FEASIBILITY STUDY REPORT

FOR

ETHYLENE AND VINYL CHLORIDE MONOMER PLANTS

IN

THE KINGDOM OF THAILAND

VOL. I

SUMMARY

APRIL 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

FEASIBILITY STUDY REPORT

FOR

ETHYLENE AND VINYL CHLORIDE MONOMER PLANTS

IN

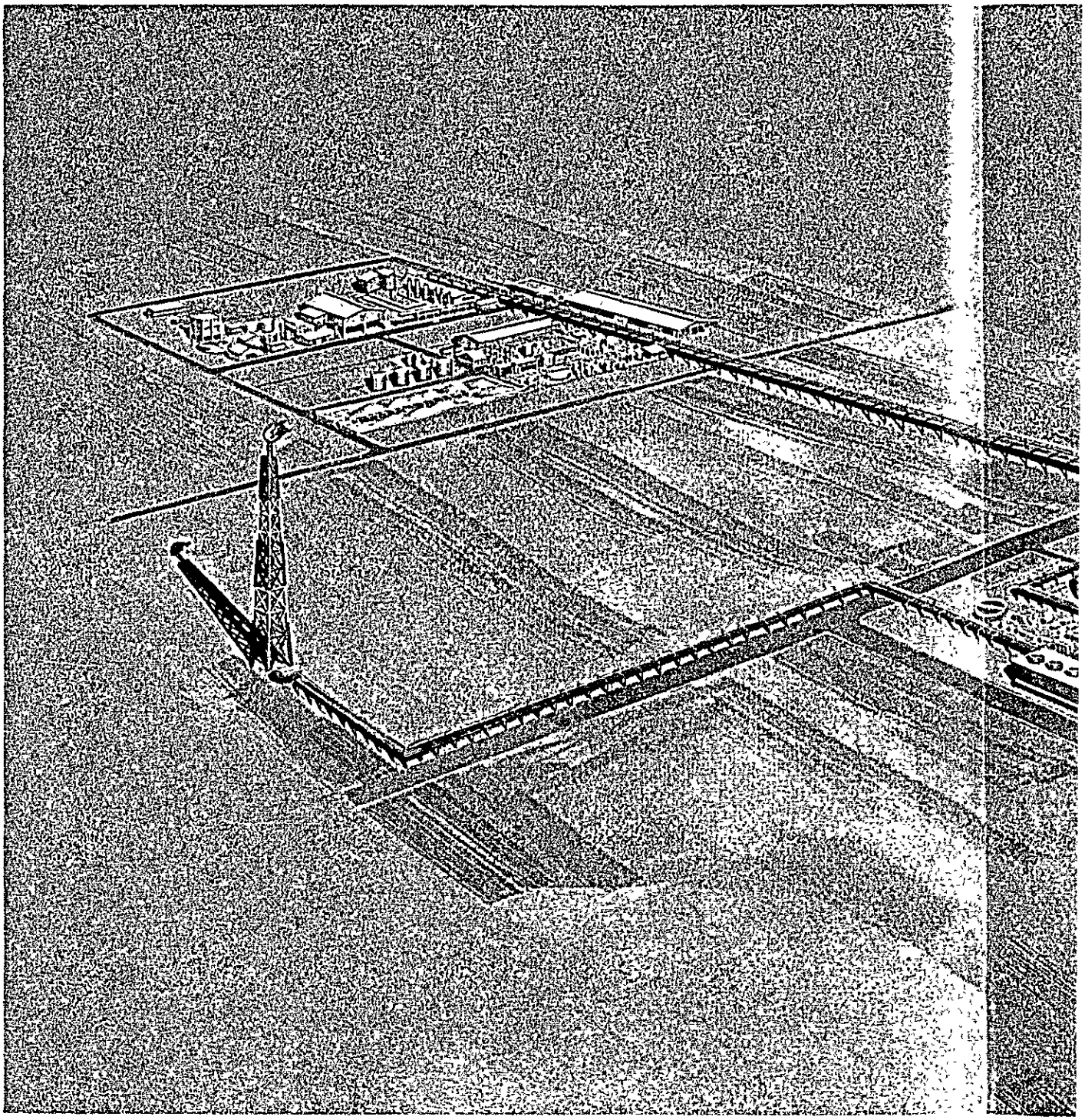
THE KINGDOM OF THAILAND

VOL. I

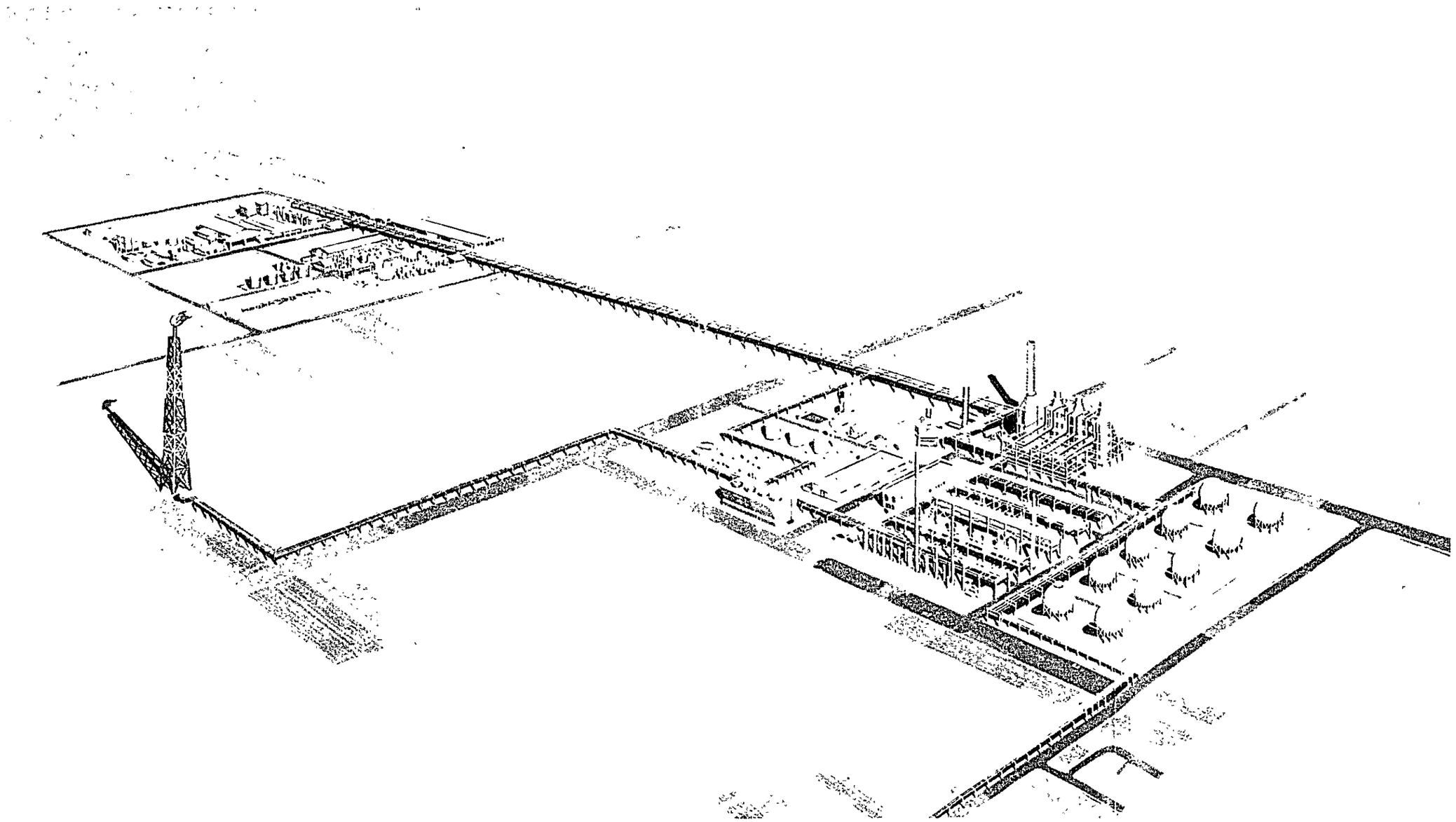
SUMMARY

APRIL 1981

JAPAN INTERNATIONAL COOPERATION AGENCY



THE ETHYLENE AND VINYL CHLORIDE MONOMER PLAN



THE ETHYLENE AND VINYL CHLORIDE MONOMER PLANT AT RAYONG IN THE KINGDOM OF THAILAND

PREFACE

It is with great pleasure that I present this report entitled "Feasibility Study on Ethylene and Vinyl Chloride Monomer Plants" to the Government of the Kingdom of Thailand.

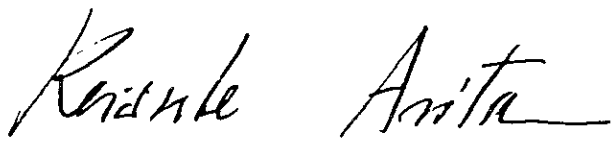
This report embodies the result of a field survey which was carried out in Thailand from October 6th to November 2nd, 1980, by a Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of the Kingdom of Thailand to the Government of Japan.

The survey team, headed by Mr. Takeshi CHINO of UNICO International Corp., had a series of discussions with the officials concerned of the Government of Thailand and conducted a wide scope of field survey and data analyses.

I hope that this report will be useful as a basic reference for development of petrochemical industry in Thailand.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to our team.

April, 1981



Keisuke Arita
President
Japan International Cooperation Agency

ABBREVIATIONS AND SYMBOLS

Unit and Conversion

mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
in	Inch (1 in = 2.54 cm)
ft	Foot (pl. feet) (1ft = 0.305m)
cm^2	Square centimeter
m^2	Square meter
ha	Hectare (1 ha = 10,000 m^2 = 2.471 acres)
ft^2	Square foot (1 ft^2 = 0.0929 m^2)
Rai	(1 Rai = 1,600 m^2)
m^3	Cubic meter
Nm^3	Normal cubic meter
MMm^3	Million cubic meters
ft^3, cu ft	Cubic foot (1 ft^3 = 0.0283 m^3)
SCF	Standard cubic foot
MMSCF	Million standard cubic feet
l	Liter
gal	Gallon (1 British gallon = 4.546 liters, 1 U.S. gallon = 3.785 liters)
bbl	Barrel (1 barrel = 42 U.S. gallons)
g	Gram
kg	Kilogram
t, T, ton, Ton,	Metric ton
lb (s)	Pound (1 lb = 0.454 kg)
LMT	Liquid metric ton (50% aques solution of caustic soda)
sec	Second
min	Minute
h, hr, Hr	Hour
d, D	Day
m, M	Month
y, Y	Year
°C	Degree centigrade
°F	Degree fahrenheit
cal	Calorie
Kcal, K cal	Kilo calorie
BTU, Btu	British thermal unit (1 BTU = 0.252 K cal)
MMBTU, MMBtu	Million British thermal units

LHV	Low heating value
HHV	High heating value
A	Ampere
V	Volt
W	Watt
kW	Kilowatt
mW	Megawatt
kVA	Kilo-volt ampere
mVA	Mega-volt ampere
kWH, kWh	Kilowatt-hour
mWG, mWh	Megawatt-hour
HP, HP	Horsepower
%	Percent
ppm	Parts per million
g/Nm^3	Gram per normal cubic meter
pH, PH	Hydrogen ion concentration
kg/cm^2	Kilogram per square centimeter
lb/in^2	pounds per square inch
mmAq	mm aqua (= water)
t/d, ton/day, T/D	Tons per day
t/y, ton/year, MTA, MT/Y T/Y	Tons per year
MMSCFD, MMscfd	Million standard cubic feet per day

Technical Terms

ABS	Acrylonitrile-butadiene-styrene copolymer
AS	Acrylonitrile-styrene copolymer
PE	Polyethylene
HDPE	High density polyethylene
LDPE	Low density polyethylene
PO	Polyolefin
PP	Polypropylene
PS	Polystylene
FS	Foamed polystyrene
GPPS (GP)	General purpose polystyrene
HIPS (HI)	High impact polystyrene
PVC	Polyvinyl chloride
EDC	Ethylene dichloride
EG	Ethylene glycol
EO	Ethylene oxide
SM	Styrene monomer
VCM	Vinyl chloride monomer
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
NG	Natural gas
NGL	Natural gas liquid
BOD	Biological oxygen demand
COD	Chemical oxygen demand
ISBL	Inside battery limit
OSBL	Outside battery limit
MSL	Mean sea level

Financial and Economic Terms

DCF	Discounted cash flow
IRR	Internal rate of return
EIRR	Economic internal rate of return
FIRR	Financial internal rate of return
ROI	Return on investment
GDP	Gross domestic product
GNP	Gross national product
C & F	Customs, and freight
CIF	Customs insurance and freight
FOB	Free on board

Exchange Rate

Baht	Thailand Baht (1 U.S. dollar = 20.5 Bahts)
$, U.S.$,	U.S. dollar
yen	Japanese yen (1 U.S. dollar = 215 yen)

Organization and Company

GOT	The Government of Thailand
PTT	Petroleum Authority of Thailand
BOI	Office of the Board of Investment
NESDB	Office of the National Economic and Social Development Board
DTEC	Department of Technical and Economic Cooperation
MOI	Ministry of Industry
ETO	Express Transportation Organization of Thailand
EGAT	Electricity Generating Authority of Thailand
NEA	National Energy Administration
PEA	Provincial Electricity Authority
IEAT	Industrial Estate Authority of Thailand
TAPLACO	Thai Plastic and Chemical Co., Ltd.
THASCO	Thai Asahi Caustic Soda Co., Ltd.
FOIS	Fluor Ocean International Services Inc.
JICA	Japan International Cooperation Agency
JETRO	Japan External Trade Organization

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

SUMMARY

I. PROJECT OUTLINE

1–1 BACKGROUND

Natural gas from offshore wells in the Bay of Siam is to be used to produce ethylene and vinyl chloride monomer which will be supplied to domestic producers of ethylene derivatives, with the general situation regarding acquisition of feedstock and sale of products envisioned as shown in Fig. 1.

1–2 TYPES OF PRODUCTS AND PRODUCTION CAPACITY

As noted above, the types of product which are the subject of this study are as follows.

(1) Ethylene
(2) Vinyl chloride monomer (VCM)

Taking domestic demand for derivatives as a basic matter of concern for this study, the most economically feasible production scale of ethylene and vinyl chloride monomer plants is to be studied.

1–3 AVAILABILITY OF FEEDSTOCK

(1) Ethylene plant

The Petroleum Authority of Thailand (PTT) is now planning construction of a gas processing plant which will process natural gas, and separate from it ethane to be supplied as feedstock to the ethylene plant.

(2) VCM plant

Ethylene produced at the plant identified above is to be used as feedstock. The availability of chlorine is investigated as part of this study.

1–4 LOCATION OF THE PLANTS

(1) Ethylene plant

To be located in the same area in Rayong where PTT is to construct the gas processing plant.

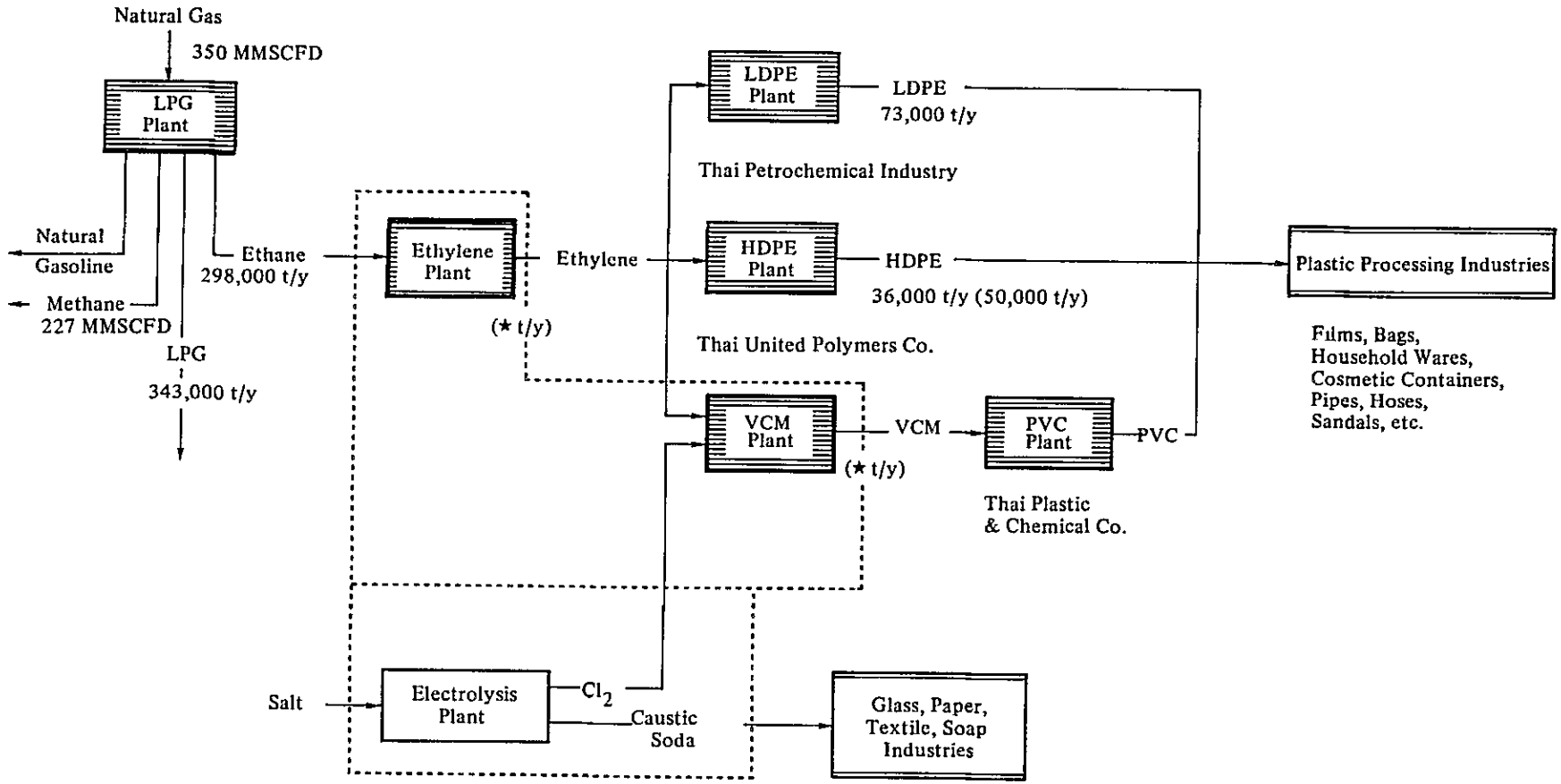


Fig. 1 BACKGROUND OF THE PROJECT AND SCOPE OF THE STUDY

(2) VCM plant

To be determined in view of the relations it is to have to the ethylene plant, electrolysis plant as well as the existing PVC plant, and with consideration also given to environmental aspects of the matter.

1–5 TYPE OF COMPANY TO IMPLEMENT THE PROJECT, AND FINANCIAL AND ECONOMIC EVALUATION

The ethylene plant is to be constructed and operated either by PTT directly or a PTT subsidiary; the nature of the entity to construct and operate the VCM plant is not yet determined. Therefore, financial and economic evaluation of the two plants is to be carried out separately.

II. MARKET STUDY

2–1 PLASTICS MATERIALS

(1) Demand trends

Total Thai demand for platstics materials is said to be about 240,000t (1978) of which general-purpose plastics materials account for about 60%, or 150,000t. The trend of the level of demand for general-purpose plastics over a recent 10-years period (1970–1979) is shown in Table 1.

Domestic production of general-purpose plastics materilas is being carried out by Thai Plastic and Chemical Co. (which makes PVC) and Dow Chemical Thailand (which makes PS); both of these companies use imported monomer as feedstock but production is not sufficient to satisfy domestic demand, so the shortfall in supply is met by imports. Other types of plastics materials not being produced in Thailand are imported.

(2) Demand analysis

Because, as is pointed out above, Thailand is dependent on imports for a majority share of demand for plastics materials, with regard to demand of general-purpose plastics materials which is sensitive to change in price, elasticity analysis using real GDP and real price as independent variables was performed with results as shown in Table 2; with exception of PVC,[1)] domestic production of which was begun in 1971, price elasticity is 1 or greater for all plastic materials.

Table 2 GDP AND PRICE ELASTICITIES OF PLASTICS MATERIALS IN THAILAND

	Elasticity	
	GDP	Price
PE	1.34	1.25
PP	2.95	1.06
PVC	2.18	0.43
PS	2.54	1.90

1) The price elasticity of PVC is very low, at 0.43. This is not only because PVC products such as pipe are used in capital projects undertaken by government but also because the market is relatively stable in the absence of competiting products.

Table 1 CONSUMPTION AND PRICE OF PLASTICS MATERIALS IN THAILAND

	PE		PP		Polyolefin[3]		PVC(as resin)		PS[4]	
	(t/y)	(Baht/kg)[1]	(t/y)	(Baht/kg)[1]	(t/y)	(Baht/kg)	(t/y)	(Baht/kg)[2]	(t/y)	(Baht/kg)[2]
1970	38,304	5.30	5,696	5.79	44,000	5.36	6,288	9.85	5,430	8.18
1971	52,027	5.23	8,483	5.44	60,510	6.30	8,719	8.04	8,246	8.24
1972	61,701	4.91	12,198	4.82	73,899	4.90	14,098	6.94	8,152	8.75
1973	61,093	7.33	13,739	8.39	74,832	7.52	15,972	14.02	7,201	14.43
1974	24,504	14.58	7,615	15.02	32,119	14.68	12,575	19.36	2,644	27.96
1975	54,509	10.56	19,992	10.69	74,501	10.59	15,202	14.29	6,326	18.12
1976	52,354	11.32	15,235	12.26	67,589	11.53	17,669	16.06	6,670	20.69
1977	65,143	11.22	19,235	12.25	84,378	11.45	25,190	16.31	9,696	21.72
1978	73,145	10.28	31,732	10.70	104,877	10.41	26,142	16.71	14,033	23.14
1979	84,364	16.61	54,205	13.00	138,569	15.20	31,895	22.90	14,847	27.78

Notes : 1) Average FOB price.
2) Average ex-factory price.
3) Total of PE and PP.
4) Including AS, ABS resins.

GDP elasticity is 2 or higher for all plastics materials other than PE, and to the extent that there is no great change in the structure of demand it is expected that a high rate of gorwth will be maintained in the future. Because the market for PE has already reached the stage of maturity in Thailand, in comparison to the rates of growth of demand for other plastics materials, demand for PE will grow at a relatively low rate; PS has a GDP elasticity of about 1.3.

As a result of demand analysis, it is estimated that the level of Thailand's demand for plastics materials in 1979 was as follows.

	(t/y)
LDPE	39,400
HDPE	26,200
PP	40,000
PVC	31,500 (as resin)
PS	13,700

(3) Demand projection

Using the results of elasticity analysis, on the assumption that in the future the real prices of these materials are constant, projections of plastics materials demand up to 2000 were made. The real growth rate of the GDP was assumed to be 6.5% a year. Results are given in Table 3.

2–2 ETHYLENE GLYCOL

(1) Demand trend

Total Thai production capacity for polyester fiber (SF and FY)[1] is 78,400 t/y (1979) and total production in the same year was 64,900 t/y. In Thailand almost the only use of ethylene glycol is for production of polyester fibers, and the major import source is Japan. The trend of imports is shown in Table 4.

1) SF : Staple fiber; FY : Filament yarn

Table 3 DEMAND FORECAST FOR PLASTICS MATERIALS

(Unit : 1,000 t)

	LDPE	HDPE	PP	PVC	PS
1980	43.4	29.0	41.2	36.7	16.4
1981	46.6	31.0	45.2	40.0	17.4
1982	49.9	33.2	49.6	43.5	19.0
1983	55.2	33.9	54.3	47.3	20.8
1984	59.2	36.3	59.6	51.5	22.7
1985	63.4	38.9	65.3	56.1	24.8
1986	69.1	40.6	71.6	61.0	27.2
1987	74.1	43.5	78.5	66.4	29.7
1988	79.4	46.6	86.0	72.2	32.4
1989	85.1	49.9	94.3	78.6	35.4
1990	91.2	53.5	103.4	85.6	38.7
1991	100.3	54.0	111.5	92.0	41.7
1992	106.9	57.6	120.3	99.0	44.9
1993	114.0	61.4	129.8	106.5	48.4
1994	121.6	65.4	140.0	114.5	52.2
1995	129.5	69.8	151.0	123.2	56.2
1996	138.1	74.4	162.9	132.5	60.6
1997	147.2	79.3	175.8	142.6	65.3
1998	157.0	84.5	189.6	153.4	70.3
1999	167.3	90.1	204.6	164.9	75.8
2000	178.4	96.0	220.7	177.4	81.7

Table 4 IMPORTS OF ETHYLENE GLYCOL IN THAILAND

	(Kl)	(1,000 t)
1974	9,228	10.3
1975	7,036	7.8
1976	14,293	15.9
1977	19,197	21.4
1978	22,005	24.5
1979	20,227	22.5

(2) Demand projection

(i) Fiber demand

Total fiber consumption in Thailand was analyzed using GDP as an independent variable and projections on the basis of that place demand at 240,000 t in 1990, and 340,000 t in 2000, as shown by Table 5.

(ii) Polyester fiber demand

As indicated in Table 6, the share which consumption of synthetic fiber occupies in total fiber consumption is expected to increase, from the present level of about 60,000 t to 125,000 t in 1990 and 200,000 t in 2000.

Moreover, it is though that there will be a gradual increase in the share polyester fiber has in total synthetic fiber consumption, to 110,000 t in 1990 and 180,000 t in 2000.

The total quantity of polyester fiber demand, taking into account exports of polyester textiles, as shown in Table 7, is estimated as 150,000 t in 1990 and 260,000 t in 2000.

Table 5 DEMAND FORECAST FOR TEXTILES IN THAILAND

	Per Capita Demand (Kg)	Total Demand (1,000 t)
1980	3.5	165
1985	3.8	201
1990	4.2	242
1995	4.6	287
2000	5.0	336

Table 6 DOMESTIC DEMAND FORECAST FOR POLYESTER FIBER

(Unit : 1,000 t/y)

	Synthetic Fiber	Polyester Fiber	
		SF	FY
1980	62	37.8	11.2
1985	89	57.0	16.0
1990	125	83.8	22.5
1995	164	114.8	29.5
2000	206	148.2	37.1

Table 7 TOTAL DEMAND FORECAST FOR POLYESTER FIBER IN THAILAND

(Unit : 1,000 t/y)

		1980	1985	1990	1995	2000
SF	Domestic Demand	37.8	57.0	83.8	114.8	148.3
	Textile Export	18.1	24.4	35.9	49.2	63.6
	Total	55.9	81.4	119.7	164.0	211.9
FY	Domestic Demand	11.2	16.0	22.5	29.5	37.1
	Textile Export	5.0	6.9	9.6	12.6	15.9
	Fiber Export	4.2	3.4	—	—	—
	Total	20.4	26.3	32.1	42.1	53.0
Grand Total		76.3	107.7	151.8	206.1	264.9

(iii) Demand for ethylene glycol

The quantity of demand for ethylene glycol which is needed for production of polyester fiber, as shown below, is projected at 53,000 t in 1990 and 93,000 t in 2000.

	(1,000 t/y)
1980	27.8
1985	36.7
1990	53.1
1995	72.1
2000	92.7

2–3 VCM AND ETHYLENE

(1) Demand projections

(i) VCM

Demand for VCM, as shown in Table 8, will increase from 58,000 t in 1985 to 80,000 t in 1989, so that it would be desirable to set plant capacity at 80,000 t/y. However, it will be necessary to double capacity at least by 1994.

Table 8 DEMAND FORECAST FOR VCM

(Unit: 1,000 t/y)

	PVC		VCM Demand
	Demand	Production	
1985	56.1	56.1	58.1
1986	61.0	61.0	63.1
1987	66.4	66.4	68.7
1988	72.2	72.2	74.7
1989	78.6	77.3	80.0
1990	85.6	77.3	80.0
1991	92.0	77.3	80.0
1992	99.0	77.3	80.0
1993	106.5	77.3	80.0
1994	114.5	114.5	118.5
1995	123.2	123.2	127.5
1996	132.5	132.5	137.5
1997	142.6	142.6	147.6
1998	153.4	153.4	158.8
1999	164.9	154.0	159.4
2000	177.4	154.0	159.4

(ii) Ethylene

Potential demand[1] for ethylene, including that for plastics materials (polyethylene, VCM) and ethylene glycol, from 165,000t in 1985, will increase to 240,000t in 1990 and 450,000t in 2000.

1) Not only ethylene but also LDPE, HDPE, VCM, PVC and ethylene glycol exports are excluded. Exports of pocessed products made from these plastics materials, and polyester textiles, are included.

However, because ethylene demand is increased when derivatives plants are constructed and start operating (creating all together "effective demand"), a gap necessarily will appear between potential and effective demand. Effective demand is expected to increase from 134,000t in 1985 to 189,000t in 1990, 307,000t in 1995, and 428,000t in 2000 (see Table 9 and Fig. 2).

Table 9 DEMAND FORECAST FOR ETHYLENE

(Unit: 1,000 t/y)

	Potential Demand for			Effective Demand[1] for		
	Plastics	EO	Total	Plastics	EO[2]	Total
1985	137.3	27.9	165.2	134.2	–	134.2
1986	147.5	30.0	177.5	142.7	–	142.7
1987	158.7	32.4	191.1	149.7	–	149.7
1988	170.6	34.8	205.4	170.6	–	170.6
1989	183.4	37.5	220.9	182.6	–	182.6
1990	197.2	40.4	237.6	189.4	–	189.4
1991	210.8	42.9	253.7	199.3	–	199.3
1992	225.2	45.6	270.8	206.6	–	206.6
1993	240.6	48.5	289.1	214.3	–	214.3
1994	256.9	51.6	308.5	240.7	51.6	292.3
1995	274.4	54.8	329.2	252.2	54.8	307.0
1996	293.2	57.6	350.8	287.2	57.0	344.2
1997	313.1	60.6	373.7	292.1	57.0	349.1
1998	334.6	63.7	398.3	334.6	57.0	391.6
1999	357.2	67.0	424.2	352.4	57.0	409.4
2000	381.6	70.5	452.1	370.6	57.0	427.6

Notes: 1) Supply to downstream plants.
2) EO plant of 60,000 t/y capacity is assumed to be started operation in 1994.

Examining the effective demand for ethylene as shown in Table 9 above, it is felt desirable for the production capacity of the ethylene plant to be made 200,000 ~ 230,000 t/y, and for capacity to be expanded during the early 1990's.

(2) Price

(i) VCM

For preparation of demand projections, it is assumed here that from 1979 onward ethylene derivatives real prices are constant. The Thai VCM price, based on this, is estimated at US$800/t (at user's plant, in 1980 price).[1]

1) Ex-plant price is assumed to be around US$750/t.

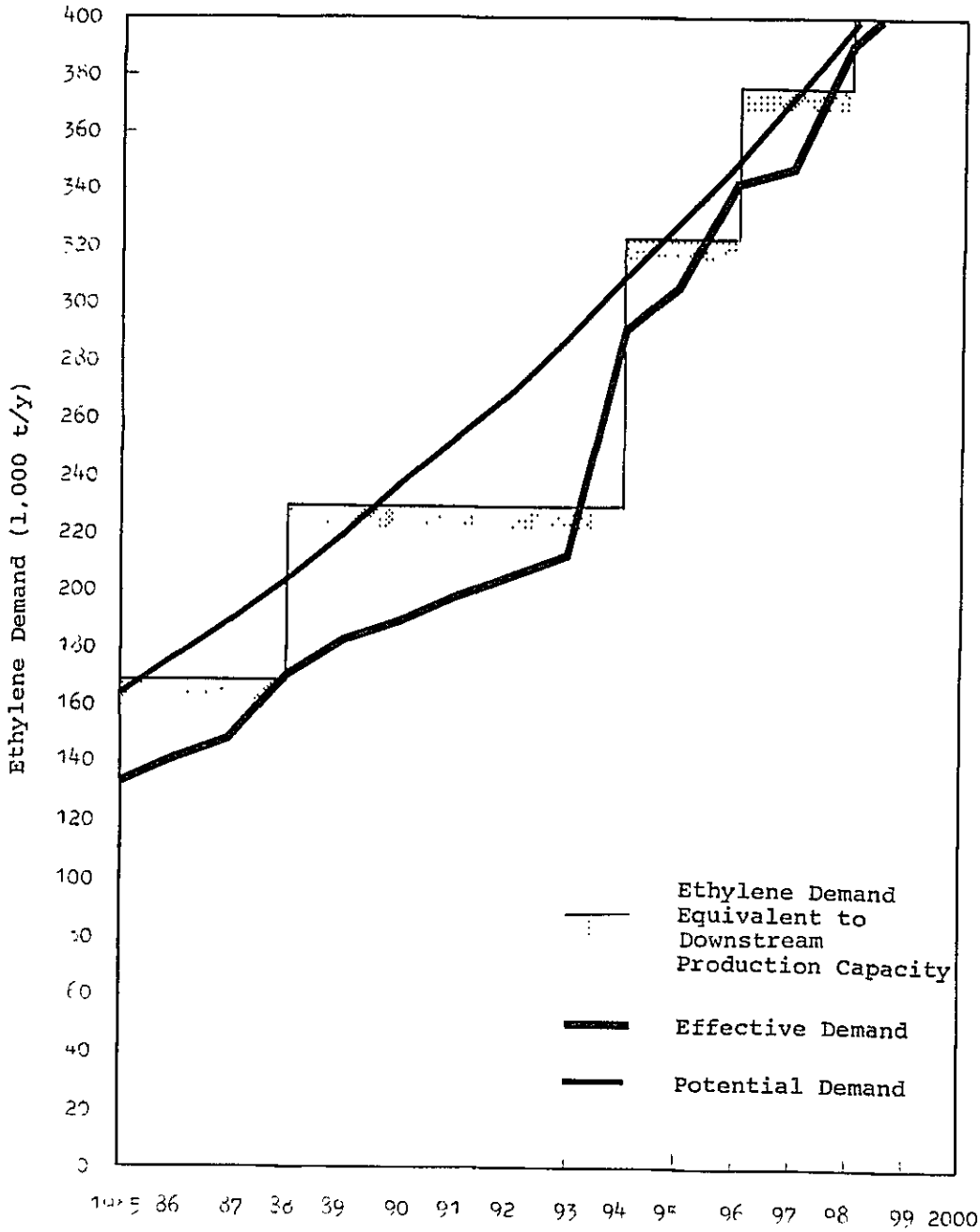


Fig. 2 FORECAST FOR TOTAL ETHYLENE DEMAND IN THAILAND

(ii) Ethylene

The domestic prices of LDPE and HDPE in Thailand are protected by a 40% customs duty, so the ethylene price was set at US$800/t (at user's plant, in 1980 price).

Because the realization of the VCM plant which would consume 20% of the ethylene plant output is of such high importance, on the basis of the assumption that the VCM plant is constructed, the suitable ethylene price which reflects consideration given to VCM production cost was studied.

2–4 CAUSTIC SODA

Of the six companies which produce caustic soda in Thailand, the only one which markets its output is the Thai Asahi Caustic Soda Co.; all the rest produce primarily for self-consumption.

Althought total production capacity for caustic soda in Thailand is 74,400 LMT/y, it is not enough to satisfy domestic demand, and at present imports at the level of 30,000 LMT/y are required. This is because the country's chlorine demand is relatively low in comparison with the caustic soda demand.

Caustic soda demand is expected to increase at 10 ~ 12% a year hereafter, and the outlook is, as shown by Table 10 below, that almost all of the caustic soda obtained as a byproduct from chlorine production for the VCM plant will be absorbed by the domestic market.

Table 10 SUPPLY/DEMAND BALANCE FORECAST FOR CAUSTIC SODA

(Unit: 1,000 LMT/y)

	Demand	Production[1]	Balance
1985	175	181	6
1986	226	234	8
1987	245	254	9
1988	266	273	9
1989	288	289	1
1990	311	(289)	(-22)
1991	342	(289)	(-53)

Note: 1) Including production by existing plants.

III. RAW MATERIALS STUDY

3–1 AVAILABILITY OF ETHANE

The quantity of ethane to be supplied from the gas processing plant (first phase, 350 MMSCFD), construction of which is being planned by PTT, is to be on the order of 298,000 t/y; this is enough to provide an ethylene plant with enough feedstock for a capacity of 230,000 t/y.

3–2 ETHANE SUPPLY PRICE

The price at which ethane will be supplied is not yet determined, but is expected to be decided as a result of this study.

3–3 CRUDE SALT

Either domestically-produced marine salt or domestically produced rock salt may be used. This study presumes that marine salt which is obtainable without fail will be used. Need exists to consider the implications of use of rock salt which may be produced in the future as part of the ASEAN Rock Salt – Soda Ash Project. The price of salt delivered to the plant has been set at 450 Baht (US$22).

IV. COMPARISON OF ALTERNATIVES, AND STUDY OF BASIC CONDITIONS OF THE PROJECT

4–1 ETHYLENE PLANT

It was adopted as assumption that the location of the ethylene plant will be at the same site as the PTT gas processing plant, and that it would be ethane gas from that plant as feedstock.

There possible production scales were compared in terms of their economics, with attentions given to the demand outlook and conditons related to raw materials; the results of the comparison are shown as Table 11 and Fig. 3. These three scales are as follows.

Base Case-1	170,000 t/y
Base Case-2	200,000 t/y
Base Case-3	230,000 t/y

As a result of preliminary comparison of these three cases it was found that there was not a great difference between them in terms of the internal rate of return (IRR). Greater influence is exerted by a difference in the supply price of feedstock (ethane) than a difference in plant scale. Among the three cases, the 230,000 t/y case is superior to the 200,000 t/y case which is in turn superior to the 170,000 t/y case in economic terms, no matters what combination of ethane and ethylene prices are used. An economically significant difference is not found between the 200,000 t/y and 230,000 t/y cases, when the ethylene plant alone is compared, but from the viewpoint of the greater contribution to value added due to recovery of the ethane fraction from natural gas in the gas processing plant, the 230,000 t/y scale is selected.

4–2 VCM PLANT

Production capacity of the VCM plant was set at 80,000 t/y by converting the domestic Thai PVC requirement five years after the start of commercial operation into VCM demand. (At the time commercial operation begins in 1985 utilization of capacity would be slightly below 80%.)

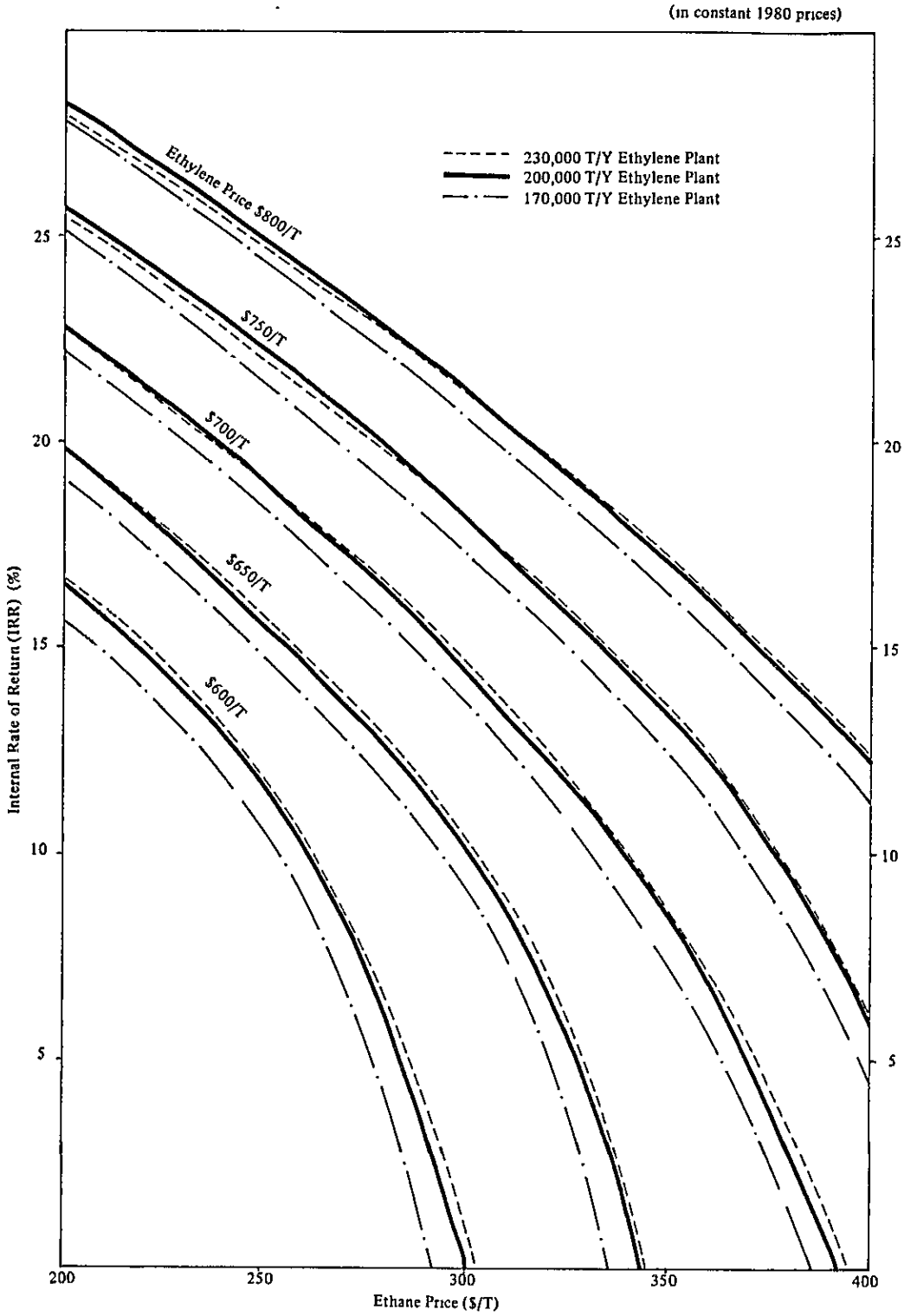
For the supply of chlorine needed for production of VCM, as a result of studying demand for caustic soda which should be a byproduct of chlorine production in the event that an industrial salt electrolysis plant is constructed in conjunction with the VCM plant, since it was found that there would not be a great surplus of caustic soda, it was decided that the electrolysis plnat is to be constructed. In the event that reliance is placed on importation of

Table 11 COMPARATIVE PRODUCTION ECONOMY (IN TERMS OF IRR)[2] FOR DIFFERENT PRODUCTION CAPACITY OF ETHYLENE PLANT BASED ON DOMESTIC DEMAND IN THAILAND

Selling Price of Ethylene (US$/T)[1]	Price of Feedstock Ethane (US$/T)[1]	Internal Rate of Return (IRR) for Different Production Capacity of Ethylene Plant		
		Base Case-1 170,000 T/Y	Base Case-2 200,000 T/Y	Base Case-3 230,000 T/Y
600	200	15.63	16.51	16.60
	250	10.63	11.62	11.80
	300	0	0.34	0.98
	350	0	0	0
	400	0	0	0
650	200	19.04	19.82	19.80
	250	14.62	15.53	15 65
	300	9.23	10.23	10.40
	350	0	0	0
	400	0	0	0
700	200	22.15	22.83	22.71
	250	18 13	18.93	18.94
	300	13.58	14.52	14.68
	350	7.29	8.51	8.64
	400	0	0	0
750	200	25 03	25.61	25.41
	250	21.31	22 01	21.92
	300	17.19	18.02	18.06
	350	12.49	13.46	13.63
	400	4.25	6.09	6.28
800	200	27.73	28.22	27 93
	250	24.25	24.85	24 67
	300	20.45	21 18	21.12
	350	16.23	17.09	17.11
	400	11.32	12.29	12.46

Notes 1) In constant 1980 prices.

2) Comparison purpose only.



Note. Comparison purpose only.

Fig. 3 COMPARATIVE PRODUCTION ECONOMY FOR THREE PRE-SELECTED PRODUCTION CAPACITIES OF ETHYLENE PLANT AT DIFFERENT PRICES OF ETHANE AND ETHYLENE

EDC, the total investment amount is lower, but the quantity of ethylene consumption is also reduced. Moreover in the event that an electrolysis plant is later constructed, investment made for the EDC cracking could be used in the case of the installation of an electrolysis plant, so at the stage of project implementation, the use of EDC deserves study as a transitory measure until an industrial salt electrolysis plant is constructed.

With regard to the location of a VCM plant, out of due consideration to technical and economic aspects of the transport of feedstock ethylene and chlorine, as well as to safety, the normal, natural practice is to locate it adjacent to the ethylene source and together with the electrolysis plant. This convention is to be followed for the present project. Moreover, by the formation of a complex, the advantage of efficiency in establishment and use of common facilities such as utilities facilities, off-site facilities and infrastructure-related facilities may be had.

4–3 BASIC CONDITIONS OF THE PROJECT

The basic conditions of the project are therefore as follows.

(1) Plant types

Ethylene plant:	230,000 t/y
VCM plant:	80,000 t/y
Electorlysis plant:	48,000 t/y (as chlorine)
	51,600 t/y (as 100% caustic soda)

(2) Location

All in Rayong

(3) Feedstock and raw materials

Ethylene plant:	ethane
VCM plant:	ethylene and chlorine
Electrolysis plant:	industrial salt

(4) Project owner

PTT:	Ethylene plant
Others:	VCM and electrolysis plant

It is expected that in Thailand production of petrochemical goods downstream from the planned ethylene plant will be done by joint ventures of Thai and foreign private interests.

V. TECHNICAL ASPECTS

5–1 PROJECT SCHEME

The basic scheme of the project is shown in Fig. 4.

5–2 POTENTIAL PLANT SITE

It has been decided that the ethylene plant will be located in the same area as the gas processing plant which PTT plans to construct in the region west of Rayong City. It is thought natural that the VCM plant be located adjacent to the ethylene plant. Results of study of the locational aspects of the planned site area are as follows.

(1) Overland transportation

The site fronts on a main highway and there are good road conditions between the site and Bangkok.

(2) Surrounding environment

The surrounding natural conditions, and social conditions, are not such as would prevent construction of a petrochemical complex.

(3) Geology

According to geological data there are some parts which are low in bearing strength, and a detailed geological survey should be carried out at the earliest possible time in the implementation stage.

(4) Water

Water supply to the gas processing plant by pipe-line from Dok Krai reservoir is to include water for this project; it is nevertheless necessary to confirm that a stable supply of water for the project will be available.

(5) Power

EGAT/PEA plans to install a substation 3 km north of the proposed site in order to be able to provide energy in keeping with the growth of demand; a transmission line (230 kV) will be installed to it from the Ao Phai substation. Need exists to confirm the timing of completion of this work.

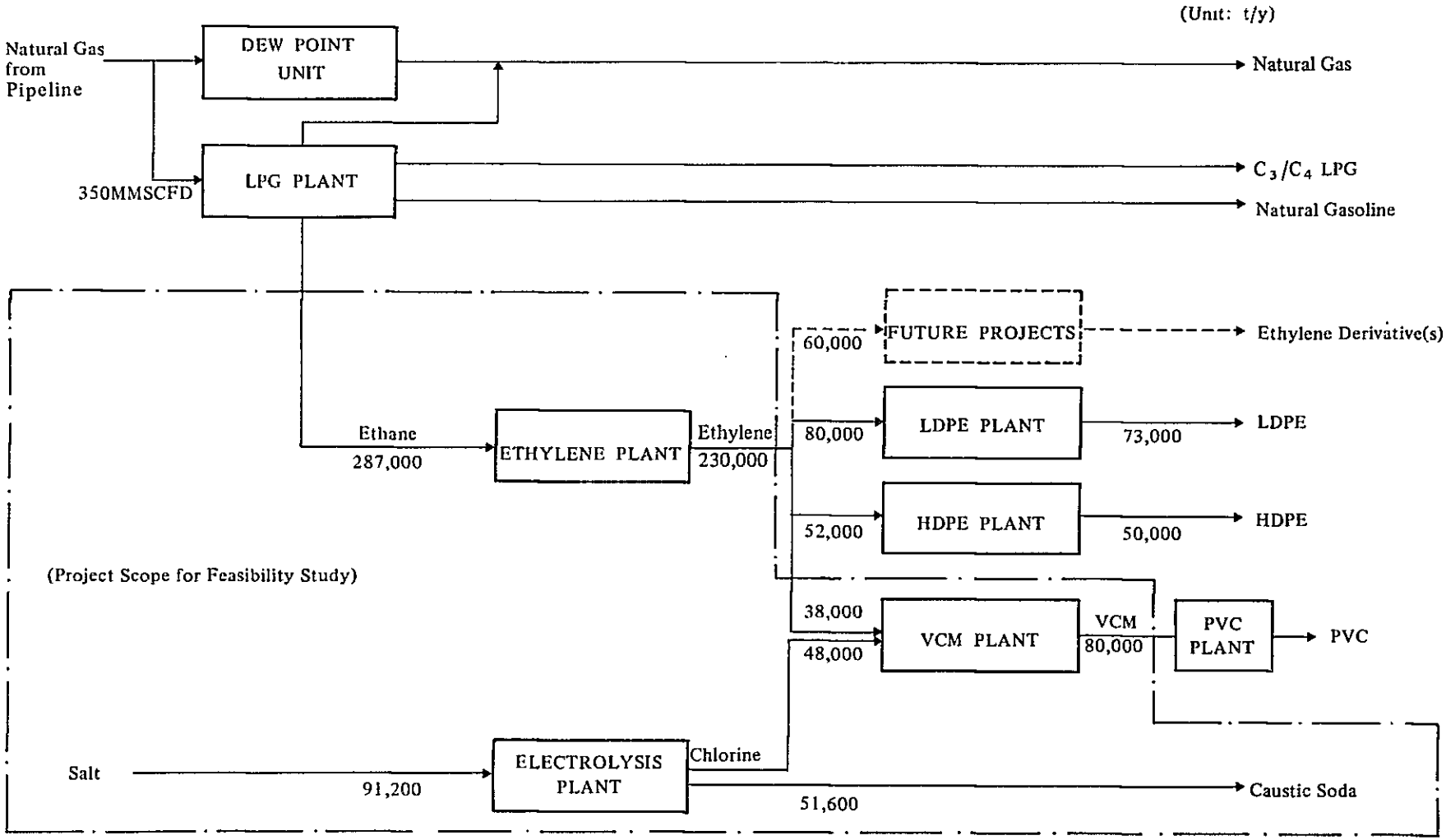


Fig. 4 BLOCK FLOW DIAGRAM FOR PETROCHEMICAL COMPLEX IN THAILAND

(6) Port and harbor facilities

The nearest port is Sattahip; because this is a military port it is suitable that it may be used only for landing construction materials and equipment. Shipments of VCM may be made by conveying the VCM by pipeline to the LDPE plant shipping terminal (the pipeline to be installed parallel to the ethylene supply pipeline) 20 km to the east, this terminal to be at the pier being constructed for importation of ethylene until supply from the ethylene plant is possible.

5–3 CONCEPTUAL DESIGN AND PROCESS SELECTION

The following points are taken into consideration regarding the ethylene, VCM and electrolysis processes, and typical processes are selected, and on the basis of the raw materials and feedstock consumption of those processes, and their utilities requirements, the required facilities are studied.

(1) The process must have been validated through being used in various parts of the world, must be highly reliable, efficient and economical.

(2) The process must not use materials which are harmful to human life, must have few sources of waste products, and must incorporate features which keep effluents and emissions to a minimum.

Further, the study is carried out on the assumption that in order to obtain maximum benefit of the advantages of forming an ethylene complex, by combining utilities facilities and waste treatment facilities in a single utilities center, the reliability of operation would be improved and economics of the project as a whole too would be improved. Supply of electricity, however, is to be done to the VCM plant and electrolysis plant by EGAT/PEA. The quantities of utilities to be purchased from outside are as follows.

Raw water:	500 m^3/hr
Electricity:	VCM plant and electrolysis plant: 25,000 kW (the ethylene plant and utilities center will generate their own power to the extent of 3,200 kW)
Fuel:	277 MMBtu/hr

For storage of raw materials, feedstock and products, a tank yard will be made for ethane, ethylene, VCM and caustic soda. Salt will be piled in the open. Ethylene and VCM supply to the LDPE plant (eastern Rayong City) will be by pipelines which bypass urbanized parts of the city.

The plant's off-site facilities will include all required facilities such as maintenance and repair facilities, a laboratory, garage shop equipment, fire-fighting equipment, offices, housing, etc.

5–4 PLANT CONSTRUCTION AND OPERATION MANNING

The study team envisions the following schedule for the project.

July, 1982	Design of ethylene plant begins
January, 1983	Design of VCM and electrolysis plant begins
End of March, 1985	Plant construction completed
July, 1985	Commercial operation begins

Because this will be the first large-scale petrochemical project in Thailand, it will be necessary for the owner to make use of an experienced foreign consultant for technical services related to project management.

With the exception of personnel assigned to the head office of the companies in Bangkok, the total manpower requirements for the plants, including production, engineering and administrative workers are as follows.

Ethylene plant (including utilities center):	344 persons
VCM plant (including electrolysis plant):	294 persons
Total	638 persons

No later than three months prior to the start of operation (i.e., the time of the start of test operation) the plant organization must be established, workers must be hired and training of operators must be completed. During the early phase of plant operation it will be necessary to obtain the services of management advisers with international experience, who will also help in on-the-job training.

5–5 MEASURES FOR PROTECTION OF THE ENVIRONMENT

To the greatest extent possible, all wastes generated in the plants are to be treated at the point where they are produced, and moreover generation of wastes is to be kept to the minimum. Thus, chlorine, hydrogen chloride, hydrocarbons and any other gases are to be treated at their source. Further, because there are no sulfur in the fuel gas, no SO_x will be released into the air. Use of a low-NO_x burner will serve to limit the quantity of NO_x released into the air. Oil and suspended solids will be removed from effluent by primary processing facilities, and secondary processing will be carried out in view of the need for COD measures, before effluent is collected in a guard basin for discharge in the ocean through

drainpipes. No mercury at all is used in the electrolysis process, and a closed-system insures that materials etc. will not be released outside of the plant. By these measures the production and discharge of emissions and effluent by the plants will be kept to a minimum in order to prevent pollution.

VI. REQUIRED CAPITAL, AND CAPITAL PLAN

6–1 REQUIRED CAPITAL

The required capital for this project (in constant 1980 prices) is estimated as follows. mated as follows.

(US$1,000)

	Foreign currency portion	Local currency portion	Total required capital
Ethylene plant[1)]	145,563 (66.2%)	74,498 (33.8%)	220,061 (100%)
VCM plant, Electrolysis plant	98,811 (70.7%)	49,948 (29.3%)	139,759 (100%)

The above sums include land acquisition cost, plant cost, pre-operation costs, initial working capital and interest during construction. Of the total fixed capital, 75% is to be obtained by a loan, and the interest during construction is assumed to be 8% p.a. on the principal of the loan.

6–2 FINANCIAL PLAN

Of the total fixed capital, 25% is to be owner's equity, and the remaining 75% as well as initial working capital is to be borrowed as a long-term loan. The financial plan is as follows (in constant 1980 prices).

	Ethylene plant[1)]	VCM plant Electrolysis plant
Equity	53,478	33,821
Long-term loan	166,584	105,938

The source of the loan is not known at the present time, but it is assumed that the terms and conditions shall be that there will be repayment in equal annual payments over a period of 10 years following a three-year grace period, and that the interest rate is 8% p.a.

1) Including the common-use utilities center.

VII. FINANCIAL ANALYSIS

7–1 CALCULATION OF PRODUCTION COST, AND MAJOR ASSUMPTIONS FOR THE FINANCIAL PLAN

(1) Production plan

	Ethylene	VCM	Caustic Soda
1985(Jul.–Dec.)	70,500t	32,160t	20,743t
1986	142,700t	62,800t	40,506t
1989	182,600t	80,000t	51,600t
1992	206,600t	80,000t	51,600t
1994 and on	230,000t	80,000t	51,600t

Note : Necessary inventory is assumed to be produced in 1985

(2) Product sales price (ex-plant, 1980 price)

Ethylene	: First iteration	;	US$800
	: Second iteration	;	US$700
VCM	:		US$750
Caustic soda:			US$350

(3) Raw materials and feedstock prices

Ethane	: First iteration	US$350
	: Second iteration	US$300
Ethylene	: First iteration	US$800
	: Second iteration	US$700

(4) Prices of utilities supplied from outside

Industrial water	:	US$0.098/t (2 Baht/t)
Fuel gas	:	US$4.218/MMBtu (low heat value)
Electricity	:	US$0.054/kWH (1.1 Baht/kWH)

(5) Depreciation method

10 years ; straight line

(6) Taxes

Corporate tax, business tax, import duty all assumed to be waived.

(7) Project life

15 years

7–2 RESULTS OF FINANCIAL ANALYSIS

(1) First iteration

Profitability (Internal rate of return)

Ethylene project	19.6%
VCM project	10.1%

Profit/loss balance (in constant 1980 prices)

	Ethylene project	VCM project
	(US$1,000)	(US$1,000)
1985(Jul.–Dec.)	1,483	-3,866
1986	4,607	-7,988
1989	21,759	- 492
1992	33,404	2,609
1994	43,525	4,304

(2) Second iteration

Profitability (Internal rate of return)

Ethylene project	17.3%
VCM project	13.1%

Profit/loss balance (in constant 1980 prices)

	Ethylene project	VCM project
	(US$1,000)	(US$1,000)
1985	-957	-1,492
1986	-600	-2,822
1989	15,093	6,650
1992	25,851	9,195
1994	35,111	10,891

Cost (in constant 1980 prices)

	Ethylene (US$/ton)	VCM and Caustic Soda (US$/ton(VCM + 0.645 NaOH))
1986	704	1,021
1990	603	882
1994	547	840

7–3 SENSITIVITY TEST (first iteration)

The results of sensitivity tests whereby major factors among those cited above are varied in order to determine their influence are shown graphically in Figs. 5 and 6.

7–4 SUMMARY

(1) First iteration (Ethylene US$800; corresponding ethane price US$350)

Although a satisfactory profit can be expected from the ethylene project, and it has no financial problems, the VCM project shows a loss in its fifth year of operation, and has low profitability which makes it unattractive to investors.

If the low-profitability VCM production is excluded from consideration, it would mean a decline in demand for ethylene and either a reduction of the scale of production of the ethylene plant or operation of the ethylene plant at a lower level of capacity utilization. This in turn would mean poorer profitability in comparison to that of the ethylene project as defined for this Feasibility Study or, in other words, would serve to lower the ethane supply price which makes the ethylene project feasible. That is, the effective use of natural gas resources and improvement of value added is not only important for the ethylene project but also is essential for downstream projects to be established. From this viewpoint, a second iteration was done for the ethylene price and corresponding ethane price.

(2) Second iteration (Ethylene US$700; corresponding ethane price, US$300)

Necessity exists for establishing a rational means of distributing costs and benefits among the three projects (gas processing plant, ethylene plant, and downstream plants) by means of the prices set for ethylene and ethane. For the second iteration the price of ethylene supplied to the VCM plant is set at US$700/t, and the ethane price which corresponds to this is US$300.

As is indicated by the results of the financial analysis, even with this set of prices, the ethylene project is profitable and shows no financial problems. Moreover, in comparison to

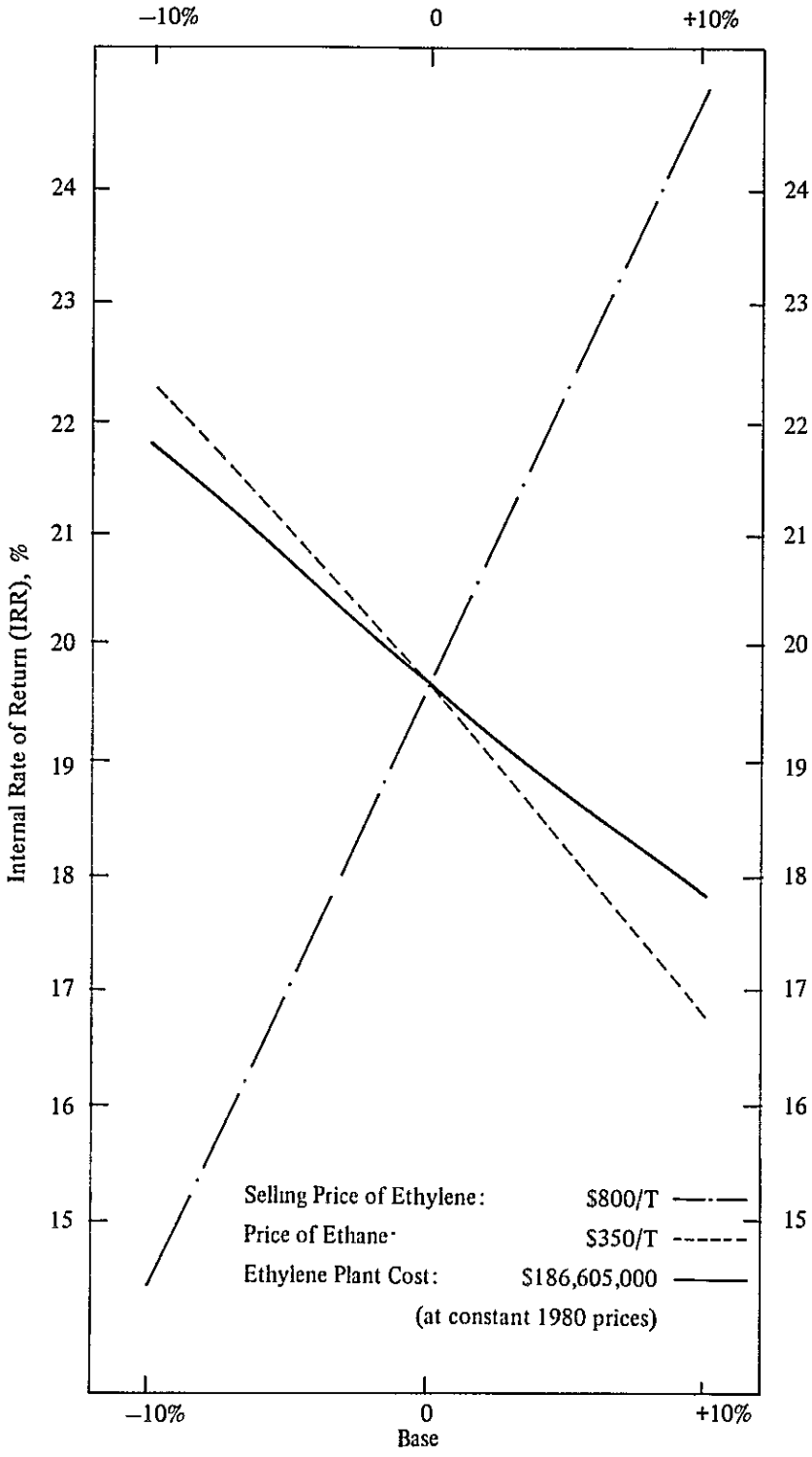


Fig. 5 RESULT OF SENSITIVITY ANALYSIS FOR PTT ETHYLENE PROJECT (CASE–B)

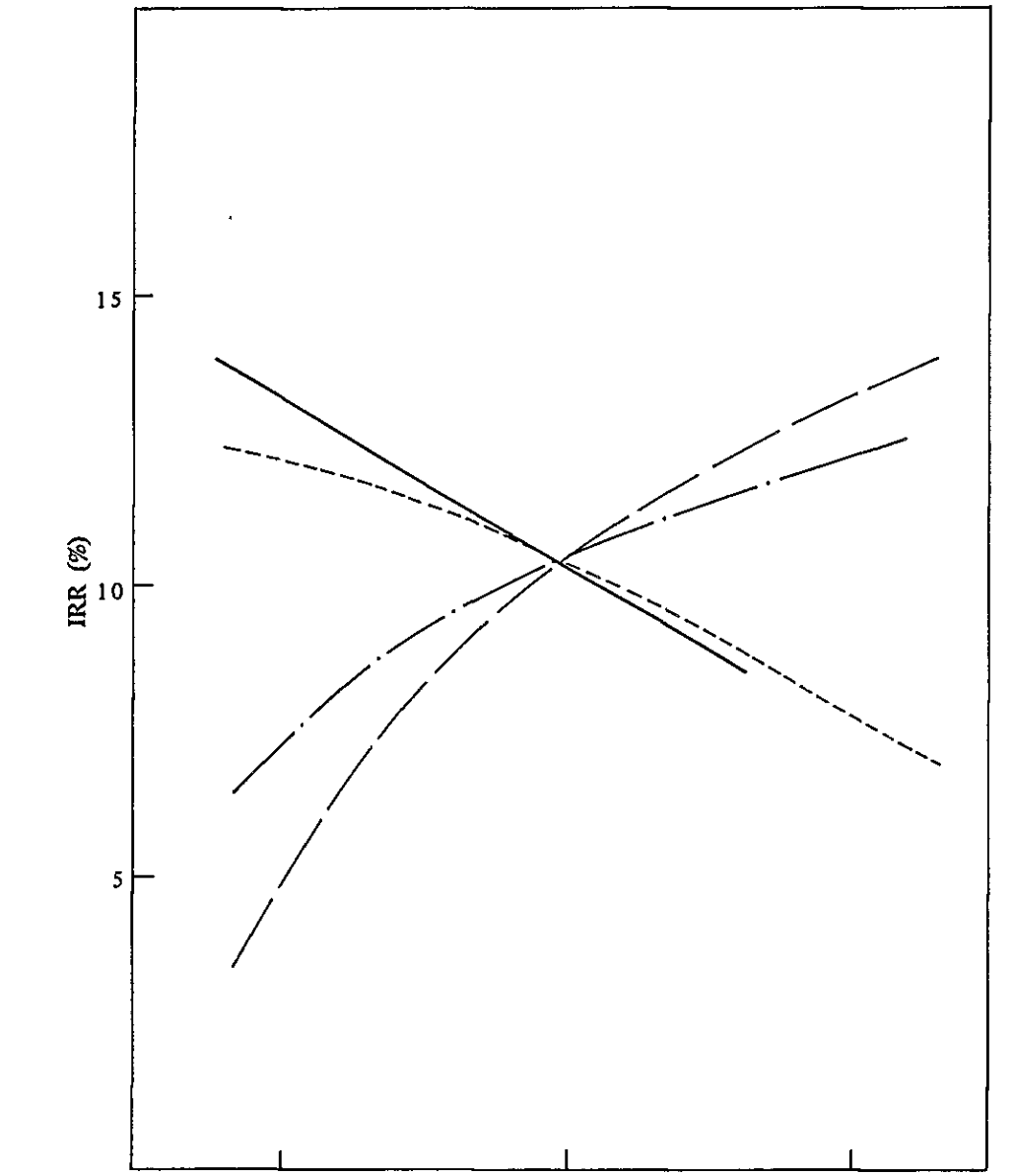


Fig. 6 SENSITIVITY TEST ON IRR OF VCM PLANT PROJECT

the situation wherein ethane is not recovered when the evaluated price is $240 (ethane recovery cost is estimated to be US$50), the ethane price used here, namely US$300, is amply suitable. For the VCM project, the IRR is improved from 10.1% to 13.1%, and a profit is obtained starting in the fourth year of operation, so the investment potential is considerably improved. The ethylene project may be considered as a prerequisite for establishment of the VCM project, and from this viewpoint it is necessary to give strategic consideration to setting of the ethylene and ethane prices. Through such consideration, and through tax relief measures, investment in the VCM project becomes possible.

(3) Setting the ethylene and ethane prices

From the study described in subsections (1) and (2) above, in order to realize the VCM project, and also enable the ethylene project to be established, the ethylene and ethane prices must be made US$700/t and US$300/t (in constant 1980 price) respectively.

VIII. ECONOMIC EVALUATION

8—1 The economic significance of implementing this project lies in increasing the value added of natural gas components, contributing to the improvement of the international balance of payments, causing ripple effects in related industries, and contributing to the promotion and development of the regional economy, through making use of natural gas resouces and human resources of Thailand, and producing ethylene and ethylene downstream products from the ethane fraction present in natural gas. From this viewpoint, the project is evaluated as making an economic contribution to Thailand.

8—2 As a result of calculation of the economic internal rate of return (EIRR) over the period of 15 years of project life, on the basis of evaluation of the economic benefits and costs of the project, it was determined that the EIRR for the ethylene project is 18.1% and that for the VCM project is 13.8%, enabling the Study Team to judge that a rate of profit approaching the financial internal rate of return could be expected.

8—3 This project is the first large-scale petrochemical industry project undertaken by Thailand, and its implementation would contribute to establishing the foundation for the future development of the petrochemical industry, in addition to which it will create employment opportunities in the Rayong district, contribute to development of the regional economy in Rayong as well as to the dispersion of the nation's industry in favor of this district, and cause ripple effects in related industries, through which the project is expected to make a strong contribution to the economic development of Thailand.

8—4 The internal rate of return for this project indicates that it would provide an adequate to national economy. From this viewpoint, as is stated above, strategic consideration are needed so that the ethylene project, and downstream projects, can all be realized.

IX. SUPPLEMENTARY STUDY

9–1 BASIC CONDITIONS FOR THE SUPPLEMENTARY STUDY

This supplementary study is a comparative evaluation of ethylene plant production capacity, done independently of the study report proper and done on the basis of the assumption that the following conditions are met.

Conditions for the Supplementary Study

A. Not only will feedstock ethane be recovered from the Phase I gas processing plant (350 MMSCFD) now being constructed but ethane from the Phase II plant to be constructed in the future is also to be used.

B. Downstream plants for ethylene derivatives (LDPE, HDPE, VCM/PVC and EO/EG) are to be constructed in order to satisfy domestic demand by means of domestic production. That is, so that potential demand for ethylene is equivalent to effective demand, capacity of downstream plants will at all times exceed demand.

C. In the event that natural gas is used as feedstock for olefin production, the yield of propylene will be less than that of naphtha, resulting in a constraint on propylene production. Further, considering the pattern of petroleum refining in Thailand, recovery of a large quantity of propylene from refineries is not to be expected. Therefore the quantity of domestically suppliable propylene will be low, to the extent that it will not be sufficient to satisfy domestic demand. Therefore, there will be no choice but to meet the shortfall in supply by means of polyethylene as a substitute.

9–2 MARKET

At present, the ratio of demand for olefins in total demand for polyolefins (polyethylene and polypropylene) in Thailand and in the Philippines is about 40%. It is assumed that the present ratio will be maintained until 1985, the year the plant starts to operate, and thereafter will decline to 20% in 1990. After 1990 it will remain at the 20% level. For this assumption to be realized, the following are required.

(1) An import tariff higher than the present tariff must be adopted.

(2) The domestic polyethylene price must be regulate to be kept at a low level.

(3) Technical problems which might prevent substitution for polypropylene by polyethylene must be solved.

On the basis of the above assumptions, demand projections have been prepared for polyethylene (LDPE and HDPE) and polypropylene (see Table 12). The ratio of LDPE to HDPE is taken to be the same as that given in the main text of the study report. For potential demand other than that for polyolefins, the same values as in the main text.

Ethylene demand derived from the above polyethylene demand, taking into account the assumption B mentioned above are shown in Table 13 and Fig. 7 (Case II).
Ethylene demand is as follows.

1985	157.3 (1,000 t/y)
1990	283.8
1995	402.1
2000	565.9

9–3 COMPARISON OF ECONOMICS AS RESULTING FROM DIFFERENCE IN PRODUCTION SCALE

Because demand for ethylene is greater in the case of this supplementary study than in the case of the study proper, economic comparison was made for the following three scales of production.

Case A-1	230,000 T/Y
Case A-2	300,000 T/Y
Case A-3	350,000 T/Y

Table 12 DEMAND FORECAST FOR POLYETHYLENE AND POLYPROPYLENE

(Unit: 1,000 t/y)

	LDPE	HDPE	PP
1981	42.5	28.3	47.2
1982	46.0	30.6	51.1
1983	49.7	33.1	55.2
1984	53.8	35.9	59.8
1985	59.9	37.2	64.7
1986	70.0	42.0	63.0
1987	81.4	47.4	60.6
1988	92.2	55.3	57.4
1989	106.4	62.1	53.2
1990	120.0	72.0	48.0
1991	131.3	74.7	51.5
1992	143.7	77.4	55.3
1993	154.2	83.0	59.3
1994	165.5	89.1	63.7
1995	177.6	95.6	68.3
1996	190.6	102.6	73.3
1997	204.6	110.2	78.7
1998	219.5	118.2	84.4
1999	235.6	126.9	90.6
2000	252.9	136.2	97.3

Table 13 ETHYLENE DEMAND

(Unit : 1,000 t/y)

	PE	PVC	Ethylene for EO	Ethylene Demand
1985	97.1	56.1	27.9	157.3
1986	112.0	61.0	30.0	177.5
1987	128.8	66.4	32.4	200.2
1988	147.5	72.2	34.8	225.1
1989	168.5	78.6	37.5	252.9
1990	191.9	85.6	40.4	283.8
1991	206.0	92.0	42.9	304.3
1992	221.1	99.0	45.6	326.3
1993	237.3	106.5	48.5	349.9
1994	254.6	114.5	51.6	375.0
1995	273.3	123.2	54.8	402.1
1996	293.3	132.5	57.6	430.5
1997	314.7	142.6	60.6	460.9
1998	337.8	153.4	63.7	493.6
1999	362.5	164.9	67.0	528.4
2000	389.0	177.4	70.5	565.9

Note : (Ethylene Demand) = (PE) x 1.05 + (PVC) x 0.49 + (Ethylene for EO).

The results of comparing the financial internal rate of return (FIRR) representing business's appraisal of the project and economic internal rate of return (EIRR) representing appraisal of the project from the viewpoint of the national economy, are shown in Fig. 8. The conditions for comparison were as follows.

Capital requirement (Figs. in parentheses are foreign currency component)

	(US$'000 in constant 1980 prices)	
230,000 T/Y	233,763	(153,775)
300,000 T/Y	261,645	(174,028)
350,000 T/Y	280,336	(186,426)

Financial plan : The capital requirement is satisfied through borrowing, at the average annual interest rate of 9.8%.

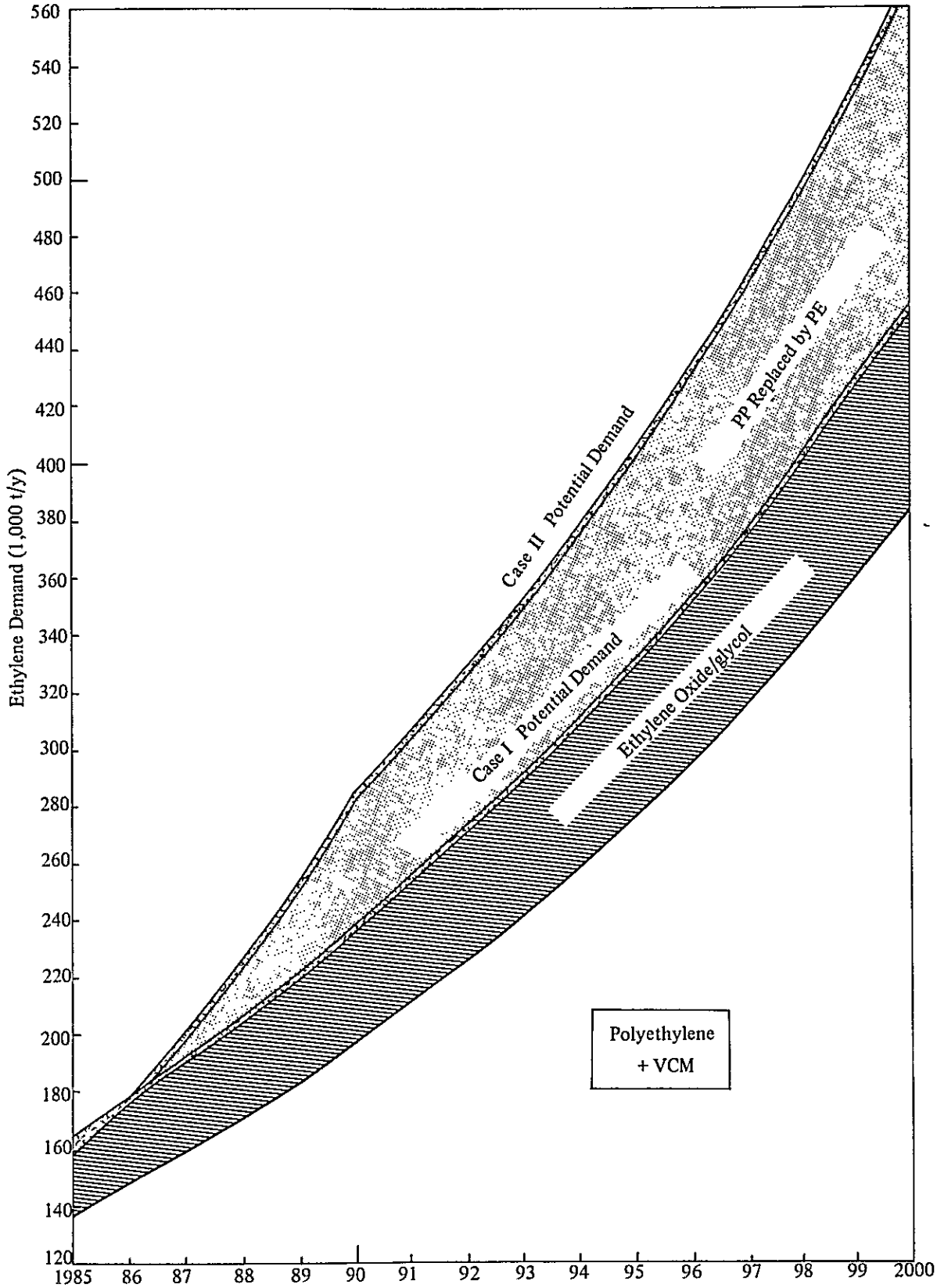
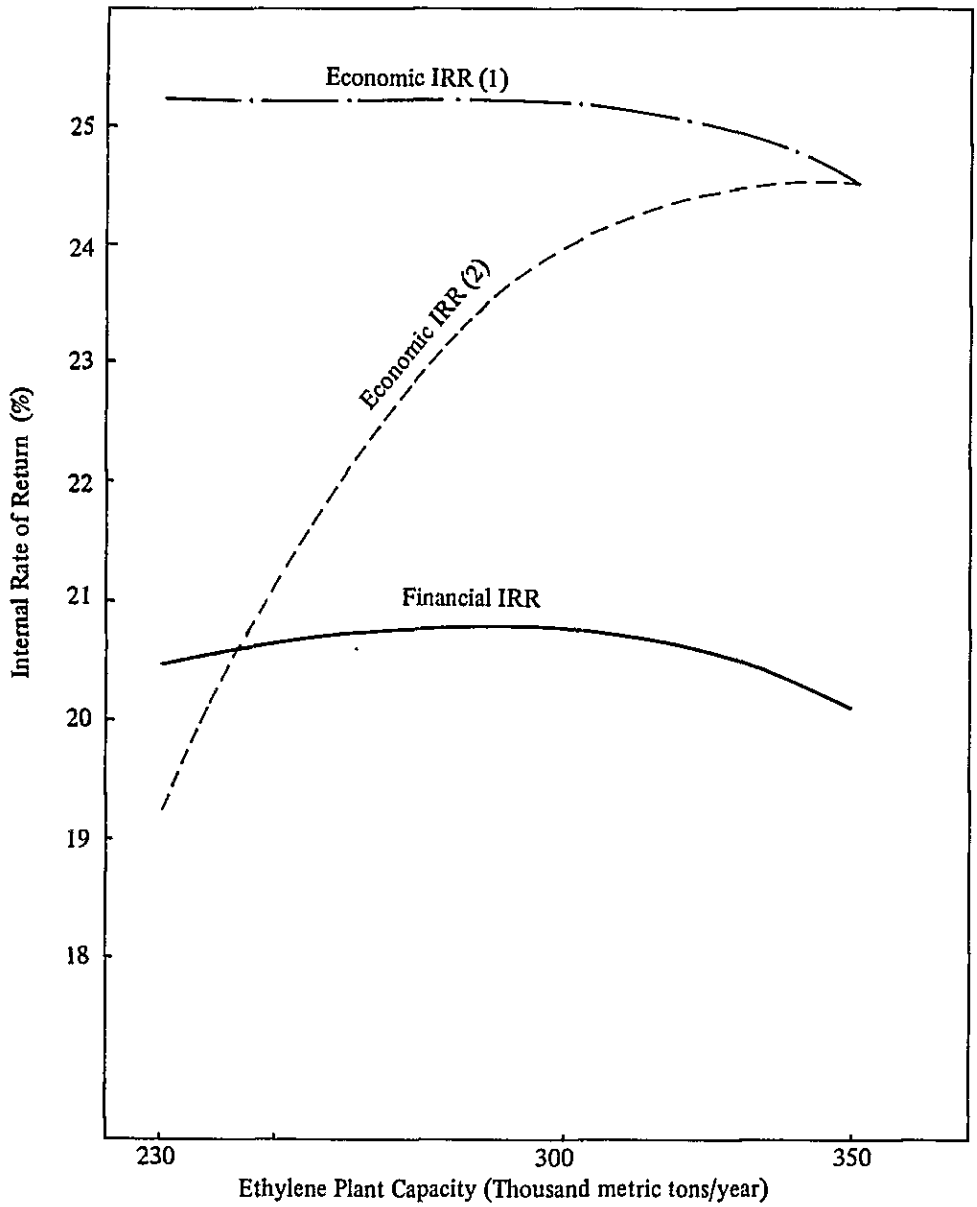


Fig. 7 SUPPLY/DEMAND BALANCE FOR ETHYLENE



Notes : 1) Opportnity loss is not taken into account.

2) Opportunity loss is taken into account.

Fig. 8 COMPARISON OF INTERNAL RATE OF RETURN FOR DIFFERENT PRODUCTION CAPACITIES OF ETHYLENE PLANT

Ethane price : US$300 (economic price, US$240)

Ethylene price : US$700 (economic price, US$600)

Other conditions are identical to those given in the text proper.

Review of the result of calculation indicates that the ethylene project is feasible at all scales of production. From the viewpoint of the national economy, in regard to the opportunity loss of utilization of recovered ethane, the 300,000 t/y scale has a higher internal rate of return than the 230,000 t/y scale.

CONCLUSIONS

The conclusions made as a result of this study are as follows.

1. Establishment of a ethylene plant in Thailand is an undertaking of high value to the nation.

   (1) There is sufficient domestic demand to justify construction of an ethylene plant.

   (2) It is possible to domestically produce and supply the ethane needed to produce ethylene.

   (3) Formidable investment effect can be expected of an ethylene project, and its contribution to the national economy would be great.

Construction of a VCM plant, similarly, is a project of high importance in the above regard, as a production facility for an ethylene derivative, and, moreover, there would be favorable investment effects and contribution to the national economy resulting from such a project.

2. The potential demand quantity of ethylene for satisfying Thailand's domestic demand for ethylene derivatives is estimated as 165,000 t in 1985 and 240,000 t in 1990. However, if the level of domestic production of derivatives is considered, the effective demand for ethylene is estimated as 134,000 t/y in 1985, and 190,000 t/y in 1990.

3. From the ethane recoverable at the PTT's LPG plant (first phase, 350 MMSCFD), annual production of 230,000 t of ethylene is possible.

   The results of study which took into consideration demand trends and raw materials or feedstock availability indicate that the ethylene plant production scale which has the highest economic potential is 230,000 t/y.

4. An additional study is made of the possibilities of an even larger ethylene plant (300,000 t/y). The following conditions would have to be satisfied in order for such a scale of plant to be possible.

   (1) There would have to be an increase in the quantity of ethane recovered, by means of the early completion of a second phase gas processing plant, in addition to the first phase plant.

(2) Potential ethylene demand would have to be converted into effective ethylene demand, through the construction of a derivatives plant.

(3) There would have to be swift progress in substitution of polypropylene demand by polyethylene, against the background of a domestic shortfall in supply of propylene.

5. The quantity of VCM required for domestic production of PVC is estimated at 58,000 t/y in 1985 and 80,000 t/y in 1990.

The scale of VCM production, with reference made to estimated demand in 1990, is taken as 80,000 t/y, and it has been determined that the best location for the plant is adjacent to the ethylene plant. It has been determined possible to obtain chlorine by constructing an electrolysis plant which would use either marine salt or rock salt, both of which are available domestically, as raw material.

6. The ethylene plant, VCM plant and electrolysis plant are envisioned as being constructed adjacent to the PTT gas processing plant in Rayong. An outline summary of major features of this site is as follows.

a. Utilities supply
Water is to be obtained from Dok Krai reservoir, by a pipeline also conveying water for the gas processing plant. Electric power for the ethylene plant (and a common utilities center) is to be self-generated, and power for the VCM plant (including the electrolysis plant) is to be purchased from PEA.

b. Port and harbor facilities; roads
It is possible to use the port at Sattahip for landing the equipment and materials needed to construct the plants. For shipment of VCM, it will be advisable to use the jetty being constructed for the LDPE plant. The site fronts on a highway and road conditions between the site and Bangkok are good.

c. Geology
Judging from information from PTT, with the exception of certain parts of the site, bearing strength is adequate.

d. Environment
The site is separated from densely-populated areas, recreation areas and military installations. It is thought that there will be no major deterrent to use of the site for construction of a plant.

7. The construction periods for the plants, from signing of contract to the start of operation, are 36 months for the ethylene plant and 27 months for the VCM plant. Therefore, the start of commercial operation of the projects is estimated to be mid-1985 at the earliest.

8. The total capital requirement for the projects is US$220 million for the ethylene project (230,000 t/y) and US$140 million for the VCM plant (80,000 t/y), which total US$360 million (in prices current as of the end of 1980).

9. It is judged that the optimum feedstock and product prices are as follows (ex-plant, 1980 price).

Ethane	US$300/t
Ethylene	US$700/t
VCM	US$750/t

It is judged that by setting the prices as shown above, both the ethylene and VCM plant projects will be economically sound, and that they will have sufficient ability to absorb the effects of change of the sale price of derivatives.

RECOMMENDATIONS

1. This project essentially comprieses one part of Thailand's effort to increase value-added of her natural resources of natural gas. It is, therefore, highly recommendable that the Government of Thailand devise policies and guidelines for the harmonious development of the petrochemical industry based on a comprehensive view toward improving the value-added of the natural gas.

2. For the successfull implementation of an internationally competitive petrochemical complex in Thailand, it is highly recommendable that a concrete and strong policy and guideline be urgently established through a thorough discussion and mutual exchange of opinions with private sector interests which will implement downstream projects such as LDPE, HDPE and VCM projects. Good coordination with the private sector parties concerned is indispensable for the materialization of PTT's ethylene project.

3. This study confirmed that both the ethylene and VCM projects can be realized provided that the ethylene price is US$700/t, and the ethane price is US$300/t. But when the actual ethylene price is set at the stage of project implementation, it will be advisable to do so on the basis of consideration of the current and anticipated conditions at that time related to the market environment and price trends for derivatives.

4. The major points deserving attention in connection with the conceptual design of the project are as follows.

   a. The process to be selected should be proven in various countries of the world, as efficient and economical.

   b. Production of waste products should be kept at a minimum by means of measures implemented at the points where the wastes are produced, and pollution prevention measures should be taken through such means as providing suitable waste treatment systems.

   c. Utilities facilities should be centralized in order to realize the potential economies of a petrochemical complex.

5. Inregard to utilities supply, as well as improvement of infrastructure, it is desirable to proceed while maintaining close relationships with related agencies and coordination activities with them.

It is necessary in particular to confirm whether there will be a sufficient supply of water from Dok Krai during the dry season.

6. It is desirable to minimize technical risk, by obtaining the services of a suitably qualified engineering firm for design and construction of the plants. Further, it is desirable that at each stage of project operation and management, namely preparation for contract signing, construction, early operation, etc., technical advice is obtained from an experienced consultant or existing production firm, so that this project, Thailand's first petrochemical complex, can be realized without delays or major problems. Moreover, it will be necessary to establish an organization for project management, and train workers, at an early time.

7. Because it is anticipated that the Thai ethylene derivative makers will be established each as a separate company, this itself will create a limitation to the funds which can be invested in research. It is therefore desirable that PTT establish a general research center on behalf of the development of the petrochemical industry in Thailand, and that that research center support the activities of the individual derivative makers.

   As research subjects of particular importance, mention may be made of technology for synthesis of monomers and polymers, analysis and study of the properties of monomers and polymers, and applied technology for the use of polymers.

8. For the development of petrochemical industry, not only production of derivatives needed but there also must be a plastics processing industry, a synthetic fibers industry, and other industries which have demand for the derivatives. It is desirable that the Government of Thailand plan and carry out policies and measures for these downstream industries.