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PROJECT PROFILE FOR THE ESTABLISHMENT OF POLYOL PRODUCTION PLANTS IN THE ARAB WORLD*

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* The views expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. Mention of firm names and commercial products does not imply the endorsement of UNIDO. This document has not been edited.

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POLYOL

INTRODUCTION

Polyol is one of the main two basic raw materials needed to manufacture polyurethane which has gained and continues to command international industrial importance. This is because of the versatility of polyurethane in the production of various end products for different applications.

The rapid growth of the polyurethane foam started around the fifties at a time when polyesters were dominating the market. During the late fifties, the lower cost and more hydrolysis resistant polyethers started to gain a strong foothold in the commercial production of polyurethane as they helped in producing a more uniform polymer structur when compared with polyesters.

Polyurethane may be classified in accordance with its applications as follows:

1. Flexible Polyurethane Foam

   This is considered one of the most important polyurethane types as it is generally consumed in cushioning applications in furniture, transportation (vehicles and railway carriages), and beddings as well as in carpet underlay and other products.

2. Rigid Polyurethane Foam

   This is an important type of polyurethane as it is used in various applications such as construction refrigeration, industrial insulations, transportation, packaging and other uses.

3. Nonfoam Urethanes

This type is generally consumed in a variety of end uses such as surface coatings, elastomers, adhesives and sealants, shoe soles and other applications.

Most of the polyols used in the polyurethane manufacture fall into two classes:

1. Hydroxyl terminated polyethers which are used to manufacture the flexible polyurethane foam.
2. Hydroxyl terminated polyesters which are used to manufacture the rigid polyurethane foam.

The molecular weight and functionality of the polyol are the main factors in determining the properties of the final polyurethane polymers even though the structure of the polyol chains also plays a prominant role in this matter. These factors are characterized as indicated in Table 1:

Table 1: Polyols for Polyurethane Manufacture*

Characteristic	Flexible Foams & Elastomers	Rigid Foams, Rigid Plastics, Stiff Coating
Molecular Weight Range	1000 - 6500	150 - 1600
Functionality Range	2.3 - 3.0	3 - 8
Hydroxyl Value Range	28 - 160	200 - 1000

*Woods, G., The ICI Polyurethane Book, John Wiley, NY,1987.

The polyether polyols have about 90% share as opposed to the 10% share for the polyester polyols in the polyurethane manufacture. In 1987, the world nameplate production capacity of the polyether polyol reached over 2.7 millon tons per year. The international average growth rate of these polyols, which basically corresponds to the polyurethane rate is forecasted to range between 1.6 - 2.5 % per year during the nineties.

Different studies prepared by Arab industrial organizations indicate the availability of a sizeable Arab market for the production and consumption of both the flexible and the rigid polyurethane foam. The Arab polyurethane annual growth rate is forecasted to be much higher than the international figures. It is believed that almost every Arab country has at least one plant producing the polyurethane end products with all the required feedstocks being imported from other producing countries.

It is clear from the above that there is a need to explore the possibility of establishing economically viable plants to produce the polyurethane foam and the basic raw materials needed for the production of this foam. These raw materials include toluene diisocyanate (TDI), methylene diphenyl diisocyanate (MDI), and polyols. TDI and polyol are normally used to produce the flexible foam while the MDI is used to produce the rigid foam. Basically, the Arab oil producing countries have the necessary feedstocks needed for the production of these raw materials.

The object of this study is to prepare a Project Profile for the production of polyether polyol in the Arab countries. The proposed production capacity will be tailored so as to satisfy the Arab consumption requirements provided this capacity is in line with the minimum ecomomic capacity for similar plants. In addition, the raw materials (propylene oxide and propylene glycol) needed to produce the polyether polyol will also be briefly discussed with emphasis on the manufacturing processes and on estimation of fixed capital needed to establish such plants in the Arab countries.

WORLD DEMAND/SUPPLY

The consummption and production of polyether polyol in the major producing regions are estimated as tabulated in Table 2:

Table 2: Production and Consumption of Polyether Polyol in the Major Producing Regions - 1986 * (ooo'MT)

Production	Flexible Foam	Rigid Foam	Nonfoam
United States	456	66	76
Western Europe	352	224	88
Japan	112	30	68
Total	920	320	232
Consumption			
United States	380	62	72
Western Europe	298	202	86
Japan	92	28	68
Total	870	292	226

*Survey of Technical and Petrochemical Marketing Literature e.g. Oil and Gas Journal Data Book, 1987 Edition, Worldwide Petrochemical Survey, Tulsa and other related ones.

It should be noted that the international production capacity for polyether polyol exceeded 2.7 million tons per year. Both the United States of America and Western Europe take the leading role with almost equal production capacities; each exceeds 35% of the total world production.

The overall world capacity utilization In 1986 was less than 70% of the nameplate capacities. As such, with an estimated growth rate of 2%, there will be no need to build new plants in the major producing countries except possibly to replace depreciated ones. The extra available production capacity will satisfy the growth at least through the year 2000. Therefore, at present, only the countries (e.g. Arab oil producing states) which possess the basic raw materials with comparative cost advantage and have sufficiently high consumption should consider establishing new polyol plants.

In addition to the above, it is conceivable that the world consumption may be negatively affected by the following issues:

A. The possibility of adopting more stringent fire standards for flexible foam. The United Kingdom has already enacted such standards. If such regulations are decreed internationally, the annual world consumption will no doubt decrease.

B. The possibility of regulating the use of chlorofluorocarbon (CFC) as blowing agents for all polyurethanes.

Both of these factors will negatively affect the capacity utilization if internationally adopted.

Propylene Glycol, one of the raw materials, is an intermediate petrochemical which is consumed in various manufacturing operations. The largest end use is in the manufacturing of unsaturated polyester resins which account for approximately 50% of the domestic consumption in the industrialized regions. In addition, there are many other uses (e.g. antifreeze, solvent in food, drugs, cosmetic preparations .. etc.)

The world capacity for propylene glycol was estimated at more than 800 thousand metric tons in 1987. The three main industrial regions (the United States, Western Europe and Japan) dominate the production of this important intermediate petrochemical as they account for better than 90% of the world total production.

Propylene Oxide is also a very important petrochemical intermediate product as it is consumed in different industrial manufacturing applications. It is used as a raw material for polyurethane polyols as well as for other uses mainly in the production of propylene glycol.

The consumption of propylene oxide for the different end uses in the USA is tabulated in Table 3.

Table 3. Consumption of Propylene Oxide in the USA in 1982* (000'MT)

End Use	Tonnage	Ratio to Total%
Polyurethane	471	64.3
Propylene Glycol	158	21.5
Glycol Ether	12	1.6
Other Uses	93	12.7

*AIDO, Petrochemicals Study - Arab World, 1988.

Even though the figures in Table 3 are for 1982, yet the ratios for the various end uses did not change noticably during the last eight years. However, the total consumption in the United State has increased to slightly over one million tons in 1989.

The USA and Western Europe are the international leaders in the production of propylene oxide. The production in West Europe is nearly equal to that in the USA. Both of these regions account for over 80% of the world production which is estimated to be approaching 2.5 million tons per year.

ARAB WORLD DEMAND/SUPPLY

The Arab Demand/Supply forecast for polyol and its basic raw materials are tabulated in Table 4.

Table 4: Forecast for Arab Demand/Supply for Polyol and its Basic Raw Materials* (000'MT)

Product	1990		2000		2010	
	Demand	Supply	Demand	Supply	Demand	Supply
Polyol	52	(42)[a]	118	(108)		
Propylene Glycol	9-18	(9-18)	24-48			
Propylene Oxide	93	(93)	129		180	
yurethane (Flexible Foam)	87	(87)	196	(196)		

a ( )Deficit - Assuming the Saudi plant (10,000 MT/Y) is operating.
*AIDO, PETROCHEMICALS STUDY - Arab World, p. III-91, 1988

Table 4 with its indicated deficit points out the the need to establish a polyol plant to satisfy Arab requirements.

It has been reported that a 10,000 MT/year polyol plant is presently operating in Saudi Arabia. This amount has been included in Table 4 above. As such, the capacity of the proposed plant during the initial phase should be 40,000 metric tons/year.

It may be of interest to point out the following:

1. Libya has already two plants producing:

   a) 170,000 MT/Y of propylene

   b) 70,000 MT/Y of polypropylene

   This leaves an excess of about 100,000 MT/Y of propylene which maybe used to produce the propylene oxide.

2. It is reported that future petrochemical plans include the following:

   a) Iraq plans to produce 254,000 tons propylene per year and possibly some polyurethane.

   b) Saudi Arabia plans to produce 265,000 tons propylene per year.

   c) Kuwait plans to produce 80,000 MT propylene per year.

   d) Bahrain plans to establish a propylene oxide plant but its proposed capacity has not been reported.

Studies have been prepared by different Arab Consulting Organizations (e.g. Saudi Consulting House, Gulf Organization for Industrial Consulting, and the Arab Industrial Development Organization) to establish plants for the production of propylene, polypropylene, propylene oxide, polyol, TDI and/or polyurethane.

The Saudi Consulting House* suggested to establish an integrated petrochemical complex to produce propylene oxide, provlene glycol, polyol and propylene. In general, it is believed that such an integrated complex will enhance the economical viability when compared with the establishment of a project to produce only polyol. This should be confirmed by a feasibility study for such a petro- chemical complex.

POSSIBLE PLANT LOCATIONS

In general, the following factors must be considered in selecting the plant location:

1. Availability of infrastructure including services, roads, ports ...etc.
2. Availability of experienced manpower with reasonable cost.
3. Availability of raw materials with reasonable prices delivered to the plant.
4. Nature of site and its effect on cost of civil works.
5. Products' local consumption and export distribution costs.
6. Atmospheric and weather conditions which may affect the project.
7. Other related factors.

Because of the nature of this report, the above mentioned

*Saudi Consulting House/AIDO, Petrochemical Study, Arab World 1983. This study was updated by AIDO in 1988.

factors have not been studied in detail. This should be done in future studies for the project. But a quick review of these factors reveals that the plant could be located in several countries where the local consumption is relatively high and the basic raw materials (mainly propylene and/or propylene oxide) are already or will become available. Such countries include Iraq, Saudi Arabia, Bahrain, Kuwait and Libya. As mentioned previously, future petrochemical plans indicate that Iraq and Saudi Arabia each hope to produce over 250,000 tons yearly and Kuwait approximately 80,000 tons per year. At present, only Libya has a polypropylene plant producing 170,000 MT/Y. In addition, Bahrain is reported to be planning to produce propylene oxide.

In principle, any of these countries would be suitable for the plant location, but this must be confirmed by the appropriate future studies. Since Bahrain is the only state reported to be planning to produce propylene oxide, it will be considered in this project profile to be the plant site for the purpose of investigating the economic viability of the project.

TECHNICAL STUDY

In this section, the following will be discussed:

- Manufacturing Processes
- Raw Materials and Costs
- Process Utilities and Costs
- Manpower Requirements and Costs

I. Manufacturing Processes

Even though the object of this report is to prepare a Project Profile for the production of polyol, nonetheless the manufacturing processes for propylene oxide and propylene glycol will be briefly presented as follows:

I-A. Propylene Oxide Manufacturing Process

Almost all the propylene oxide is produced by the Chlorohydrin or the Hydroperoxide processes.* A broad outline of each process is given below.

a) Chlorohydrin Process

The chlorohydrin process is the older of the two and is based on reacting propylene with chlorine and water. This process was first used during World War I by BASF* and others. At present there are only two active plants in the United States which are operated by Dow Chemical Co. The chemical reaction for this process is indicated below:

$CH_3CH{=}CH_2$	+	$HOCl$	--->	$CH_3CH\text{-}CH_2$ OH Cl
propylene		hypochlorous acid		propylene chlorohydrin

$2CH_3CH\text{-}CH_2$ OH Cl	+	$Ca(OH)_2$	--->	$2CH_3CH\text{-}CH_2$ O	+	$CaCl_2$	+	$2H_2O$
propylene chlorohydrin		calcium hydroxide		propylene oxide		calcium chloride		

It is clear that the propylene reacts with the hypochlorous acid (consisting of water and chlorine) to first form the propylene chlorohydrin. This chlorohydrin is then

* -Kirk-Othmer, Encyclopedia of Chemical Technology, Vol. 19, p. 253, 1981.
-Other Technical sources.

treated with lime (or caustic soda) to yield the desired propylene oxide. A simplified flow sheet for the chlorohydrin process is presented in Figure 1.

Several modifications of the chlorohydrin processes have been proposed with the idea of minimizing the brine effluent and achieving continuous operation. Commercialization of such modifications is not well known. Nonetheless, Figure 2 presents a simplified flow sheet for the closed-loop chlorohydrin process which was developed by Lummas Industries. It intended to reduce the chlorine consumption and to minimize the brine solution.

b) Hydroperoxide Process

The hydroperoxide process which is referred to as the Oxirane process involves the use of organic hydroperoxide as an oxygen carrier to epoxidize propylene. It was develoooped by Halcon International and Atlantic Richfield Corporation. These two companies formed a third company, Oxirane, which carried out the commercial development of this pro- cess.

The epoxidation of propylene by an organic hydroperoxide is based on the following reaction:

$$RH + O_2 \text{ ---> } ROOH$$

$$ROOH + CH_3CH = CH_2 \text{ ---> } \underset{O}{CH_3CH - CH_2} + ROH$$

At present, ethylbenzene and isobutane are being used industrially as the main starting materials as indicated in the following chemical reactions:

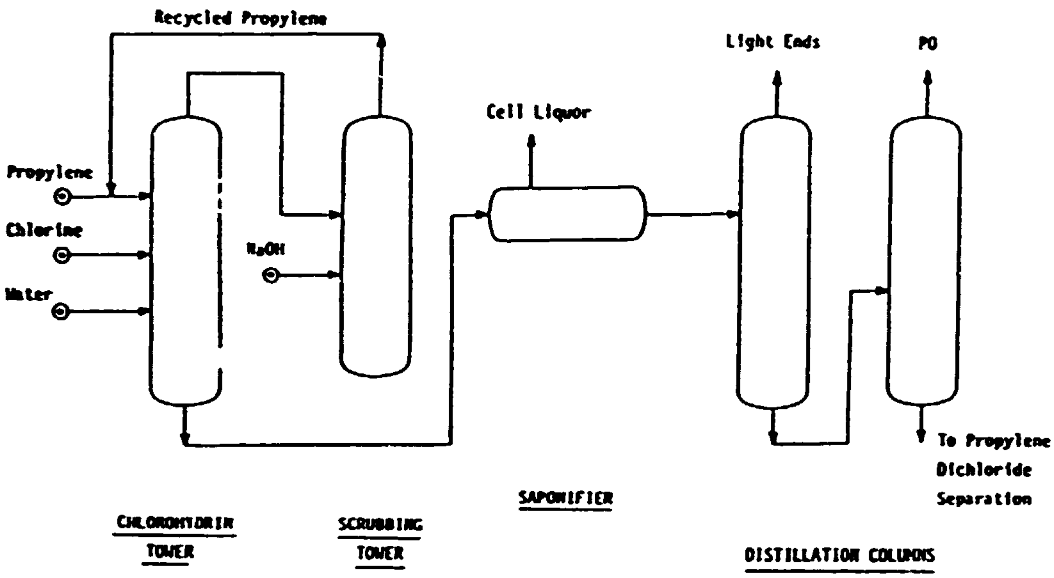

Figure 1. Chlorohydrin Process

Source: Chem.Systems "How to Start Manufacturing Industries" UNIDO, Vienna, Austria

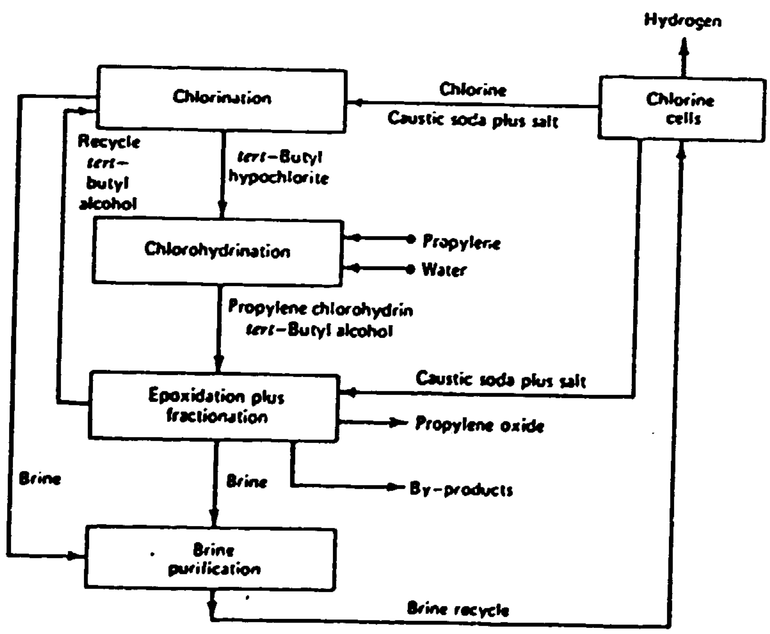

Figure 2. Lummas Hypochlorite Chlorohydrin Process.

Source: Kirk-Othmer, Encyclopedia of Chemical Technology, Vol. 19, p. 257

b-1) Ethylbenzene:

The chemical reaction for the process utilizing ethylbenzene is indicated as follows:

$$C_6H_5CH_2CH_3 + O_2 \longrightarrow C_6H_5CHOOHCH_3$$

ethylbenzene	oxygen	ethylbenzene hydroperoxide

$$C_6H_5CHOOHCH_3 + CH_3CH{=}CH_2 \longrightarrow CH_3\underset{O}{CH - CH_2} + C_6H_5CHOHCH_3$$

ethylbenzene hydroperoxide	propylene	propylene oxide	methyl phenyl carbinol

It should be noted that a large amount of methyl phenyl carbinol is produced as a by-product. This is normally dehydrated to produce styrene.

b-2) Isobutane

The chemical reaction for the process utilizing isobutane is as follows:

$$(CH_3)_2CHCH_3 + O_2 \longrightarrow (CH_3)_3C\text{-}O\text{-}OH + (CH_3)_3COH$$

isobutane	oxygen	tert-butyl hydroperoxid	tert-butyl alcohol

$$CH_3CH{=}CH_2 + (CH_3)_3C\text{-}O\text{-}OH \longrightarrow CH_3\underset{O}{CH\text{-}CH_2} + (CH_3)_3COH$$

propylene	tert-butyl hydroperoxide	propylene oxide	ter-butyl alcohol

Similar to the ethylbenzene process, tert-butyl alcohol is produced also in large quantities as a by-product. This is generally used as a solvent or is converted to methyl tert-butyl ether which is used to enrich the gasoline octane.

A simplified flow sheet of the ethylbenzene process with the production of styrene is presented in Figure 3.

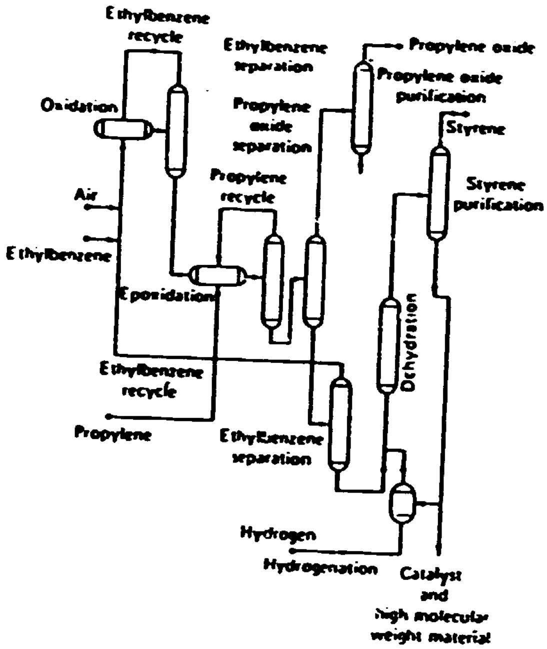

Figure 3. Propylene Oxide-Styrene Hydroperoxide Process
Source: Kirk-Othmer, Encyclopedia of Chem. Tech.,Vol. 19, p.260, 1981

Production of propylene oxide is carried out by two major producers who are utilizing the above mentioned technologies as indicated in Table 5.

It is obvious from Table 5 that propylene oxide is presently produced in the USA either by the chlorohydrin or the hydroperoxide (Oxirane) processes. But internationally the commercial production of propylene oxide by the chlorhydrine process still predominates. However, the Oxirane process is becoming increasingly important and has already captured

30% of the world production.*

Table 5. U.S. Propylene Oxide Capacities and Technology*

Producer	Location	Capacities (000'MT) 1979	Planned Increase	Technology
Dow	Freeport, Texas	436	364 by 1985	chlorohydrin
	Plaquemine, La.	155	45 by 1982	chlorohydrin
Oxirane	Bayport, Texas	398	45 by 1981	hydroperoxide, tert-butylcohol coproduct
	Channelview, Texas	180		hydroperoxide, styrene coproduct

*Kirk-Othmer, Encyclopedia of Chem.Technology, Vol. 19, pp. 261-263, 1981.

Fixed Investment-Production of Propylene Oxide

Estimation of the total fixed capital needed to establish a propylene oxide production plant in the Arab World will be based on the following:

1. Selection of the Hydroperoxide (Oxarine) Process
2. Capacity of 180,000 MT/Year
3. Use of ethylbenzene as the starting material
4. Estimate of Chem Systems "How to Start Manufacturing Industries". File G 64, UNIDO, Vienna.

The battery limits and the off-sites for a 180,000 MT/Y plant located at Benelux, W. Europe and adjusted to an Arab location are estimated as shown in Table 6.

It should be noted that the by-products which amount to better than twice the propylene oxide have a direct effect

*Oertl, G., "Polyurethane Handbook", p. 48, Hanser Publisher, Munich, Vienna, N.Y., 1985

Table 6: Fixed Capital Investment Estimate (000'US$)
Production of Propylene Oxide (180,000 MT/Y)

	Benelux, W. Europe	Location Factor	Estimated Arab Cost
Battery Limits	225,000	1.3	292,000
Off-Sites	90,000	1.3	117,000
Total	315,000		409,000

on the economics of the project. As such, it is important to first review the market for both the product and its by-products and then select the process accordingly.

I-B. Propylene Glycol Manufacturing Process

Propylene glycols include the following:

1. Monopropylene Glycol which is mainly used in the production of unsaturated polyester resins.
2. Dipropylene Glycol which is normally produced as a by-product in the production of monopropylene glycol. The commercial dipropylene glycol (a mixture of three isomers) is used in hydraulic fluid, cutting oil, textile lubricants, industrial soaps, as a solvent and as an indirect food additive.
3. Tripropylene Glycol which is also produced as a by-product in the production of monopropylene glycol. It is used in cleansing creams, textile soaps, lubricants and cutting oil concentrates.
4. Polypropylene Glycols which are low molecular weight liquids obtained from propylene oxide and

water or monopropylene glycol. They are used as rubber lubricants and mold-release agents, lubricants in metal rolling, drawing and machining, anti-foam agents...etc.

The propylene (monopropylene) glycol is produced by the propylene oxide hydration at 200°C and a pressure of 15 atmospheres in accordance with the following chemical reaction:

$$\underset{\text{O}}{H_2C\text{-}\overset{CH_3}{CH}} \quad + \quad H_2O \;\text{--->}\; HO\overset{CH_3}{CH}CH_2OH$$

propylene oxide propylene glycol

The plants producing propylene glycol are normally linked with partially captive propylene oxide. The hydrolysis takes place in two serially connected stirred reactors which are operated under a pressure of 15 atmospheres. The reaction is carried out without the use of a catalyst so as to avoid contaminating the reaction mixture. A typical flow sheet of the hydration process* is presented in Figure 4.

As stated above, the dipropylene, the tripropylene and minor quantities of higher glycols are produced as co-products. The proportion of the monopropylene glycol to the higher glycols is controlled by the molar ratio of water to the propylene oxide in the feed to the reactor. In order to maximize the monopropylene glycol production, a molar ratio of 15 to 1 water and oxide respectively will be maintained.

*Chem.System - How to start Manufacturing Industries, UNIDO; Vienna, Austria.

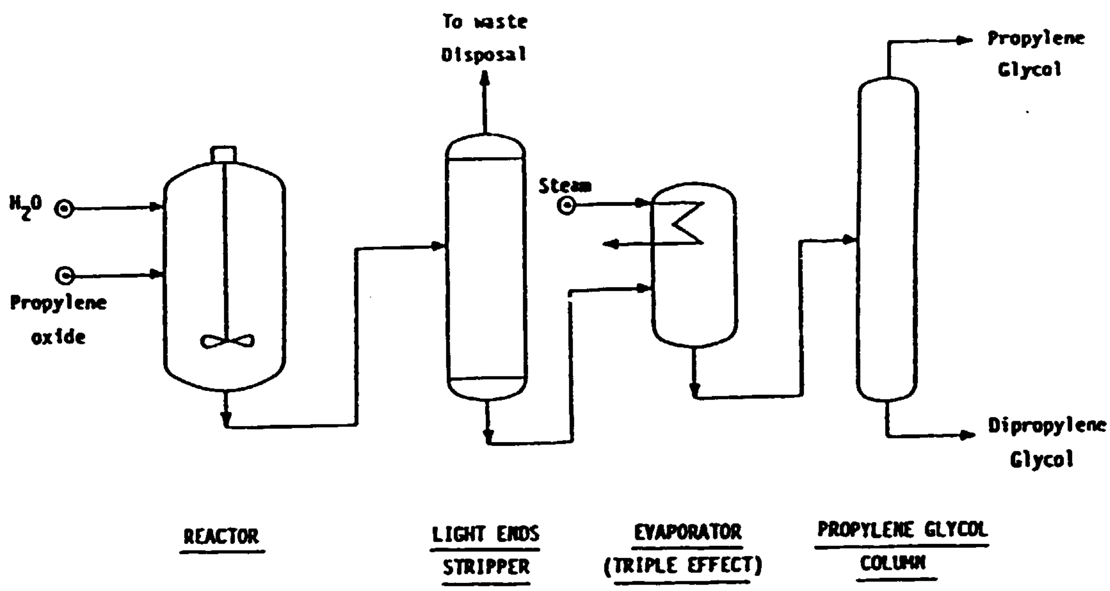

Figure 4. Flow Sheet - Propylene Oxide Hydration Process

With this molar ratio, for every ton of monopropylene glycol, an estimated 0.11 tons of dipropylene glycol and 0.01 tons of tripropylene glycol are also produced.

Fixed Investment - Production of Propylene Glycol

Estimation of the total fixed investment required to establish a plant to produce 50,000 metric tons of propylene glycol by the propylene oxide hydration process is based on the following:

1. Estimates of Chem Systems, "How to Start Manufacturing Industries" for a similar plant located in Benelux.
2. Use of a location factor 1.3 to adjust to an Arab location site.

The results are tabulated in Table 7:

Table 7: Capital Investment Estimate (000'S)
Production of Propylene Glycol (45,000 MT/Y)

		Benelux	Estimated Arab Cost
Battery Limits		8,400	10,920
Off-sites		3,380	4,400
	Total	11,780	15,320

I-C. Polyol Manufacturing Process

There are three groups of materials which are required for the production of polyether polyols*:

1. Oxygen containing ring compounds like epoxides or tetrahydrofuran:

   The most important epoxides are propylene and ethylene oxides. The tetrahydrofuran is of limited importance. The production of high quality polyethers is only possible when especially high requirements are set for the purity of the epoxides. This includes particularly the carbonyl, chlorine and water content.

2. Starter compounds with active hydrogens:

   Basically, all organic compounds with active hydrogen atoms are suitable. These compounds include propylene, diethylene and ethylene glycols. Water also belongs to this group; the epoxide first reacts

*Oertel,Gunter, "Polyurethane Handbook", p. 49, Hanser Publisher, Munich, Vienna, N.Y.,1985 with water to form a glycol which behaves as a starter compound. For the production of branched trifunctional polyethers, glycerine and trimethylolpropane are commercially accepted primary starters. The properties of typical commercial polyethers are presented in Table 8.

3. Ionic catalysts:

   For the commercial production, strong bases are almost exclusively being used as the catalysts in amounts ranging from 0.1 to 1.0% of the total feedstock charge. Generally, aqueous potassium hydroxide solution or solid potassium hydroxide is mixed with the starter alcohol.

Polyethers made from epoxides are produced worldwide according to the same basic process. The discontinuous batch plant is common practice. On the other hand, even though continuous processes have not gained international importance, yet it is reported that at least one manufacturer is using continuous processing for higher volume polyols. Figure 5 shows a flow sheet for the production process of polyether.

The production operation is represented by the simplified chemical reactions for the major polyurethane polyether polyols as illustrated below:

Polypropylene Glycol

CH_3		CH_3	base	CH_3 CH_3
$HOCHCH_2OH$	+	nH_2C-CH	------>	$HOCHCH_2(OCH_2CH)_nOH$
		O	catalyst	
propylene glycol		propylene oxide		polypropylene glycol (PPG)

Table 8: Properties of Typical Polyethers

Polyether-Type[a]	Type 1	Type 2	Type 3
Structure	Propylene glycol Propylene oxide	Trimethylol-propane Ethylene oxide Propylene oxide	Glycerin Propylene Oxide
Average molecular weight	2.000+100	4.800+300	3.000+200
Appearance	Clear, colorless slightly colored, low viscosity liquid	Same as 1	Same as 1
Hydroxyl number	56+3	35+2	56+3
Acid number	<0.1	<0.1	<0.1
Viscosity at 25°C in mPa.s	250 to 350	750 to 900	450 to 550
Water content in %	<0.1	<0.1	<0.1
pH	6.5 to 8.0	6.5 to 8.0	6.5 to 8.0
Density in g/cm³	1.00	1.02	1.01
Pour point in °C	-36	-38	-31
Flash point in °C (DIN 51758)	>100	>100	>100
Average specific heat in cal/g/K	0.48	0.47	0.47
Thermal conductivity in kcal/m/h/K	0.13	0.13	0.12
Ash in %	<0.05	<0.05	<0.05
Peroxide content (in ppm, calculated as H_2O_2)	<8	<8	<8

[a] Polyether-types are commercial products from Bayer AG.

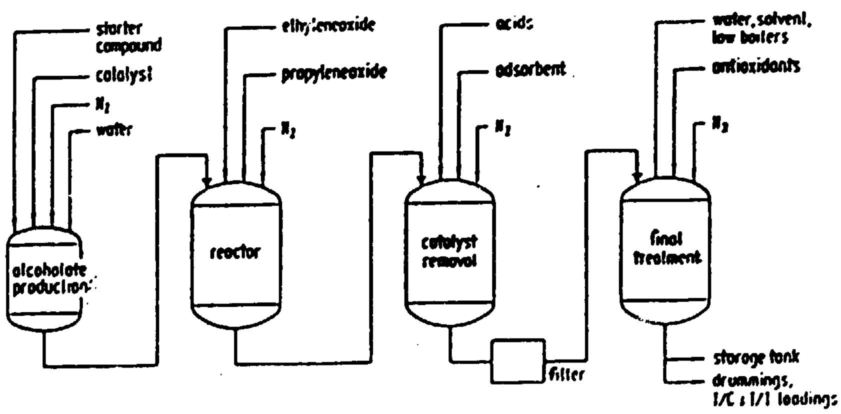

Figure 5. Production Process for Polyether

Polyol Adducts:

```
                                                            CH3

                                                      CH2O(CH2CHO)xH

CH2OH                   CH3                                 CH3
                                      base
CHOH        +        nH2C-CH      --------->  CHO(CH2CHO)yH
                          O         catalyst
CH2OH                                                       CH3
                                                      CH2O(CH2CHO)zH

glycerin         propylene                    glycerin adduct
                    oxide                        (n=x+y+z)
```

The operation of the process may be divided into several steps (see Figure 5) as follows:

1) The starter components are mixed with the catalyst. The alcoholate is generally formed through removal of the water by distillation.

2. The liquid epoxides are continuously fed at a temperature of 80 to 150°C, at a pressure of 0.1 to 8 bar over atmospheric pressure, at a rate determined by how fast the reaction procedes.

3. After reaching the desired degree of polymerization, the catalyst is removed either by adding an absorbent (magnesium silicate) or by neutralizing it with an acid, whereby salts, which are insoluable in polyethers, are formed.

4. The mixture is dewatered before filteration.

5. The solids are removed by filteration with chamber filters, precoat filters or filter presses.

6. The product is purified under reduced pressure so

as to remove volatile side products such as water. Residual solvents may be removed through distillation.

7. The sensitivity of the polyether linkages increases very rapidly especially at high temperatures. As such, antioxidants (such as ditert-butyl-p-cresol BHT) are added to the final product.

It should be emphasized that the reactor and all vessels for the operation steps including final storage tanks should be padded with nitrogen so as to prevent oxidation and formation of color bodies in the product. The reactor and all the vessels are normally made from 316 stainless steel.

The final field storage in a polyol plant tends to be rather complex because of the requirement for storing the diverse product range typically produced in the plant and from the occasional need for blending different polyols for customers. In addition, there is a need to provide heating and cooling equipment in the storage area. Some polyols products are frequently shipped to customers in accordance to temperature specifications. Normally the urethane foam producers tend to have minimum polyol storage facilities in their plants. Therefore, the polyether polyol producer may have to increase his storage facilities to satisfy the needs of such urethane foam producers.

As stated above, polyether polyol is internationally produced by the discontinuous batch process. Therefore this process is recommended for this project profile. The capital investment and all other economic factors will be estimated accordingly.

II. Raw Materials and Cost

The main primary types of the polyether polyols available are polypropylene glycol, glycerine adducts of propylene oxide, other propylene oxide-based adducts, and polytetramethylene ether glycol polyol. The glycerine adducts polyols account for better than 70% of all the polyols and therfore, this profile will be geared for the production of this type.

The recommended capacity for the proposed plant is 40,000 MT/Y of polyol. The conversion factors and prices of the required raw materials are listed in Table 9.

Table 9 : Raw Materials and Costs

Product	Consumption* (Ton/Ton)	Total Amount (Tons)	Price** ($/Ton)	Total Cost (000'$)
Propylene Oxide	0.9147	36588	1210	44,272
Ethylene Oxide	0.1007	4028	1340	5,398
Glycerine	0.031	1240	1800	2,232
Potassium Hydroxide	0.02	800	400	320
Antioxidant	0.003	120	15000	1,800
Filter Aid			0.40	16
Magnesium Silicate	0.015	600	300	180
			G. Total	54,218

* AIDO, Petrochemical Study in the Arab World, Vol. 2, p. 5-121, 1988.

**Prices of raw materials were based on:
- Contact with a European producer/consumer
- Chemical Marketing Reporter for 1989
- Average prices for the past 5 years

III. Process Utilities and Costs

The required process utilities and their costs are estimated and tabulated in Table 10.

Table 10: Process Utilities and Costs

Utility	Consumption per Ton Polyol	Total Consumption	Price ($/Unit)	Total Cost ($)
Electricity	60 KWH	2.4 MM	.015	36,000
Cooling Water	20 m^3	800,000	.03	24,800
Steam	0.40 Ton	16,000	11	176,000
Inert Gas	50 NM^3	2 MM NM^3	.03	60,000
				296,000

IV. Manpower Requirements and Costs

The manpower requirements and their estimated costs are listed in Table 11.

Table 11: Manpower Requirements and Costs

Category	Number	Salary Month ($)	Total Annual Costs ($)
Plant Manager	1	1500	18,000
Production Manager	1	1300	15,600
Operators	15	400	72,000
Lab. Control	3	1300	46,800
Staff	6	400	28,800
	26		181,200

Note: 1. Salaries were based on information published by the Gulf Organization for Industrial Consulting for the Arab Gulf States.

2. The estimation of the required manpower is based on the assumption that skilled labor is available in the area where the plant will be located.

ECONOMIC EVALUATION

This section provides the estimates of the investment requirements and the expected operating costs for the establishment of a manufacturing plant to produce 40,000 metric tons polyol per year.

In calculating the profitability, it will be assumed that customs duties or taxes will not be levied on equipment, machinery or imported raw materials.

The following items will be estimated and/or calculated:

A. Fixed Capital

B. Annual Operating Costs

C. Working Capital

D. Total Investment

F. Finance

F. Depreciation

G. Total Annual Production Cost

H. Project Fixed and Variable Costs

I. Estimation of Sales Revenue

J. Calculation of Annual Net Profit

K. Calculation of Rate of Return

L. Calculation of Pay-back Period

M. Determination of Break-even Point

N. Summary of Project Economics

A. Fixed Capital

The costs estimates of the Battery Limits and the off-sites for a plant with an annual production capacity of 40,000 metric tons polyol were based on estimates presented by Chem Systems (How to Start Manufacturing Industries, UNIDO, Vienna) for a similar capacity plant located in Benelux, W. Europe.

These estimates were then adjusted for a Bahraini site using a location factor of 1.3. The resulting figures which include 20% contingency are listed below:

	Estimated Costs (000'$)
Battery Limits	14,585
Off-sites	5,830
Total Fixed Capital	20,415

The estimated required land area is 3800m². It is assumed that it will be rented at nominal rates.

B. Annual Operating Costs

The expected operating costs are estimated as follows:

	Cost (000'$)
1. Raw Materials	54,218
2. Utilities	296
3. Salaries and Wages	182
4. Maintenance - 3% of errected plant cost for materials and labor	613
5. Insurance - 0.5% of errected plant cost	102
6. General Expenses	200
7. Packaging and handling	1,200
Total	56,811

C. Working Capital

	Value (000'$)
Imported Raw Materials (3 months)	13,555
Utilities (3 months)	74
Wages and Salaries (3 months)	46
Total	13,675

D. Total Investment

	Amount (000'$)
Fixed Capital	20,415
Working Capital	13,675
Total Investment	34,090

E. Finance

It is assumed that the project will be established on a 100% of equity financing.

F. Depreciation

Assuming a useful lifetime of 12 years for the plant. the yearly depreciation will be U.S. $1,701,000.

G. Total Annual Production Costs

	Cost (000'$)
Annual Operating Costs	56,811
Annual Depreciation	1,701
Total	58,512

H. Project Fixed and Variable Costs

a) Fixed Costs

	Annual Amount (000'$)
Annual Depreciation	1,701
Maintenance	613
Insurance	102
Salaries*	91
Total Fixed Costs	2,507

b) Variable Costs

	Annual Amount (000'$)
Raw Materials	54,218
Utilities	296
General Expenses	200
Labor Cost	91
Packaging and Handling	1,200
Total Variable Cost	56,005

I. Estimation of Sales Revenue

The estimated ex-works selling price is $ 1670 per metric ton. This price is based on figures received from a major polyol consumer in Europe.

Total Sales Value = 40,000 x 1,670 =		66,800,000
Loss through operating and packaging	3%	2,000,000
Total Net Sales Value U.S.$		64,800,000

*Assume 50% of the salaries/wages as fixed costs and the other 50% as variable costs.

J. Calculation of Annual Profit

Total Net Sales Value	US$	64,800,000
Total Production Cost	"	58,512,000
(assuming no taxes) Total Annual Profit	US$	6,288,000

K. Calculation of Annual Rate of Return

Assuming a plant operation at full capacity starting the first year, the rate of return is calculated as follows:

$$\text{Rate of Return}^* = \frac{\text{Annual Profit}}{\text{Total Investment}}$$

$$= \frac{6,288,000}{34,090,000}$$

18.4%

L. Calculation of Pay-back Period

$$\text{Pay-back Period} = \frac{\text{Total Investment}}{\text{Annual Profit + Depreciation}}$$

$$= \frac{34,090,000}{6,288,000 + 1,701,000}$$

= 4.25years

M. Calculation of Break-even Point (BEP)

The Break-even Point is the point at which the project income is equal to the total expenses and thus the project produces no profits or losses.

$$BEP = \frac{\text{Average Fixed Costs}}{\text{Net Sales Value} - \text{Average Variable Costs}}$$

$$= \frac{2,507}{64,800 - 56,005}$$

$$= 28.5\ \%$$

The BEP is determined graphically as indicated in Figure 6.

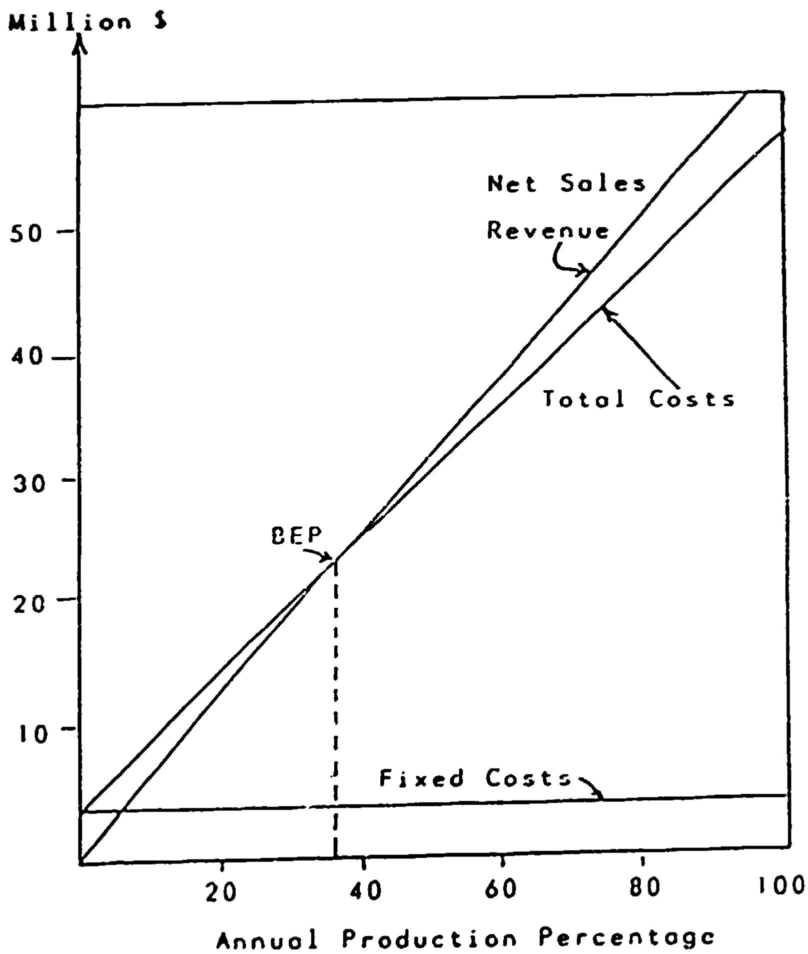

Figure 6: Determination of Break-even Point

X. Summary of Project Economics

Production Capacity	MT	40,000
Total Investment	US$	34,090,000
Working Capital	"	13,675,000
Production Cost	"	58,512,000
Raw Materials Cost	"	54,218,000
Cost of Utilities	"	296,000
Salaries and Wages	"	182,000
Depreciation	"	1,701,000
Fixed Costs	"	2,507,000
Variable Costs	"	56,005,000
Net Sales Revenue	"	64,800,000
Annual Profit	"	6,288,000
Rate of Return		18.4 %
Pay-back Period		4.5 years
Break-even Point		28.5 %
Total Number of Manpower		26
Land Area Required		3800 m^2

POSSIBLE RISKS

Even though the economic results of this project profile are very encouraging, yet one still should take into account certain possible risks as indicated below:

1. The feedstocks have a definite effect on the total production costs. This profile is based on importing the feedstocks from other producing countries. Therefore the plant will depend on outside factors such as the prices and the availability of the feedstocks. Because the needed raw materials to produce the feedstocks are available in the Arab countries, it would be economically advantageous to plan to produce these feedstocks locally. This would avoid dependency on outside sources and will no doubt improve the economic viability of the project and the value-added to the raw materials. But in doing so, the planners should consider the size of the project and the marketability of the products.

2. The operation requires highly skilled operators. Therefore, one needs to thoroughly train the appropriate number of required staff. The number of staff mentioned in this profile was based on the assumption that skilled labor is locally available. If proper training cannot be achieved than the need may arise to utilize expatriates which could prove to be an economical burden on the project.

3. This report is only a Project Profile. Therefore, it is of utmost importance to have the results verified by a more detailed study before a final decision is taken.

CONCLUSIONS AND RECOMMENDATIONS

I. Conclusions

a) Most of the Arab World demand of polyols is presently satisfied by imports from other producing countries.

b) The growth rate for urethane foams has rapidly increased in the Arab World during the past 2-3 decades.

c) The available world nameplate polyol capacities will be sufficient to satisfy the international demand at least through the year 2000.

d) At present, only countries possessing the raw material with comparative cost advantage and sufficient local polyol consumption can economically establish polyol plants. The Arab oil producing countries are potential candidates to establish such projects.

e) The cost of the feedstock has a very significant effect on the total production cost as it reaches 95%. Industial plans in Bahrain indicate that the main raw material (propylene oxide) may be produced in the future.

f) Despite the strong effect of the raw materials on the production cost, the project as discussed seems very economical with a 18.4% rate of return and a 4.25 year payback period. However, it must be pointed out that the prices of the raw materials and the final product are cyclic and can change from one year to the other.

2. Recommendations

a) It is recommended that serious plans should be made to establish a polyol project in the Arab countries. A feasibility study is definitely needed to confirm the findings of this profile as well as to select the most suitable location.

b) It is also recommended to carry out a study for the establishment of an integrated chemical complex to produce propylene oxide, propylene glycol and polyols. This may improve the economic viability and enhance the value-added for the locally available raw materials.