No. 59

THE FINAL REPORT
FOR
THE FEASIBILITY STUDY
ON
EFFECTIVE UTILIZATION OF BANKO COAL
IN
THE REPUBLIC OF INDONESIA

—— SUMMARY ——

March 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

MPI
~~OR(3)~~
89-85

PREFACE

In response to a request from the Government of the Republic of Indonesia, the Japanese Government decided to conduct a feasibility study on Effective Utilization of Banko Coal and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA has sent to Indonesia a study team headed by Mr. Takehiko Sato, the Institute of Energy Economics, Japan, as many as eighteen times during the period of five years from May 9, 1984 to December 20, 1988.

The team has had a series of discussions with concerned officials of the Government of the Republic of Indonesia, and conducted field surveys, gasification tests, and so on. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the development of the project and to the promotion of friendly relations between our two countries.

I wish to express my sincerest appreciation to the concerned officials of the Government of the Republic of Indonesia for their close cooperation extended to the team.

March, 1988

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

1. EXECUTIVE SUMMARY AND RECOMMENDATION

1. Banko Coal Gasification was proven technically feasible
2. The proposed Project is to produce 1.5 million t/y of fuel methanol from N.W. Banko coal, starting in year 2000
3. The proposed Project was evaluated as "marginally viable"
4. A pilot test for fuel methanol utilization in automobiles and electricity generators should be carried out

1) Summary

i) This feasibility study was proposed by the State Minister for Research and Technology of Indonesia, Prof. Dr. Ing. B. J. Habibie

ii) Technical reliability of Banko coal gasification by a molten iron bath process has been proven through the coal gasification test

iii) The proposed Project is as follows:

Coal basin	N. W. Banko
Coal consumption	3.7 million t/y as mined
Methanol production	1.5 million t/y
Utilization of methanol	Fuel for internal combustion engines
Start of operation	Year 2000
Build-up of plant	Three phases of each 0.5 million t/y

iv) Initial fixed capital investment is appr. 860 million US$

v) Financial IRR is 11.9%, in case of 175 US$/t of fuel methanol price

vi) If oil price is higher than 30 US$/bbl, fuel methanol from Banko coal is more economical than petroleum fuel

2) Recommendation

i) Political measures for introduction of fuel methanol should be studied

ii) A pilot test for fuel methanol utilization, in taxies, buses, trucks, diesel engine generators and gas turbine generators, should be carried out

2. OUTLINE OF THE STUDY

To establish a master plan and examine its technical and economic feasibility

TYPE OF PROGRAM	Government-sponsored technical cooperation
AGENCY FOR THE IMPLEMENTATION Japanese side Indonesian side	 JICA (Japan International Cooperation Agency) BPPT (Agency for the Assessment and Application of Technology)
OBJECTIVE	Feasibility study on effective utilization of Banko coal in Indonesia
COAL RESOURCES	Non-transportable brown coal reserved in Banko area of South Sumatra
APPLICATION TECHNOLOGY	Coal gasification and gas synthesis
PRODUCTS	Synthetic fuel oil, chemicals
SCOPE OF THE STUDY	1) Market survey on alternative liquid fuel and basic chemicals in Indonesia 2) Survey on reserves, quality and mining cost of Banko coal 3) Survey on gasification characteristics of Banko coal, using a small scale test plant 4) Investigation of a master plan for effective utilization of Banko coal 5) Financial analysis and economic evaluation for the proposed project
DURATION	1984 – 88 (5 years) 1) Strategic investigation stage : One year 2) Coal gasification test stage : 2.5 years 3) Feasibility study stage : 1.5 years

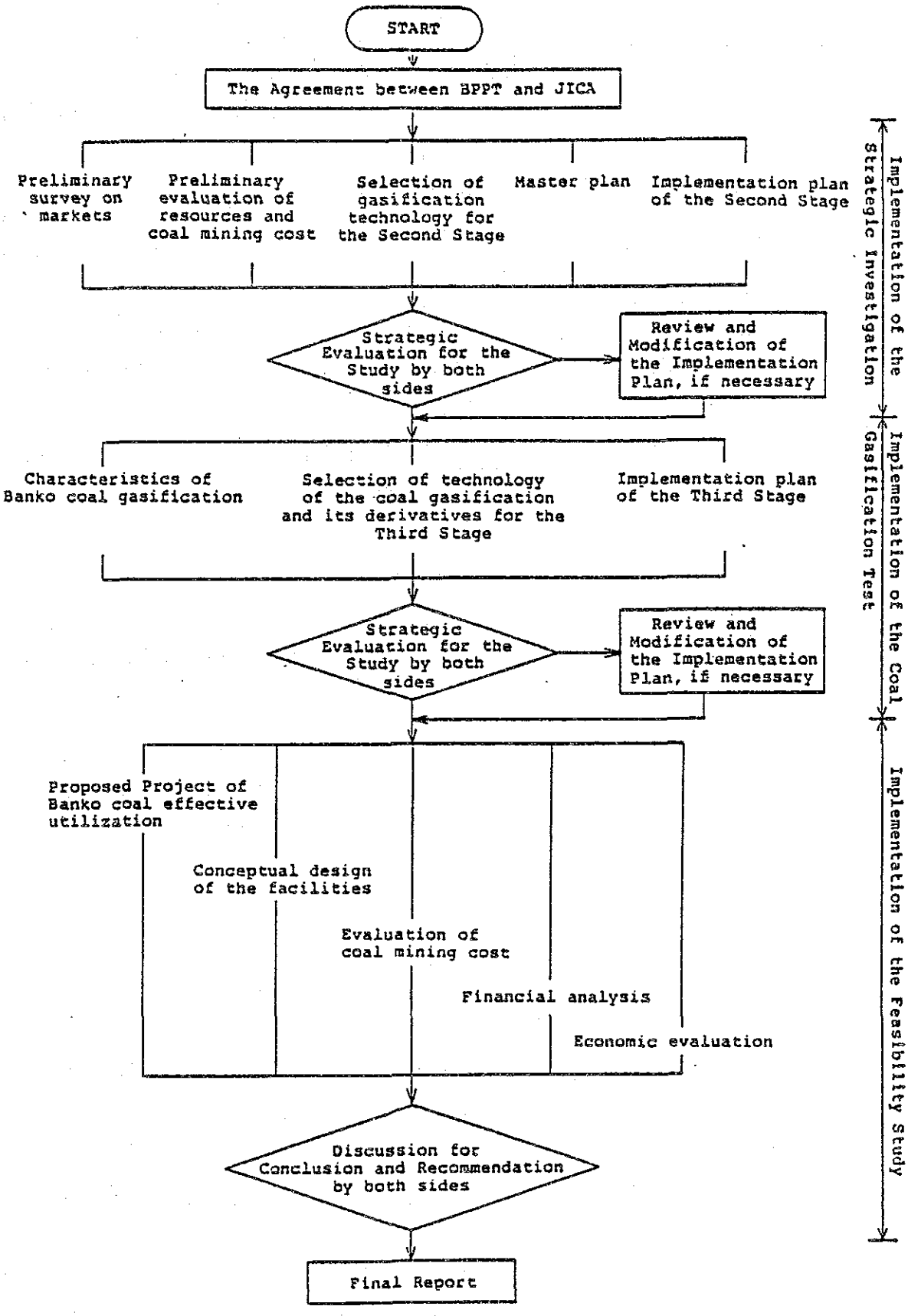
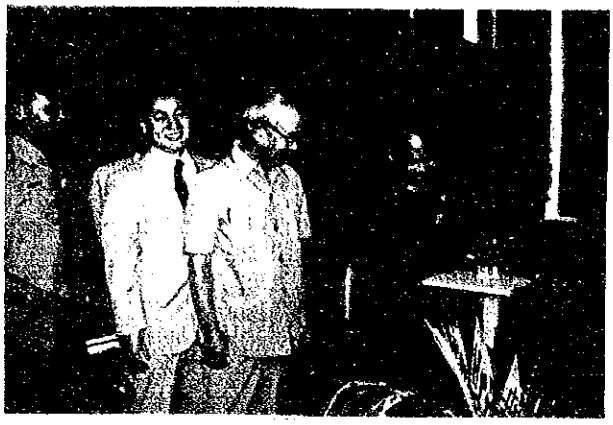


Fig. 2-1 Flow Chart of Implementation Plan

3. PROGRESS MADE IN THE STUDY

1. As schedule without any trouble
2. Success in Banko coal gasification
3. Execution of technology transfer

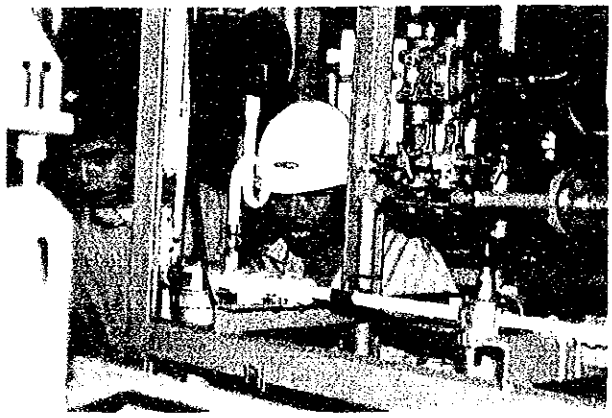
1) FY 1984
   i) Preliminary survey on market, Banko coal resources and brown coal utilization technology
   ii) Stratigic study for establishment of the master plan
   iii) Basic design of the coal gasification test facilities
2) FY 1985
   i) Detailed design of the test facilities and procurement of equipment
   ii) Survey on coal quality by shallow boring
   iii) Preliminary evaluation of economic feasibility for methanol production
3) FY 1986
   i) Fabrication and construction of the test facilities
   ii) Coal sampling work in N.W. Banko by deep boring
   iii) Preliminary evaluation of economic feasibility for coal mining, urea production and electricity generation
   iv) Survey on market of fuel alcohol in Indonesia
4) FY 1987
   i) Coal sampling work in Central Banko and North Suban Jeriji by deep boring and coal analysis
   ii) Coal gasification test and data analysis using 20 kinds of coal samples
   iii) Survey on coal utilization technology, including methanol engines
5) FY 1988
   i) Final study on market, Banko coal resources and Banko coal utilization technology
   ii) Conceptual design of the facilities
   iii) Financial analysis and economic evaluation



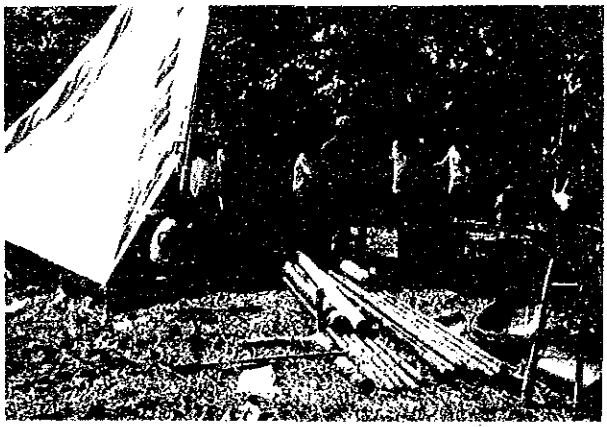
Switch-on of operations at Banko coal gasification test plant by Minister B.J. Habibie and Ambassador T. Muto (1987)

Measurement of the temperature of the molten iron bath

BAKOREN members visited the plant (1987)



On-line gas analyzer



Coal sampling work at Banko, South Sumatra

Coal and slag analysis

4. RESULTS OF SURVEY ON MARKETS

0.85 and 3.0 million tons of fuel methanol demand for internal combustion engines is expected in 2000, and 2005 respectively

1) Demand forecast for petroleum products

BPPT's MARKAL study predicts the domestic demand for petroleum products as follows

Year	2000	2005	2010
High oil price scenario (million kl)	31.5	35.0	39.1
Low oil price scenario (million kl)	28.5	30.0	31.0

Note: Assumed oil prices for export are as follows;

Year	2000	2005	2010
High oil price scenario (US$/bbl)	28	36	45
Low oil price scenario (US$/bbl)	21	25	29

2) Demand forecast for fuel methanol vs. oil price

Potential fuel methanol demand vs. oil price, according to LP model study, is illustrated in Fig. 4-1.

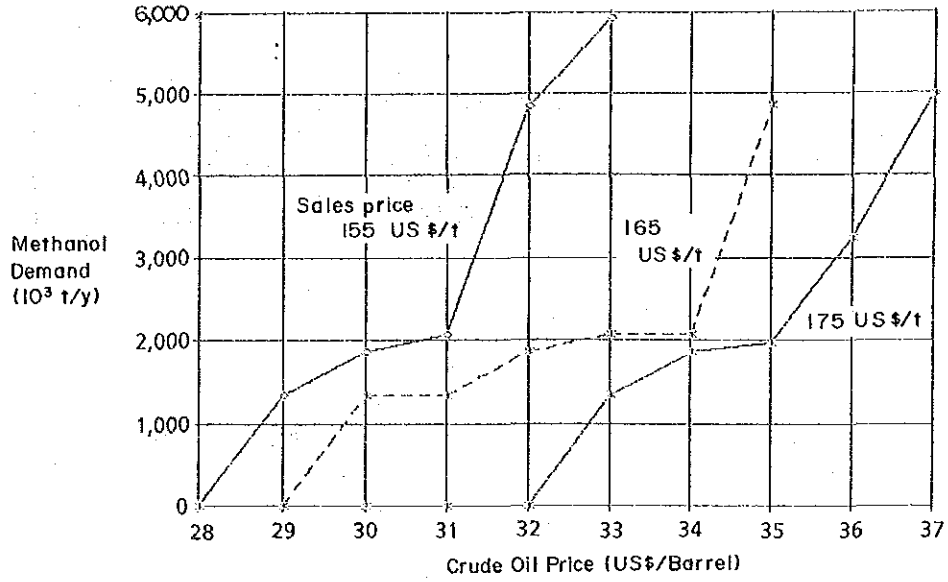
3) Demand forecast by year

Potential fuel methanol demand by year is estimated on the base of average values of assumed oil price as follows; (Fig. 4-2)

Year	2000	2005	2010
Expected oil price for export (US$/bbl)	24.5	30.5	37.0
Methanol demand (10^3 t/y) (Sales price: 175 US$/t)	850	3,030	12,915

Note: USDOE and IEE, Japan estimate oil prices as follows;

Year	2000	2010
USDOE (US$/bbl)	29~37	44~62
IEE, Japan (US$/bbl)	28~38	48~50



Economic benefits obtained by introducing fuel methanol into Indonesia was determined by the difference between the cost for introduction of fuel methanol and increase in profits obtainable from the increase in the export of oil and oil products. Problems caused by the decrease of oil export are not considered in this LP model study.

Fig. 4-1 Fuel Methanol Demand vs. Oil Price

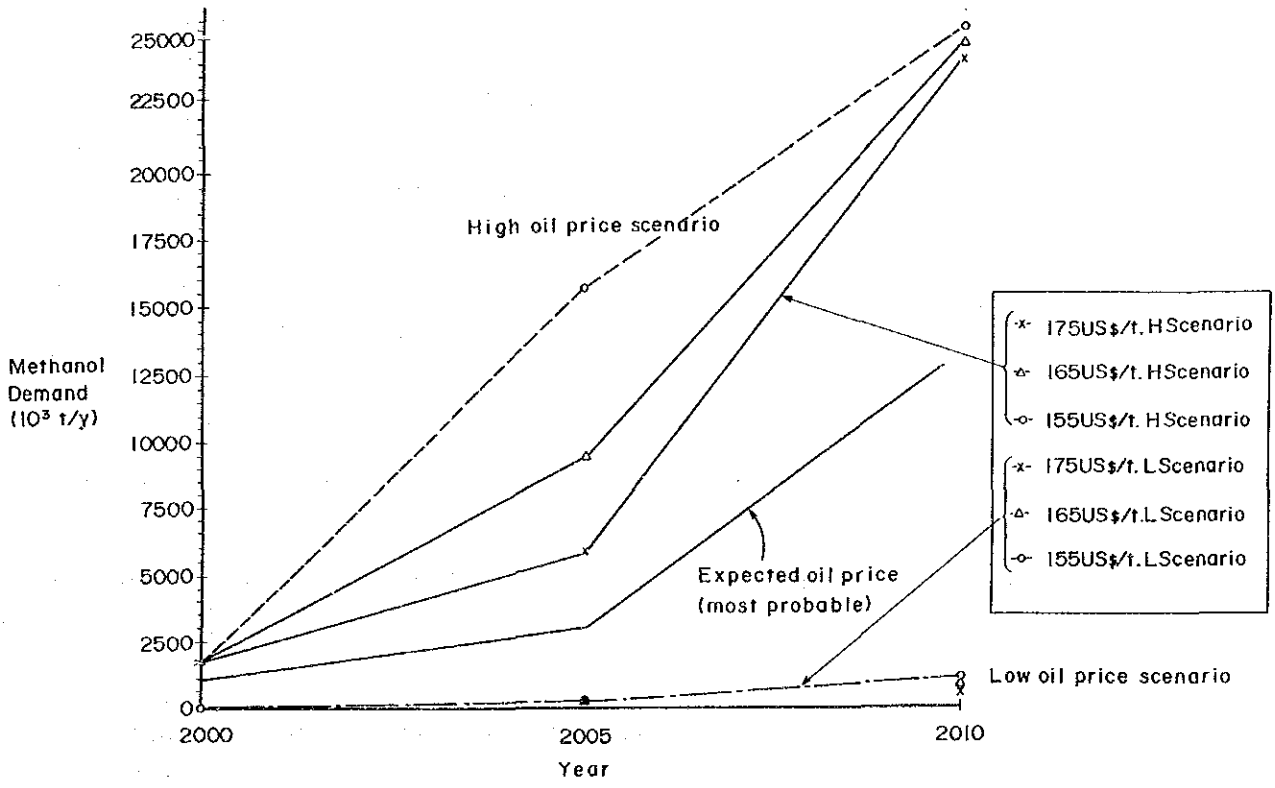


Fig. 4-2 Fuel Methanol Demand by Year

5. RESULTS OF SURVEY ON COAL RESOURCES

1. Coal reserves are abundant, more than 500 million tons
2. Mining cost of N.W. Banko coal is 14.0 $/t as mined
3. Banko coal is a low grade coal with high sodium content

1) Contributions by the Counterpart

i) Topographical maps and geological maps of Banko area

ii) Boring data in Banko area and F/S report of N.W. Banko coal mining

2) Coal resources

i) Coal reserves (up to 100 meter depth)

N.W. Banko	:	130 million tons
Central Banko	:	130
N. Suban Jeriji	:	240

ii) Coal quality

Low grade coal with high sodium content

	T. moisture*1 (%)	Calorific value*1 (kcal/kg)	C	H (%)	O*2
N.W. Banko	27.6	4,650	74.4	5.8	17.9
Central Banko	36.7	3,800	71.7	6.6	19.9
N. Suban Jeriji	42.5	3,150	69.9	5.7	23.1

Note: Sodium content depends on coal seam and depth, but it is in the range of 0~20% in ash.

*1 as mined

*2 dry-ash-free base

3) Coal samples for coal gasification test

20 kinds, 200 kg per each sample from N.W. Banko, Central Banko and N. Suban Jeriji

4) Spontaneous combustion test

105°C within 24 hours after start of storage by 5 m × 5 m × 2 m high

5) Coal mining cost

14.0 $/t as mined in case of N.W. Banko coal

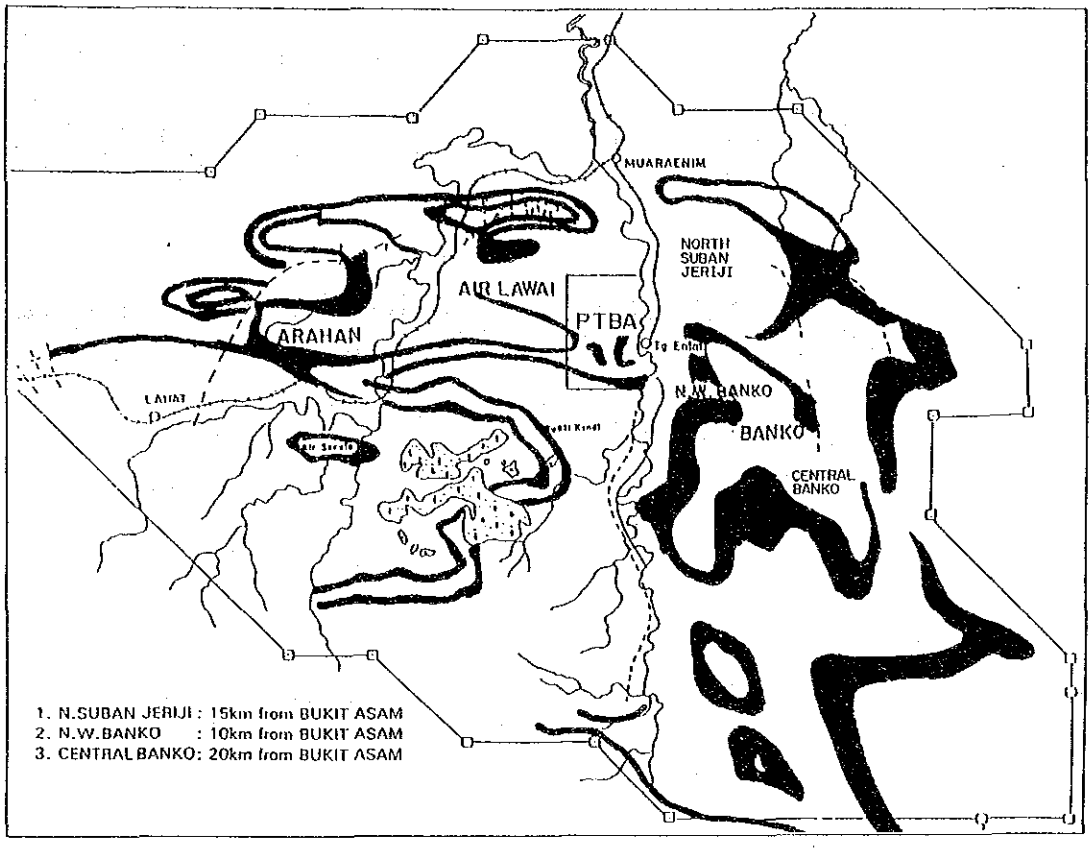


Fig. 5-1 Coal Resources in Western Part of South Sumatra Area.

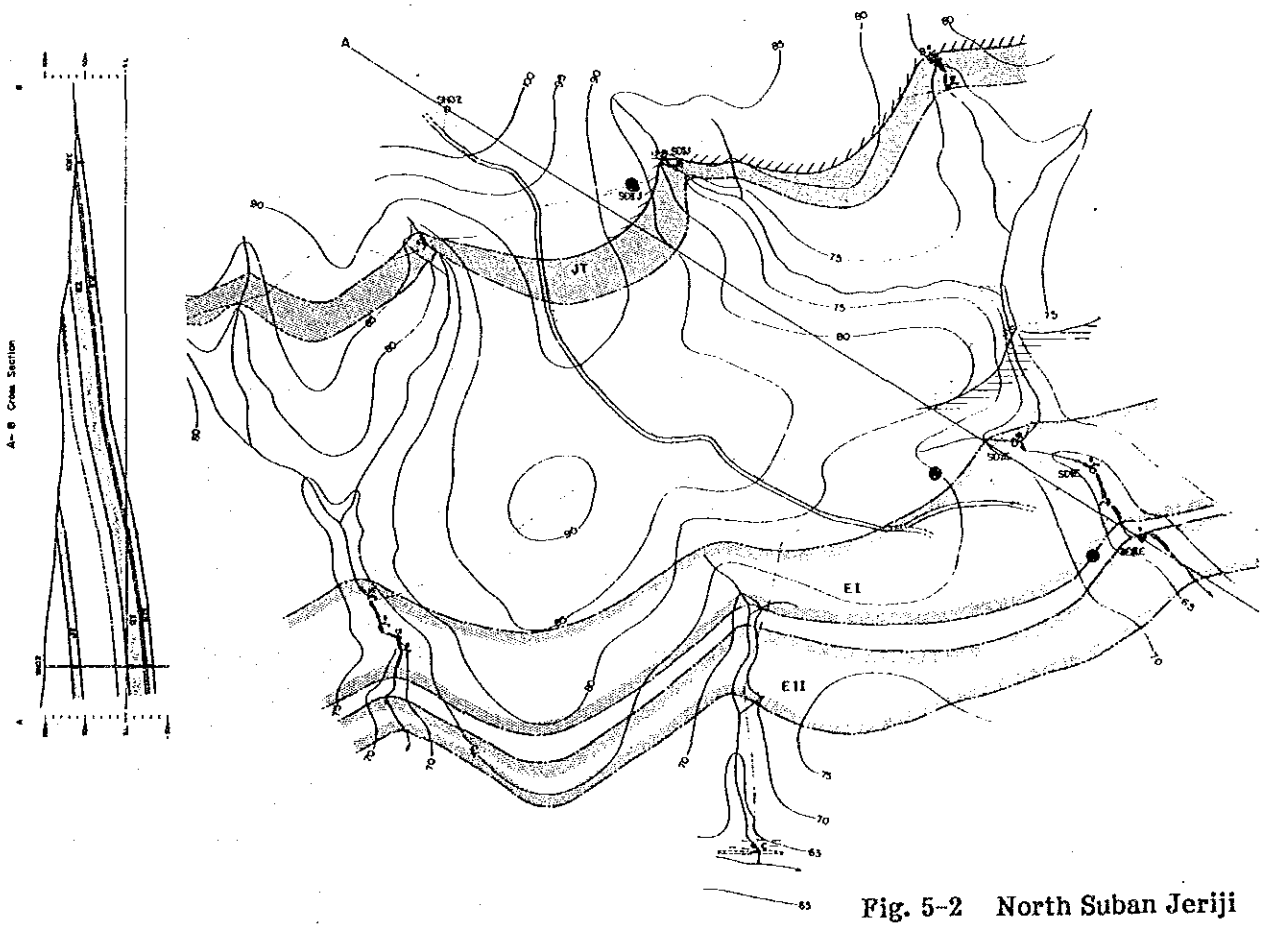


Fig. 5-2 North Suban Jeriji

6. RESULTS OF BANKO COAL GASIFICATION TEST

1. Banko coal gasification by a molten iron bath process was technologically proven to be feasible
2. Technology transfer was pursued through the coal gasification test

1) Coal gasification test facilities

Process : Molten iron bath
Capacity : 30 kg/h of coal
Place : Laboratory for Energy and Energy Resources at PUSPIPTEK, Jakarta

2) Coal gasification test

Schedule : July – December, 1987
Coal samples tested : 20 kinds
Test method : Twice per sample coal
30 minutes per test run

3) Gasification characteristics of Banko coal

Coal basin	CO	H_2 (%)	CO_2	Gas volume (Nm^3/t coal as mined)
N.W. Banko	59.0	28.1	3.9	1530
Central Banko	55.2	29.6	4.3	1310
N. Suban Jeriji	57.5	27.8	4.5	1130

Note: i) All coals can be gasified without any technical difficulty
ii) Allowable moisture content in the feed coal is 10% in case of N.W. Banko

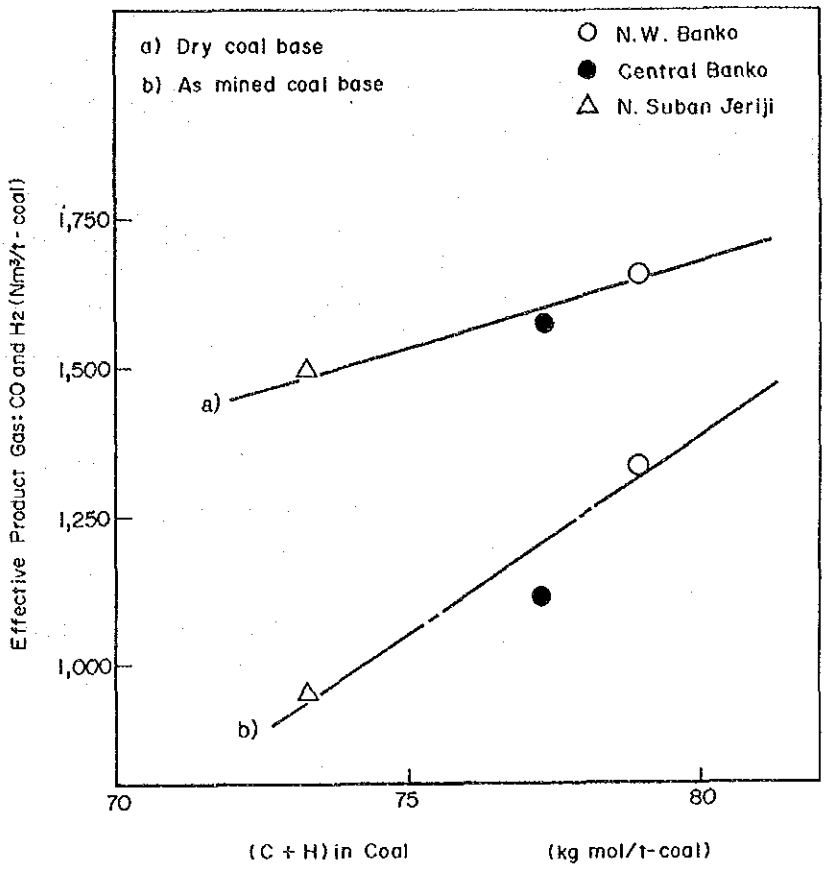


Fig. 6-1 Effect of Coal Quality on Effective Product Gas Volume

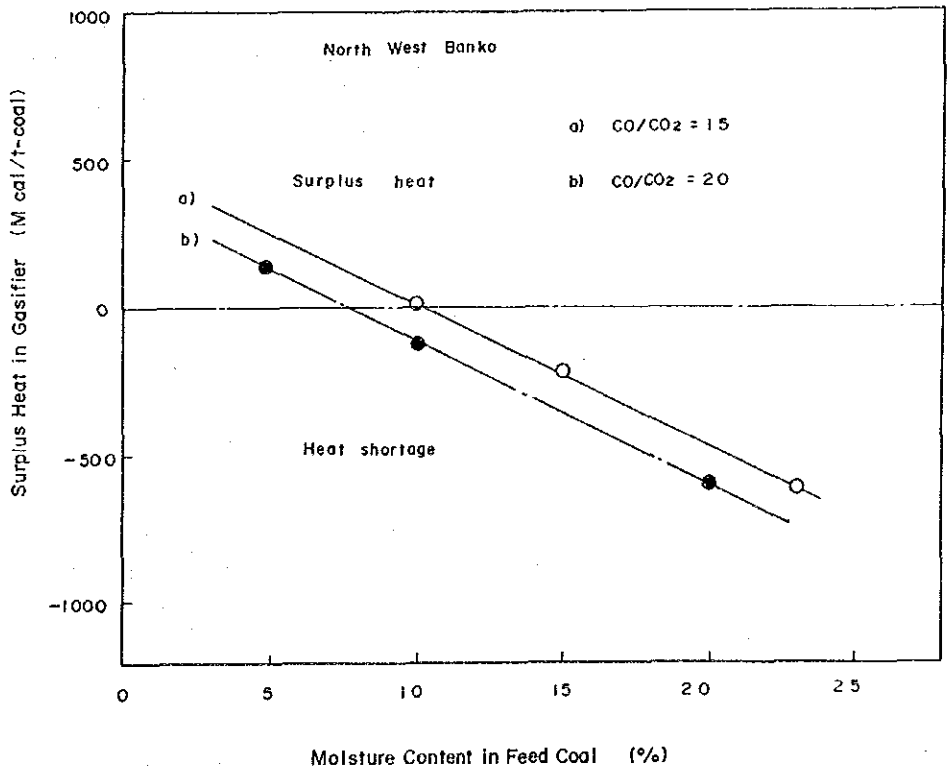


Fig. 6-2 Effect of Moisture Content in the Feed Coal on the Heat Balance

7. RESULTS OF SURVEY ON BANKO COAL UTILIZATION TECHNOLOGY

All of the necessary technology for Banko coal utilization through gasification have been developed at commercial scale

1) Technology for coal gasification

Molten iron bath process : 240 t/d prototype test stage

Note: Evaluation of coal gasification technology for synthesis gas production from Banko coal is shown in Table 7-1.
Availability of molten iron bath process for Banko coal was proven through coal gasification test at PUSPIPTEK

2) Technology for derivatives

Methanol		:	Commercialized and proto type test stage
Urea		:	Conventional, commercialized
Electricity	FBCB	:	Commercialized and prototype test stage
	CGCC	:	Prototype test stage

Note: i) Many plants are producing methanol and urea from natural gas. There would be no difficulty in replacing natural gas with synthesis gas from coal
ii) Conventional pulverized coal combustion boiler is not preferable because of high sodium content in ash

3) Technology for methanol utilization

Chemical	:	Conventional, commercialized
Engines	:	Fleet test stage
Fuel cell	:	Development stage
Special chemicals	:	Development stage

Note: i) Research and development of fuel methanol engines is being carried out worldwide, including practical-use tests
ii) Gasoline engine is ready for commercialization, if required
iii) Diesel engine is still in the fleet test stage
iv) Existing gas turbines can be easily modified to fuel methanol
v) Fuell cells can be used as back-up system for photovoltaic power generation in remote areas

Table 7-1 Evaluation of Coal Gasification Technology for Synthesis Gas Production

	Fixed bed (dry ash)	Fluidized bed	Entrained flow	Molten iron bath
Availability for Banko coal	10	1	10	1
Gas composition	5	5	2	1
Impurity	4	3	2	1
Overall thermal efficiency	3	2	3	1
Gas pressure	1	1	1	3
Operatability and safety	1	1	3	1
Construction cost	3	2	2	1
Commercial experience	1	1	1	2
Total	28	16	24	11
Overall evaluation (ranking)	4	2	3	1

(Note) Lower number is better in performance.

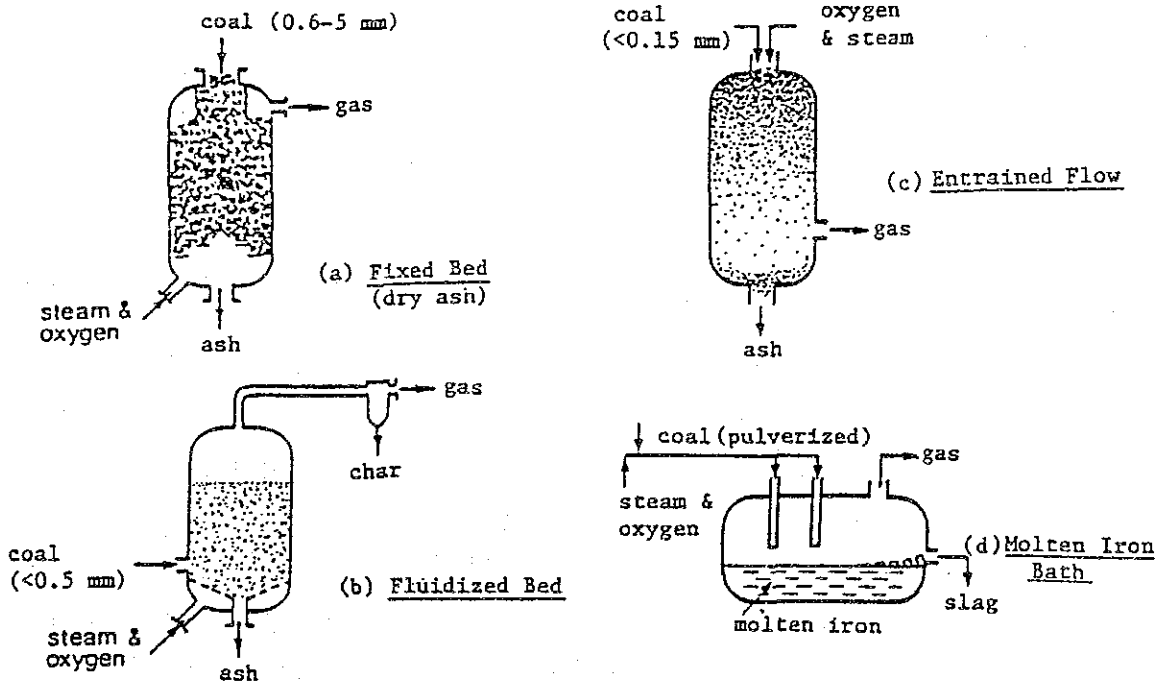


Fig. 7-2 Classification of Principal Coal Gasifier Type

8. ESTABLISHMENT OF THE MASTER PLAN

1. N.W. Banko is the most economical coal basin
2. Methanol production alone (case 1) is more advantageous
3. Three phased construction is advantageous

1) Evaluation of coal basins

		N.W. Banko	Central Banko	North Suban Jeriji
Coal cost	(%)	20.0	24.0	27.7
O_2 cost		28.0	27.6	26.7
Scrap cost		1.5	1.5	1.6
Lime cost		0.5	2.3	1.7
Fixed capital cost Labor cost Utility cost Interest etc.		50.0	52.4	55.0
Total production cost	(%)	100.0	107.8	112.7
Rank		1	2	3

2) Evaluation of overall scheme

		Case 1	Case 2
Coal feed rate	10^3 t/y	3,700	4,000
Methanol production	10^3 t/y	1,500	1,200
Urea production	10^3 t/y	–	560

Note: Table 8-1 suggests case 1, methanol production alone, is more advantageous

3) Proposed master plan

Coal basin : N.W. Banko
Overall scheme : Case 1, see Fig. 8-1
Plant capacity and sales plan : See Fig. 8-2

Note: Delay of fuel methanol introduction and a rather gradual increase in actual demand are considered in built-up of sales plan

Table 8-1 Results of Preliminary Financial Analysis

Case	Case 1*	Case 2**		
Selling Price of products	Methanol 175 $/t	Methanol 175 $/t Urea 100 $/t	Methanol 175 $/t Urea 150 $/t	Methanol 175 $/t Urea 200 $/t
IRR on Total Investment	13.5%	10.6%	12.3%	13.8%

* cited from Interim Report, May 1986
** cited from Interim Report, July 1987

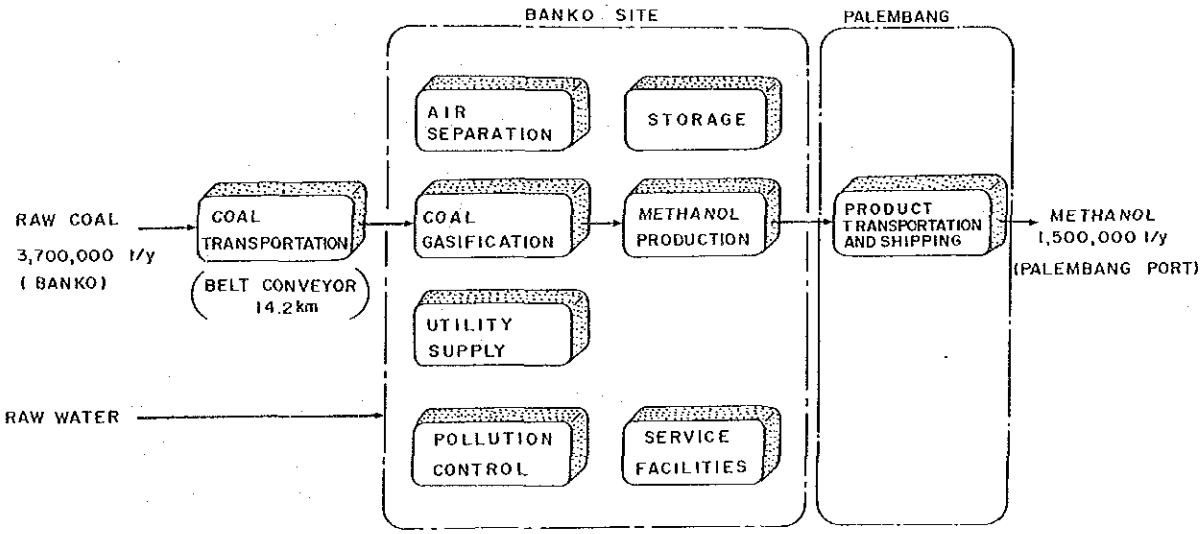


Fig. 8-1 Overall Block Flow Diagram

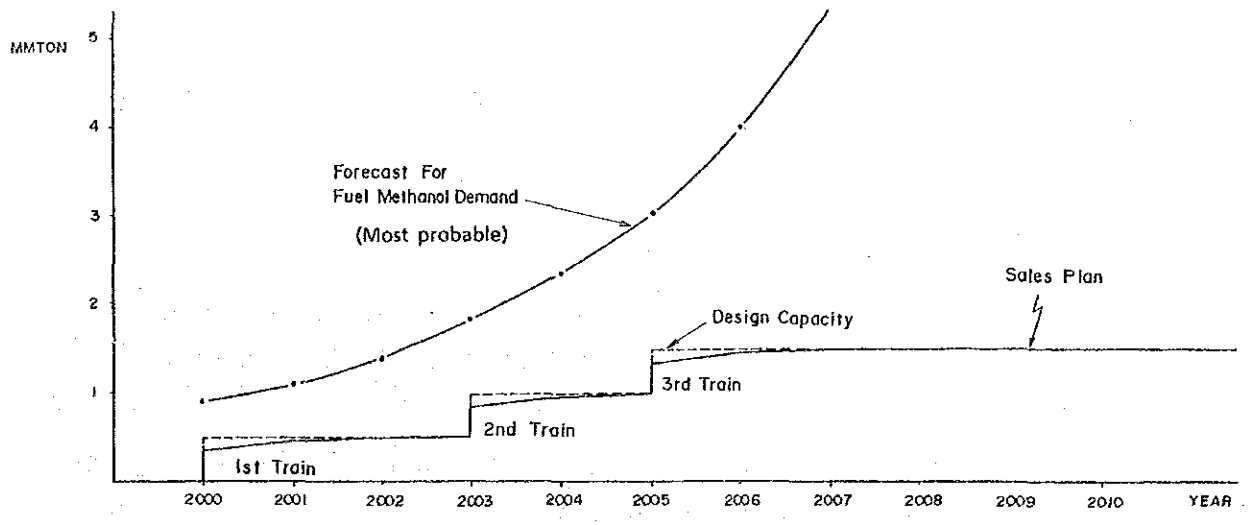


Fig. 8-2 Fuel Methanol Demand and Sales Plan

9. CONCEPTUAL DESIGN OF THE PROPOSED MASTER PLAN

1. There is no objection to mine mouth plants
2. Capital investment is appr. 860 million US$
3. Total cargo weight is 300,000 F/T

1) Conceptual design

Plant location	:	Muara Enim near Banko
Equipment transportation	:	Palembang port and Lematang River
Product transportation	:	By pipeline to Palembang port
Plant space	:	500,000 m^2 (on-site)
		3,200,000 m^2 (off-site)
Process		
Coal gasification	:	Molten iron bath process
Electricity generation	:	Fluidized bed combustion boiler system
Others	:	Conventional process

2) Capital investment and operation cost

	On-site	Off-site	Total
Capital investment costs (million US$)	793	69	861
Fixed capital investment	(776)	(69)	(844)
Working capital	(10)		(10)
Start-up expense	(5)		(5)
Training cost	(2)		(2)
Operation costs (million US$/y)	59		59
Raw materials	(59)		(59)

Note : Coal mining is out of the project. Therefore mining cost of 14.0 $/t as mined is included in operation costs

3) Equipment transportation

Total equipment weight	:	94,000 t
> 35 ton	:	18,000 t, through the Lematang River
< 35 ton	:	76,000 t, through the Sumatra Highway

4) Environmental analysis

Predictions on environmental impacts satisfy the environmental standards of both Indonesia and Japan.

Capital investment cost			Outline of the facilities
%	Million US$	%	
	Coal mining 112.5	11.6	3.7 million tons/y (as mined) Shovel and truck system
1.7	Coal transportation 14.5	1.5	Belt conveyor : 14.2 km. 1 train
34.6	Coal gasification 298.2	30.6	Molten iron bath process 2.5 million tons/y · coal (as mined) Gasifier : 5.4mϕ×18mL×6 units
19.1	Methanol 164.5	16.9	Medium pressure process Double tube type reactor 1,500 tons/d methanol/train×3 trains
9.5	Air separation 81.4	8.4	Cryogenic cold box system 200,000 Nm^3/h·air × 3 trains
10.4	Power plant 89.2	9.2	Fluidized bed boiler system 298 t/h steam · 37MW × 3 trains
1.5	Tank yard 12.8	1.3	15,000 kℓ × 3 tanks
9.1	Utility facilities 78.0	8.0	Cooling water, air, etc.
1.8	Support facilities 15.1	1.6	Administration office, workshop, residential facilities, etc.
4.7	Product transportation facilities 40.7	4.2	Pipeline : 12"ϕ×200 km, Tank: 22,500 kℓ×4
5.8	Equipment transportation 49.7	5.1	Tug boat: 1,500 HP, Barge: 3,000 DWT Total cargo weight: 300,000 F/T
2.0	Miscellanious costs 17.2	1.8	Working capital (10), Startup expense, training cost (7)
961.3	Total	973.8	

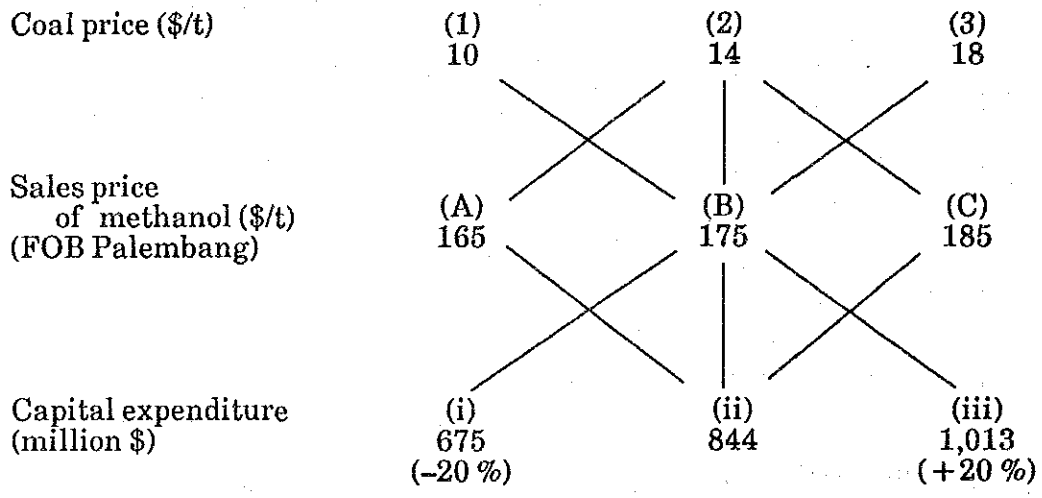
10. FINANCIAL ANALYSIS AND ECONOMIC EVALUATION

1. 11.9% of Financial IRR of Base case is evaluated as "marginally viable" based on energy project criteria
2. If oil price is higher than 30 US$/bbl, fuel methanol from Banko coal is more economical than petroleum.

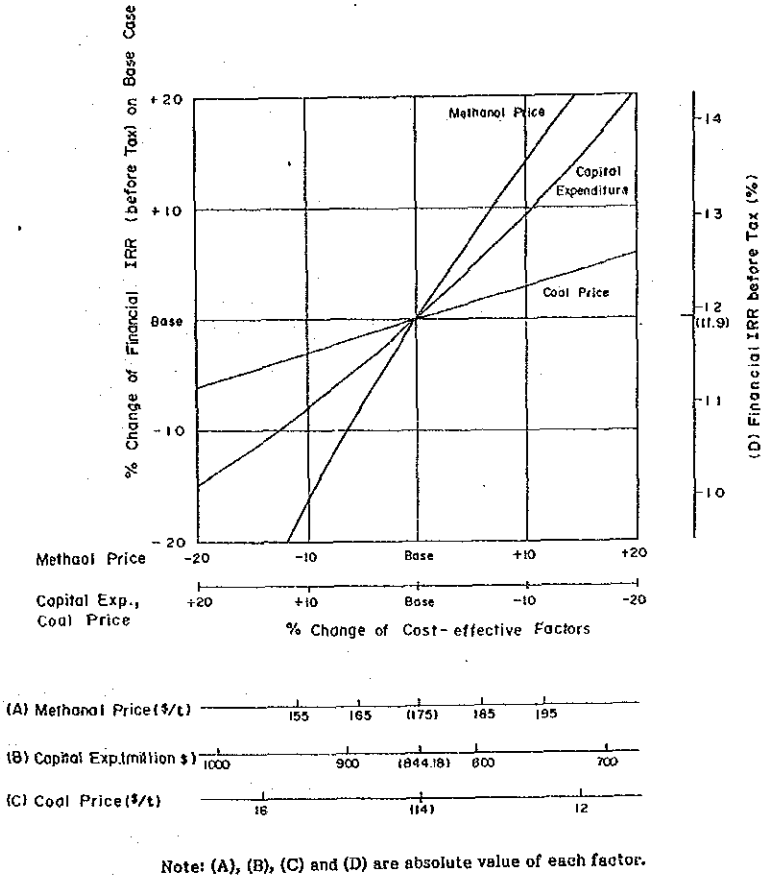
1) Principal factors for financial analysis

Equity: debt	:	25 : 75
Project life	:	20 years
Escalation	:	None
Interest	:	10.8 %/y

2) Results of financial analysis and economic evaluation



		Financial IRR (%)	Economic IRR (%)
Base Case	(2) - (B) - (ii)	11.9	15.0
Case 1	(2) - (A) - (ii)	10.9	13.8
Case 2	(2) - (C) - (ii)	12.9	16.0
Case 3	(1) - (B) - (ii)	12.9	16.0
Case 4	(3) - (B) - (ii)	10.9	13.9
Case 5	(2) - (B) - (iii)	10.0	12.7
Case 6	(2) - (B) - (i)	14.3	17.9
Financial Cost		10.8	



Note: (A), (B), (C) and (D) are absolute value of each factor.

Fig. 10-1 Financial IRR Sensitivity of Cost-effective Factors

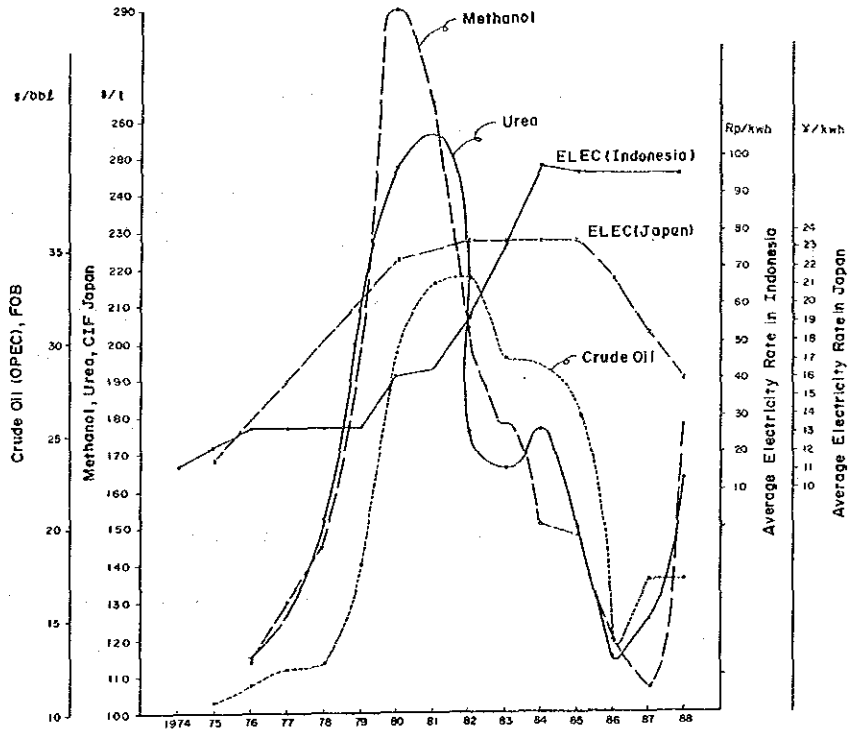


Fig. 10-2 Shifts in Price of Crude Oil (FOB OPEC), Methanol and Urea (CIF Japan), and Electricity Rate in Indonesia and Japan

11. PROPOSED PROJECT AND RECOMMENDATION

1. The proposed Project is to produce 1.5 million t/y of fuel methanol from N.W. Banko coal, starting in year 2000
2. A pilot test for fuel methanol utilization in automobiles and electricity generators should be carried out

1) Proposed Project

i) Configuration of the proposed project

Coal resources	:	N.W. Banko
Product	:	Fuel methanol (chemical grade)
Design capacity	:	1.5 million t/y of methanol
Plant location	:	Muara Enim, South Sumatra
Equipment transportation	:	By Lematang River
Product transportation	:	By pipeline to Palembang port

ii) Construction schedule and capital investment

Three phased construction is proposed.

		Phase 1	Phase 2	Phase 3
Design capacity	Million t/y of methanol	0.5	0.5	0.5
Start of construction	Year	1996	2000	2002
Start of operation	Year	2000	2003	2005
Coal consumption (N.W. Banko coal)	Million t/y	1.23	1.23	1.23
Capital investment	Million US$	427	244	190
Cargo weight	10^3 F/T	164	84	52
Employee		732	+142	+138

2) Recommendation

i) Political measures for introduction of fuel methanol should be studied

ii) A pilot test for fuel methanol utilization in taxies, buses, trucks, diesel engine generators and gas turbine generators, should be carried out

Table 11-1 Time Schedule of the Project Implementation

Years	Period (Years)				Earliest Schedule
		Phase I	-	Feasibility Study Completed in FY 1988.	1988
0					
	2	Bridging I	-	Coordination for Entry into Phase II	1990
2					
	3	Phase II	-	Basic Design, Engineering, Final Feasibility Study	1993
5					
	2	Bridging II	-	Coordination for Entry into Phase III	1995
7					
	4	Phase III	-	Detail Design, Construction	1999
11					

Note: 1) In the period of Bridging I

A) To establish a consensus on whether or not to introduce fuel methanol into Indonesia if conditions are satisfied in the future.

B) To establish a consensus on how to finance, if conditions are satisfied in the future.

C) To establish responsible organizations for Phase II.

D) Assessment and decision on expenditures required for Phase II by responsible organizations.

2) In the period of Bridging II

A) To establish responsible organizations and management organizations for Phase III and operation.

B) To make a decision on the total investments.

C) To enter into a financial contract

D) To enter into a sales/ purchase contract.