical development, while in Egypt there is a well-established fertilizer industry but little likelihood that that country will become a major petrochemical producer. Summaries for each of the major eight projects are given in appendix 5B.

* Petroleum Industies Co. (PIC), Societe Nationale de Transport et de Commercialisation des Hydrocarbures (Sonatrach), Qatar Petroleum Co. (QAPCO). Bahrain National Oil Co. (BANOCO).

Saudi Arabia

Saudi Arabia is the model case of a well-financed developing country seeking to develop a modern petrochemical industry through joint ventures with foreign companies. From the foreign partner perspective, profits, crude oil, and prospects for new business have all been important incentives for participation.

Saudi Arabia has undertaken an aggressive program to establish itself as a significant world petrochemical center, although this is not immediately apparent when comparing Saudi capacity for various chemicals to world capacity. It becomes clearer in terms of the Saudi percentage of total world trade. For example, in the late 1980's, Saudi Arabia is expected to have an estimated 4 to 5 percent of world LDPE and LLDPE capacity; however, it is expected to control approximately 20 percent of world trade in this product. (Kuwait and Qatar combined could represent an additional 10 percent.)

The Saudi program includes five olefins and derivatives projects, two methanol projects, and two ammonia projects. The size and type of each of the olefins projects are shown in table 42. All of these projects are scheduled for completion in the mid-1980's and, if successful, can be expected to be followed by a second generation of projects in the 1990's. However, some of these projects may be delayed. For example, the Arabian Petrochemical Co. project recently lost Dow Chemical as a participant. While SABIC has stated that it would assume responsibility for the Dow olefins complex,[6] some delay in startup can be assumed. Moreover, the quantity of ethylene to be produced and the outlook for the LLDPE that Dow was to produce are still in question.

Most of the projects now being developed were conceived in the period 1972-74 when Petromin (the National Oil Co.) invited proposals from foreign companies. The United States, Japan, and European countries responded. However, changes in the underlying crude oil situation led some companies to pursue these negotiations less vigorously, and many of the projects, including all of European origin, were dropped. Others were deferred, then revived again in 1977-78. Today, these projects are under the jurisdiction of the Ministry of Industry and Electricity.

The so-called first-stage petrochemical projects in Saudi Arabia are 50/50 joint ventures between SABIC and foreign companies or consortia. SABIC is a limited company, established in 1976 for this specific purpose. It is responsible to the Ministry of Industry. All of its shares are held by the Saudi Government, but the Articles of Association specify that within 5 years of its establishment, a majority of the shares would be offered to the Saudi public, with the government maintaining a minority interest. This is now beginning to take place; 10 percent of the SABIC shares were recently allocated for public subscription to Gulf Corporation Council citizens.[7]

A driving force behind the establishment of these projects was the desire to utilize the large quantities of associated gas being flared at the wellhead. ARAMCO[8] was instructed to prepare and implement a gas-gathering and extraction project. The gas-gathering scheme was originally estimated at $7 billion, but estimates rose to over $17 billion before implementation. This project is expected to be completed at a lower cost of between $10 billion and $12 billion, owing to a combination of scope modification, competitive bidding on all procurement items, the impact of the world recession on prices, and careful project management. The project is now virtually complete, and liquefied petroleum gas (LPG) has been exported for some time. Ethane and methane

[6] Toby Odone, "Petrochemicals-Dynamo or Drain?," Middle East *Economic Digest,* vol. 27, No. 42, Oct. 21-27, 1983, pp. 12-19. The downstream aspect of the project has fallen to the Mitsubishi-led consortium participating in cooperation with Eastern Petrochemical Co. in what is often referred to as the SHARQ project.

[7] Saudi Press Agency–Major News Events, Sept. 26, 1983.

[8] ARAMCO (Arabian American Oil Co.) began with a concession agreement between Saudi Arabia and Standard Oil Co. of California (Socal) in July 1933. Texaco, Exxon, and the Mobil Oil Co. were subsequently added to ARAMCO to gain investment capital and marketing outlets. The Saudi Government had a 25 percent ownership in ARAMCO in 1972, 60 percent in 1974, and now has complete ownership.

Table 42.—SABIC's Petrochemical and Fertilizer Projects

Projects	Location	Foreign partner	Estimated Cost	Percent completed by 12/31/83	Feedstock	Products	Capacity (tonnes/yr)
Saudi Petrochemical Co.	Al-Jubail	Shell	$3.0 billion	78%	Ethane	Ethylene	656
					Salt benzene	Ethylene dichloride	454
						Styrene	295
						Crude industrial ethanol	281
						Caustic soda	377
Saudi Yanbu Petrochemical Co	Yanbu	Mobil	$2 0 billion	78	Ethane	Ethylene	455
						Linear low-density polyethylene	205
						High-density polyethylene	90
						Ethylene glycol	220
Al-Jubail Petrochemical Co	Al-Jubail	Exxon	$1.3 billion	85	Ethylene	Linear low-density polyethylene	260
Saudi Methanol Co.	Al-Jubail	Mitsubishi	$500 million	00	Methane	Chemical grade methanol	600
National Methanol Co.	Al-Jubail	Celanese/ Texas Eastern	$500 million	86	Methane	Chemical grade methanol	650
Arabian Co.	Al-Jubai	Formerly Dow	$1.5 billion	14	Ethane	Ethylene	500
						Linear low-density polyethylene	120
						High-density polyethylene	60
Eastern Petrochemical Co.	Al-Jubail	Mitsubish	$1.5 billion	27	Ethylene	Linear low-density polyethylene	130
						Ethylene glycol	300
Al-Jubail Fertilizer Co.	Al-Jubail	Taiwan Fertilizer	$350 million	100	Methane	Urea	500

NOTE: All of these plants are expected to be completed by 1985

SOURCE: Carla Rapoport, "All Eyes on the Petrochemicals Launch," *Financial Times*, Apr. 24, 1984, p. 5.

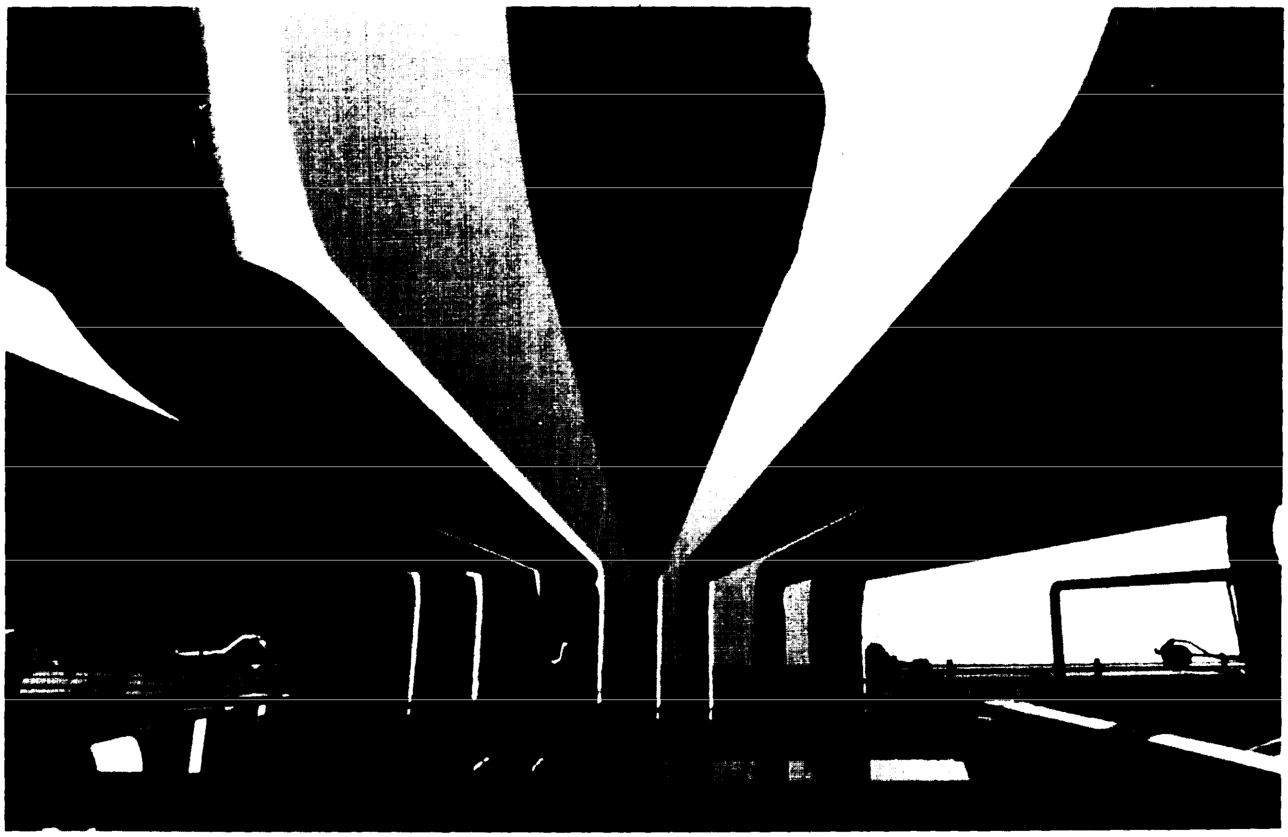

Photo credit Aramco World Magazine

Part of Saudi Arabia's Immense coast-to-coast network of plants and pipes for collecting, treating, and distributing oil-associated gases which were previously flared

are available for petrochemical and energy uses.

As part of the Saudi Arabian master plan for industrialization, two large manufacturing cities were established: Al-Jubail, located on the Persian Gulf, and Yanbu, located on the Red Sea. Plans for each include a petrochemical center, refinery, and other petroleum-related industries. The overall plan for development comprises: 1) a gas-gathering system; 2) petrochemical complexes at Al-Jubail and Yanbu; 3) methanol, ammonia and urea plants; 4) a steel mill; and 5) an infrastructure program that includes new port facilities, roads, airports, schools, universities, hospitals, housing, power generation, and desalinization facilities. Responsibility for the establishment and development of these sites was vested in a Royal Commission for Al-Jubail and Yanbu.

Many U.S. contractors are involved in this development program, with Bechtel having overall management responsibility for the Al-Jubail Industrial City. It is also the primary contractor for the Yanpet Petrochemical Project. Fluor is the contractor for the gas-gathering pipeline network and petrochemical projects in Al-Jubail. Parsons manages the Yanbu Industrial City. In addition, large numbers of subcontracts have been let to both U.S. and other foreign firms for various phases of the projects.

Goals and Objectives.–The impetus behind the Saudi petrochemical program involves a desire to diversify the economy, national pride, a determination to avoid wasting natural gas and gain value-added from downstream development, and human resources development. Balance of payments considerations also underlie petrochemical development because Saudi Arabia's main resource (crude oil) is being depleted and it has few renewable resources, and because Saudi Arabia depends on imports not only for most manufactured goods but also for a large proportion of its food supplies. Consumer spending is increasing rapidly as prosperity spreads across a larger proportion of the population. In 1978, current expenditures began to exceed oil revenues, and budgets had to be cut back. The 1979 oil price increases temporarily transformed the situation, but concerns were once again raised by the decline in crude prices in the early 1980's.

Project Organization and Structure.–Although differing in some details, the projects in Saudi Arabia have been developed and are being implemented according to what is essentially a standardized scheme similar to that used by most other countries in the region. The main features of project organization and structure are detailed below:

1. Preliminary studies to establish the feasibility of the project (known as prefeasibility studies) are carried out, financed by aspirant joint venture partners.
2. Following acceptance of prefeasibility study findings by SABIC and the potential partner, an interim agreement is negotiated, covering:
   - terms for a jointly financed, full-scale feasibility study, to include sufficient engineering to establish reliable capital and operating cost estimates;
   - establishment of a joint team to carry out this feasibility study; and
   - training of key personnel.
3. Detailed agreements for feedstock supply, finance, training, marketing, licensing, technical, and management assistance are negotiated. Also negotiated are the basic principles for the agreements that define the terms under which the project will be implemented.
4. On completion and acceptance of the feasibility study, the joint venture agreement is signed authorizing the establishment of a joint company to implement the project and operate the plant. The detailed agreements referred to above form appendixes to the joint venture agreement.
5. The joint company is formed, and the project team that has supervised the feasibility study is transferred to the new company.
6. Technology is selected, and engineering and construction agreements are negotiated with contractors.
7. Recruitment of personnel commences, and full-scale training programs are implemented.

The projects in Saudi Arabia were conceived as joint ventures in which the partners make equal contributions to, and derive equal benefits from, the projects. Thus, Saudi Arabia contributes feedstock (at well below world prices),[9] financing, and a developed site with services and utilities. The foreign partners contribute technology, management, markets or marketing skills, and training of Saudi Arabian nationals.

The projects are expected to meet profitability criteria on the part of joint venture partners. The original Saudi proposal supposedly entitled a joint venture partner, from the time of signing the agreement, to lift 1,000 barrels per day (b/d) of crude oil for every $1 million invested in the joint venture. It is believed that this ratio has been changed to approximately 500 b/d of crude oil per $1 million investment. Under present world market circumstances, the value of this crude oil entitlement (to be lifted at posted prices) may be questionable. However, in more normal times, even a 2 percent net profit in handling and processing the crude would be equivalent to a 12 percent return on equity invested in the petrochemical project, and therefore, would be comparable to dividends expected from the joint venture.

[9] The Saudi Government is reportedly charging the new petrochemical producers 50¢/million Btu for their feedstock. This compares with $4.50 to $5.00/million Btu in Western Europe, and a U.S. average of $3.30 to $3.50. While some call this a subsidy, U.S. firms involved call it a natural resource of the host country (not a subsidy). See Carla Rapoport, "All Eyes on the Petrochemicals Launch," *Financial Times,* Apr. 24, 1984, p. 5 of Special Report on Saudi Arabia.

Technology Transfer. -In the case of the SABIC/Mitsubishi Gas Chemical methanol project (now Saudi Methanol Co.), the technology (developed by Mitsubishi Gas Chemical) to be used and the engineering contractor (Mitsubishi Heavy Engineering) were specified in the interim agreement. In this case, technology transfer could be regarded as embodied in the package supplied by Japanese companies. There was, therefore, no competitive element in the selection of processes, licensers, or contractors. Chem Systems, an outside U.S. consultant, was called in to assist SABIC in evaluating the Japanese package.

In all other cases, SABIC has insisted that technology selection and engineering be on a fully competitive basis. This implies that even when the foreign partner has technology of its own for the proposed operations, it must be assessed by the joint project team against other competitive technologies. Similarly, although the foreign partner's advice is sought regarding the selection of contractors, contractors are selected on a competitive basis—by the joint project team for preliminary engineering and by the joint venture company for full engineering and construction. Thus, no firm link exists between basic technology transfer and the identity (or nationality) of the foreign partner.

Contractor Agreements.—All agreements with licensers and contractors are subject to competitive bids that allow a reasonable profit and hence incentive for the contracting party to participate in the project yet not take undo advantage of the situation.

The provision of technical and management know-how by the foreign partner is covered by a service agreement. This includes both project implementation and subsequent operation. The foreign partner is expected to be able to provide this know-how even though the basic technology may be obtained from another source.

The licensing of the basic technology is covered by separate license agreements between the joint venture company and the licensers. Such agreements normally cover startup assistance and (in some cases) continuing technology transfer relating to the specific process or products. Royalties are paid by the joint venture company or the licensers, as specified in these agreements. In the case of LLDPE, Union Carbide Corp. licensed its process to SABIC rather than to the individual joint venture companies producing LLDPE.

In all cases, the foreign partner assumes some responsibility through marketing agreements for disposal of products from the joint venture company. In most instances, this takes the form of a commitment to market on behalf of the company a specified minimum quantity of products, normally representing a high proportion of the output of the plant. This is accomplished through the foreign partner's international distribution network. There is also provision for disposal by the partner of any additional quantity on a best-endeavors basis.

These commitments imply that where the foreign partner has capacity to produce the products in question elsewhere in the world, it will, if necessary, be prepared to consider the cutback of production from this capacity in order to meet its commitment to the Saudi joint venture. This situation could, in times of recession, be a serious problem for the foreign partner and a penalty for the non-Saudi countries in which the partner operates. This type of problem exists whenever a company decides to locate a production facility at a foreign location—especially when payouts on new facilities are compared to those on old facilities. Escape clauses that allow reduced production when market conditions so dictate are reported to be included in Saudi Arabian project agreements. Continuing concerns regarding crude oil security may provide an added incentive to maximize production from Saudi sites.

When the foreign partner has its own requirement for the products of the company, it may be covered by a separate offtake agreement. Such a commitment to take products may be substituted, in whole or in part, for a quantitative commitment under marketing agreements.

Financing.–The financial provisions for Saudi joint ventures apply to all projects, though there may be minor variations. They are as follows:

1. all projects are financed with 30 percent equity, shared equally by the two partners, a 60 percent loan from the Saudi Public Investment Fund (PI F), and a 10 percent loan from commercial banks, Saudi or foreign;
2. financing covers initial fixed capital investment, interest during construction, capitalization of all expenditures under the interim agreement, initial working capital, and preoperating expenses;
3. PIF loan and equity are in strict 2:1 proportions, with a commercial loan to cover the final 10 percent of the capital requirements;
4. typical terms for commercial loans are for 5 years, with repayment in 10 equal installments, beginning at the time of startup. The PI F loan is for 20 years, with repayment in 22 equal installments commencing in the fifth year after startup;
5. the interest rates on commercial loans are negotiated with banks, the PIF loan is given at 3 to 6 percent of the outstanding sum, the actual rate is dependent on the project's return on equity;
6. dividend payments beyond a partner's share of net income after tax are subject to agreed on (debt) prepayment terms and conditions;
7. any excess of cash income over net income is to be used, after meeting other cash requirements, for prepayment of PIF loan; and
8. prepayment terms are set.

Manpower and Socioeconomic Considerations.—The objective behind the training programs is not to employ large numbers of people as much as to develop a class of technically competent individuals. Hence large, efficient, capital-intensive petrochemical projects are perfectly suited for Saudi Arabia and meet the country's training and economic development goals. Universities are being built and professors are being hired to teach engineering and science. King Fahd recently opened (coinciding with the 50th anniversary of ARAMCO) the new Petroleum Exploration and Engineering Center in Dhahran, which is considered the most modern center for oil technology in the Middle East.[10]

Photo credit Aramco World Magazine

A Saudi geologist uses a petrographic microscope at the Petroleum Exploration and Engineering Center in Dhahran

The true test of domestic economic development will be the Saudis' capability to develop and manage their own projects when the second generation of petrochemical projects are undertaken in the 1990 's. Another sign of development will be the ability to hold market position through expansions in capacity,

The issue of having development hinge on a large cadre of foreign laborers (and to a lesser extent managers), as is the case in the Saudi Arabian fertilizer complex and refinery, does not seem to worry many Saudis: the Saudi Arabian population is small, with an indigenous element variously estimated in the range of 4 million to 7 million and an immigrant portion exceeding 1 million. The success of the Saudi national development program over the long term, however, will depend on the ability of the indigenous population to absorb and effectively use the technology they have purchased, a process expected to bear fruit in the 1990's. Nevertheless, Saudi Arabia's goal of

[10] New Oil Center opened, "Saudi *Report,* April-May 1983.

preserving Islamic traditions" must be carried out in the context of a large foreign work force.

The potential problem of foreign corporations preempting the growth of home-grown industry is being dealt with in a number of ways. First, SABIC maybe made a completely publicly held corporation. In addition, incentives are being provided to domestic companies to go into downstream product development. Saudi Arabia's ability to influence the price of products their projects produce and their joint venture partners' expected desire to assist in downstream development should allow local industry to develop and prosper.

Kuwait

The Kuwaiti petrochemical project is the responsibility of Petrochemical Industries Co. (PIC), whose main business (started in the 1960's) is the production of ammonia and urea. PIC is a subsidiary of the state-owned Kuwait Petroleum Corp. (KPC), which is responsible for hydrocarbon exploration and development worldwide. The investment strategy of KPC distinguishes it from other petrochemical firms in the Middle East. Kuwait also has major investments in the United States, perhaps the most well-known being the Santa Fe International Corp. which is the corporate parent of C. F. Braun Engineering. Kuwait participates in projects in Bahrain, oil and gas exploration in Morocco and Tunisia, and a Volkswagen manufacturing facility in Brazil. Its most recent investments in Europe are a 25-percent share of Hoechst Chemical and the purchase of both Gulf Oil's refinery and gasoline station network in Western Europe. To support its hydrocarbon-related activities, the Kuwaiti Government is melding KPC into what is quickly becoming a fully integrated, multinational oil company with production, refinery, and marketing capabilities as well as chemical and petrochemical operations.

Goals and Objectives.—The basic rationale for a Kuwaiti petrochemical project differs little from the Saudi Arabian example. Reasons include national pride, diversification away from dependence solely on future crude oil production, availability of ethane from associated and nonassociated gas, and revenues from crude sales to finance the project. In addition, Kuwait has large earnings from foreign investments and a relatively small indigenous population (1.4 million), which matches well with the capital intensiveness of petrochemical production. Kuwait has made a great drive to expand its portfolio of investments away from oil, particularly if sufficient added value exists in downstream investments. Thus, it is developing its position as a major international investor equal in strength to its position as an oil producer. In fact, foreign investment capitalized from oil income reserves recently surpassed revenues from oil income.

One fundamental difference between the Kuwaiti and Saudi Arabian approaches is that the former stresses outright equity participation in foreign downstream operations, while the latter focus on joint ventures in Saudi Arabia with foreign partners who have established expertise in petrochemical production. Kuwait, for example, acquired 3,000 gasoline stations and a number of refineries and other facilities located throughout Western Europe, purchased from Gulf Oil (U. S.). [12]

Another fundamental difference between the situations of Saudi Arabia and Kuwait is the absence of large quantities of flared gas in Kuwait. As a consequence, if Kuwait proceeds with its project, it will have to address two major issues: 1) does the return on the petrochemical project meet the standards set for their portfolio of investments? and 2) can the requisite return be realized if their natural gas is priced at a value equal to that of heavy fuel oil?

It can be argued that with the absence of large quantities of excess gas, heavy fuel oil would have to be substituted for the gas currently being used for utilities and industry.

[11] Mohammad Ali Hafiz, *Journal of Contemporary Business,* vol. 9, No. 3, 1981.

[12] "Downstream Moves Complete KPC Jigsaw,'" *Middle East Economic Digest, Special* Report on Kuwait, May 1984, p. 10. See also Louis Turner, "Planning an Assault on World Markets, " *Middle East Economic Digest,* Aug. 12, 1983, p. 42.

Hence, this opportunity cost should set the price for ethane and the gas currently being used in utilities and for ammonia production. However, such gas is presently priced in a fashion similar to that of Saudi Arabian gas.

Project Organization and Structure.– Preliminary studies, feasibility studies, and marketing studies have proceeded in a fashion similar to that of the Saudi projects. Hoechst of West Germany is the only likely joint venture partner. Kuwait's leaders hope that the project will bring a good return on investment. Kuwait would also have the security of having its asset (the PIC complex) on its own soil. In addition, the project would add to the industrial base of the country. If a joint venture approach is not pursued, Kuwait is likely to structure a marketing agreement with a major marketer or consumer of petrochemicals, such as its current agreement with Hoechst.[13]

Initially, the intent was to have foreign joint venture partners. BASF (West Germany) was associated with the ethylene project and W.R. Grace (U. S.) with aromatics production. After a series of studies, completed by 1977, the petrochemical project was effectively shelved. Meanwhile, the new gas-processing project began operating in the late 1970's. Feedstock was thus directly available, and after the oil price rises of 1979-80, the petrochemical proj-

[13] Hoechst of West Germany signed two letters of intent formalizing plans both to buy ammonia and to market chemical fertilizers from the Kuwait Petrochemical Industries Co., a subsidiary of KPC. See Carla Rapoport, "Hoechst Signs Deal With Kuwait Petrochemicals, " *Financial Times*, Feb. 2, 1984, p. 5. See also Jumada al-Thani, "Hoechst Plans to Service Kuwait and Saudi Arabia, " *Arabia*, March 1984, p. 59.

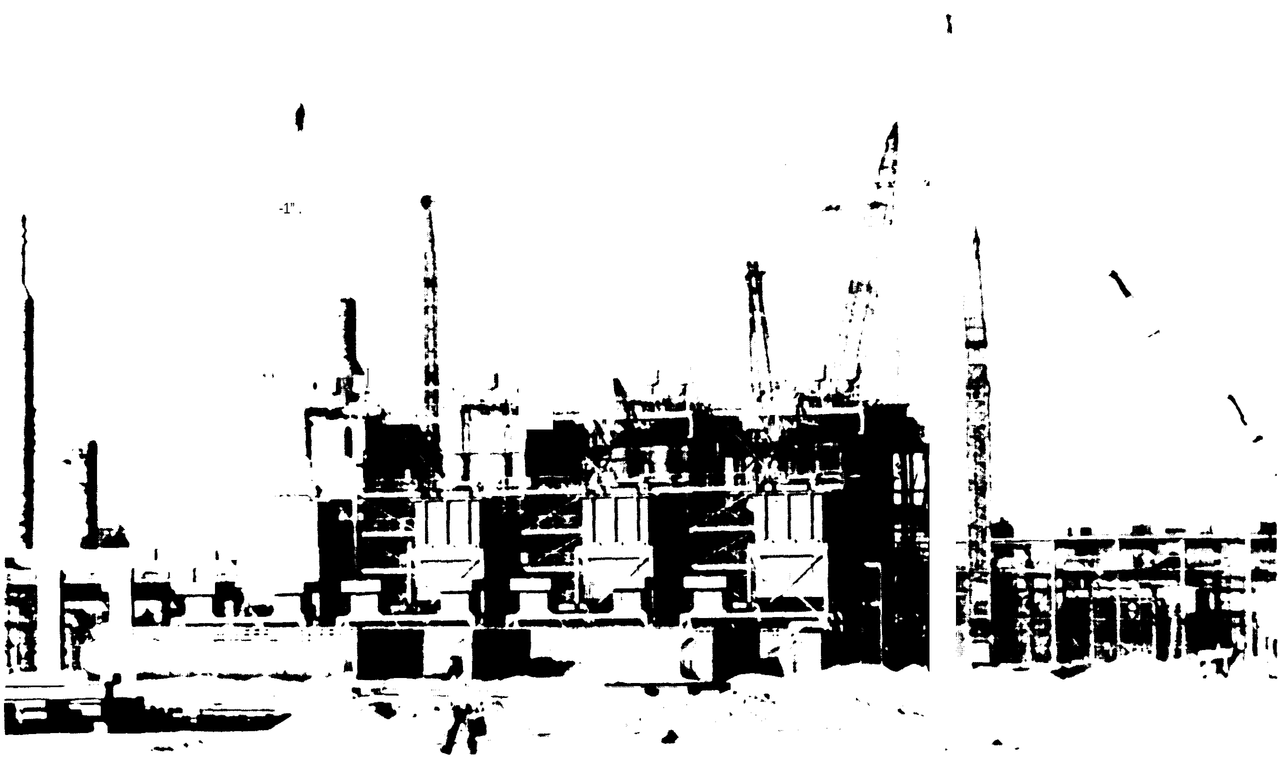

Photo credit: Bechtel Group, Inc.

Gas gathering and processing plant in Kuwait ect was revived. Preliminary engineering work was entrusted to C. F. Braun. The plan was for KPC and PIC to agree on the viability of a project and then proceed in concert with "unrelated" foreign partners.

PIC commissioned development of a marketing plan for a set of proposed products. This study was completed in the fall of 1982, with indications that the project was proceeding. In 1983, however, there were reports that the project had been shelved once again, but due mainly to marketing considerations and difficulties in anticipating feedstock supplies as a result of vagaries in the oil market. The status of Kuwait petrochemical project thus remains uncertain. 14

Technology Transfer.–The project is thus still in the planning stage. C. F. Braun would eventually be its likely transferring agent if the project is implemented. Since it is likely that Kuwait will not have a joint venture partner, and it owns the engineering firm, the only source of truly foreign technology will be licensors.

Socioeconomic Considerations.–Along with its decisions to conserve its oil, to export increasing quantities of refined products rather than crude oil (to derive added value), and to limit heavy industrialization in favor of supporting the service sector (i.e., banking and reexports), Kuwait will support petrochemical development as long as it provides a good return compared to that of other investments in its portfolio. Within this context of a general development strategy focusing on service sector expansion, petrochemical development, with its spinoff effect on employment, education, and support businesses, is far less important to Kuwait than to Saudi Arabia.

While a fundamental difference between Kuwait and Saudi Arabia is Kuwait propensity to invest in foreign ventures, Kuwait also differs in its conduct of domestic projects. The Kuwaitis are involved in fewer projects, and do not favor joint venture arrangements. This reflects their desire to realize maximum benefit from their investments. The Kuwaitis, like the Saudis, are not averse to employing noncitizen Arab (e.g., Palestinian) and Western workers to run their projects as long as this employment practice does not detract from their project expectations.

Algeria

Algeria is a country distinctly different from the Gulf countries previously analyzed. Perhaps more concerned to limit participation by foreigners, Algerians nevertheless find themselves in a position similar to that of many Gulf States in their need for foreign technology to effectively use hydrocarbon resources. Unfortunately, Algeria is not as rich in oil as Saudi Arabia, and therefore does not have the financial resources to purchase the technology, infrastructure, education, and industrial base at the same rate or magnitude as Saudi Arabia. Nevertheless, hydrocarbons represent over 25 percent of Algeria's gross domestic product, approximately 50 percent of government revenues, and more than 95 percent of export earnings. Crude oil and LNG exports are the major factors in export earnings.

Algeria is the first OPEC nation to attempt building a modern petrochemical industry using natural gas and natural gas liquids. The impetus behind its efforts reflects its determination to industrialize and reach self-sufficiency in those commodity areas where it has an advantageous position in raw materials. Sonatrach, the state energy company, is responsible for all petrochemical projects. It has been involved with one olefin and derivatives complex, three ammonia projects, and three LNG projects.

A massive program of capital investment in the late 1960's and 1970's was largely directed at converting Algeria's abundant reserves of

[14] The project may have been effectively canceled in November 1982. There was still a certain amount of confusion with PIC spokesmen insisting that the project was still going ahead, although KPC officials said it was dead in its current form. Some combination of worries about end markets, competition from the new Saudi ventures, and perhaps the availability of sufficient gas feedstocks within Kuwait meant that the advantages of the project became less and less convincing; Wharton Middle East Economic Service, *The Petrochemical Industry in the Middle East: Current Status, Uncertainties, Global Impact,* Special Report #2, April 1983, pp. 27-28.

natural gas into export products. Thus, LNG, LPG, and condensate" recovery plants were authorized as well as ammonia and petrochemicals (from ethane). During this period, Algeria's principal income was from a modest volume of crude oil exports which was insufficient to support the investment program.

In recent years, the rate of capital expenditure slackened dramatically as planners faced construction and then operating problems.[16] Many of the ambitious plans of the 1970's were shelved, including a refinery, an aromatics project, and a second ethylene project.

Construction of the first ammonia project in Algeria was initiated by Chemico (U.S.), using its own technology. The project was later taken over by Technip and Creusôt-Loire, however, employing the same Chemico technology. Completed in the early 1970's, the project included a downstream urea facility, The ammonia plant never operated satisfactorily, despite repeated modifications by the contractors, and was finally shut down in 1980 for a major revamping, which was carried out by Technip/Creusôt-Loire.

In the meantime, two new ammonia project contracts, one at Arzew and one at Annaba/ Skikda, were awarded in 1974-75 to a group of licensers and contractors. The Arzew project was commissioned in early 1981. The U.S. firm Kellogg, which has a technical assistance contract with Sonatrach to operate the ammonia plant, has assigned approximately 50 men to Arzew. With Kellogg's involvement, this plant is thought to run well and is approaching design capability. However, actual production from the facility has been limited. The Annaba plant has not begun operations.

The Algerians have had similar operating problems with LNG facilities. The first major LNG facility was engineered by Chemico but was completed by Bechtel. The project took over 4 years to complete. Difficulties relating to pricing policy resulted in its having only limited use. The second major LNG facility was constructed by Kellogg, also in Arzew. This facility also took a comparatively long time by Western standards to build—reportedly because of the lower level of technical skills in Algeria. For a time the facility was operated by El Paso Gas, but that arrangement failed when the issue of pricing to the United States could not be resolved. Kellogg is now responsible for the operation of both complexes under a management and training service agreement. A third LNG complex in Arzew has been shelved. A major LNG complex in Annaba/Skikda is being operated under a management assistance contract with Kellogg.

Goals and Objectives.–The objectives of the Algerians are similar to those of the Gulf States, but terrain, population, hydrocarbon resources, and political outlook differ. The role of chemicals and petrochemicals in Algeria is to: 1) provide added value to their hydrocarbons; 2) provide import substitution; 3) contribute to Algeria's base and future economic development; 4) train a technical class which may either stay in this industry or filter into other parts of society; and, finally 5) in the case of ammonia, to assist in increasing agricultural yields and in deriving export income, since agricultural products are presently a major Algerian import.

Project Organization and Structure.–While as in other countries, studies are prepared prior to a project decision, the absence of joint venture partners and the lack of a technical experienced cadre in Algeria are particularly distinguishing features. Moreover, in earlier projects Algerians were said to distrust contractors and consultants because of limited Algerian technical expertise, language barriers, and infrastructure problems. Much of this is changing, however. Projects are now better defined; Kellogg is providing construction, operating, and training assistance; and a more

' Natural gas when extracted is mostly methane hut it also contains higher hydrocarbon such as propane, butane, and ethane which can create difficulties in pipeline transport. Thus the natural gas is first cooled and the higher hydrocarbons are condensed, forming natural gas liquids,

[16] See Nigel Harvey, "Algeria Rethinks Its Petrochemicals Strategy," *Middle East Economic Digest*, Mar. 23, 1984, p. 11; Nigel Harvey, "Al~wria Fails To Realize Its Full Potential," *Middle East Economic Digest*, Aug. 12, 1983, p. 49.

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skilled cadre is emerging to work with contractors. Still, this is an evolutionary process; relatively long construction periods on new projects and less-than-efficient operation (by Western standards) of producing facilities can be expected for many years to come.

Technology Transfer.—Technology transfer is accomplished via contractors installing turnkey projects and training Algerian personnel. In the ammonia and LNG projects, contractors were hired to provide both technology and construction services. Hence, contractor fees were paid rather than licensing fees. Typically, the trend has been for contractors to be hired to operate the facilities and train personnel. Although the incentives for chemical and related projects in Algeria have many similarities to the Saudi projects, technology transfer appears to be less efficient, in the sense that some plants are completed but not operating.

Financing.–Algeria has typically been in a cash-deficient position and has borrowed funds from the international banking community to fund projects. They have frequently obtained favorable loan terms via intergovernmental loans. Moreover, due to Algeria's abundant gas reserves, as compared to crude oil reserves, a major strategy has been to export natural gas in liquid form (LNG) at a price equal to its crude oil energy equivalent (measured in Btu). If this endeavor is successful—and the undersea pipeline to Italy and associated contracts would indicate this—Algeria will increase its ability to finance its economic development.

Socioeconomic Considerations.–The role of chemicals and petrochemicals in Algerian development must be viewed in the context of Algeria's overall philosophy and development program. Since independence, Algeria has tried to modernize with financing from hydrocarbon export revenues, while managing the process through a combination of socialism and Islam. The first development plan of 1970-73 focused on the development of hydrocarbon, chemical, iron and steel, and engineering industries to serve as a base for economic growth. This was followed by a second plan in 1974-77, with emphasis on agriculture, water resources, and a continuation of the previous industrialization program. Unfortunately, in Algeria's attempt to push forward rapidly, infrastructure and human development were neglected. No new plan was initiated until 1980. In the current plan (1980-84), heavy emphasis is placed on infrastructure, housing, agriculture, education, and lighter industry along with some continued thrusts into industrial development. The plan also provides for training young Algerians who can play a role in industry, government, and the army, and for remedying the country's chronic underemployment. Nonetheless, East and West Asian labor is used extensively in construction projects, a function of both Algerian work attitudes and contractor cost concerns. Finally, while economic development is a key incentive for Algerian projects, rules and regulations with regard to Islamic law and the conduct of foreigners are well defined.

Qatar

The small state of Qatar has a population of approximately 220,000, of whom approximately 70,000 are Qataris. Qatar became an independent state in 1971, having been formerly a British protectorate, part of the Trucial states. When the other Trucial states formed the United Arab Emirates, Qatar declined to join.

Petroleum exploration, production, and related businesses are handled by the Qatar General Petroleum Corp. (QGPC). When a decision was made to enter into petrochemical production, the Qatar Petrochemical Co. (QAPCO) was created by the government to handle petrochemical production. CdF Chimie (France) is a 16 percent joint venture partner in QAPCO; the other 84 percent is owned by QGPC.

Qatar is a minor crude oil producer (1981 production rate of 350,000 bbl/d), and its reserves are declining rapidly. However, the country possesses remarkably large natural gas reserves, with the offshore North Field allegedly containing 100 trillion cubic feet (ft^3) of recoverable gas. This substantial position in natural gas underpins the country's future prospects and makes it an attractive market for international process contractors, gas companies, and process companies.

Goals and Objectives.–Qatar has a relatively limited flow of hydrocarbons on which to support its economy. It has therefore selected industrialization and, in this case, petrochemicals to support its development effort. Realizing value for Qatar's flared gas has been an impetus for petrochemical development.

Considering Qatar's size, the country has embarked on a very aggressive industrialization program, In fact, it is the first of the Arab Gulf States to establish ethylene production. Apart from the ethylene, the LDPE plants, and the proposed HDPE facility, it has built a major ammonia/urea complex and a steel plant, all using natural gas. Two gas-processing units strip the gas of ethane for ethylene and LPG, which are then exported. The ammonia/urea complex is owned by QAFCO (Qatar Fertilizer Co.), a joint venture of QGPC and Norsk Hydro (Norway), with minor participation by Davy-McKee (the original U.S. contractor) and Hambros Bank. The steel plant is a joint venture of QGPC, Kobe Steel, and Tokyo Boeki (the latter two Japanese firms).

With the help of the French, Qatar brought onstream the first major olefins derivative project in the region dedicated to the export market. This project represented a major effort by the French Government and CdF Chimie to establish a position in the Middle East. In an arrangement unique among Middle Eastern petrochemical projects, the terms of the agreement called for an investment by Qatar in a French LDPE project located in Dunkirk and a similar investment by the French in the Qatar LDPE project, located in Umm Said. The French Government aggressively pursued the French venture, secured the construction and procurement activities for French-based companies, and realized an inflow of funds from Qatar (QAPCO) as a result of Qatar's 40 percent position in the project. CdF Chimie took a 16 percent position in the Qatari project. France provided export credits and guarantees to help finance the project and exempted QAPCO from French income taxes. The actual inflow of French funds to Qatar was limited, owing to licensing and management fees earned by CdF Chimie. Engineering, construction, and procurement are primarily controlled by French companies. CdF Chimie later declined crude oil entitlements made available because of the pricing of the crude oil and CdF Chimie's lack of adequate handling facilities.

Project Organization and Structure.—As in Saudi Arabia, preliminary studies, feasibility studies, and the like were conducted. Unlike the Saudi Arabians, however, Qatar has taken a major position in its domestic project, as well as a position in its joint venture partner's project in France. Qatar has provided financing for both the Qatar project and the Dunkirk project and is providing low-cost feedstock for the Qatar project. However, Qatar used considerably more commercial financing than Saudi Arabia. The French contributions to the Qatar project are export credits for its suppliers, licenses, management know-how, and marketing. The principles behind the Dunkirk project are similar to those of most joint ventures in the West.

Technology Transfer.–Agreements developed in the QAPCO project that concern technology transfer are similar to those in Saudi Arabia. However, similar to the Saudi/ Mitsubishi agreement, the venture partner, licensor, and construction contractors are virtually all one nationality—in this case, French. CdF Chimie is primarily responsible for all marketing. Since CdF Chimie receives a commission on all sales, it has a continuous incentive to move large volumes of product.

Financing. –The exact nature of the project financing of the LDPE project in Qatar is not known. However, it is thought that France provided approximately $300 million in export credits at rates of approximately 8 percent. Euroloans represented approximately $200 million. This debt was eventually assumed by the Qataris at preferential rates. Nevertheless, since Qatar owns virtually all assets (84 percent) and CdF Chimie has a commission sales agreement and as such is more concerned with sales volume than with a project return on investment, the question of financing is not of critical importance.

Socioeconomic Considerations.–Qatar is a small country which is similar in population and closer in temperment to Bahrain than to Saudi Arabia. Its incentive for an LDPE complex is economically motivated. As such, it has taken an aggressive stance in upgrading its hydrocarbons and establishing with this project a future economic base for its development. It had the first petrochemical project in the region as well as the first Arab investment in a West European petrochemical project. Moreover, it used the joint venture approach towards technology transfer. Whether their arrangement with the French is superior to that established by the Saudi Arabians with others is open to debate.

Bahrain

Bahrain is a small country with a population of approximately 350,000 and declining oil and gas reserves. Future prospects for gas look better than those for oil. As with other countries in the region, Bahrain uses hydrocarbon revenues to ensure a base for future economic development. Bahrain's petrochemical project is unique as an Arab joint venture.

Bahrain's participation in hydrocarbon projects dates back to drilling and exploration activities in the early 1920's. By 1929 the Bahrain Petroleum Co. (BAPCO), a jointly owned entity of Standard Oil of California and Texaco, had built the first oil refinery in the region. A series of negotiations over 30 years resulted in the nationalization of BAPCO to BANOCO (Bahrain National Oil Co.).

Aside from the oil refinery and the proposed methanol/ammonia facility, Bahrain has a gas separation plant and exports LPG. The country is a major Arab banking and recreational center.

Goals and Objectives.–The Bahrain petrochemical project located at Sitra Island represents the first Arab petrochemical joint venture. The project is a joint venture between BANOCO, PIC (Kuwait), and SABIC (Saudi Arabia). Project completion is expected by 1985. In addition to inter-Arab cooperation, the project is stimulated by the fact that Bahrain has a limited crude oil capability to sustain its growth, but has significant quantities of gas.

Project Organization and Structure.–The chemical project was initially an ammonia project. Kuwait, which has considerable experience with ammonia projects, contributed personnel in the early days of the project. These individuals were generally considered to be quite competent. However, as the project progressed and became more complex, a contract estimated at $9 million was awarded to King Wilkinson (U. S.) to help select contractors and technology and generally manage the project. Although based in Houston, King Wilkinson manages this contract from its offices in The Hague. Construction contracting was later awarded to Snamprogetti (Italy), while design and engineering of the methanol and ammonia processes were awarded to Uhde (West Germany).

Technology Transfer. -Technology transfer is being facilitated via the King Wilkinson organization. At its direction, contractors and licensers have been selected, and training programs developed. Technology is simply being purchased in this project. The Arab joint venture participants will be contributing money and possibly some personnel. The structure of marketing and offtake agreements with the joint venture partners has not been published. However, it is thought that GPCO (Gulf Petrochemicals Co.) will market the material. An agreement with an international marketer is also possible.

Financing.— Studies have been conducted and jointly funded. However, at this juncture, technical issues associated with joint venture participation are being considered, particularly by experts at King Wilkinson. The final structure and management roles are not known and are thought to be still evolving. The project is expected to receive equal contributions from the joint venture partners and to provide equal returns. The gas is expected to be priced in a fashion similar to that in Saudi Arabia. Financing reportedly will be provided on soft interest terms, probably in the 5- to 6-percent range by an Arab consortium, with a debt/equity structure of 85/15.

Socioeconomic Considerations.–The country's future economic growth is expected to be based on its growth as a regional banking and commercial center. This is reflected in Kuwait's location of its Kuwait-Asian Bank (to support West and East Asian business) in Bahrain and the large dry dock project recently completed in the country. Chemical projects, such as the ammonia-methanol project, are not expected to play a major role in the country's future economic development. However, this project, like similar projects in the region, will assist in the country economic growth by efficiently using natural gas resources. It also represents joint Arab participation in the development of a neighbor Arab country. The exact participation of Kuwait and Saudi Arabia in this project is not known since it is currently in the planning stage.

Other Recipient Countries

Iran.– Iran's relatively well-advanced plans for constructing ethylene-based complexes have foundered on a variety of problems. When the Shah of Iran fell from power, Iran had the most developed petrochemical sector in the Middle East region, and the Iran-Japan Petrochemical Co. (IJPC) complex was on the verge of completion. Even in comparison to the various Saudi Arabian petrochemical ventures, this project at Bandar Khomeini (previously Bandar Shahpur) would have remained the most ambitious single project in the region through the 1980's and possibly into the 1990's.

The Iranian chemical industry dates back to the 1960's, when a fertilizer plant was constructed near Shiraz. In 1965, the National Petrochemical Co. (NPC) was created as an autonomous subsidiary of the National Iranian Oil Co. (NIOC). NPC was allowed to enter into joint venture agreements with foreign concerns. In 1969, the Abadan Petrochemical Co. began with 26 percent of its shares owned by B. F. Goodrich. Its main products were PVC, benzene, and liquid caustic soda. Further joint ventures followed, with Amoco and the Cabot Corp. A large fertilizer plant, the Shahpur Chemical Co., started in 1971 as a 50/50 venture with Allied Chemical. Another large joint venture was the Iran-Nippon Petrochemical Co., which entailed cooperation between NPC and the Japanese companies Nissho-Iwai and Mitsubishi Chemical. It began operation in 1976, but owing to financial disagreements, the Japanese stake in the venture had decreased to 30 percent by the time the Shah fell.

The project at Bandar Khomeini is a joint venture of the Iranian NPC and a Japanese consortium dominated by Mitsui. When completed, this venture was to be a sophisticated complex producing ethylene, propylene, butadiene, and aromatics, as well as a variety of intermediate chemicals, with a total capacity of over 1.6 million tons annually.[17] Although this plant would produce a substantial amount of exportable chemicals, it was envisaged prior to the Iranian revolution that the Iranian economy would absorb much of the output of the IJPC venture.[18] This project was conceived in 1969 and construction began around 1971. Construction was halted in 1974 due to cost increases, but resumed in 1976 after project refinancing. Construction was halted again in 1979 because of the revolution.

The Japanese recognized from the beginning the advantages to be gained from cheap gas feedstocks ($0.35 to $0.60 per million Btu) and pursued the Mitsui petrochemical project in Iran as a part of their official oil diplomacy.[19]

[17] D. T. Isaak, "Basic Petrochemicals in the 1980's, "RSI Working Paper, Honolulu, Hawaii: East-West Center, 1982.

[18] Fereidun Fesharaki and David T. Isaak, *OPEC, the Gulf, and the World Petrochemical Market—A Study in Government Policy and Downstream operations* (Boulder, Colo.: 1983), Westview Press, Inc., pp. 204-205.

[19] Martha Caldwell Harris, "The Dilemmas of Japan's Oil Dependency," *The Politics of Japan Energy. Strategy*, Institute of East Asian Studies, University of California, Berkeley, 1981, pp. 65-84.

The Japanese Government disassociated itself somewhat, and what was once called a "national project" is now called "a nationally supported project.[20] The on-again off-again nature of the IJPC complex and the uncertainties of the Iran-Iraq War make it difficult to predict when it might come onstream. In mid-1983, Iran agreed to take on a larger financial burden, and emphasized completion of 3 of the 13 complexes originally planned.[21] This project will, however, probably be completed someday, since the present Iranian authorities are strongly, committed to developing the petrochemical sector. The new 5-year petrochemical plan is budgeted at nearly $3 billion, which allows for planned renovation of existing chemical units and the commissioning of some new ones (although completion of Bandar Khomeini alone could absorb most of this).

It would probably be a mistake to write off the Iranian petrochemical industry. It should be remembered that despite all the disruption of recent years, chemical plants remain in existence, and some are operational. However, for the present and near-term, dramatic changes are unlikely in the Iranian petrochemical sector. Official commitment to this sector is strong, and the Iranians will probably concentrate on import-substitution in the short run; export-oriented projects are not in the immediate future.

Iraq.— Until the outbreak of the war with Iran, Iraq gave its petrochemical sector a fairly high priority. Iraq used some of its associated gas[22] to produce nitrogenous fertilizers and ethylene and was continuing construction of gas-gathering projects for the South Rumaila fields and for various northern oil fields. In fertilizers, Iraq has the added benefit of having phosphate deposits that could be exploited with mining operations. Rejecting joint ventures in petrochemicals, Iraq emphasizes turnkey plants.

Iraq's problems in the petrochemical sector are similar to those of Iran. Its ethylene complex in Basra is affected by the war. However, unlike the Bandar Khomeini plant, this plant has good prospects for rapid completion after the end or abatement of the war. Present damage to the complex is difficult to gauge. Compared to the IJPC project, the Basra facility is fairly simple, being an ethylene cracker[23] with capacity to make polyethylenes and PVC plastic. It is directed primarily at the domestic market and is solely owned by the Iraq Ministry of Industry. The Basra project has not apparently experienced an exodus of talented technicians and administrators, and thus has a good chance of coming onstream by the end of the decade if the war abates.

Egypt.–As a significant producer of oil, Egypt has the potential to develop a petrochemical industry that could serve its large but relatively poor population. Although Egypt is determined to enter the commodity petrochemical sector, its impact on world markets will be small. The Egyptian Petrochemical Co. (E PC) is planning a two-phase petrochemical project in Alexandria that will result in Egypt's first ethylene-based complex. In late 1982, EPC started awarding letters of intent for this complex. Due to go onstream in 1985, the project will use imported ethylene. Phase one will include production of 80,000 tons/yr of PVC and 60,000 tons/yr of chlorine/caustic soda. The second phase of the project is expected to expand capacity to 100,000 total tons/yr of HDPE and LLDPE and 760,000 tons/yr of LDPE.

Egypt is well established in the fertilizer sector, having ammonia plants at Aswan, Helwan, Tilkha, and Abu-Qir. Together, these have a capacity for 1.1 million tons/yr of ammonia and 950,000 tons/yr of urea. Also, the plant under construction at Abu-Zaabal will produce 218,000 tons/yr of sulfuric acid and 66,000 tons/yr of phosphoric acid. From its West Sebayea mine, Egypt supplies phos-

[20] Wharton: op. cit., p. 23.

[21] "Iran's White Elephant Limps on,'" Middle *East Economic Digest*, Special Report on Japan, December 1983, p. 14.

[22] Wharton, op. cit., p. 25. Presently, eighty percent of Iraq's associated gas is flared.

"A cracker is used for thermal decomposition of petroleum to extract low-boiling fractions, phates to the Abu-Zaabal fertilizer plant. Egypt will ultimately become a major end-user of commodity petrochemicals. For now, however, activity in this area is limited.

ABSORPTION OF PETROCHEMICAL TECHNOLOGIES

Training Programs

Considerable attention is placed on manpower training programs in the various countries examined. As might be expected, the most extensive programs have been instituted in Saudi Arabia. However, the logic behind all the training programs is similar: for true economic development to occur, a team of nationals must be trained to manage, operate, and support industrial growth. The gains derived from manpower training represent a continuous return on investment. For example, SABIC considers personnel training a means for: improving the efficiency of operation and maintenance; using a secured local resource; raising the productivity of employees; and increasing net returns in the long run.[24]

Although the petrochemical plants involved in the Saudi Arabian joint ventures are not labor-intensive, the total number of personnel involved is greater than in comparable U.S. plants. This is because each project, large or small, is an entirely separate company and because SABIC insists that a high proportion (now 75 percent) of the staff should be Saudi Arabians at the time of startup. An inevitable duplication in management and administrative effort results.

SABIC conducts training programs independently and with its joint venture partners, as appropriate. These programs provide both theoretical knowledge as well as on-the-job training. At the end of 1981, 75 percent of the personnel in SABIC joint ventures were reported to be Saudi Arabians. By the time all SABIC projects reach production, 7,000 to 10,000 Saudi Arabians should be employed. (These data include a broad range of projects outside the petrochemical sector.)

Programs conducted by Mobil and Exxon fall within the purview of SABIC. Trainees from Saudi Arabia, of junior high school age, are sent to the United States to take programs in English, science, mathematics, and specific technical skills ranging from welding and machine shop skills to operating engineers. These programs last up to 3 years, of which the last 18 months include on-the-job training. In most training programs, students are housed on campus for a period of time in order to reduce culture shock and introduce them gradually to American culture. (This acclimation period is, of course, not needed for trainees who have gone to universities in the United States.)

Kellogg's program for the Algerians is similar to the program U.S. companies have for the Saudi Arabians; however, Kellogg makes greater use of plant operation simulators. In addition, it also assists in on-the-job training in the Algerian plants,

The Saudis may have comparative success, due to prior experience of some trainees with ARAMCO. In addition, they plan to build a national oil training center to train 300 to 400 students which will contribute to expansion of the technical work force.[25] Eventually,

[24] SABIC, 5th *Annual Report, 1981.*

[25] The $16 million training center will be built in the Eastern Province and three additional centers are planned, See Middle East *Economic Digest,* Sept. 30, 1983, p. 38.

Photo credit Mobil Oil Corp.

Saudi Arabian trainees at Mobil's petrochemical plant in Beaumont, Tex.

both the Saudi Arabians and the Algerians should be able to operate their own facilities by the 1990's. One concern is whether this will involve excessive requirements for technical manpower, leading to shortages in other sectors. It is likely that foreign training programs with a small core of foreign personnel will still be required initially to help operate the new ventures of the early 1990's.

Inter-Arab Cooperation

Cooperation among Arab nations is another potential method for transferring skills. The transfer of technology or skills from Saudi Arabia or Kuwait to other countries in the region (i.e., Bahrain) seems remote, however, during the 1980's and is probably questionable during the early 1990's. In the Bahrain methanol/ammonia project. it is not clear how future inter-Arab cooperation will progress. It would seem that the major contributions by Saudi Arabia and Kuwait will be financial. Some Saudi management personnel and some Kuwaiti (PIC) personnel may participate in the venture. During the 1980's, however, both countries are expected to be strained for trained personnel even for their domestic operations.

Nevertheless, interest in inter-Arab cooperation in petrochemical development continues. The six-member Gulf Cooperation Council (GCC) recently agreed to work with the Organization of Arab Petroleum Exporting Countries (OAPEC) in energy-related training programs.[26] Joint financing capabilities may be enhanced through the formation of the Gulf Investment Corp. (GIC), setup by GCC states to jointly fund development projects. The rationale for joint training programs and financing is clear, but the question is whether cooperation can be built among nations whose domestic resources are now more constrained.

[26] "GCC, OAPEC Promote Energy-Related Cooperation, " Kuwait *KUNA in* English, Dec. 26, 1982, reported in F.B.I.S. Daily *Report–Middle East and North Africa,* Dec. 29, 1983.

PERSPECTIVES OF SUPPLIER COUNTRIES AND FIRMS

FOREIGN COMPANY PARTICIPATION

The transfer of technology to the various countries examined in this study can be performed through: 1) joint venture partners, 2) Licensers, and 3) contractors. Only Saudi Arabia and Qatar have taken advantage of all three principal mechanisms. The remaining countries, for the products being investigated, have selected only the licensor and contractor routes.

Joint Venture Partners

The foreign joint venture approach is practiced almost exclusively by Saudi Arabia. The principal incentives for foreign partners entering into Saudi joint ventures include profits, crude oil entitlements, and the potential for expanding production and marketing.

The return on equity is expected to reach approximately 15 percent over time. This calculation is based on a number of factors, prime among them being low-cost feedstocks. The principle is that associated gas will be considered to have zero value at the wellhead during the initial years of any consuming project. The consumer at the point of use would pay a charge of: a fixed element, related to the fixed (investment) costs of the gas-gathering project; and an element adjusted to the crude oil price to cover the energy costs of gas gathering and separation. The process of adjustment means that, with time, the energy-related portion of the price will represent an increasing share of the total, and the overall rate of price escalation also increases. In addition, a profit-sharing formula will be applied when the cumulative average return on equity for any consuming project exceeds a specified figure, i.e., one-half of any excess profit will

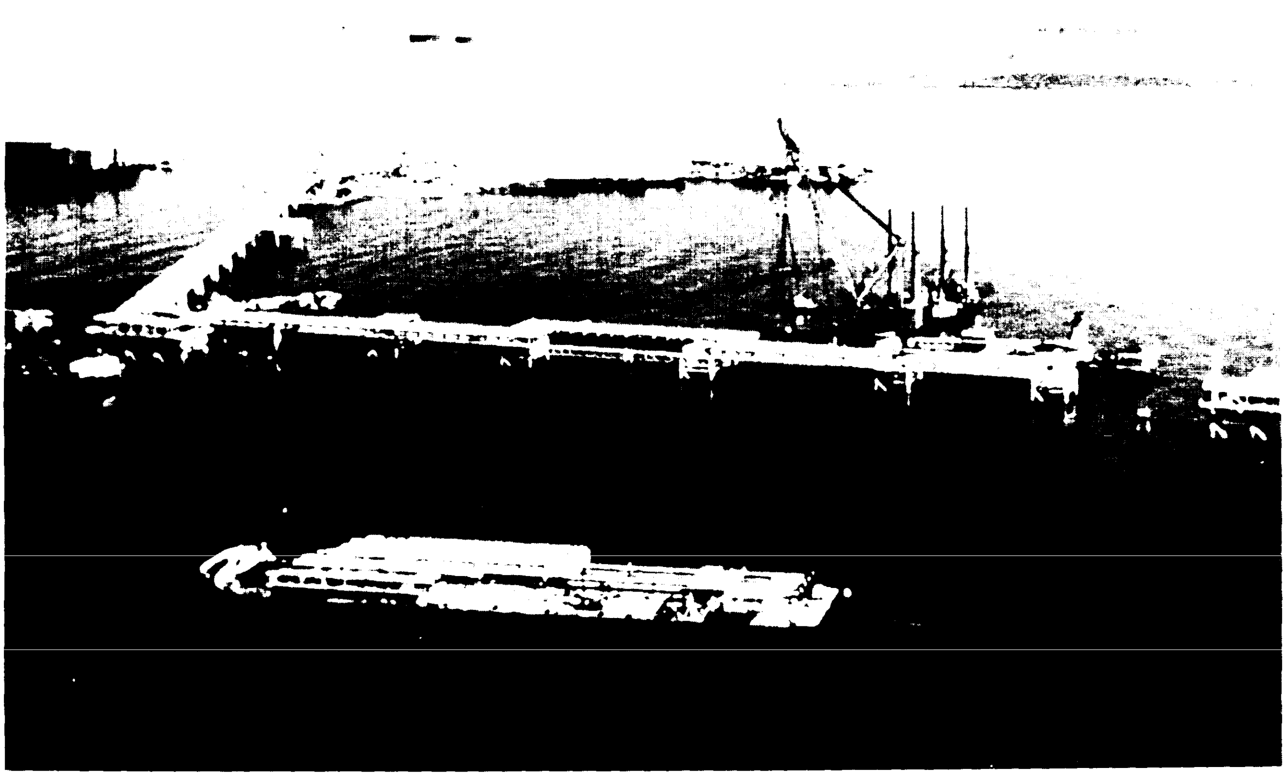

Photo credit: Aramco World Magazine

Marine terminal at Yanbu, Saudi Arabia, from which first west coast shipments of Saudi gas were made in 1982

be taken by the gas supplier, Petromin. A second factor in the calculation of return on investment is low-cost debt. Financial provisions involve coverage by Saudi Government loans at favorable rates of interest: 3 to 6 percent interest on the approximately 90 percent of debt provided by Saudi Arabia, Commercial rates would apply for the remaining 10 percent of debt provided by commercial institutions.[27] Finally, return on investment is enhanced by assistance provided by recipient governments in infrastructure development. At Al-Jubail and Yanbu, the Saudi Government is responsible for the investment burden for site development, infrastructure, and major utilities. However, operating companies will be charged by the Royal Commission on a commercial basis for services provided. The operating companies include the entire joint venture, one-half of which is Saudi Arabian.

A second general incentive has been access to crude oil. Crude oil entitlements authorize the foreign partner to receive a guaranteed supply of crude oil at a commercial price and of an amount related to the partner's investment in the project. Crude oil entitlements appear to have been a major incentive to foreign partners, particularly oil companies such as Shell Oil, which has no share in ARAMCO, and Mobil, whose share is only 15 percent. In the present climate of crude oil supply and demand, the value of crude oil entitlements is questionable. However, long-term security of crude oil supply is still an important objective for these companies.

27 Foreign partners will enjoy a 10 year Saudi Arabian tax holiday on their share of net income from the joint ventures. However, under U.S. tax law. American companies are unlikely to derive much benefit from this provision, since the earnings are subject to foreign source income rules.

Finally, foreign companies expect to expand their production and market reach through participation. The companies establishing production bases in the Middle East have diversified their sources of product supply to a location that will facilitate their marketing operations in Southern Europe, Africa, and Asia. Also, from a long-term perspective, they are in a region where the next generation of competitive facilities will be located. The value on contracts won by C. F. Braun since its parent company (Santa Fe International) was purchased by KPC was reported at $3 billion.[28]

From the perspective of the supplier firms, the major impediments to the success of joint venture projects are risks, which could arise from: 1) revolution and the rise of an anti-Western government, 2) industry nationalization, 3) insistence that indigenous personnel operate the facilities before they are ready, thereby reducing efficiency of operations, 4) requirements to market the product in international markets at depressed prices, and 5) fixed crude oil prices regardless of (lower) spot market prices.

While these risks arise whenever a project is considered in a developing country, the large number of projects in Saudi Arabia multiply the risks from a national point of view. Some companies have chosen to proceed after negotiating to soften the risks (i.e., renegotiating crude entitlement agreements, raising profitability goals, eliminating take-or-pay product contracts). Access to crude oil clearly tipped the balance in favor of many decisions made during the 1970's.

All U.S. companies participating in Saudi joint ventures are major oil or chemical companies. In terms of total investment, most are the former. As publicly held corporations, all have, as their long-term objective, the maximization of return to shareholders. Some of the most important considerations influencing U.S. investments in these joint ventures include: 1) the addition of long-term supplies of imported crude, 2) repatriated profits from handling and/or producing this crude, 3) royalties to U.S. licensers, 4) profits to U.S. contractors involved in engineering and construction, 5) repatriated dividends from Saudi Arabian joint ventures, and 6) net receipts for technical and commercial services rendered to the venture, representing a net foreign exchange gain even in a no-profit situation.

The most serious factor now working against a joint venture partner relationship for a U.S. firm is the potential for reduced sales in other non-Middle East markets. In the Saudi-type joint venture, the foreign partner will be expected to provide 70 to 90 percent of the market opportunity, mostly on a committed basis. In the present climate of low market growth for petrochemicals, commitment to market large quantities of petrochemicals produced in the Middle East could limit production in older facilities elsewhere in the world. Clearly, there are cases where a market can be better serviced from the Middle East than from the United States or elsewhere. In such a situation, the U.S. partner's share of the net income may exceed that to be gained from locating in the United States. Finally, there is the argument that if the company does not engage in the joint venture, another will.

In the case of Mobil Oil and Exxon, objectives are clear. These firms seek to maintain their relationships with the Saudi Arabians, obtain crude oil entitlements, expand their position in global petrochemical trade, locate petrochemical facilities in areas providing a long-term advantageous cost position, and realize an acceptable return on their investments. Nevertheless, in the slack oil market of 1983, these firms were in a difficult situation, partly because of their commitments to these ventures.[29]

No West European companies participate in Saudi petrochemical joint ventures. However, the previous discussion about U.S. involvement will apply qualitatively to any future West European activities, though in some

[28] Shaikib Otaqui, "Petrochemicals Award Strengthens Braun's Kuwaiti Presence," Middle *East Economic Digest,* Aug. 13, 1983, p. 26.

[29] See "Mobil's Costly Saudi Strategy, " *Business Week,* Oct. 17, 1983, p. 76.

cases (West Germany and France in particular), there is likely to be a stronger bias toward the use of home-based contractors and equipment suppliers.

In the case of Qatar the French company CdF Chimie is the joint venture partner. Its objectives, and those of the French Government that promoted the arrangement, were to expand global market position, minimize cash outflow while maximizing revenues from a low-cost source of polyethylene, acquire financial infusions for a new domestic operation from a source that would not interfere with French management of the facility, gain oil entitlements, and secure a position for French contractors in a Middle East project. In this case, the French Government and the French firm perceived their interests to coincide.

Japanese involvement in Saudi Arabia arises from objectives similar to those of the French in Qatar. The Japanese, however, did not exchange management fees and royalty payments for hard investments. Similarly, they will be responsible for profits and losses on an equal basis and will not, as in the French case, realize commissions on sales. Alternatively, and unlike the U.S. example, Japanese firms have, with their government support, put together contract packages that involve Japanese partners, licensers, contractors and equipment suppliers. This approach has been relatively successful in the case of the Saudi Methanol Co. There has been less success in the case of SHARQ (the SABIC/Japanese olefin-based complex). Mitsubishi, the lead Japanese operator, has been forced to go through the motions of competitive assessment or bidding for both technology and engineering. The approach of the Japanese Government and Japanese companies differs fundamentally from that of the United States. Japanese Government agencies are active participants in both the Japanese consortia involved at Al-Jubail, and these ventures were planned with the national interests of Japan uppermost.

Licensers

Much has been written about product lifecycles and the tendency of multinational corporations to exploit developing countries through the licensing of inferior technologies. The petrochemical technology licensed to the countries examined in this study is, however, state of the art. Moreover, the intense licensing activity in the Middle East reflects the viability of the market for petrochemical technology.

Technology is licensed in two ways. In one case, a licenser makes an arrangement with a licensee. In the other, the contractor includes the technology as part of the total project package. Appendix 5B includes information about major technology licensers in the Middle East.

Licensers operating in the Middle East are more often faced with incentives than with impediments in transferring technology. Firms such as Union Carbide and Scientific Design established the goal long ago to sell as many licenses as possible. Profits are the central motive, with fees negotiated separately in each agreement. Infrastructure and operating conditions are not major concerns. Training considerations are factored into the fees while market forces determine the value of the technology. With the slowdown in new capital investments in the West, the less developed countries—in the Middle East particularly—represent a primary market for Western petrochemical technology sales.

The only risks for technology licensers are the possibilities that licensing agreements may be broken or that a foreign licensee may penetrate domestic markets. However, since the technology provided is state of the art and is sold at internationally competitive prices, there is no incentive for Middle Eastern producers to break a licensing agreement by sharing the technology with others. Moreover, although these countries have the funds to support the licensing fees, they will not have the research and design capability in this decade to modify or improve a licensed technology to the point where they can claim they no longer need the license because they have their own technology .[30] Finally, every indication suggests that they want to be accepted as full partners in the international business community, a desire that would not be fostered if they were to break licensing agreements.

In the case of market penetration by a licensee, the risks are weighed when the corporate entity decides to market its technology aggressively. Hence, Union Carbide will market its LLDPE technology to all interested partners, while Dow is more selective in which LLDPE technology it promotes. The incentives to U.S. firms for allowing the licensing of chemical process technology are revenues from royalty payments and the maintenance of good government-to-government relations, the latter also important to the U.S. Government.

Generally speaking, there is little difference between petrochemical technology available from the United States, Western Europe, or Japan. Hence, technology is made available globally on a competitive bid basis. U.S. firms have some of the best chemical process technology in terms of performance and cost; but, other good sources of the technology are available to Middle Eastern countries. The technological reputation of certain suppliers gives them a definite competitive edge: 1) Kellogg of the United States for ammonia plants, 2) Imperial Chemical Industries of the United Kingdom for methanol plants, 3) Dutch State Mine Co. for urea fertilizer plants, and 4) Union Carbide for the production of LDPE. Certain European firms (Dow Chemical Europe and Charbomage de France) have adapted the Union Carbide technology and can be expected to give Union Carbide strong competition.

[30]The OPEC countries are limited by their weak technical capabilities in petrochemical industry development. See K. Nagaraja Rae, F. Baddour, and Christopher T. Hill, "Strategic Aspects of Chemical Industry Development in Rapidly Industrializing Nations, " *Technology in Society,* vol. 4, 1982, p. 153.

The contents of the various licensing agreements are generally confidential and are often negotiated differently for each agreement. However, in the case of LLDPE, sufficient information is public knowledge to serve as a model of how these agreements operate and to indicate the magnitude of the revenues associated with them. Union Carbide Corp. has licensed LLDPE technology to an estimated 30 companies worldwide. Its cost to develop this process is not known. However, its revenue structure is thought to include a $100,000 fee and a secrecy agreement just to review the details of its process. If a potential client company wants to purchase the license, it is charged $18 million to $25 million up front for the process license. In addition, a royalty payment of 2 to 4 percent of net sales is paid over a 10- to 15-year period to the licenser. In some arrangements the licenser has an agreement to share new resin breakthroughs with the licensee, and if the licensee develops resins with new properties, it must share them with the licensor. Training programs and startup assistance are provided. Union Carbide does not usually take an equity position in a project in lieu of its fees. With this structure, a licensee producing 200,000 metric tons per year of LLDPE and selling it for $551/ton (25¢/lb) on a constant dollar basis might provide Union Carbide with revenues of $21 million up front and approximately $3.3 million a year (3 percent of net sales) for 15 years or approximately $70 million (in constant dollars) over the time period. Union Carbide is the licenser of LLDPE technology for all SABIC projects. Its specific terms with SABIC are not known.

Engineering Contractors

An engineering contractor is relatively far removed from the decisionmaking processes involved in a manufacturing joint venture. It is unlikely that refusal by a U.S. contractor to bid for, or even to license technology for a prospective project would influence the decision to go ahead with the project. The only decision open to the contractor is whether to bid for the contract or leave it to others.

A contractor's reasons for operating in the Middle East are fees, the slowdown in major global projects outside of the Middle East, a desire to increase or create market share in this region, and the need to develop a regional track record for consideration in future projects as well as for projects in other developing countries. Most major engineering contractors view their projects from an international perspective. Thus, they tend to view risk more according to which bank or institution is securing their payment, rather than to the specific project location. Also, their fees take into account the complexity and risk involved in working in a developing country.

Based on profit concerns and procurement bidding pressures by the host governments, subcontracts and equipment purchases can frequently be made from a large number of companies worldwide. Hence, the actual value of dollars flowing back to the prime contractor may not be anywhere near the total value of a given project. The typical cost structure associated with a capital project is 45 percent for procurement, 24 percent for construction, 10 percent for design and engineering, and 20 percent for owners' costs, fees, and contingencies. (This will vary somewhat, depending on the project specifics.) The actual fees or profits earned on these projects by contractors are thought to be ± 3 percent of all tangible costs. Contingency costs tend to be greater on lump sum contracts than on "open or "cost plus contracts.

Since a Middle Eastern project will in most cases involve competitive international bidding for each major phase of engineering, construction, and procurement, there is no guarantee that the establishment of a managing contractor of U.S. origin will lead to detailed engineering and construction contracts for U.S. companies, and still fewer guarantees for procurement from U.S. suppliers.

Thus, although there may be some bias toward U.S. contractors and suppliers arising from a U.S. prime contractor from U.S. reputation and skill, the main benefit is from the revenues and profits gained by the prime contractor. Many of the Middle East contracts are very large, which is reflected in the contractor's fees. On the other hand, there has been, and probably will be in the future, strong pressure for fixed price contracts or contracts with a guaranteed maximum. If this is the case, the risks to U.S.-based contractors will be relatively great. Nevertheless, Japanese and West European firms are prepared to bid on this basis if U.S. companies choose not to bid.

Requirements To Modify Technology and Project Approach

Operating in Middle Eastern or other developing countries requires a reexamination of approaches that U.S. engineering contractors have utilized in projects in the West. Major differences include the nature of clients, scale of operations, lack of infrastructure, and availability of local skilled manpower.

Typical projects in the industrial nations result from the needs of clients which are usually major operating companies with extensive experience with these types of facilities. This experience of client companies tends to minimize contractor involvement with the recruitment and training of operators, maintenance, and management personnel. In addition, while the startup and operating capabilities tend to reside with the client, the contractor must meet various performance guarantees.

In the Middle East, the clients are typically either joint ventures of the operating company and host government national firm, *or* a government-related national firm alone. In both situations the contractor can be called on to provide special services not normally performed by a contractor in industrial countries. For example, hiring and training of operating and maintenance personnel may be carried out by the contractor. In addition, a contractor may provide personnel to assist in the startup and early operation phases; in some instances, contractors even operate the plant for an extended period of time. For example, very close coordination with SABIC is maintained by Fluor, Lummus, and Bechtel in their respective projects to assure the proper development and startup of the projects. Lummus is also playing an important role in developing process simulators for training Saudi Arabians. In the case of Bahrain, contractor operators may continue for some time. Algeria continues to use Kellogg's assistance in its ammonia and LNG facilities.

The projects in the Middle East are quite significant in size. The Saudi Arabian industrialization program is probably the largest program of its kind ever undertaken. Such programs require the mobilization of large numbers of people and huge quantities of material and require new management approaches and strategies for projects such as the transformation of Al-Jubail and Yanbu into modern industrial cities. The scope of these projects is so vast that no single contractor can provide 100 percent of the services necessary. Hence, while the large management contracts have been given to American firms, many subcontracts have been let to Japanese, South Korean, and firms from developing countries due to their low labor costs and limited infrastructure requirements.

Most of the areas in which these industrial projects are located lack developed infrastructure. Port and road facilities, housing, hospitals, schools, pipelines, maintenance shops—all of which add to the complexity of the venture and require contractor adaptation–must be built in conjunction with the projects.

Since the major planned construction sites in Saudi Arabia are in remote locations and the size of the work force to be employed is large, there has been a need to provide extensive auxiliary facilities. Harbors, roads, housing, and recreational facilities have been built. Other projects have included the gas-gathering system, a major desalinization effort, significant increases in electrical production in the eastern province, and building crude oil and natural gas pipelines across the desert from the Persian Gulf to the Red Sea. The effective advance provision of these infrastructural facilities has allowed the contracting work on the Saudi petrochemical projects to proceed more rapidly than originally expected and at a lower cost.

The ability to coordinate the numerous activities required in building large-scale projects in remote locations is an art that has been developed through many years of experience by major contractors. In virtually all cases, there has been a need to establish a supply system and to recruit personnel from a variety of nations, presenting formidable obstacles to construction efforts. Major U.S. companies have service divisions that support operations managed from the United States and are also capable of undertaking certain projects independently. These overseas facilities enable firms to procure required materials and equipment on a worldwide basis and to maintain sophisticated computerized inventory procedures for managing the large stocks of necessary supplies.

Remote locations also necessitate modified engineering approaches. For example, modu-

Photo credit: Middle East Economic Digest

Modularized methanol facility, supplied by Mitsubishi (Japan) larization and barge-mounted construction techniques are two modifications that are becoming more commonplace. In one petrochemical project, Bechtel subcontracted the modularization of many of the process components to Belleli of Italy. Mitsubishi modularized much of its methanol facility and then shipped it to Saudi Arabia. The roads in Saudi Arabia have been specially built to handle these unusually heavy loads.

Manpower is another key consideration in remote locations, For many projects, work forces from many countries have been gathered. The major contractors have developed relationships in many countries and have the ability to directly hire needed individuals. Frequently, subcontracts are let to Japanese or South Korean firms who bring in large numbers of Asian employees for a given period. These subcontracts are normally cost-effective and have the virtue, from a Saudi Arabian perspective, of using imported labor, managing it within a small perimeter, and then reducing the labor force when the construction phase is complete. Asian labor has been used in virtually all projects examined in the Middle East and North Africa.

With the exception of Algeria, all the countries examined in depth with regard to petrochemicals have relatively small indigenous populations and a general dislike by the local population of manual labor. Therefore, contractors must recruit crews, operating labor, management, and maintenance personnel from many nations.

Almost all engineering and management personnel in these petrochemical projects are from the United States, Western Europe, and Japan. Field construction forces and maintenance and operating crews come from either the host country or countries such as India, Pakistan, Egypt, Indonesia, South Korea, Turkey, the Philippines, Taiwan, and Thailand. Many of these work crews have at least some experience.

All major contractors are willing to work with local contractors and individuals depending on specific conditions. This approach seems to be working well in Saudi Arabia, while in Algeria, due to English language problems, it has reportedly led to additional inefficiencies. Training is a key issue. U.S. contractors provide training programs that extend to all skill levels. In Algeria, Kellogg has trained field crews in basic construction skills (welding, pipefitting) and is also providing basic elementary education in mathematics and science.

In many instances, construction personnel are subsequently transferred to maintenance groups after additional training. Contractors arrange for vendor personnel to provide training in specialized equipment such as pumps, compressors, and turbines. In addition, supervisors receive onsite training and the contractor typically works with local supervisors through the precommissioning phase.

The lack of fully experienced local labor forces, coupled with the multinational nature of their work forces, presents both cost and efficiency problems for Middle Eastern countries. The productivity of work crews from local or developing country firms maybe lower than that of comparable U.S. and/or West European and Japanese work crews. Meeting work schedules may consequently be a difficult task for contractors,

The design of facilities in these often remote locations, which often experience either extreme or unusual weather conditions (e.g., sandstorms, high heat, and humidity) and are subject to labor force constraints, sometimes involve nontraditional approaches. In some cases, different construction materials or backup facilities are required; in the case of a petrochemical complex, decoupling operations are generally incorporated in process designs. Modular or prefabricated construction techniques are often utilized to minimize field assembly. Contractors must also design with an eye toward ease of maintenance and toward limiting the risk of extended downtime.

Contractors generally prepare complete lists of required spare parts and-review them with clients. If the buyer agrees, the contractor will arrange for all parts to be delivered onsite. In some instances contractors provide preventive maintenance schedules and computerized inventory control procedures.

Most contracting firms are willing to assume the maintenance responsibility for a facility during its operating phase. However, this service is generally not sought. If a plant were to face serious maintenance or spare parts problems, the contractors would be willing to provide assistance for operating a plant they built. In most countries in the Middle East, operating maintenance has been a problem.

THE ROLE OF U.S. FIRMS IN COMPETITION AMONG SUPPLIERS

Factors that influence the choice of one supplier over the other include: 1) cost/financing, 2) technological differentiation, 3) track-record experience, 4) marketing, 5) scope of services (including training), 6) political/historical ties, and 7) effective use of local agents. In the Middle East, training, experience, and effective use of local agents (for joint ventures) have been particularly important.

U.S. companies are major project participants in the Persian Gulf and Algeria, and compete on all three levels; namely, as operating-joint venture partners, as licensers, and as engineering contractors. The ability of U.S. firms to compete on these three levels reflects their major strengths in marketing and sales, technology, management techniques, and plant operating skills. Japanese (methanol and olefin derivatives) and Taiwanese (fertilizer) participation in projects in Saudi Arabia reflects the desire of Saudi Arabia to diversify its mix of venture partners and aggressive supports by the supplier governments.

In the case of CdF Chimie in Qatar, the French Government actively pursued the project, seeing it as a national priority. At the time, few U.S. companies were interested, partly because of their extensive involvement in Saudi Arabia.

The case of licensers is similar to that of operating companies. U.S. firms have a well-known technical expertise. U.S. technology produces quality products at low prices, as illustrated by polyethylene and ethylene glycol technologies provided by Union Carbide and Scientific Design in the Mobil and Exxon projects in Saudi Arabia and the Kellogg ammonia technology used in Algeria.

Contractors face intense competitive pressures, owing to the sheer size of the projects in which they participate. In the projects examined here, U.S. companies have been a dominant force. However, substantial subcontracts and procurement agreements were also given to other foreign companies because of lower costs (often reflecting lower labor rates).

While U.S. companies exhibit many strengths when bidding against foreign competitors, they also have certain disadvantages. These have included tax and export financing policies.[31] Saudi Arabia provides a 10-year corporate tax holiday. U.S. companies are taxed by the U.S. Government on this income as foreign source income, while their competitors are not. To put it another way, other supplier governments subsidize projects through tax exemptions. Saudi Arabia does not charge an income tax on foreign employees working in the Kingdom. U.S. employees are taxed in the United States on their foreign income (above a certain level). A higher wage scale has sometimes been paid to compensate for this factor. It should be noted, however, that U.S. tax regulations have recently been liberalized in favor of the overseas employee. Companies from Japan and France have more aggressively pursued overseas petrochemical projects with government financial support. Export financing has not, however, been a major factor in awards of contracts in the Gulf States since they have had the capital to finance projects themselves.

[31]0ther concerns expressed by U.S. companies relate to the Foreign Corrupt Practices Act and antiboycott legislation. However, in the analysis performed, no projects were identified where a U.S. company actually lost a bid because of these laws.

In the final analysis, strong and friendly relations between the United States and Saudi Arabia have been an important factor, setting a context for extensive involvement by U.S. firms. At the same time, the standing of U.S. firms as technology leaders has also been a key factor, although the advantages accruing from this technological lead have been gradually eroding.

LONG-TERM DEVELOPMENTS

GENERAL TRENDS

The petrochemical industry is presently undergoing a difficult restructuring process, resulting from stagnant demand and uncertain growth prospects for petrochemicals and feedstock costs. This situation will be further exacerbated by the entry of Middle Eastern and other new producers—with their relatively inexpensive feedstocks for methanol, ammonia, and olefin derivatives based on natural gas and on natural gas liquids recovered from associated gas.

The petrochemical world was less complex in the 1970's, when there were, in essence, three major areas of petrochemical production and consumption: the United States, Western Europe, and Japan. These areas represented 63 to 65 percent of world demand, as well as 68 to 70 percent of the world production. Manufacturers in these large homogeneous market areas were able to construct large-scale plants. In addition, feedstocks were readily available at sufficiently attractive prices to enable manufacturers in these regions to import feedstocks for conversion to intermediates and final products. Often, intermediates were exported for conversion to polymers. These products were ultimately upgraded into fabricated products for consumption in the manufacturing area, or reexported to the three major economies.

Since the oil crises of 1973-74 and 1979, significant changes have been occurring in the global manufacture, as well as consumption, of the key petrochemicals, Four more major geographic entities are likely to become more important sources of petrochemical intermediates and derivatives: Canada, Mexico, the Middle East, and Southeast Asia. The Canadian and Middle Eastern developments will have the most significant impact on global trade in the mid-1980's. From Canada, manufacturers will export very significant volumes of methanol, ammonia, and ethylene derivatives. The Mexican petrochemical industry will send petrochemical derivatives to the international market. Major petrochemical centers in the Middle East, previously discussed, will come onstream during the 1980's and will export products. Finally, Southeast Asia (the ASEAN countries of Thailand, Malaysia, Singapore, and Indonesia) will become an increasingly important center of petrochemical production, consumption, and exports during the late 1980's. During the mid to late 1980's, ASEAN projects will come onstream competing with products from the new export centers of the Middle East and Western Canada in market areas once dominated by products produced in the United States, Japan, and Western Europe.[32] A major question is what effect the new petrochemical projects in the Middle East will have on producers in the United States and elsewhere.

THE RESTRUCTURING OF GLOBAL TRADE IN COMMODITY CHEMICALS

Since the majority of the petrochemicals to be produced in the Middle East and the products of most concern to world market trade

[32] While the feedstock base of this Southeast Asian region will not be as favorable as that anticipated for the Middle East and Western Canada, Southeast Asia will be a significant domestic market. Also, Southeast Asia, being on the prime shipping lane between the Middle East and Japan, has a strategic location, and all material that will likely move from the Middle East to the Pacific will pass the proposed petrochemical complexes of Southeast Asia.

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are commodity chemicals, OTA analyzed prospects for market restructuring in several of these chemicals: polyethylene, ethylene glycol, styrene, methanol, and ammonia. The analysis covers the decade through 1990.

Factors such as global economic performance, oil price trends, and a variety of political and other issues affect the global development of the petrochemical industry. Specific developments in each country combine to determine future trends in demand, supply, trade, and prices for each product. In order to anticipate the positions of Middle East petrochemical producers in world trade, global and country-specific demand for each type of product was first considered. (App. 5C includes tables showing these demand expectations.) Domestic supply in each country was assessed by considering available capacity, production economics, market demand (local and export), and plans for new/expanded capacity.

From these national and regional projections of demand and supply, preliminary global balances were developed for each petrochemical product. These highlighted possible imbalances in the future world supply/demand position. In practice, apart from minor inventory swings, global supply must balance demand in each year, and there must be zero net global trade. Thus, a projected potential global oversupply in the near future must be primarily accommodated by reduced operating rates in high-cost exporting regions such as Western Europe and Japan.

It should be noted that many factors affect different countries' petrochemical product competitiveness: 1) raw materials/feedstock price and availability; 2) size of the domestic market and economies of scale; 3) exchange rates; 4) R&D capabilities relative to new and improved products and process technologies; 5) investment levels in new plant and equipment; 6) government actions that increase the price of petrochemical products at home and abroad (e. g., taxes on raw materials or petrochemical products) or actions that assist, protect, or subsidize the domestic petrochemical industry; 7) regulatory impacts and cost; 8) labor costs–as determined by availability and skills; 9) profitability—return on investment; 10) marketing strategies and distribution systems; 11) energy fuel use and costs; and 12) capacity utilization—or production efficiency/productivity.[33] On most of these counts, the U.S. petrochemical industry has some special strengths.

The analysis that follows indicates that the impact of Middle Eastern petrochemicals on the U.S. market will probably be concentrated on a relatively few products. According to one forecast, in 1990 products produced in Saudi Arabia will win a relatively small share of the U.S. market: 1 percent of LDPE, 0.5 percent of HDPE, 3.6 percent of ethylene glycol, 8.6 percent of methanol, and 5 percent of styrene.[34] While U.S. specialty chemicals may actually gain strength, the United States will become a net importer of ethylene glycol and methanol, mostly from Canada. The negative impacts of petrochemical trade restructuring will be felt especially in Japan and Western Europe. Map 4 shows the location of major projects and projected production capacity for 1990.

Low-Density Polyethylene/ Linear Low-Density Polyethylene (LDPE/LLDPE)

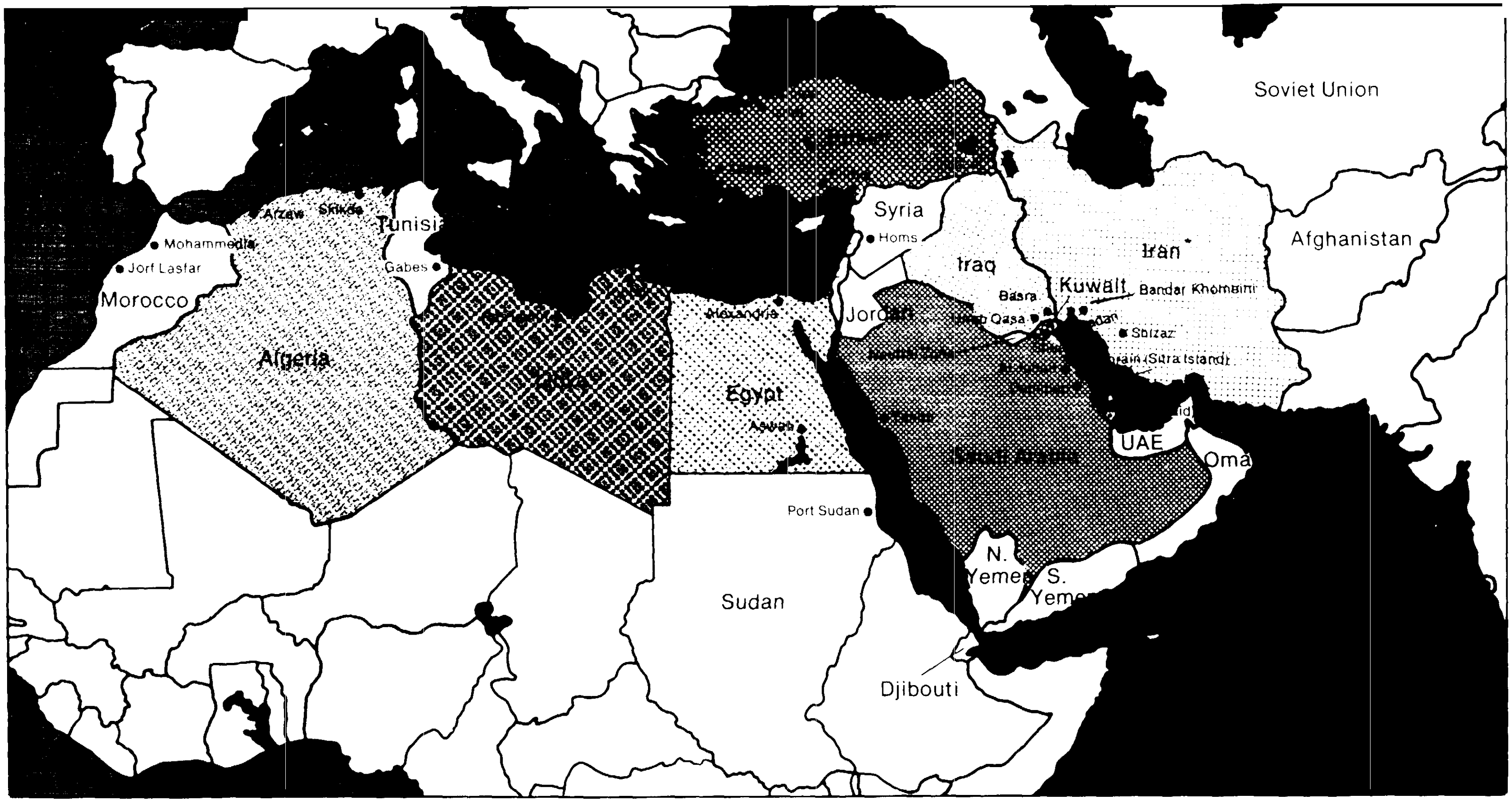
Total free world consumption of LDPE, including linear material, was 9.8 million tonnes in 1981. The industrialized regions, defined here as Western Europe, North America, and Japan, accounted for 79 percent of this total. By 1990, total consumption is anticipated to reach 15.6 million tonnes, with the industrialized regions' share declining to approximately 72 percent. By the year 2000, the industrialized regions' share of total consumption may recede to approximately 65 percent.

Global growth rates will be relatively high for this product owing primarily to expected rapid growth in consumption in the developing regions. Table 43 shows the varied uses of polyethylene products. In these countries

[33]U S. Department of Commerce, .4 Competitive *Assessment of the U.S. Petrochemical) Industry.\'*, Office of Competitive Assessment, Washington, D. C., Aug. 31,1982.

[34]Wharton, op. cit., pp. 67-68.

Map 4.—Petrochemical Production in the Middle East and North Africa (location of major projects; projected production capacity for selected petrochemicals in 1990)



Key: • Location of major petrochemical projects

Projected capacity of LDPE and LLDPE by 1990 (1000 metric tons per year)	Projected Methanol Capacity by 1990 (1000 metric tons per year	Projected Ammonia Capacity by 1990 (1000 metric tons N)
1-50	1-100	1-250
51-100	101-350	251-500
101-150	351-600	501-750
151-200	601-1000	751-1000
More than 200	More than 1000	More than 1000

Iran's projected LDPE/LLDPE capacity depends entirely upon completion of the Bandar Khomeini project, where work remained suspended as of 1984.

NOTE: The delineation of boundaries on this map must not be considered officially accepted. Geographic names or their spellings do not necessarily reflect recognition of the political status of an area.

SOURCE: Office of Technology Assessment.

Table 43.— Middle East Petrochemical Product Uses

Petrochemical products:
Uses in various Industrial and consumer products

1. ***Polyethylene:***
   - Low-density polyethylene (LDPE)—plastic bags, agricultural films
   - Linear low-density polyethylene (LLDPE)—tourist gift bags, films, moldings
   - High-density polyethylene (HDPE)—sewer and drain pipes, wire and cable covering; household chemical and food bottles; replacement of ½ gallon paper milk containers; injection molding of beverage crates, paint cans, food containers and base cups for polyethylene terephtahalate (PET) bottles; heavy-duty film for food packaging bags.
2. ***Ethylene glycol:***
   - Used in polyester apparel; antifreeze/coolant; production of PET
3. ***Styrene:***
   - Used in polystyrene plastics and synthetic fibers
4. ***Methanol:***
   - Used in gasoline octane boosters, deicers, and other fuels; in thermoset resin adhesives used in plywood and chip wood industries; in resins such as DMT used in the production of polyester fibers and films, Used in production of formaldehyde.
5. ***Ammonia:***
   - Used directly
   - Used in fertilizers (Including urea), synthetic fibers
   - Industrial uses in fiber, resin, and elastomer intermediates; explosives, livestock feed supplements

SOURCE Off Ice of Technology Assessment

Table 44.– LDPE/LLDPE Net Interregional Trade (thousand metric tons)

	1981	1985	1990
Western Europe	323	—	(loo)
North America:			
United States	424	180	15
Canada	84	270	455
Japan	135	30	(180)
Pacific Basin and Indian Subcontinent.	(284)	(253)	(235)
Latin America	(293)	(180)	(498)
Africa	(216)	(182)	(58)
Middle East	(81)	110	641
Eastern Europe	100	125	110
People's Republic of China	(I00)	(I00)	(150)
Total	92	—	—

NOTE Parentheses indicate net imports
SOURCE Office of Technology Assessment

paper and other competing materials will be replaced by LDPE/LLDPE, and market stimulus will be provided by new local production of petrochemicals, and growth in exports of finished products to the industrialized countries. Market growth in the industrialized regions, particularly in Western Europe and Japan, will however be limited by slow economic growth, market maturity, downgauging (use of thinner film), and growing imports of finished products from the developing regions.

The global supply pattern for LDPE/LLDPE will change dramatically over the next few years. Table 44 shows that the most rapid increases in supply will be in the Middle East, which is developing several export-oriented projects. In addition, Canada is also developing export-oriented projects with a focus on Pacific Basin markets; and Latin America and Southeast Asia producers will expand their capacity to meet increases in domestic demand and, in the case of Southeast Asia, for export.

Because of the increasing economic advantages enjoyed by producers with access to low-cost ethane feedstock, the overall level of interregional trade in LDPE/LLDPE will grow, and the pattern of trade will change significantly, as shown in table 44. It is anticipated that: 1) Western Europe and Japan will become major net importers, a reversal of their traditional positions; 2) Latin American imports will probably grow significantly since local production will be unable to keep pace with demand and many of these countries do not have the resources to support local production; 3) Southeast Asian projects will "backout" some exports from the Pacific Basin but will be unable to balance regional demand; 4) Canadian exports will grow, despite the current project development delays; and 5) Middle Eastern exports will grow to dominate global trade patterns, with continuing project development expected in the 1990's after the current round of projects is completed.

The major factor in the U.S. domestic LDPE market is the impact of LLDPE rather than any major import threats. The competitive effect of LLDPE will be felt most strongly in the film area, where LLDPE offers excellent properties. Thus, a gradual decline in the importance of LDPE over the period can be expected. At the present time, the demand for LLDPE is limited by supply, while U.S. producers now have more than enough plant capacity to meet current and future demand for LDPE. The decline in consumption forecast for LDPE indicates that producers will probably convert some of their capacity to LLDPE. Also, plans for producing LLDPE in Western Canada could relieve potential shortages of LLDPE in the United States. It is anticipated that the United States will retain a net positive trade balance in LDPE/LLDPE during the forecast period; however, U.S. exports are expected to become marginal because of the emergence of major export-oriented facilities in Western Canada and the Middle East.

While material produced in Canada and the Middle East is not expected to penetrate the U.S. domestic market significantly,[35] it is expected to expedite the conversion of much of the U.S. industry to LLDPE. Other segments of the industry will exploit specialty applications, catering to those markets best serviced by LDPE, or will shut down.

In general, the West European market for both LDPE and LLDPE is expected to be highly competitive during the 1990's, arising from a continuing overcapacity for LDPE and substantial imports of LLDPE. In the early 1980's, the United States is expected to be a major source of these imports; however, in the mid-1980's and into the 1990's, the new and more cost-competitive plants in the Middle East will supply a growing proportion of West European imports.[36] These imports will be handled by U.S. companies such as Exxon and Mobil, which have ventures in the Middle East and are able to sell the product through their own European organizations.

Lack of West European competitiveness due to its feedstock position, small unit size, and age of facilities is expected to result in sizable LDPE shutdowns in the future. Established producers of LDPE in Western Europe will attempt to use their plants for specialty grades and in some cases will convert these grades to the production of LLDPE. Except for companics with access to North Sea gas, it will become increasingly difficult to compete with Middle Eastern general-purpose resin. These conditions, combined with market maturity and greater use of LLDPE, will result in rising net imports for Western Europe during a period of significant overcapacity.

Japan will eventually become a significant net importer of LLDPE, a change from its current position as a major exporter. Japanese producers will, however, maintain minimum exports of 100,000 to 125,000 tonnes per year of specialty grades while importing commodity grades such as LLDPE. Japan's loss of international competitiveness is being partially offset by Japanese offshore projects in Saudi Arabia and Singapore. Traders can be expected to market additional supplies of LLDPE from non-Japanese associated Middle East projects, in Japan as well as in traditional Japanese export markets in Asia.

While producers have expressed an interest in producing LLDPE, the Japanese Government has approved only three ventures, each of which involves the participation of more than one producer: Mitsubishi Petrochemical, Mitsui Petrochemical Industries, and Nippon Unicar. Other producers are evaluating the feasibility of retrofitting existing high-or low-pressure polyethylene capacity for the manufacture of LLDPE. Thus, both Western Europe and Japan will become net importers of LDPE/LLDPE while the United States will remain in net trade balance.

High-Density Polyethylene (HDPE)

Free world consumption of HDPE should increase from 5 million (1981) to nearly 10 million tonnes (1990), with the industrialized regions' share declining from 80 percent (1981) to approximately 75 percent (1990).

Although global growth rates of HDPE will be relatively high, growth in many developing countries will be uneven. Nevertheless, countries in Africa and the Pacific Basin may experience comparatively high growth in demand (more than 10 percent growth annually). Market growth in industrialized regions, par-

[35] Canadian imports are expected to rise, but from a net trade position, they are expected to be offset by equal amounts of U.S. exports to Latin America and elsewhere.

[36] This assumes that excessive tariffs or other protectionist measures are not instituted by the Europeans.

ticularly Western Europe and Japan, will be limited by slow economic growth, low population growth, market maturity, and competition from polypropylene.

The global supply pattern for HDPE will change over the next few years with the greatest supply increases coming from: 1) Canada, which will become a major exporter to the Asia/Oceania markets; 2) Mexico and South America, which will add HDPE plant capacity to satisfy the projected strong increase in demand; 3) Eastern Europe, which will also add capacity to remain self-sufficient in HDPE; and 4) the Middle East, which will be a significant factor in global trade with its export-oriented projects.

Due to the increasing economic advantages enjoyed by producers with access to cheap ethane feedstock, the overall level of interregional trade in HDPE will grow, with the Middle East producers becoming important exporters, as shown in table 45. This increase in trade will be further facilitated by LLDPE producers, who will be able to produce HDPE with their spare LLDPE capacity. The major changes in trade shown in table 45 are based on the anticipated completion of a number of export-oriented plants in Canada and the Middle East. Japan will shift to a net import position by 1990 and both the United States and Western Europe should be able to maintain a reduced net export position. However, exports from Canada and the Middle East will be relatively limited and are not expected to offset exports from the United States or Western Europe. Japan and East Asia may be major target export markets for Middle Eastern HDPE.

Table 45.—World HDPE Trade (thousand metric tons)

	1980	1981	1985	1990
Western Europe	304	250	170	165
North America:				
United States	280	250	135	180
Canada	25	36	75	70
Japan	138	131	45	(120)
Pacific Basin	(176)	(180)	(109)	3
Latin America	(195)	(185)	(243)	(302)
Africa	(114)	(110)	(183)	(221)
Middle East	(80)	(87)	10	125
Other	20	20	100	100
Total	202	125	—	—

NOTE: Parentheses indicate net imports.

SOURCE: Office of Technology Assessment.

Blow molding, used to produce household chemical and food bottles, will continue to be the largest outlet for HDPE in the United States, accounting for about three-fourths of current demand. Table 43 shows the various product uses for HDPE. U.S. HDPE producers have a current production capacity of 2.7 million tonnes per year. New capacity is expected to be brought onstream during the mid-1980's to meet domestic requirements and incremental exports.

No significant restructuring of the U.S. HDPE industry as a result of Middle East or Canadian export projects is expected. However, LLDPE will influence HDPE production as a result of some market penetration and the ability of some LLDPE facilities to make a full range of polyethylene products-from LLDPE to HDPE.

In Western Europe no significant restructuring of this industry as a result of Middle East projects is expected. Unlike the United States and Western Europe, Japan is expected to move into a deficit position in HDPE by the later 1980's as a result of Middle Eastern and other projects. This is the result of Japan's conscious move to discontinue expansion of olefins projects, which will limit its position in HDPE as well. Nevertheless, Japan is expected to maintain an export position in specialty grades for film, fiber, and other extruded products. Imports will consist of molding and blow molding grades of resin.

Ethylene Glycol

By 1990 total consumption of ethylene glycol will probably have risen 50 percent from 1980, with the industrialized regions' share dropping from 83 to 75 percent in 1990 and to 70 percent by 2000. The relatively strong annual growth rate in demand in developing countries is driven by several factors; for example, continued strong growth in domestic polyester textile use in Southeast Asia, India, Latin America, and other developing areas, expansion of polyester apparel exports to the United States and Western Europe from the low labor-cost areas, particularly Southeast Asia, and increased use of ethylene glycol as an antifreeze/coolant while local demand and availability increases. In the industrialized regions, growth will be influenced by several opposing factors. These include slow growth in polyester fiber production, little or no growth in antifreeze use in Western Europe and the United States, and strong growth in polyester film and in PET resin for bottles.

The global supply picture for ethylene glycol will change substantially over the next decade. The most rapid increases in supply will be in the Middle East, which will become the largest regional exporter by far (see table 46). Canada, which has recently started one large export-oriented project and has another under development, and several countries of the Pacific Basin (India, Taiwan, Thailand, Indonesia) will also be important interregional exporters. As with LDPE, the increasing economic importance of access to less expensive ethane feedstocks will result in a substantial increase in the overall level of interregional trade in ethylene glycol. The major source of U.S. imports is expected to be Canada. Middle Eastern exports will dominate global trade patterns from the late 1980's onwards; additional projects are expected during the 1990's.

While the pricing of this material is not expected to be disruptive or destabilizing, the current world recession could cause rates of growth in demand to be below anticipated levels. The net effect of this could be large volumes of product with smaller markets than originally expected for the mid-1980's, and severe price competition erupting during the startup period for many projects. Tariffs currently in force will make Middle Eastern ethylene glycol economically unattractive in the United States. In Western Europe, tariffs are not currently in force, but have been discussed.[37]

Table 46.—Ethylene Glycol Net Interregional Trade (thousand metric tons)

	1981	1985	1990
Western Europe	100	30	(120)
North America:			
United States	75	83	(50)
Canada	94	195	220
Japan	(30)	(80)	(280)
Pacific Basin	(126)	(131)	33
Latin America	(13)	(23)	(96)
Africa	(34)	(42)	(42)
Middle East	(35)	(12)	360
Eastern Europe	(75)	(20)	(25)
Total	(44)	—	—

NOTE: Parentheses indicate net imports.
SOURCE: Office of Technology Assessment.

With the decontrol of natural gas prices in the United States, ethylene glycol costs will rise. However, imports may come primarily from Canada rather than the Middle East.[38] The major producers are coremitted to limited domestic expansion and recognize that strong international positions can only be maintained by countries having access to low-cost, gas-based feedstocks. With limited future capacity expansion likely, due to the loss of export markets and pricing strongly influenced by feedstock factors, plant shutdowns by the smaller, high-cost U.S. producers appear inevitable. The major producers have expressed little desire to invest in additional ethylene glycol capacity, preferring instead to upgrade available ethylene oxide (a precursor to ethylene glycol) to higher valued derivatives such as surfactants, glycol ethers, and ethanolamines. By 1990, therefore, it is likely that the United States will become a net importer of ethylene glycol.

Western Europe will also become a net importer of ethylene glycol. Any capacity additions are likely to be offset by shutdowns of small, old units. Material coming onstream in the Middle East, in combination with Canadian and East European capacity, will preclude Western Europe from export markets. Several West European producers *are* considering closing their glycol plants.

[37] Susannah Tarbush, "Euro-Unions Tackle 'Threat' of Gulf Chemicals," *The* Middle *East,* September 1983, pp. 55-56.
[38] Union Carbide will import from Alberta, Canada, where it is constructing a new facility. Union Carbide dominates the U.S. ethylene glycol industry, with 40 percent of total installed capacity.

Japan will import material from offshore projects in which it is a participant and also from the international merchant market. With the import of ethylene glycol, the integrated ethylene oxide-glycol producers would be able to upgrade available ethylene oxide to higher valued derivatives, an option that would not necessitate additional investment in ethylene oxide-glycol facilities. Thus, it is anticipated that Japanese ethylene glycol producers will come through the petrochemical industry restructuring period intact because part of the reduction in Japanese ethylene glycol production will be compensated for by the growth in nonglycol markets for ethylene oxide, in which the Japanese producers will retain their strong position.

Styrene

In 1981, the industrialized regions of Western Europe, North America, and Japan accounted for over 89 percent of total styrene consumption. By 1990, total styrene consumption is expected to reach 10.5 million tonnes, of which the industrialized regions' share will decline to 82 percent. By the year 2000, the industrialized regions' share of global demand is expected to decrease further to approximately 75 percent.

The relatively strong growth in demand in the developing regions reflects the rapidly growing markets for appliances and other consumer durables in the more advanced countries such as Korea, Taiwan, the ASEAN countries, Mexico, and Brazil, growth of the electronics industry in the East Asian countries, and development of large markets for disposable products. In the industrialized regions, growth will be constrained by slow growth in consumer durables, production market maturity in disposable products (and some consumer/environmental reaction against them), mature synthetic rubber (SBR) markets, and increased competition for polystyrene from polypropylene.

The global supply picture for styrene will change substantially over the study period, with the most rapid increases in supply occurring in the Middle East, Canada, Latin America, the Pacific Basin, and the United States. The Middle East will become the largest regional net exporter by 1990, as shown in table 47, while Canada now has a strong export position and another export-oriented project under development. Latin America (Mexico and Brazil) and several countries of the Pacific Basin (India, Taiwan, Korea, and, ultimately, Indonesia) will produce the styrene required for their growing polystyrene and other derivatives industries. The United States, which will continue to be cost-competitive, will increase production to meet domestic demand and support continued exports.

Demand growth, coupled with benzene limitations,[39] will result in rapidly growing imports to Japan and other Pacific Basin countries and will result in a steady increase in the overall level of interregional trade in styrene. Japanese imports will grow substantially, owing to benzene supply limitations; Hong Kong will continue as a major importer; and Korea and Taiwan will ultimately become major importers. U.S. exports of styrene can be expected to decline but remain substantial. Canadian exports will grow with the completion of major export-oriented capacity, and Latin America will continue to import, despite production growth. Finally, Middle Eastern exports will become a major factor in global

"' The composition of styrene is approximately 70 percent benzene, a refinery product, and only approximately 30 percent ethylene. Lack of refining capability limits benzene supply and hence limits styrene production.

Table 47.—Styrene Net Interregional Trade (thousand metric tons)

	1981	1985	1990
Western Europe	(I00)	(I00)	(I00)
North America:			
United States	508	500	295
Canada	157	200	210
Japan . . . . , ...	(161)	(250)	(390)
Pacific Basin	(187)	(136)	(246)
Latin America , ...	(120)	(141)	(185)
Africa ., ... , ...	(15)	(28)	–
Middle East	(5)	(12)	450
Eastern Europe	(50)	(30)	(30)
People's Republic of China . .	—	—	—
Total	27	3	4

NOTE Parentheses indlcate net imports

SOURCE Office of Technology Assessment

trade patterns from the late 1980's onwards, with most production flowing into Japan and East Asia.

Historically, the United States has been a major producer and exporter of styrene. Polystyrene accounted for 62 percent of total U.S. styrene consumption in 1981. Over 60 percent of the styrene produced in the United States is used for captive (within plant) purposes. Packaging and disposable items consume approximately one-half of the general-purpose and impact grades. Over the next decade, export shipments of styrene are not expected to decline as dramatically as those of other ethylene derivatives. U.S. producers are expected to maintain their export positions because of the availability of benzene from refinery and olefin operations that will be cost competitive with those in other areas of the world. There is adequate U.S. styrene capacity to last through the late 1980's. However, additional capacity will be required during the 1990's.

The relatively weak position of the West European styrene industry reflects a combination of very mature markets (i.e., polystyrene) and a weak raw material position. As such, net imports of styrene have been 100,000 to 150,000 tonnes per year for the past several years. These have come mainly from North America. This condition is expected to continue, with the source of imports switching in favor of the Middle East.

Japan's three largest styrene producers have capacities smaller than the large low-cost facilities in the United States. The combination of these scale factors and the feedstock costs in Japan relative to those in the United States minimizes the competitiveness of the Japanese styrene producers in the international market. Over the next few years, it is anticipated that the Japanese styrene industry will be restructured to reflect its changing situation. A number of small and energy inefficient units will be shut down, although some may be rebuilt into a unit having a higher capacity. New units will be at least 150,000 tonnes per year in size. In addition, Japan's imports of styrene are anticipated to grow substantially.[40]

Methanol

The United States, Western Europe, Eastern Europe, and Japan now account for approximately 90 percent of the global demand for methanol. This market share is expected to recede to approximately 75 percent by 2000.

Current global methanol demand is almost entirely for chemical applications. Growth in this area will be led by rapid growth in methanol demand for acetic acid manufacture because of the preferred economics of methanol carbonylations as compared to alternative techniques. Formaldehyde, by far the largest current market for methanol, will continue to grow in line with the demand for forest products, the most significant formaldehyde end-use market (see table 43). The rapidly growing methanol markets will be for fuel-related uses such as for MTBE (methyl tert-butyl ether), an effective gasoline octane booster. Direct blending with gasoline is a potentially large market, but this end-use will develop slowly, owing to concerns about performance as well as the short-term soft outlook for fuel products. These fuel-related uses may account for approximately one-quarter of total methanol demand by the year 2000.

In 1981, production in the United States, Western Europe, and Japan accounted for 63 percent of the global supply, reflecting the historical concentration of methanol capacity in industrialized nations. However, over 80 percent of the new methanol plants being built worldwide are outside the three major consuming regions. This is reflected in table 48, where major new suppliers are seen to be Canada, the Middle East region, and the ASEAN region. This highlights the economic advantage en-

[40] Japanese styrene producers have pursued equity participation in offshore styrene projects, such as those in Canada, to obtain low-cost styrene or benzene to enhance either their domestic or export market position. See Takuya Araoka, "Petrochemical Industry Striving for Revitalization," Journal *of Japanese Trade and industry, No. 6, 1982,* pp. 18-21.

Table 48. —Global Methanol Supply/Demand Balance (thousand metric tons)

	1981	1985	1990
North America:			
United States	300	155	(1,400)
Canada	200	1,370	1,440
Eastern Europe	100	600	800
Western Europe	(580)	(1,740)	(3,105)
Japan	(326)	(1,030)	(1,970)
ASEAN	(55)	723	1,225
Australia/New Zealand	(63)	230	320
Other Asian	(121)	(505)	(600)
Mexico	35	0	810
Central and South America	(75)	32	233
Middle East/Africa	345	1,200	2,065
Other	(80)	(128)	(200)
Total	(320)	907	(382)

NOTE: Due to timing uncertainties associated with the growth in fuel demand, no attempt was made to zero balance trade as was the case with other products in this study. Parentheses indicate net imports.

SOURCE: Office of Technology Assessment.

joyed by producers with access to larger supplies of relatively inexpensive gas. It is expected that Canada and Mexico will become major sources of U.S. methanol imports as well as significant competitors in East Asian markets. Western Europe and Japan will continue as the largest net importers of methanol. The Middle Eastern suppliers will become the largest net exporters of methanol worldwide.

The future of methanol has been fiercely debated in the chemical industry during recent years. Already the sixth largest industrial chemical in volume, methanol has been promoted as one of the leading candidates for a nonpetroleum-based fuel for a variety of applications. These markets are potentially many times the size of the chemical markets. Nevertheless, the U.S. industry is in an uncertain state since the recent global recession depressed the chemical demand for methanol. At the same time, while the current weak energy market is undermining the impetus for development of fuel-related applications of methanol, major export projects in Canada, the Middle East, Mexico, and Trinidad are in various stages of completion to take advantage of anticipated fuel markets.

The United States will gradually become a net importer of methanol. Additional domestic methanol capacity beyond that already announced will not likely be based on natural gas because of inadequate supplies. U.S. methanol producers are reluctant to commit themselves to alternate feedstocks such as coal-based plants because of the high capital costs and fear of competition from Canada and the Middle East, where relatively inexpensive natural gas is available. Unless more domestic capacity is planned beyond that currently foreseen, a major deficit in methanol supply could result by 1990. It is expected that substantial methanol imports will be utilized in advance of the construction of coal-based methanol plants in the 1990's, with the most likely sources being Canada, Mexico, Trinidad, and Saudi Arabia.

Western Europe, which is already a net importer, will continue to experience shutdowns in its methanol industry caused by lack of competitiveness with Middle Eastern and East European projects. New capacity will be limited and keyed to North Sea gas and possibly coal gasification in West Germany. Western Europe will face a rising deficit in methanol supply from regional sources and therefore will increase its dependence on imported methanol. Low-cost imports will likely lead to a situation in 1985 where European consumers rely on imports to meet 40 percent of demand.

Likewise, Japan will become an increasingly large net importer. Due to Japan's weak raw material position, it will be increasingly dependent on Canada, Saudi Arabia, New Zealand, and ASEAN nations as its primary sources of supply. Japan's methanol industry is not cost-competitive with methanol produced at these locations, which have natural gas costs that are substantially lower than those of Japan's current supply sources. Methanol production in Japan may eventually decline to about 400,000 tonnes per year.

Ammonia

Nitrogen fertilizer supply is increasing rapidly in the gas-rich developing countries,[41]

[41] "Demand will grow especially in highly populated developing countries including the Indian Subcontinent, Latin America, Africa, and China.

while the developed countries are unable to justify new capacity additions because of high feedstock costs. This is a reversal in the historical pattern of world trade. The United States, Western Europe, and Japan will become (as a group) net importers of nitrogen fertilizers.

Historically, anhydrous ammonia has not been a major item of interregional trade, owing to its high shipping costs. However, a major long-distance international trade has developed, and can be expected to grow. Major importers will be the United States, Western Europe, and Japan. Three of the major exporters will be the Middle East, Mexico, and Canada (see table 49).

The United States consumes large quantities of ammonia primarily to support its role as a global exporter of foods and grains. Approximately 80 percent of all ammonia consumed in the United States is for fertilizer. Currently over 97 percent of U.S. ammonia capacity is based on natural gas feedstock. As U.S. natural gas becomes less abundant and more costly, the United States will continue to import large quantities of ammonia. Future coal gasification projects are expected to be insufficient to close this trade gap, and while some new capacity will be added it probably will not replace capacity lost to the closing of old units.

The most important suppliers of import nitrogen to the United States (mostly anhydrous ammonia) are currently Canada, Mexico, the U. S. S. R., and Trinidad/Tobago. The importance of these major sources of supply is expected to grow with little or no prospect for Middle Eastern exports to the United States. Imports of ammonia and urea from the U.S.S.R. will grow if the political climate is favorable. Since U.S. companies are closely involved in the Trinidad/Tobago operations, a large part of this production will enter the United States.

Table 49.—Anhydrous Ammonia Trade (thousand metric tons)

	1979-80	1984-85	1989-90
Asia/Orient	(43)	(814)	(1,186)
Indian Subcontinent	(loo)	(200)	(500)
People's Republic of China			
United States	(1,073)	(2,400)	(3,000)
Canada	400	450	550
Latin America	935	1,200	1,500
Middle East	70	680	1,010
Africa	—	320	440
Western Europe	(1,080)	(1,730)	(2,870)
Eastern Europe	1,400	2,540	4,060

NOTE Parentheses indicate net Imports
SOURCE Office of Technology Assessment

The West European ammonia industry is strained. Escalating feedstock costs and continued pressure on ammonia and nitrogenous fertilizer prices are squeezing profit margins for the traditional producers in Western Europe. The forecasted global overcapacity and the concentration of competitive plants in the Middle East and Eastern Europe present a long-term threat to the West European countries. Many high-cost plants have already been closed, and more closures are expected. As imports grow, some producers and industry associations may seek government protection in the form of import quotas, tariffs, or subsidies. Pressure from the farming lobby for continued access to low-cost nutrients, plus external political and economic constraints, will limit such protection, provided total imports do not exceed levels considered strategically reasonable.

At present, ammonia and urea production in Japan are conducted under a cartel arrangement set up when Japanese firms lost their cost-competitiveness as a result of high feedstockprices.[42] Under this arrangement, ammonia and urea capacities were reduced, and a ban was placed on ammonia and urea imports until 1984. Despite this arrangement, the Japanese competitive position has deteriorated further.

Effects of Crude Oil Price Decreases

Currently, much uncertainty exists in world energy markets. Crude oil prices have declined, and supplies have generally grown in a manner unforeseen by governments, economists, or industry. This situation has simultaneously

“Naptha accounts for 50 percent of the feedstock used for ammonia production in Japan.

stimulated the economies of many nations and aggravated the debt position of others. In this environment, even those nations on the Persian Gulf with relatively small populations may be forced to delay some projects, withdraw foreign investments, or consider developing nonassociated gas for their hydrocarbon-based projects. The net effect of this would be decreased competitiveness with the United States in some markets, after allowance for freight to target markets. Moreover, these project delays are expected to have a delaying effect on second generation projects in the region." The slower growth in crude oil prices has also reduced the petrochemical production costs of regions such as the United States, Japan, and Western Europe. Middle Eastern nations will at best have the same zero value for their raw materials, thus making them less competitive with these industrial regions.

The major industrial trading regions will benefit from the decline in crude oil prices. There will be an upward push on GDP and a downward pull on inflation. This may further stimulate GDP-related demand, which already benefits from the current economic recovery. In addition, synthetic (petrochemical-derived) materials, which have been competing with natural materials, will receive an added boost. This should be the pattern even for products having high energy costs. It reflects the nature of petrochemicals, which use energy products for fuel as well as for raw materials. Products using natural raw materials such as paper, however, can only take advantage of low crude oil prices in their fuel costs.

The recent effect of increased demand (due to GNP growth), delayed projects, and more competitive traditional petrochemical producers can be expected, in most instances, to result in firmer prices (in the West), a greater utilization of capacity already in place (healthier domestic industries), and a more gradual rationalization of the West European and Japanese petrochemical industries. As far as the United States is concerned, it will make it even less likely that Middle Eastern olefin derivatives will penetrate its shores. Moreover, the lower profitability profile expected for the Middle East argues against any attempts by these producers to penetrate U.S. markets by undercutting prices.

Olefins Derivatives.—The olefins derivatives examined here are polyethylene, ethylene glycol, and styrene. In each case, the impact of lower crude oil prices will be to increase consumption. Since the decline in crude oil costs will lessen the cost of petrochemical-derived products more than it will lessen the cost of naturally derived products, consumption of petrochemical-derived products will increase. Although this may not be reflected in mature markets such as those for bread wraps, it can be expected to help LLDPE penetrate the U.S. grocery (Kraft) bag market and the more GNP-sensitive applications, where increased consumer disposable income provides added impetus to demand. This latter category includes agricultural films (LDPE), tourist gift bags (LLDPE), and injection molded toys, and household, consumer, and industrial items (HDPE and styrene). In addition, from a national standpoint, lower crude oil prices will increase U.S. competitiveness in foreign markets.

Ethylene glycol is used primarily for polyester and automobile anti-freeze. Growth prospects for these applications will tend to reflect the simulative effect of lower crude oil prices on individual national economies. However, while polyester fiber may also benefit from increased cost competitiveness with cotton, fashion trends also tend to dictate the amounts of each consumed.

Styrene trade has been less affected by the drop in crude oil prices because only 22 percent of styrene is ethylene, the balance being benzene. Moreover, benzene prices in the Middle East tend to follow West European prices (any reduction in profitability would be shown

[43] As stated in Wharton op. cit., April 1983, p. 78), "A sustained fail in oil prices toward $251 barrel is unlikely to have much effect on the generation of petrochemical plants already being constructed in the Middle East. Their economics may become marginally less attractive, but not enough to lead to any further significant cancellations. Where an oil price fall will have an effect is on the next generation of plants, which are still at the stage of initial discussion.

in the refinery operations from which the benzene is produced). Nevertheless, the United States will benefit to some degree in styrene export markets, owing to its increased competitiveness (U.S.-manufactured benzene is competitive, and its ethylene will become more competitive). In addition, styrene consumption will improve because of the improved nature of the world economy. (This may be reflected in increased demand for styrenics in toys and appliances.)

Methanol and Ammonia.—The impact of lower crude oil prices on methanol and ammonia will vary. While consumption will be favorably influenced by increased U.S. automobile usage and continuing demand for food worldwide, U.S. firms will continue to lose competitiveness in methanol and ammonia production, and significant imports can be expected in the future.

In the case of methanol, lower crude oil prices will result in more competitive U.S. facilities since the gap between U.S. costs and foreign competitors raw materials costs will not be as great (as in a $34/barrel market crude oil scenario). However, if marginal U.S. producers continue operations and lower crude oil prices result in a delay in the use of methanol in energy applications, the world oversupply would be further aggravated, pricing pressures would continue, and imports would still be expected. A delay in using methanol in gasoline blends, for example, could result simply from the availability of crude oil, a perception that energy alternatives are not necessary and, in those markets where methanol will be used as an octane enhancer rather than as a gasoline extender, increased competition from other materials (toluene).

In the case of ammonia, U.S. producers, with or without renegotiated natural gas contracts, can be expected to stay competitive longer. However, since there are fewer new ammonia projects coming onstream (as compared to methanol) and demand is large, the business environment is expected to be different than that for methanol. Nevertheless, the United States will import sizable quantities of ammonia during the 1980's.

IMPLICATIONS OF MIDDLE EAST PETROCHEMICAL INDUSTRY DEVELOPMENTS

IMPACTS ON RECIPIENT NATIONS

As petrochemical plants are built in the Middle East, a major effect has been rising demand for skilled manpower. These effects have been strongly felt in Saudi Arabia and Kuwait, where dependence on foreign manpower at all levels (but particularly in technical, professional, and managerial occupations) is high. These trends can be expected to continue for the foreseeable future.

The petrochemical industry has a broad occupational profile. The wide variety of jobs is partially due to the diverse range of products created in the industry, as well as to the industry's complexity. The high skill levels required in the industry indicate the need for extensive specialized training, for technicians, scientists and engineers, mechanics, and machine operatives. The occupational breakdown of this labor force may be approximated using the labor profile developed for the Middle East petrochemical industry by the United Nations Industrial Development Organization. Approximately 20 percent of these jobs will be technical or managerial.[44] All evidence indicates that in Saudi Arabia the great majority of these jobs, especially at the higher skill levels, will have to be staffed by nonnationals for several years into the future. In 1981, the

[44] International Centre for Industrial Studies, *Draft World-Wide Study of the Petrochemical Industry* (Vienna: United Nations Industrial Development Organization, 1978).

Saudi labor force in the chemical, petroleum, and plastics sector numbered approximately 8,000. About 87 percent were non-Saudis.[45] A doubling in this work force may be required. Like Saudi Arabia, Kuwait will also rely very heavily, almost exclusively, on foreign workers if its expansion in petrochemicals proceeds.

Algeria, on the other hand, may need approximately 3,000 workers to satisfy its petrochemical program, most of whom are already in place. This would include about 600 professional and technical workers, 500 skilled workers, 900 operatives, and 500 clerical workers. With over 200,000 professional and technical workers in the Algerian labor force, and around 2,000 new university graduates per year in science and technology fields, the requirement of a few hundred additional technical workers should not present a problem to their petrochemical sector. Similarly, Egypt will probably be able to meet its manpower needs. The only possible problem area could be in the managerial positions, owing to limited previous labor force experience with petrochemical production. The major manpower difficulty in Egypt would thus be the quality of labor and its productivity.

In contrast, both Iraq and Iran had substantial petrochemical manpower forces prior to the Iran-Iraq War. The Iraqi labor force in petrochemicals was estimated at over 17,000 workers in 1977. Iran also had a large trained cadre of petrochemical workers operating about 10 petrochemical plants. The ongoing war between Iran and Iraq and the unknown damage to their petrochemical plants make future manpower supply or needs impossible to predict for these two countries.

IMPLICATIONS FOR U.S. POLICY

A gradual erosion in the competitiveness of U.S. petrochemical producers can be expected because of feedstock advantages in other regions of the world, among other factors. The impending decontrol of natural gas prices will make U.S. commodity petrochemicals less competitive on world markets and may further increase imports of ammonia into the United States. The U.S. petrochemical industry may, however, remain strong, owing to large domestic demand, increasingly efficient operations, and R&D efforts. The industry's major loss will be in exports. No major loss of U.S. jobs in the petrochemical sector is anticipated. U.S. contractors and licensers have had a strong presence in the Middle East and projects there yield revenues to the United States through taxes and income. U.S. producers will, however, be challenged to adjust their production and strategies in order to respond to anticipated changes in the world petrochemical market.

No cases were identified where contracts were lost because of the Foreign Corrupt Practices Act or antiboycott legislation, and recent changes in the tax laws concerning income tax on U.S. citizens' foreign earnings have reduced this as a disadvantage to U.S. firms. Export financing has been a less significant factor in contract awards in this sector than in some others examined by OTA, due to the fact that the Gulf States (Saudi Arabia in particular) have been in a position to provide attractive financing terms to foreign investors.

A major concern for U.S. policy makers will be with potential protectionist measures abroad. U.S. tariffs on petrochemicals after the Tokyo round of tariff reductions are not generally judged excessive, but countries in the Middle East want more favorable tariff treatment. Restructuring of the U.S. petrochemical industry is occurring, as in Japan. In Western Europe, however, the admittedly necessary restructuring is progressing slowly, as political pressures make plant closures or "rationalization difficult.[46] In 1983 in the

[45] Kingdom of Saudi Arabia, *Census of Primary Establishments*, 19/+1, cites a total figure of 8,196 workers in these categories. See also Federal Democratic Republic of Algeria, AS IDC, UNIDO, *Status of Arab Industry and Future Concept for Arab industrial Development Up to the Year 2000*, 1979, which gives a figure of 6,400 workers in the chemical industry for 1973.

[46] A Working Group's Report to the European Economic Commission. 'restructuring the West European Petrochemical Industry," ("Gatti-Grenier Report"), May 1983. In this report, the following reductions in West European petrochemical capacity were recommended: ethylene 20% (from 15 to 12 million tons/year), LDPE 24.5% (from 5.3 to 4.0 mt/yr), and HDPE

European Economic Community, **capacity** utilization remained below 60 percent on average, despite a beginning upturn in production worldwide.[47] If protectionist measures are imposed by the West Europeans, more product than anticipated could end up flowing to the United States, at best; at worst, severe commodity chemical price cuts could occur. Table so shows tariff rates on petrochemicals imported to the United States, Japan, and Western Europe.

The Middle East producers aspire to be accepted as major players in worldwide petrochemical trade. If the need arises, however, they have the wherewithal (owing to inexpensive feedstocks, surplus capital, and state-of-the-art facilities) to force their entry." In the long run, however, price cutting would be detrimental to all producers. In response, the Europeans will be reluctant to take a purely protectionist stand against the new petrochemical exporters, because this would be a diplomatic embarrassment to the ECC.[49] On the other hand, protectionist advocacy has been evident in West Europe, directed against the Japanese

24% (from 2.5 to 1.9 mt / yr). See also Paul Cheeseright and Carla Rapoport, "European Groups Fail to Agree on Chemicals Cuts, " Financial Times, June 1, 1983, p. 1.

"See Commission of the European Communities, *European Economy,* Supplement B, No. 11, November 1983, pp. 4-5; "Facts and Figures for the Chemical Industry, "Chemical and *Engineering News,* June 13, 1983, p. 26.

[48] "Saudi Counter-Measures if Europeans Impose Protectionism, " reported in JPRS, Near East.)South Asia, Oct. 12, 1983, from *Al-Mustaqbal,* in Arabic, No. 333, July 9, 1983, pp. 51-52. See also "SABIC Warns Against Protectionism, " *Middle East Economic Digest,* Aug. 12, 1983, p. 45, and "Petrochemical Producers Urged to Cooperate," *Middle East Economic Digest,* November 11, 1983.

[49] Wharton, op. cit., pp. 66-67.

Table 50. —Petrochemical Tariffs (percent)

Product	Western Euro pea	United States	Japan[a]
Polyethylene ... . . , . .	14.7	13.4	6.2
Ethylene glycol.	15.1	13.1	12.0
Styrene monomer.	6.3	9.0+0.7¢/lb	8.0
Methanol	13.7	18.6	5.3
Ammonia	11.1	—	3.8

[a] Middle Eastern imports are currently duty free However, as Middle Eastern exports increase in volume, they may be subject to the same tariff rates used by the United States

SOURCE Off Ice of Technology Assessment

and the newly industrializing countries, such as Hong Kong, South Korea, and Taiwan. Perhaps the greatest contribution the United States can make is to encourage multilateral agreements so that the new petrochemical producers of the Middle East and other regions, whose entry into world markets is certain, will cause as little disruption as possible.

Thus, U.S. policy options are limited. Measures which encourage U.S. firms to adjust to the anticipated worldwide restructuring of the petrochemical industry could be a contribution. The traditional stress on R&D characteristic of the industry must be maintained so that U.S. firms can specialize in the development of higher valued-added fine chemicals, produced through more efficient processes. Opportunities for the U.S. industry lie in operations further downstream. Rather than sector-specific policies, those that promote the development of technical manpower in the United States, and those that encourage R%D across a broad spectrum of industries should contribute to readjustment.

CONCLUSION

A major shift is occurring in the worldwide petrochemical industry. The Middle East (as well as Canada, Mexico, and Southeast Asia) will become more important as a source of petrochemicals in the near to midterm. Canadian and Middle Eastern developments will have the most significant impact on global trade in the mid and late 1990's. Middle Eastern producers, such as Saudi Arabia, want to be world-scale producers of petrochemicals and have the means to do it. Generally speaking, they intend to prevent large disruptions in petrochemical markets, but they hope to reach their goals.

Firms in western Canada and Mexico are more likely to make significant inroads into the U.S. petrochemical market than Middle East manufacturers. In any case, U.S. petrochemicals will remain generally strong despite the fact that the United States will become a net importer of ethylene glycol and methanol by 1990 (mostly from Canada). The United

States is already a net importer of ammonia. However, U.S. specialty chemicals may actually gain strength, and employment effects should be minimal because U.S. producers can be expected to continue to supply the domestic market in many product areas.

The effects of the growth of petrochemical production in the Middle East may be more severe in Western Europe and Japan. Western Europe must continue to rationalize its petrochemical industry, but this will be a painful process. Japan has already realized that it cannot compete against low-cost feedstocks and is bowing out of direct production. Japanese firms are participating in development of the Middle East petrochemical industry because this is viewed as in the national interest, among other reasons.

Manpower and maintenance will be the key problems for Middle Eastern petrochemical producers. However, for many of these countries petrochemical production **is** an appropriate technology. As a result of their aim to become world-class exporters of petrochemicals, Middle East manufacturers will remain strongly dependent on foreign expertise until the turn of the century. By working with foreigners and obtaining technology developed abroad, they should be able to achieve these goals.

Technology transfers to the Middle East will contribute to the growth of a major petrochemical export industry there. While it appears that U.S. producers will remain significant in most product areas, their exports will diminish as the new plants now under construction in the Middle East and elsewhere come on line. Because petrochemical production technology has become fairly standardized (with the exception of some catalysts), no one nation can maintain a position of clear leader as a supplier across the board. Technology transfer to Middle Eastern and other developing countries will increase regardless of the strategies adopted by specific U.S. firms.

From the perspective of U.S. policy makers, policy options to offset these trends are fairly limited. On the one hand, efforts to negotiate multinational agreements supporting free trade may help to stave off a protectionist backlash in Europe which could result in increased flows of product to the United States. On the other hand, policies designed to encourage R&D and expansion of the technical manpower pool may ease adjustment in the U.S. petrochemical industry as in other industries facing global trade restructuring.

APPENDIX 5A: PETROCHEMICAL PRODUCT USES[1]

At the heart of the petrochemical industry are key chemical "building blocks" (e.g., ethylene) that can be derived from the processing of natural gases or from byproducts of the oil refining process. Some building blocks can be produced from either source,

Oil refineries produce a range of produces including naphtha and gas oil which can be treated in plants known as crackers to produce building blocks such as ethylene, propylene, or butadiene (generically, these are called olefins). Naphtha can also be processed in a reformer to produce the major aromatic building blocks, benzene, toluene, and the xylenes. These building blocks can then be processed further to produce derivative products ranging from explosives to plastic films.

The problem with the refinery-based approach is that the more gasoline needed from a refinery, the less naphtha is produced; this, in turn, forces petrochemical producers to build expensive steam crackers to convert more difficult refinery byproducts, such as gas oil, into the desired building blocks.

In the case of olefins, it is possible to take the alternative route of using natural gas. Natural gas

[1] Based on the appendix of Louis Turner and James M. Bedore, Middle East industrialization— A *Study of Saudi and Iranian Downstream Investment*. Saxon House, 1980, pp. 203-206. Also see Dale F. Rudd, *Petrochemical Technology Assessment* (New York: Wylie Interscience, 1981).

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can be broken down into the simplest carbon molecules, C_1(methane), C_2(ethane), C_3(propane), and C, (butane). Methane can be further processed into products such as ammonia or methanol. The other three feedstocks can be turned into varying proportions of the olefin building blocks. (By weight, ethane yields 80 percent ethylene, while butane yields proportionally less ethylene and more propylene.)

Figure 5A-1 gives a simplified illustration of the various ways the basic building blocks of the petrochemical industry can be produced. It clearly shows that there is considerable flexibility in producing olefins. Much of the controversy about the comparative economics of producing these in the Middle East or in the industrialized world rests on the fact that one can start with either gas or crude oil. Typical end-uses of derivative chemicals produced from the main building blocks are:

1. Outlets for ethylene derivatives:
   - Polyethylene–films, moldings, pipes, cable covering, netting, etc.
   - Ethylene oxide—intermediate product in chain leading to antifreeze, polyester fibers (terylene) and detergents.
   - Styrene–polystyrene plastics and synthetic fibers.
   - Ethylene dichloride-step towards polyvinyl chloride (PVC) plastics, used for leathercloth, piping, guttering.
   - Other derivatives–ethyl alcohol and acetaldehyde,
2. Outlets for propylene derivatives:
   - Polypropylene- films, fibers, and plastic moldings.
   - Cumene–intermediate products for plastics, nylon, and solvents.
   - Acrylonitrile–base for acrylic fibers; used in chain leading to nylon.
   - Propylene oxide-intermediate for manufacture of plastic foam.
   - Other products are involved in detergent and resin manufacture.
3. Outlets for butadiene and other C_4 olefins:
   - Butadiene's derivatives are heavily used in synthetic rubber production.
   - Other end-uses of butadiene and the other C_4 olefins include solvents, sealing compounds and the raw material for nylon.
4. Outlets for aromatic derivatives:

Benzene—
   - Styrene (also from ethylene) —polystyrene plastics and synthetic rubber.
   - Phenol—intermediate for resins.
   - Cyclohexane-intermediate for nylon production.
   - Other products are used for detergents, dyestuffs and polyester glass-fiber plastics.

Toluene—
   - Derivatives used for plastic foams, resins, explosives (TNT), and paints.

Xylenes–
   - Derivatives used for paints, lacquers, insecticides, polyester fibers, and resins.

SPECIALTY CHEMICALS

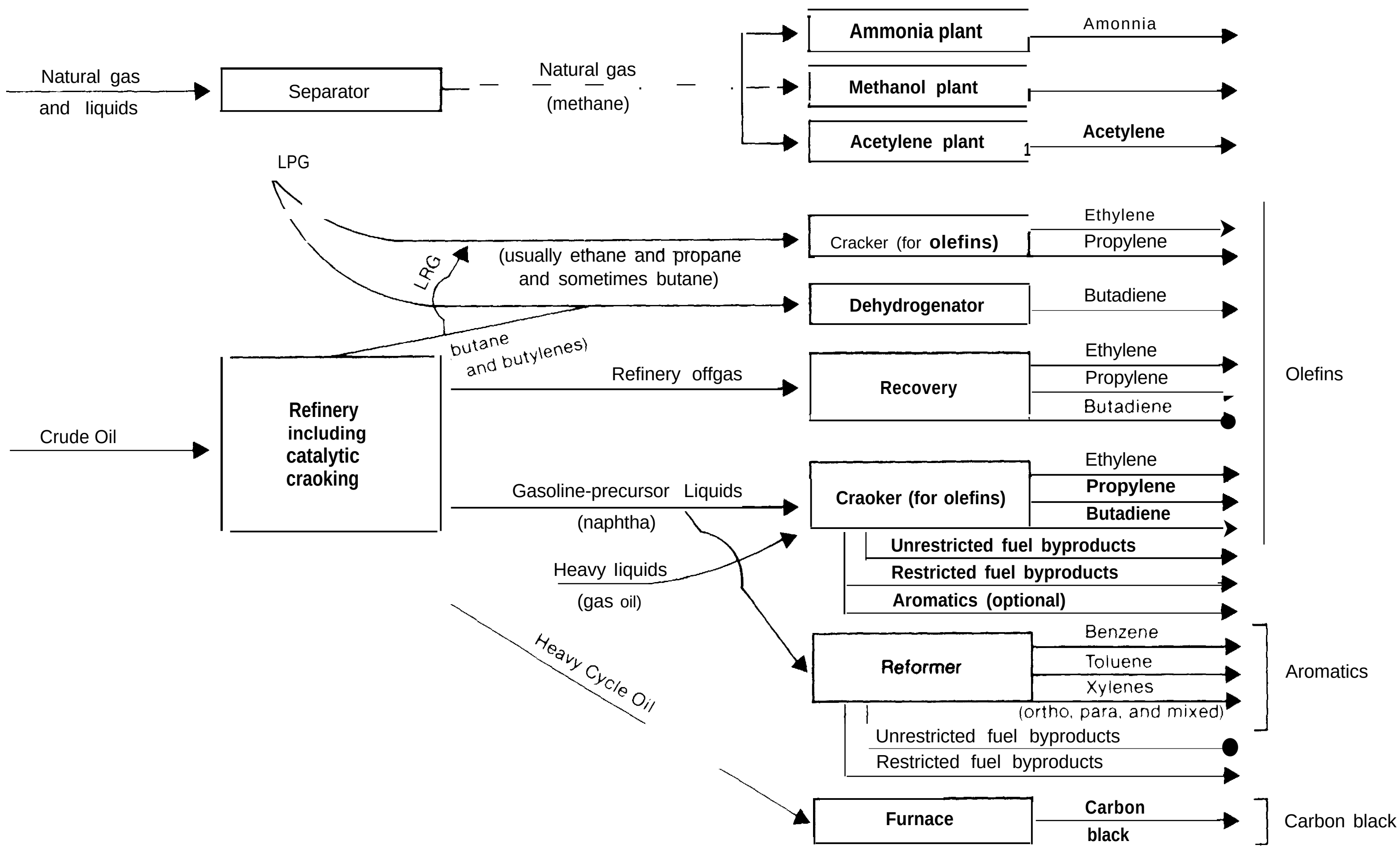
Specialty chemicals can be defined as small volume products, with a variable composition, that are sold to a performance specification. Examples include antioxidants and oil field chemicals. These types of chemicals have higher value added, and hence profit, than commodity chemicals for those companies that can produce them.[2] They are also generally identified by brand name and are often produced by proprietary processes. Due to competitive pressure facing commodity chemicals manufacturers from rising raw material costs, slower than expected growth in demand, and increasing competition from new export-oriented petrochemical plants, specialty chemicals have received renewed interest.

Specialty chemicals cannot, however, by themselves be the salvation of petrochemical companies forced out of the commodity chemical business due to competition. The changing environment of the petrochemical industry encourages a move toward the higher margins afforded by some specialty chemicals. In order to realize these margins in practice, however, there must be careful selection and promotion, and increased R&D funds generally are required.[3] In addition, it must be recognized that the cash flow associated with specialties will be small in comparison to commodities. If production of the specialty begins to reach substantial quantities, new producers can be expected to enter the market. Thus these low-volume, high value-added specialty chemicals are unlikely to be a complete answer to petrochemical industry problems, but if carefully selected can be a welcome addition to the companies' operations.

[2] See for example: Larry D. Rosenberg and Charles H. Kline, "Seeking Profits Downstream: The Lure of Specialty and Fine Chemicals, *Platts Petrochemical Conference*, Lausanne, Switzerland, May 12, 1981; **and** Peter B. Godfrey, "Specialty and Fine Chemicals: A Panacea for Profits?" *The Outlook for Petrochemicals–profiting in a Troubled World*, paper presented at a conference held by the Energy Bureau, Inc., Nov. 30—Dec. 1, 1982, Houston, Tex.

[3] "Specialties pOSe Problems, Challenges for Chemical Firms, *Chemical and Engineering News*, Apr. 23, 1984, pp. 8-9.

Figure 5A-1 .—Simplified Flow Diagram of Primary Petrochemical Production



APPENDIX 5B: PETROCHEMICAL PROJECT PROFILES

Table 5B-1 .—Saudi Arabia—Mobil Joint Venture

Venture name:	Saudi Yanbu Petrochemical Co. (Yanpet)
Products:	Ethylene; LLDPE; HDPE; ethylene glycol (EG)
Capacity:	Ethylene—455,000 metric tons LLDPE—205,000 metric tons HDPE—90,000 metric tons EG—220,000 metric tons
Location:	Yanbu
JV partners:	SABIC 50%; Mobil 50°/0
Financing:	Debt: 60% Saudi loan (preferred rates) . . . .$1,200 million 10% commercial loan (standard rates) ., ... 200 Equity: 15% Saudi . . . . 300 15% Mobil . . . . 300 Total . . . .$2,000 million
Structure:	• Standard Saudi Arabian agreement • Based on this project and the refinery project, Mobil will receive an estimated 1.4 billion barrels of crude over 15 years • Mobil is committed to market approximately 75 percent of products produced, while SABIC can market up to 25 percent. In the initial years Mobil is likely to market nearly all material produced • Mobil is responsible for technical, marketing, and management training
Project initiation:	1980. First study was conducted in 1976 with Mobil and Bechtel. The estimated value at that time was $817 million for the project, The study cost an estimated $10 m i I lion
Project startup:	1985
Major contracts:	Bechtel—Project management, construction, procurement. Also process engineering for LLDPE/HDPE Lummus— Design and engineering of ethylene facility and process license. Will also develop process simulators for training Union Carbide Corp.—LLDPE/HDPE license Scientific Design (SD)—EG license Halcon (SD subsidiary) -Process engineering of EG facility Belleli (Italy)—Construction of modular units under Bechtel contract
Target markets:	Japan, Southeast Asia, Western Europe, Africa, and miscellaneous other, Limited exports to the United States are possible in the late 1980's

SOURCE Office of Technology Assessment

Table 5B-2.—Saudi Arabia—Exxon Joint Venture

Venture name	Al-Jubail Petrochemical Co. (Kemya)
Product	Linear low-density polyethylene
Capacity	260,000 metric tons
Location	Al-Jubail
JV partners	SABIC 50%: Exxon 50%
Financing	Debt 60% Saudi loan (preferred rates) . . . .$ 780 million 10% commercial loan (standard rates) . . . . 130 Equity 15% Saudi . . . ., ... 195 15% Exxon . . 195 Total ... .$1-,300 million
Structure:	• Standard Saudi Arabian agreement • Exxon's crude entitlement is 405 million barrels over a 19-year period • Ethylene is received from Shell JV (Saudi P/C—SADAF), Total volume is approximately 260,000 metric tons • To avoid paying an ethylene transfer price to SADAF, Exxon payed for approximately 38 percent of the cost of the olefins cracker and support facilities. Since Exxon does not own a percentage of the facility, it is equivalent to paying for ethylene in advance, Once the facility comes on-stream, Exxon will pay for its proportionate share of operating costs. The rationale for this structure was the difficulty in finding a suitable benchmark mechanism for establishing an ethylene transfer price in Saudi Arabia • Exxon is responsible for all export sales, except for the surrounding region. SABIC would like to eventually assume the responsibility for 50 percent of all sales • Exxon is responsible for the technical and market training program
Project initiation:	1980, Preliminary study and discussions in 1977
Project startup:	Contingent on Shell startup, approximately 1985-86
Major contracts:	Fluor—Project management. construction and procurement Union Carbide Corp.—LLDPE/HDPE license Daewdo Shipbuilding (South Korea)—Modules, under Fluor contract
Target markets:	East Asia, Western Europe, Africa, and miscellaneous other

SOURCE Office of Technology Assessment

Table 5B.3.—Saudi Arabia—Mitsubishi Joint Venture

Venture name:	Saudi Methanol Co. (SAMCO)
Product:	Methanol
Capacity:	600,000 metric tons
Location:	Al-Jubail
JV partners:	SABIC 50%; Japanese Consortium (JSAMC)—50%
JSAMC partners:	Mitsubishi Gas Chemical—40% of JSAMC Japan Overseas Economic Cooperation Fund—40% of JSAMC Sumitomo Chemical–5% of JSAMC Mitsui Toatsu—5% of JSAMC Kyowa Gas, Chemical—5% of JSAMC C. Itoh—5% of JSAMC
Financing:	Debt: 60% Saudi loan (preferred rates) ... ...$161 million 10% commercial loan (standard rates) . . . . 27 Equity: 15% Saudi . . . . , ... 40 15% JSAMC . . . . 40 Total . . . .$268 million The total cost of this project when completed in 1983 was estimated to be $500 million
Structure:	• Standard Saudi Arabian agreement • Japanese Government uses the Overseas Economic Cooperation Fund (OECF) to support the joint venture. OECF's **$14** million project loan was instrumental in securing this venture as well as additional oil supplies, The exact amount of crude entitlement is not known but is estimated at approximately 20 million barrels per day over a 15-year period
Project initiation:	1979
Project startup:	1983
Major contracts:	Chem Systems—Advisors to SABIC on project definition and process design Mitsubishi Heavy Industries—Project management, construction (built modules in Japan) and procurement Mitsubishi Gas Chemicals—Process license, design, and engineering
Target markets:	Japan, East Asia, and miscellaneous other

SOURCE Off Ice of Technology Assessment

Table 5B-4.—Kuwait Petrochemical Project

Venture name:	PIC Petrochemicals
Products:	Olefins and derivatives; possibility of aromatics derivatives
Capacity:	Products under consideration are: ● Primary products: ● —Ethylene—350,000 metric tons per year —LLDPE—165,000 metric tons per year —Ethylene glycol—135,000 metric tons per year —Styrene—340,000 metric tons per year —Benzene—280,000 metric tons per year (for styrene production) ● Secondary (speculative) products: —o-Xylene—60,000 metric tons per year —p-Xylene—90,000 metric tons per year
Location:	Shuaiba
JV partners:	None intended at present, earlier proposals included BASF (LDPE) and W. R. Grace (aromatics). Hoechst would be a logical choice
Financing:	Would likely be internally financed. Total value $1.3 billion
Structure:	Intended ownership (100 percent) Petrochemical Industries Co. KSC (PIC), a wholly owned subsidiary of Kuwait Petroleum Co. (KPC). The latter is a state-owned holding company
Project initiation:	Feasibility study for olefins and derivatives undertaken in 1976-77 by Chem Systems
Project startup:	Not yet fully committed. Likely start up in late 1980's
Major contracts:	Chem Systems—Feasibility study, 1976; market study, 1982 C. F. Braun[a]—Preliminary engineering 1981-82
Target markets:	East Asia, Western Europe, and miscellaneous other. Potential exports to the United States

[a]C. F. Braun is controlled by KPC, being a subsidiary of Santa Fe Corp., recently acquired by KPC.

SOURCE Off Ice of Technology Assessment

Table 5B-5.—Qatar—CdF Chimie Joint Venture

Venture name:	Qatar Petrochemical Co. (QAPCO)
Product:	Ethylene/LDPE
Capacity:	Ethylene—280,000 metric tons LDPE—150,000 metric tons
Location:	Umm Said
JV partners:	CdF Chimie—16%; QGCP—84%
Financing:	Total value $600 million. Exact structure or payments by CdF not known due to complexity of associated agreements. However, general structure is an 85/15 debt/equity arrangement. Euroloans were once associated with the project, but later assumed by Qatar Debt: 50% French credits (@ 8.25%) . . . .$300 million 35% Qatar loans (preferred rates). . . . . 210 Equity: 13% Qatar, ... 76 2% CdF Chimie , ., ... 14 Total . . . . , ...$600 million
Structure:	• Project was conceived as a back-to-back deal following 60-40 JV with CdF Chimie and Qatar in Dunkirk, France. Capacity at Dunkirk is 225,000 metric tons ethylene and 150,000 metric tons LDPE. The JV was French-Government promoted to foster "French Arab Cooperation' and the recycling o f petrodollars. The Dunkirk startup was in 1978 • CdF will manage Qatar facilities and be responsible for marketing. Revenues will be earned on a commission basis. Sales offices have been set up in Hong Kong, Singapore, and Bangkok
Project initiation:	1977
Project startup:	1980
Major contracts:	Chem Systems—Prefeasibility of Qatar Project; Assessment of Dunkirk **Facility** Technip (France)—Construction of ethylene cracker Coppee Rust (Belgium)—Construction of LDPE plant (stamicarbon process) Turbotechnica—Supply to 50-MW power station CdF Chimie—Supply LDPE technology and overall project responsibility
Target markets:	Middle East and Southeast Asia

SOURCE Off Ice of Technology Assessment

Table 5B-6.—Bahrain

Venture name:	Gulf Petrochemical Co. (GPCO)
Product:	Methanol/ammonia
Capacity:	Methanol—270,000 metric tons per year Ammonia—270,000 metric tons per year
Location:	Sitra island (artificial island)
JV partners:	BANOCO (Bahrain National Oil Co.)/PIC/SABIC—equal ownership
Financing:	Debt: Arab Consortium (85%; soft terms) . . . .$300 million Equity: (15%) ., ... 50 Total . . . . , ... , ...$350 million
Project initiation:	1980-81
Project startup:	1984-85
Major contracts:	Snamprogetti — Engineering services and construction, detailed engineering, equipment procurement, construction Uhde—Responsible for licensing ammonia technology and Uhde/lCl methanol technology King Wilkinson—Engineering and construction advisors Wimpy Labs (UK)—Site survey and sales analysis Cowiconsult (UK)—Project site consultants
Target markets:	China and Southeast Asia

SOURCE Office of Technology Assessment

Table 5B.7.—Algeria—Sonatrach Ammonia (Arzew)

Venture name:	Sonatrach
Product:	Ammonia
Capacity:	272,000 metric tons
Location:	Arzew
JV partners:	None
Financing:	International commercial rate; total value estimated at $150 million as compared to the 1976 estimate of approximately $100 million to $115 million
Project initiation:	1976
Project startup:	1981
Major contracts:	Creusôt-Loire (CLE)—Project management, installation Pullman Kellogg—Design, engineering, and training prior to startup; operating and training contract since startup Chem Systems–Technical advisors through 1978
Target markets:	Domestic consumption and incremental exports

SOURCE: Office of Technology Assessment.

Table 5B-8.—Algeria—Sonatrach LNG #2 (Arzew)

Venture name:	Sonatrach	
Capacity:	1 billion scfd of gas	
Location:	Arzew	
JV partners:	None	
Financing:	Local commercial financing	$ 300 million
	Foreign government financing:	
	Canada	125
	U.S. Ex-Im Bank	350
	Japanese Government financing	350
	Belgium/Holland financing	100
	Total	$1,225 million
Structure:	Foreign government loans tend to be tied to procurement from those nations. The United States does not maintain this type of policy. However, the United States requires 50°/0 of the value of its loan shipped on U.S. flag ships	
Project initiation:	1976	
Project startup:	1981	
Major contracts:	Kellogg—Project management, design/engineering, and construction	
Target markets:	United States and Western Europe	

SOURCE: Office of Technology Assessment

APPENDIX 5C: PETROCHEMICAL PRODUCT DEMAND PROJECTION

Table SC-1 .—Free World LDPE Demand (thousand metric tons)

	1981	1985	1990	Compound annual growth rate, % 1981-90
Western Europe	3,450	3,930	4,330	2.6
North America:				
United States	2,985	3,930	4,985	5.9
Canada	345	450	575	5.8
Japan	920	1,170	1,440	51
Pacific Basin and Indian Subcontinent	721	1,083	1,537	8.8
Latin America	850	1,165	1,768	8.6
Africa	304	397	563	7.1
Middle East	229	300	418	6.9
Total	9,804	‘12,425	15,616	5 . 3 (average)

SOURCE Offlce of Technology Assessment

Table 5C-2.—Canadian and Middle Eastern LDPE/LLDPE Export Mix, 1990 (percent)

	Middle East	Canada
United States	N	N
Western Europe	10-15	—
Japan/East Asia	45	60
Other	38-40	40
Total	100	100

N = negligible

SOURCE Office of Technology Assessment

Table 5C-3.—U.S. Demand for LDPE/LLDPE (thousand metric tons)

	1980	1981	1985	1990	Compound annual growth rate, % 1981-90
Film and sheet	1,824	1,856	2,365	2,996	4.9
Injection molding	235	238	390	490	6.2
Extrusion molding	235	256	270	280	1.0
Wire and cable	152	157	235	295	57
Other	414	478	670	925	6.3
Total	2,860	2,985	3,930	4,985	5.1 (average)

SOURCE Office of Technology Assessment

Table 5C-4.— Free World HDPE Demand (thousand metric tons)

	1980	1981	1985	1990	Compound annual growth rate, % 1980-90
Western Europe	1,424	1,450	1,700	2,000	3.6
North America:					
United States	1,720	1,880	2,960	4,165	9.2
Canada	177	186	270	390	8.6
Japan	543	507	755	920	6.8
Pacific Basin	392	384	648	994	11.1
Latin America	383	374	578	872	9.9
Africa	169	165	258	431	11.3
Middle East	80	87	135	180	8.4
Total	4,888	5,033	7,304	9,952	7.9

SOURCE Office of Technology Assessment

Table 5C-5.—U.S. High-Density Polyethylene Demand (thousand metric tons)

	1980	1981	1985	1990	Compound annual growth rate, % 1981-90
Blow molding	733	781	1,175	1,645	8.6
Injection molding	425	457	685	885	7,6
pipe and conduit	175	194	355	465	10.2
Film and sheet	136	170	280	530	13.5
Wire and cable	48	50	80	115	9.7
Other	201	227	385	525	9.8
Domestic demand	1,718	1,879	2,960	4,165	9.3 (average)

SOURCE Office of Technology Assessment

Table 5C-6.—Free World Ethylene Glycol Demand (thousand metric tons)

	1981	1985	1990	Compound annual growth rate, % 1981-90
Western Europe	690	735	805	1.7
North America:				
United States	1,779	2,075	2,545	4.1
Canada	136	143	165	2.2
Japan	400	495	575	4.1
Pacific Basin	370	517	720	7.7
Latin America	164	258	381	9.8
Africa	34	72	127	15.8
Middle East	35	62	94	11.6
Total	3,608	4,357	5,412	4.6 (average)

SOURCE: Office of Technology Assessment

Table 5C-7.—Projected Canadian and Middle Eastern Export Mix, 1990 (percent)

	Middle East	Canada
United States	N	23
West European	33	—
Japan/East Asia	45	45
Other	22	32
Total	100	100

N = negligible

SOURCE Office of Technology Assessment

Table 5C-8.—United States Ethylene Glycol Demand (thousand metric tons)

	1980	1981	1985	1990	Compound annual growth rate, % 1981-90
Antifreeze	769	733	800	’895	2.2
Polyester fibers	760	796	905	1,075	3,4
Polyester film	67	65	90	130	8.0
PET bottle resins	58	68	140	260	16.1
Other	122	116	140	185	5.3
Total	1,776	1,778	2,075	2,545	4.1 (average)

SOURCE Office of Technology Assessment

Table 5C-9.—Free World Styrene Demand (thousand metric tons)

	1981	1985	1990	Compound annual growth rate, % 1981-90
Western Europe	2,500	2,600	2,700	0.9
North America:				
United States	2,647	3,175	3,830	4,2
Canada	219	280	360	5.7
Japan	1,256	1,495	1,785	4.0
Pacific Basin	413	615	858	8.5
Latin America	384	606	880	9.7
Africa	34	47	70	8.4
Middle East	23	30	35	4.8
Total	7,476	8,848	10,518	3.9 (average)

SOURCE Office of Technology Assessment

Table 5C-10.—Projected Middle Eastern and Canadian Styrene Export Mix (percent)

	Middle East	Canada	United States
United States	—	—	—
Europe	30	—	—
Japan/East Asia	60	100	50
Other	10	—	50

SOURCE Office of Technology Assessment

Table 5C-11.—U.S. Demand for Styrene (thousand metric tons)

	1980	1981	1985	1990	Compound annual growth rate, % 1981-90
Polystyrene	1,595	1,633	1,970	2,320	4.0
SBR/SBR latex	254	238	265	290	2.2
ABS resins	238	234	285	375	5.4
SB latex	168	177	215	255	4.1
Polyesters	150	169	205	285	6.0
SAN resins	37	38	45	50	3.1
Other	152	158	190	255	5.5
Total	2,594	2,647	3,175	3,830	4.2 (average)

SOURCE: Office of Technology Assessment.

Table 5C-12.—Global Methanol Demand (thousand metric tons)

	1981	1985	1990	Compound annual growth rate, % 1981-90
North America:				
United States	3,510	5,025	7,170	8.3
Canada	240	290	580	10.3
Eastern Europe	2,600	3,300	4,100	5.2
Western Europe	3,060	3,990	4,905	5.4
Japan	1,060	1,430	2,370	9.4
ASEAN Group	85	137	205	10.3
Australia New Zealand	63	525	1,580	43.1
Other Asian	378	600	800	8.7
Mexico	145	200	720	19.5
Central and South America	205	303	422	8.4
Middle East/Africa	85	120	815	28.6
Other	80	128	200	10,7
Total	11,511	16,048	23,867	8.4 (average)

SOURCE: Office of Technology Assessment.

Table 5C-13.—Global Methanol Market by End Use, 1981 (thousand metric tons)

Chemical applications	11,061
MTBE	350
Gasoline blending	390
Power generation	10
Total	11,811

SOURCE Office of Technology Assessment

Table 5C-14.— Global Methanol Supply/Demand Balance[a] (thousand metric tons)

	1981	1985	1990
North America:			
United States.	300	155	**(1,400)**
Canada	200	1,370	**1,440**
Eastern Europe	100	600	**800**
Western Europe	(580)	(1,740)	**(3,105)**
Japan	(326)	(1,030)	**(1,970)**
ASEAN	(55)	723	**1,225**
Australia/New Zealand	(63)	230	**320**
Other Asian	(121)	(505)	**(600)**
Mexico	35	0	**810**
Central and South America.	(75)	32	**233**
Middle East/Africa	345	1,200	**2,065**
Other,	(80)	(128)	**(200)**
Total	(320)	907	(382)

[a]Due to timing uncertainties associated with the growth in net demand, no attempt was made to zero balance trade as was the case with other products in this study Parentheses Indicate net Imports.

SOURCE Office of Technology Assessment

Table 5C-15.—United States Methanol Demand (thousand metric tons)

	1980	1981	1985	1990	Compound annual growth rate, % 1981-90
Applications:					
Formaldehyde	1,280	1,290	1,630	1,880	4.3
Dimethyl terephthalate	147	145	160	160	1.1
Methyl halides	238	240	335	405	6.0
Methylamines	168	165	195	228	3.7
Methyl methacrylate	153	150	222	310	8.4
Solvents	315	320	395	485	4.7
Miscellaneous	267	500	638	847	6.0
Subtotal	2,568	2,810	3,575	4,315	4.9
Emerging applications:					
Acetic acid	315	420	450	700	5.8
MTBE	165	150	450	555	15.7
Gasoline	90	120	500	1,300	30.3
Power Generation	15	10	50	300	45.6
Subtotal	585	700	1,450	2,855	16,9
Total demand	3,153	3,510	5,025	7,170	8.3

SOURCE Office of Technology Assessment

Table 5C-16.—Global Fertilizer Demand (thousand metric tons)

	1979-80	1984-85	1989-90	Compound annual growth rate, % 1980-90
Asia/Oceania	3,8	4.9	5.9	3.9
Indian Subcontinent	4.8	7.8	11.4	7.2
People's Republic of China	7.0	9.7	13.2	5.7
United States	9.9	11.8	13.3	2.1
Canada	0.7	1.0	1.2	3.9
Latin America	2.8	4.5	6.3	6.9
Middle East	1.2	1.5	2.0	5.6
Africa	1.5	2.2	3.0	6.2
Western Europe	9.2	10.4	11.8	2.1
Eastern Europe	13.3	16.0	19.0	3.6
Total,	54.2	69.8	87.1	4.3

SOURCE Office of Technology Assessment

Table 5C-17.—Global Ammonia Demand (thousand metric tons)

	1979-80	1984-85	1989-90	Compound annual growth rate, % 1980-90
Asia/Oceania	5.4	6.5	7.7	3.1
Indian Subcontinent	2.9	6.4	10.0	9.6
People's Republic of China	6.3	8.7	12.7	6.5
United States	15.1	15.2	17.0	1.2
Canada	1.5	1,8	2.3	3.9
Latin America	2.0	4.4	6.5	9.2
Middle East	1.4	2.2	3.2	8.5
Africa	1.0	2.1	3.1	11.2
Western Europe	13.7	14.6	16.4	1.8
Eastern Europe	19.4	25.3	29.6	3.8
Total	68.7	87.2	108.5	4.1

SOURCE Office of Technology Assessment

Table 5C-18.—U.S. Ammonia Demand (thousand metric tons N)

	1978-79	1979-80	1984-85	1989-90
Synthetic fertilizer production	10,906	12,015	11,235	12,330
Ammonia demand:				
Fertilizers	11,260	12,175	11,580	12,720
Industrial demand	3,060	2,940	3,690	4,315
Total	14,320	15,115	15,270	17,035

SOURCE" Office of Technology Assessment.

Table 5C-19.—U.S. Nitrogen Imports, 1979.80

Country	Metric tons
Canada	847
U.S.S.R.	689
Mexico	286
Trinidad/Tobaga	276

SOURCE. Office of Technology Assessment

APPENDIX 5D: REFINING CAPACITY IN THE MIDDLE EAST

The close relationship which exists between petrochemical production and refinery product mix makes the status of Middle Eastern refining capacity and future plans important.[1]

Surplus capacities and low operating rates have resulted in poor profitability in the world refining industry in recent years. Despite this, plans for construction of new distillation capacity in the Middle East have continued unabated through the late 1970's and into the 1980's. At the end of 1981, plans were announced for new projects that would increase world crude distillation capacity by approximately 10 million barrels per calendar day (mmb/cd) or 12 percent over current capacity. In view of small predicted growth in demand and a current world overcapacity in excess of 20 mmb/cd, if these were to be completed, the world surplus would surpass ***30*** mmb/cd, for a surplus of ***50*** percent. The fact that capacity is planned does not, of course, mean that it will actually be built. Fesharaki[2] predicts that as much as ***7.6*** mmb/cd will come onstream, with 60 percent of this likely increase coming from major crude oil exporters—OPEC, Mexico, and Egypt. About half of the planned capacity increase in OPEC nations is already under construction, while most of the other OPEC projects planned for the mid-1980's have already gone through the feasibility and engineering stages.

There are several reasons for OPEC nations to push ahead with downstream processing. Four of them, however, may ensure their aggressive pursuit of oil refining as a downstream operation. These are: 1) limited alternative development opportunities within many OPEC nations; 2) massive amounts of capital can be channeled into these prestigious and visible investments without contributing significantly to inflation in the domestic economy; 3) OPEC nationals have already achieved considerable experience and success in the hydrocarbon sector; and 4) these countries hope to capture a major share of the world market. Table 5D-1 shows present and planned refining capacities in OPEC and the Gulf through 1986. More than a 50-percent increase in OPEC capacity is planned for the mid-1980's.

Kuwait Petroleum Corp. (KPC) has acquired West European firms such as Gulf Italiana SPA, allowing it to market oil output in the form of products rather than crude oil. The goal of the strategy is to obtain the maximum value-added. It was reported that in December 1983, 118,000 b/d were sold by KPC and its subsidiaries in Europe, where the firm sells under the Gulf brand name. During the **12** months ending in September 1983, Kuwait sold 5 million tonnes of refined products in Europe, considerably less than Algeria (7.75m) or the Soviet Union (32.5m).[3]

[1] Material in this appendix comes from F. Fesharaki and D. T. Isaak, *OPEC, the Gulf, and the World Petroleum Market*, 1983; "Chapter 2 — The Refining Industry," *Competitive Economics of United States and Foreign Refining*, prepared for the U.S. Department of Energy by the PACE Co. Consultants and Engineers, Inc., Houston, Tex., December 1979 Section C and E; National Petroleum Council, Committee on Refinery Flexibility, *Refinery Flexibility*, December 1980, "Chapter 3 — Competitive Position of Various Segments of the U.S. Refining Industry"; "Chapter 1 — Competitive Economics of Supplying Incremental U.S. East Coast Product Demand From Domestic Refineries and Foreign Export Refineries." See also Nigel Harvey, "What Future for Arab Refiners?," *Middle East Economic Digest*, Feb 3, 1984, pp. 20-22, and John Tagliabue, "Europe's Worried Refiners," *The New York Times*, May 1, 1984, p. D1.

[2] Ibid, p 86.

[3] See Richard Johns, "Kuwait Takes Up Gulf Oil's European Mantle," *Financial Times* (London), Feb 1, 1984, p. 11.

Table SD-1 .–Current and Projected Refining Capacity in OPEC and the Gulf, 1981-86 (thousands of barrels per calendar day)

	1981	(+) Under construction	(+) Additional planned	(=) 1986
Iran [b]	1,235	—	—	1,235
Iraq [b]	249	140	—	389
Kuwait	554	58	154	766
Qatar	14	47	—	61
Saudi Arabia [c]	787	734	466	1,987
UAE	126	56	172	354
OPEC Gulf	2,965	1,035	792	4,792
Algeria	442	—	344	786
Ecuador	87	—	108	195
Gabon	20	—	—	20
Indonesia	486	196	265	937
Libya	142	220	—	362
Nigeria	260	—	—	260
Venezuela	1,349	—	150	1,499
Other OPEC	2,786	406	867	4,059
Total OPEC	5,751	1,441	1,659	8,851
Bahrain	274	—	—	274
Oman	47	—	—	47
Other Gulf	321	—	—	321
Total OPEC and Gulf	6,072	1,441	1,659	9,102

[a] As discussed in the text, plans exist for refining additions beyond those shown in this table; some are spurious some speculative and others fairly clearly planned, but for the post-1986 period.

[b] The situation in Iran and Iraq is confused. The extent of the war damage is not clear. Moreover, both countries had completed new capacity on the eve of the war and both had plans to scrap someoutmoded capacity These capacity estimates should be treated with circumspection

[c] Saudi Arabia Includes Neutral Zone refining of 80 rob/cd

SOURCE: Fesharaki, 1983