Figure 2 . 1
Ethylene Cumulative Capacity
Future Persian Gulf new capacity based on historical growth

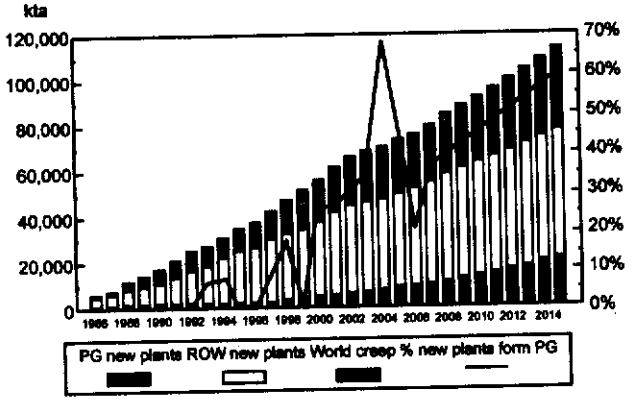


Figure 2.7
Ethylene Cumulative Capacity
Future Persian Gulf new capacity

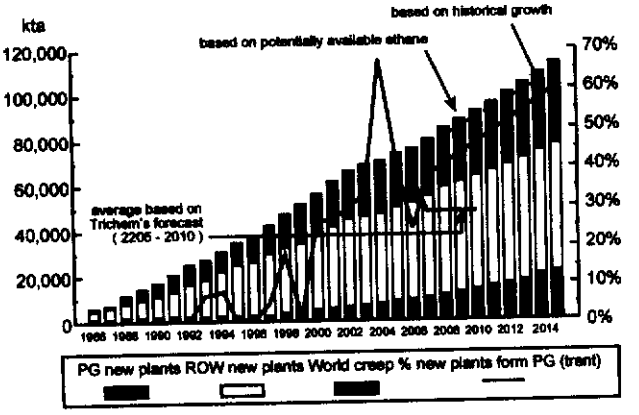


Figure 2.6
Ethylene Cumulative New Plant Capacity in PG (form 1980)
Impact of low - cost ethane

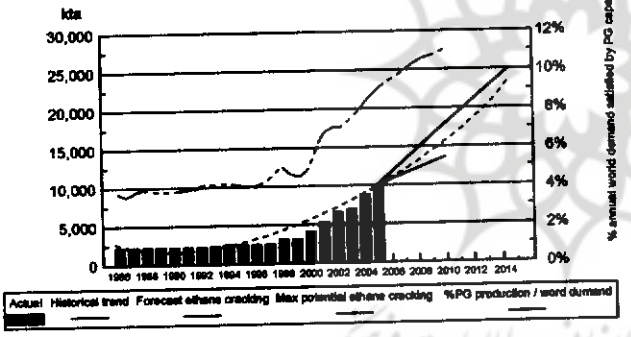


Figure 2.2
Ethane Production Costs and Pricing
(2005-2015)

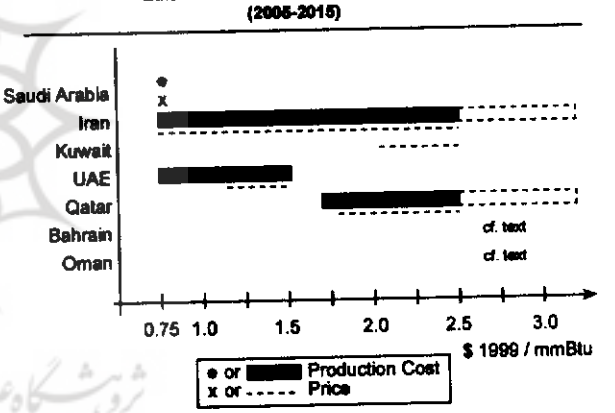
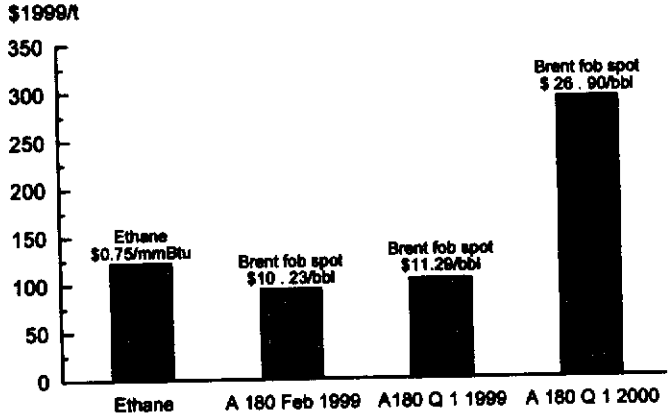


Figure 2.3
Ethylene Cash Costs
Ethane and A180 Cracking in Saudi Arabia



overwhelming incentive for all of the above five Gulf producers to make ethane available for petrochemical production.

Overall conclusion

We estimate that by 2010 the seven Gulf countries will have approximately 21 million tons/year of ethane potentially available for recovery over the period 2000-10 (in addition to the 5.2 million tons/year recovered in 2000).

Considering the uncertainty of future crude oil price levels (which critically affect competitivity and profitability of ethane based petrochemical projects), the financial and infrastructure constraints of countries like Iran, Oman and Qatar and the availability of ethane in Bahrain, it appears reasonable to foresee the recovery and utilisation of just over half of the 21 million tons/year ethane potentially available.

Our forecast of likely extra ethylene capacity in the seven Gulf countries studied is summarised in Table 2.2 the following is a short explanation for each country.

Saudi Arabia- Competitive and profitable at likely ethane price. 3.3 Mta extra ethane recovery already authorised. Expect authorisation of additional 1.7 Mta by 2010.

Iran- Current plans are for three ethylene plants totaling 3.3 Mta ethylene by 2005 from ethane or ethane mix. Financial constraints and potentially high costs of ethane recovery make further realisation before 2010 unlikely.

Kuwait- Naphtha cracker currently being considered alongside aromatics complex. Any additional ethane recovered from new associated gas development likely to be utilised in expanding existing Equate ethylene plant.

At a 15% ROIBTD hurdle rate and the low price PEL forecast, only ethane based projects in Saudi Arabia and perhaps Iran (if ethane is priced close to Saudi) would be competitive and profitable

UAE- New gas development project currently in planning stage is expected to yield sufficient ethane for one ethylene plants by 2010 in addition to the Borouge plant planned onstream in 2001.

Qatar- Relatively higher recovery costs of ethane from non-associated gas is likely to limit recovery to one new plant additional to QGPC/Phillips plant onstream in 2001.

Bahrain- Potential ethane availability is inadequate for ethylene plant of world scale capacity.

Oman- Economic feasibility of ethane recovery is linked to co-development of aluminium plant consuming natural gas. Constraints on finance make project unlikely by 2010.

To summarise:

- Five of the seven Gulf study countries are likely to see investment in new ethane based petrochemical projects by 2010 corresponding to approximately 9.8 Mta ethylene capacity. Saudi Arabia is likely to account for nearly half of this new investment, being the best placed in terms of ethane availability and recovery. Iran is expected to account for nearly a third of the investment.

- Such new capacity will comprise 25% of the 39 Mta additional global ethylene capacity expected by 2010, increasing Gulf ethane-based share of global ethylene demand from 5.1% in 2000 to 11.0% in 2010.

Despite this likely increased importance of PG, Trichem expects ethane cracking in the region to increase at a lower rate than historical growth beyond 2005 as illustrated in Figures 4 and 5. Figure 5 presents the future PG new ethylene capacity based on historical growth, as shown in Figure 1, on the potentially available ethane and on Trichem's forecast of PG new ethylene capacity up to 2010. Figure 5 shows that over the next decade, Trichem expects a third of the world new ethylene capacity, i.e. total capacity less creep, to be built in the Persian Gulf.

- Production of an additional 9.8 Mta ethylene from ethane in the Gulf would reduce the supply of approximately 4.5-5.5 Mta propylene co-product from potential alternative naphtha based plants elsewhere. To satisfy the global propylene supply/demand balance, this reduction in supply should encourage higher propylene/ethylene cracking ratios in new naphtha based plants outside the Gulf and additional investment in increased propylene production from refinery FCC units.

- The impact of ethane based Gulf ethylene on global ethylene and propylene supply could double if current high crude price were to be sustained over the next decade. Such a scenario is highly unlikely bearing in mind the likely effect on world oil demand growth and the encouragement of alternative non-OPEC supply.

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cracking profitability and competitivity because the export prices obtained for ethylene derivatives are linked to naphtha cracking, and the price of naphtha is strongly linked to the price of crude. In view of the uncertainties inherent in all crude oil price forecasts, the study considers the impact on Gulf ethane of three crude price scenarios for the period 2005-15.

(i) A low price in the range $11-15/bbl (in $1999) forecast by Petroleum Economics Ltd (PEL) equating to the marginal cost of non-OPEC crude production.

PEL believes that this long term trend will be sustained by an inherent surplus in the market (contrary to current short term conditions). It foresees ample investment in OPEC capacity, which will be sustained by Saudi Arabia's determination to ensure a capacity cushion so as to avoid uncontrollably high prices which would promote investment in alternative energy sources, particularly non-OPEC crude.

(ii) A medium $19-22/bbl (in $1999) forecast by Trichem.

Trichem's trend forecast assumes a fluctuating differential above the marginal production costs of crude oil.

(iii)A high $22-28/bbl forecast representing OPEC's target oil price management range.

Competitivity and Profitability of Persian Gulf Ethane based on Petrochemical Production

Although there is some export of ethylene from the Gulf, the profitability of ethane based ethylene production is obtained from complexes, which convert ethane via ethylene to derivatives such as polyethylene and ethylene glycol that are less costly to ship to the two main target markets, Asia and W. Europe. Thus a valid analysis of Persian Gulf ethylene from ethane competitivity is to compare the cash cost of delivering a key derivative such as HDPE (high density polyethylene) from a Gulf petrochemical complex to Asia or W. Europe with that of local producers or other HDPE exporting countries. Such a competitive analysis was made.

The cash costs of the Gulf producers in figure 4 can be conveniently translated into a profitability increase i.e. simple return on capital investment before tax and depreciation (ROIBTD).

This assumes that future W. European HDPE prices will equate to the cash production cost of a marginal Key producer plus a cash margin set by supply/demand considerations. Trichem's forecast of HDPE price over the period 2000-2010 were used to estimate the average cash margin.

According to the results of studies, it seems that:

- Future oil and ethane pricing is crucial to the competitivity and profitability of ethane based petrochemical investment in the Gulf.
- At a 15% ROIBTD hurdle rate and the low price PEL forecast, only ethane based projects in Saudi Arabia and perhaps Iran (if ethane is priced close to Saudi) would be competitive and profitable.
- If the crude price is assumed to be within the range of the Trichem scenario then projects in the UAE, Qatar and Kuwait would also appear tobe competitive and profitable.
- If crude oil price at current levelscould be sustained over the next 10 years there would be an

Table 2.2
Forecast of Committed Ethane Demand in 2010
(Mta)

Country	Extra potential Ethane supply(1)	Forecast of extra committed Feedstock demand(2)	Forecast of extra Ethylene capacity(2)
Saudi Arabia	6.2	5.0	4.0
Iran	7.0	3.3	3.0
Kuwait	1.1	0.1	0.1
UAE	2.2	2.2	1.7
Qatar	2.8	1.2	1.0
Bahrain	0.5	0	0
Oman	1.0	0	0
Total	20.8	11.8	9.8

Note:
(1) Total potential supply in 2010 less committed feedstock demand in 2000
(2) Extra ethane based capacity in 2010 compared with ethane based capacity in 2000

Table 1
PG Ethane Supply/Demand Balance
(Mta)

	Total Potential Supply	Committed Feedstock Demand	Potential Surplus
2000			
Saudi Arabia	4.7	3.9	0.8
Iran	3.3	0	3.3
Kuwait	1.1	0.7	0.4
UAE	0.7	0	0.7
Qatar	0.8	0.6	0.2
Bahrain	0.3	0	0.3
Oman	0.6	0	0.6
Total	11.5	5.2	6.3
2005			
Saudi Arabia	7.4	7.2	0.2
Iran	5.0	3.3	1.7
Kuwait	1.6	0.9	0.7
UAE	2.2	0.8	1.4
Qatar	3.1	1.2	1.9
Bahrain	0.4	0	0.4
Oman	0.9	0	0.9
Total	20.6	13.4	7.2
2010			
Saudi Arabia	10.1	7.2	2.9
Iran	7.0	3.3	3.7
Kuwait	1.9	0.9	1.0
UAE	2.2	0.8	1.4
Qatar	3.4	1.2	2.2
Bahrain	0.5	0	0.5
Oman	1.0	0	1.0
Total	26.1	13.4	12.7
2015			
Saudi Arabia	13.6	7.2	6.4
Iran	8.7	3.3	5.4
Kuwait	2.2	0.9	1.3
UAE	2.2	0.8	1.4
Qatar	4.8	1.2	3.6
Bahrain	0.7	0	0.7
Oman	1.0	0	1.0
Total	33.2	13.4	19.8

Hence, in countries with low ethane recovery costs (Saudi Arabia and the UAE), ethane is usually priced at its alternative value i.e. fuel gas. Where recovery costs may be higher (possibly Iran, Qatar and Kuwait) this could be reflected in the price. More particularly, where foreign partners are invited to participate in petrochemical joint venture, the price is usually a commercial negotiation (Kuwait, Qatar and UAE).

Based on these considerations and the pricing precedents already set, our assessment of production costs and pricing over the period 2005-15 is shown in Figure 2.

Feedstock Alternatives to Ethane Cracking in the Persian Gulf

Large scale investment in ethylene production in the Gulf was initially driven by the availability of low priced ethane and was centered for many years in Saudi Arabia.

The feasibility of earning high returns in petrochemicals mainly from exports to the Far East and Europe was proven. Keys to the success were low cost feedstock and large capacity ethylene plants feeding world scale capacity derivative units. When ethane availability started to become constrained for additional ethylene complexes the authorities decided to supply propane and A180 condensate (naphtha) at a market price discount in order to bolster low cost feedstock supplies. An additional incentive to do so was to widen the product slate to propylene and to a lesser extent aromatics as building blocks for their derivatives. The strategy was to diversify into competitive oil-based industries, which would add value to crude oil and gas. Thus high additional export revenues could be earned even when crude oil production was constrained by adherence to OPEC quotas.

There are at least two downside risks to such a discounting strategy. First, there is the prospect that it could be seen as unfair trading practice because feedstock is being subsidised. Second, it could be much less economic at the current Saudi discount for LPG and naphtha of 30%, if ethane could be made available and the crude oil prices are maintained above around $12/bbl. This is illustrated in Figure 3 to which must be added the revenues foregone by not exporting the discounted liquid feedstock.

The economic uncertainties and risk of trade repercussions are sufficient to conclude that large scale development of ethylene plants in the Gulf based exclusively on propane and naphtha feedstock is unlikely.

Crude Oil Pricing

As already mentioned, crude oil pricing is central to the issues of ethane

capacitygrowth trend in the Gulf can be sustained in the future is highly questionable. The study examines the main drivers of ethylene plant capacity growth and the constraints on ethane availability and ethylene/derivative plant competitivity and profitability, which could limit investment in the new plant in each of the study countries.

The Main Drivers for Ethane Recovery

The three main driving forces for the recovery of ethane in the Gulf countries considered in the study are:

The Availability of Gas

The key parameters are the availability and ethane concentration of "Associated Gas" (i.e. gas associated with the production of crude oil or condensate) and "Non-Associated Gas" (i.e. dry gas produced from natural gas reservoirs).

Usually, the most prolific and economic source for ethane recovery is associated gas. Its availability is of course directly linked to the production of crude or condensate as well as to the gas/oil ratios in each particular reservoir.

The Price of Crude Oil

World ethylene and derivative prices are directly linked to the crude oil price via naphtha, the marginal economic feedstock for ethylene production. Ethane, on the other hand, has no direct price link with crude oil in the Gulf countries, as its alternative value is that of fuel gas, which is usually priced below $1.0/mmBtu in the seven study countries. At this level of ethane pricing, ethylene production costs have been very much lower in the Gulf making investment in the ethylene and its derivatives very profitable for most Gulf producers while crude has fluctuated above $15/bbl (Brent basis).

Future oil and ethane pricing is crucial to the competitivity and profitability of ethane based petrochemical investment in the Persian Gulf

The Recovery Cost of Ethane

The floor level for ethane prices is the value of leaving ethane in associated or non-associated gas stream from which it is recovered, i.e. equal to methane fuel gas priced locally. However, ethane's cost of recovery can be much higher than this floor depending on its concentration and the processing route employed.

In summary, therefore, the prospects for future investment in ethane recovery and ethylene/ethylene derivative production will be determined fundamentally by:

- the amount of future crude oil and gas production
- the price of future crude oil
- ethane recovery costs and prices in each of the seven study countries

Long Term Prospects for Crude/Gas Production and Ethane Availability

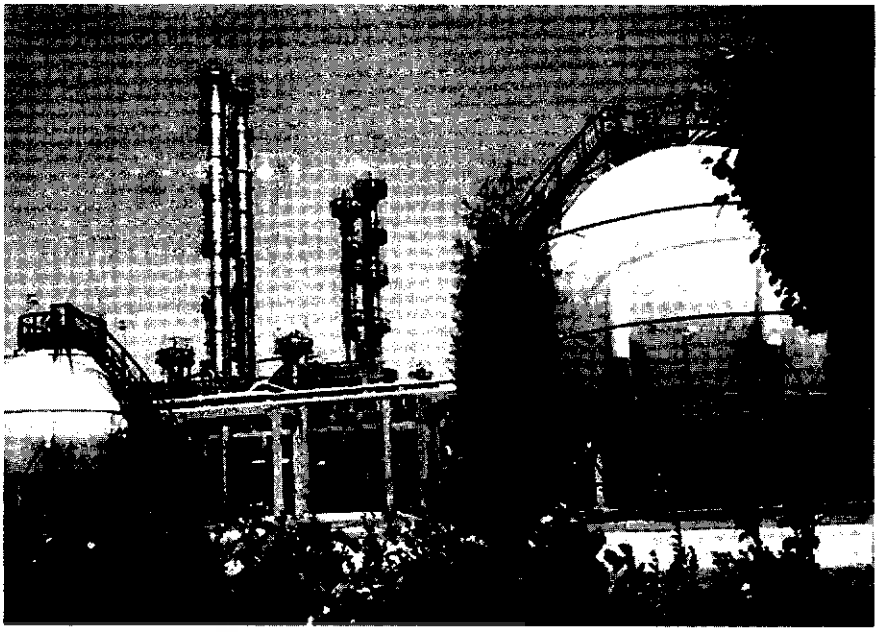
Two independent forecasts of future crude oil production, globally and within OPEC were made by Petroleum Economics Limited (PEL) and Trichem. These agreed closely so that only PEL's results are included in Part 1, Section 3.0 of the study. In summary, the outlook foresees total crude production in the seven study countries rising from around 17 mmbpd in 1999 to 24.7 mmbpd in 2010 and 30 mmbpd in 2015, i.e. an increase of 45% over the next decade, and 76% over the next 15 years. Associated gas production will also increase at approximately the same rate as crude production and there will be major increases in non-associated gas production in Iran and Qatar and, to a lesser extent, in Saudi Arabia, the UAE, Oman and Bahrain. The potential amount of ethane available from these associated and non-associated gas streams is assessed in the study and compared with commitments already made for ethylene plants in operation or under construction. This allows an assessment of the potential theoretical surplus ethane that might be made available in the future. Table 1 summarises this theoretical supply/demand balance.

It should be noted, however, that investment in ethane recovery facilities (gas collection, treatment and fractionation) in order to be able to utilise the theoretical supply of ethane has only been made up to 2005 for the ethylene plants already committed. Hence, the potential ethane surplus beyond 2005 is theoretical only and will only be recovered if ethane recovery costs and ethylene/ethylene derivative plants can be justified economically. These issues are discussed in the sections which follow.

Ethane Recovery Costs and Pricing

Ethane recovery costs vary significantly with the concentration of ethane in the gas. Ethane recovery from wet associated gas or from wet non-associated gas prepared for liquefaction to LNG adds little to the normal separation costs of methane from other liquid components provided that such as recovery facility is incorporated in the original separation plant. Retrofitting to permit ethane recovery can be expensive and separation of a dry methane /ethane fuel gas is very expensive.

Impact of Persian Gulf Ethane on The Global Petrochemical Industry



Study Objective

Starting from almost Zero in 1973, production of ethylene based petrochemicals in the Persian Gulf has grown so explosively that the region is now the predominant exporter to the world market. This success has been propelled almost exclusively by the recovery of low cost ethane from natural gas as feedstock for ethylene production.

The objective of this study is to analyse the outlook for additional ethane recovery and its utilisation as ethylene plant feedstock in seven of the Gulf countries physically endowed with natural gas resources, namely:

- Saudi Arabia
- Iran
- Kuwait
- UAE
- Qatar
- Bahrain
- Oman

The future growth in Persian Gulf ethane based ethylene production capacity is of crucial importance to the industry in at least two respects. First, ethylene is the most utilised building block in the petrochemical industry and its derivatives account for the largest proportion of the petrochemical market. Second, most of global ethylene production is based on naphtha which, unlike ethane, is cracked not only to ethylene but also to propylene, butadiene and aromatics. This means that investment in new ethane based instead of naphtha based ethylene plants reduces the global co-production of propylene, butadiene and aromatics. Additional demand for these co-products have to be met from other production routes such as new investment in fluidised catalytic cracking (FCC), dehydrogenation etc. The impact on the propylene supply/demand balance of such developments could be of considerable significance to refiners creating greater opportunities in the petrochemical market.

Consequently, new additional investment within the Gulf in ethane based ethylene capacity significantly impacts upon the global supply/demand balance not only of ethylene and its derivatives but also the supply/demand balance of propylene, butadiene and aromatics.

Historical Impact of Persian Gulf Ethylene Production on Global Ethylene Supply/ Demand

The Share of supply of the Persian Gulf (PG) to the global ethylene demand by 2005 appears relatively modest at around 8%, assuming a 90% operating rate. However, the PG share will have doubled between 1987 and 2005. A better measure of the impact is the annual percentage of new plant capacity contributed by the PG. This is shown in Figure 1. The bars represent the cumulative capacity of new plants and capacity creep. The solid line represents the additional new plant contribution annually from the PG.

Based on current plants under construction, the PG region's share of the world's new plants will rise from 26% in 2000 to about 44% in 2005. If new ethylene plants in the Gulf continue to be added at the same rate as achieved historically then over the period 2005-2015 about half of the new ethylene plants built globally will be located in the PG, almost all within five of the seven countries studied. However, and this is a large "however" the assumption that the historical