THE REPUBLIC OF INDONESIA
REPORT
ON
UTILIZATION OF SOUTH SUMATERA COAL
FOR
ELECTRIC POWER

JULY 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

BY TOKYO ELECTRIC POWER CO.INC.

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PREFACE

The Japanese Government received a request from the Indonesian Government to conduct fundamental activities on electric power system research in Indonesia.

The Japan International Cooperation Agency (JICA) organized an investigation team comprising four experts headed by Hajime Nakamura, Deputy Director, Engineering Department, Tokyo Electric Power Co., Inc.

The team departed from Tokyo in September 1975 and stayed in Indonesia about seven months.

During this period, the team conducted investigations on the electric power system and held many discussions about current and future problems with the authorities concerned.

After the team returned to Japan, results of the investigation were completed, and a final report is herewith submitted to the Government of Indonesia.

Finally, on behalf of the JICA, I take this opportunity to express our deepest appreciation to the Government of Indonesia for its cooperation with and assistance to the team during its stay in Indonesia.

July 1976

Shinsaku Hogen
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

July 1, 1976

Mr. Shinsaku Hogen
President
Japan International Cooperation Agency
Tokyo Japan

Dear Mr. Hogen,

I have the great pleasure of submitting to you herewith this final report on the study for an electric power system in Indonesia.

The study team stayed in Indonesia from September 19, 1975 to April 4, 1976 and completed studies on an electric power system with the combined cooperation of not only counterparts singled out among members of the State Electric Power Utility of Indonesia, but also those persons concerned among all the electric power organizations in Indonesia.

During our stay in Indonesia, the team conducted investigations and held discussions with the authorities concerned, and compiled the results of studies on an electric power system into the interim report which was submitted to and agreed upon by the Steering Committee of the State Electric Power Utility on March 29 and 30, 1976.

In the final report, some parts were revised based on discussions at the last Steering Committee and reviews which were made in Japan.

The study team is convinced that this report will contribute to the development of electric power utilities in Indonesia.

In submitting the final report, I take this opportunity to express my sincere appreciation for the great assistance and the splendid cooperation of all persons concerned which were generously given us not only during our investigation in Indonesia but also throughout our preparation of this final report subsequent to our return to Japan.

Respectfully,

Hajime Nakamura
Team Leader
Study Team for Electric Power System
in Indonesia

FOREWORD

1. The Government of Indonesia requested the Government of Japan to cooperate in the responsibility of conducting fundamental research activities on electric power system research in the Power Research Institute (PRI) which belongs to the State Electric Power Utility (PLN).

In response to this request, the Japan International Cooperation Agency (JICA) organized an investigation team composed of four experts headed by Hajime Nakamura, Deputy Director, Engineering Department, Tokyo Electric Power Co., Inc., and dispatched the team in September 1975.

This project, based on the ETA-21 Technical Assistance Proposal in Indonesia, was a continuation of assistance subsequent to a previous team.

At the first conference between the Study Team and the PLN, it was clarified that the most important and imminent matter necessary for cooperation in the PLN was to prepare the Power Development Plan of the Third Five Year Plan and to submit the plan to the Government of Indonesia before mid-1976.

In concrete terms, it was urgent for the PLN to devise an electric power development plan for all major islands outside of Java, while the plan for Java island was already formulated.

And the PLN eagerly anticipated that the study team would carry out the planning.

In compliance with this expectation, the study team agreed with this proposal by consulting the authorities concerned.

Afterwards, as a result of reorganization and personnel changes of top-level executives of the PLN, the study team received the following new proposal from the Steering Committee:

(1) To concentrate planning activities on Sumatera island instead of carrying out power development plans for all major islands outside of Java.

(2) To make a utilization plan of coal resources of South Sumatera for the electric power sector to meet the request of the Ministry of Mining.

After holding detailed discussions with the authorities concerned, the study team finally agreed with this revised proposal. Subsequently, the work scope of the study team was confirmed to be as follows:

(1) Power development planning on Sumatera for the Third Five Year Plan of Indonesia.

(2) Guidance and instruction on the methodology of power system planning.

(3) Planning of coal utilization on South Sumatera for the electric power sector.

Based on the above scope of work, the study team conducted its study and submitted an interim report to the PLN in March 1976.

After the team returned to Japan, subsequent work has been continued for preparation of the final report which is revised based on discussions of the final Steering Committee.

The final report will be submitted to the PLN in July 1976.

2. Members of the Study Team

Chief	Hajime Nakamura (Deputy Director, Engineering Dept., Tokyo Electric Power Co., Inc.)
Member	Hiroshi Nishimura (Manager, Thermal Power Dept., Tokyo Electric Power Co., Inc.)
Member	Isao Shinohara (Assistant Manager, Engineering Dept., Tokyo Electric Power Co., Inc.)
Member	Yasutaka Hinata (Assistant Manager, Construction Dept., Tokyo Electric Power Co., Inc.)

3. Period of Stay in Indonesia

From September 1975 to April 1976

4. Organization of Indonesian Side

The PLN organized a Steering Committee and a Counterpart Team to cooperate with the study team.

The Members are listed below.

(1) Steering Committee

First Term (September 1975 ~ December 1975)

Chairman	Ir. Sufrani Atmakusmah (Director of Planning)
Vice Chairman	Dr. A. Arismunandar (Director of Power Research)
Secretary	Ir. Imam Sugandi (Head of Planning Dept., PRI)

Member	Ir. Hartojo Notodipuro (Deputy Director of Planning)
Member	Ir. Bambang Sarah (Deputy Director of Operation)
Member	Ir. Soehirno Soemodinoto (Head, System Analysis Dept.)
Member	Ir. E. Darianto (Head, System Planning Dept.)

Latter Term (December 1975 ~ March 1976)

Chairman	Dr. A. Arismunandar (Director of Power Research)
Vice Chairman	Ir. Hartojo Notodipuro (Deputy Director of Planning)
Secretary	Ir. Imam Sugandi (Head, Planning Dept., PRI)
Member	Ir. Supangkat (Head, Planning Dept.)
Member	Ir. Sambodho Sumani (Head, Network Planning Dept.)

(2) Counterpart Team

Chief	Ir. Imam Sugandi	(PRI)
Planning Group	Ir. Soepartomo	(PRI)
	Ir. Azhar Razif	(PLN)
	Ir. Abdul Fatah	(PLN)
System Group	P. Sihombing M. Sc	(PRI)
	Ir. Wardhani	(PRI)
	Ir. Imam Santoso	(PRI)
	Mustofa BE	(PRI)
	Ir. Adi Satria	(PLN)
	Ir. Rumah Lewang	(PLN)
Hydro Group	Ir. Bondantojo	(PRI)
	Ir. Ridwan Rasjid	(PRI)
	Soewartojo BE	(PRI)
	Sri Suwardo BE	(PRI)
	Hadi Pradono B. Sc.	(PRI)
	Harjono BEE	(PLN)
Thermal Group	Istigno M. Sc.	(PRI)
	Alven David Butarbutar	(PRI)
	Ir. Hutabarat	(PLN)
	Ir. Zulkarnaen	(PLN)

SUMMARY AND CONCLUSION

SUMMARY

1. The amount of coal utilization for future coal-fired electric power generation corresponding to the high- and low-load forecast in Java will be as listed below. Electric power requirements used in this study are mainly derived from a paper of the International Atomic Energy Agency, 'IAEA Nuclear Power Planning Study' for Java.

Amount of Coal Utilization

Unit: x 10^6 ton/yr.

	1980	1985	1990	1995	2000
Java High Forecast	–	5	8/5	12/7	19/11
Java Low Forecast	–	2	4/2	7/4	11/7

Note: Including Sumatera use. Plant factor 50%/30%

2. To meet the demands of Palembang City and also the Shell mining operation, it is preferable to construct the coal-fired power plant in the vicinity of the Bukit Asam mine site. This implies that the present program of installation of 2 x 25 MW or 1 x 50 MW coal-fired power plant at Bukit Asam will have to be expanded during REPELITA III.

The coal for this use will be supplied from Bukit Asam.

3. To meet the demand of Java herself, it is preferable to construct coal-fired power plants at some suitable locations in West, Central, and East Java.

Coal for this use will be transported from the Shell mine in South Sumatera.

4. Otherwise, if the present environment of a big city in Java (such as Jakarta) is not deemed profitable for installation of a large-scaled power plant, the South Sumatera coast (for instance, Lampung Bay area) will be considered for the site.

In this plan, the coal should be transported from the Shell mine as a matter of course; also, electric power generated at the coastal site will have to be transmitted to Java across the Sunda Strait.

Thus, the necessity of constructing a trans-Sunda Strait transmission line will pose as the most important problem.

5. Assuming that the above plan receives consideration, it is not desirable to transmit

a large amount of electricity to Java across the Sunda Strait from the viewpoint of power supply reliability in Java.

Namely, the maximum transmissible amount of electricity will be limited to around 20 ∿ 30% of the demand of Java. Otherwise, restricting the power supply in Java will be unavoidable should some damage occur in the trans-Sunda Strait transmission system. Further, the same condition will occur in East Java should the interconnection between West and East Java suffer an accident.

Thus, the maximum power from Sumatera to Java would be limited to a certain amount, and other necessary electricity for Java should be supplied by Java coastal site power plants.

6. The development program and construction cost of above items 2., 3., and 4. are as follows:

Power Development Program

(Java/Sumatera Independent System) Unit: MW

Fiscal Year	Location					Installed Capacity	
	Java		Mine Site	Tg. Karang	Other Sumatera	Java High	Java Low
	High	Low					
1980	500					500	0
81	500	200	25			1,025	225
82	500	200	25			1,550	450
83	500	200	50		50	2,150	750
84	500	500				2,650	1,250
85	500			25		3,175	1,275
86						3,175	1,275
87	500	500	50	25		3,750	1,850
88	500				25	4,275	1,875
89		500	50			4,325	2,425
1990	1,000				50	5,375	2,475
91		500		25	100	5,500	3,100
92	1,000		100			6,600	3,200
93		1,000	100		50	6,750	4,350
94	1,000			25		7,775	4,375
95			100			7,875	4,475
96	1,000	1,000		25		8,900	5,500
97				50	100	9,050	5,650
98	1,000			50		10,100	5,700
99	1,000	1,000	100	50	100	11,350	6,950
2000						11,350	6,950
Construction Cost of Power Plants (US\$ x 10^6)							
	4,480	2,534	337	178	280	5,275	3,329

Power Development Program

(Java-Sumatera Interconnected System) Unit: MW

Fiscal Year	Location						Installed Capacity	
	Java		Lampung		Mine Site	Other Sumatera	Java High	Java Low
	High	Low	Java High	Java Low				
1980	500						500	0
81	500	200			25		1,025	225
82	500	200			25		1,550	450
83	500	200			50	50	2,150	750
84			500	500			2,650	1,250
85			500				3,150	1,250
86							3,150	1,250
87			500	500	50		3,700	1,800
88			500			25	4,225	1,825
89				500	50		4,275	2,375
1990			1,000			50	5,325	2,425
91				500		100	5,425	3,025
92			1,000		100		6,525	3,125
93				1,000	100	50	6,675	4,275
94			1,000				7,675	4,275
95					100		7,775	4,375
96			1,000	1,000			8,775	5,375
97						100	8,875	5,475
98			1,000				9,875	5,475
99			1,000	1,000	100	100	11,075	6,675
2000							11,075	6,675
Construction Cost (US$ x 10^6)								
Power Plants	920	294	3,480	2,190	337	280	5,017	3,101
Transmission Line							758	554

CONCLUSION

1. Coal is available for use in many kinds of industries, not only for heat energy. Whereas heavy and chemical industrialization is not only a way for contributing to the prosperity of Indonesia, it is also important to effect more utilization of coal. For this purpose, the authorities concerned should cooperate to utilize the coal for other sectors.

2. Considering the developing progress of new engineering methods utilizing of coal in addition to pulverized combustion engineering, the long-range plan of a coal-fired plant should be promoted steadily toward the year 2000.

3. Due to the necessity of expanding the Mine site power plant, the site survey should be executed in more detail.

4. For the plant sites in Java and on the Lampung coast, actual planning will have to be decided in the near future.

5. The approval of a comparison of certain kinds of developing programs of coal-fired power plants depends on the possibility of the realization of trans-Sunda Strait transmission, as to whether the power will be transmitted by an AC or DC system. If the trans-Sunda Strait transmission poses difficult problems, there may be no choice of variety in the utilization of coal.

*Thus, the most urgent matter at present is to begin a feasibility study of the trans-*Sunda Strait transmission as soon as possible.

CONTENTS

I. UTILIZATION OF COAL RESOURCE

1. Recent Trend of World Energy Consumption

The increase rate of energy consumption of each world country during the past 10 years is listed in Table 1.

According to these statistics, except for the 10% marks of Iran and Japan, the increase rates of most of the industrialized countries are 4 ∿ 6%. It is notable that the increase rate of England is lower than that of any other countries. This result might explain that the economic development in England has been rather low compared with other countries in recent years. Still, *the 3.8% for Indonesia does not indicate such a high rate among the developing countries, while the* absolute value of energy consumption is not small. The particular feature of energy production in Indonesia is that a greater part of this production is directed to exports, illustrating the typical feature of OPEC countries as a matter of course.

Referring to the composition of the primary energy, those countries which depend highly on oil are almost all oil-producing countries except France, Italy, and Japan. For a long time, prior to the oil crisis, the price of oil had been cheaper than any other energy resource. This is the reason for a high dependence on oil in such countries. Since America, England, and Germany are blessed with abundant energy resources such as natural gas and coal, the dependence percentage on such resources is higher than that on oil.

As for Indonesia, coal and natural gas resources are said to be plentiful, although the exploration of domestic energy resources is not being well executed. Thus, she still depends mainly on oil for her energy resources. This is exemplified in Table 2.

The self-support ratio (See Table 3), that is, the ratio of energy production by self-resources to derive necessary energy, would be --- generally speaking --- proportional to the resource deposits in one's own country. Thus, the U.S.A., being in stable circumstances from the viewpoint of energy conditions, now has an 86% self-support ratio. Nevertheless, the dependence of Japan on self-resources is only 9% because of their insufficiency, creating unstable circumstances.

Such stability in Indonesia viewed from energy conditions seems to be excellent; whereas, at present, the use of energy is not so necessary.

Table 1 Increase Rate of Energy

	Indonesia	W. Malaysia	India	Philippines	Iran	Brazil
Increase rate	3.8	6.9	3.7	7.3	13.7	8.1
Consumption	19.26	5.15	110.42	12.22	32.87	63.42
Production	104.78	0.14	93.48	0.30	459.56	22.61

Notes: Increase rate 1964~1973
Consumption 1973
Production 1973

* World Energy Supplies 1975 (United Nations)

Table 2 Composition of Primary Energy

	Indonesia	W. Malaysia	India	U.S.A.	England
Oil	90.5	97.0	25.1	44.3	44.4
Natural gas	7.8	-	0.7	33.5	12.7
Coal	0.5	0.3	70.8	20.3	41.6
Hydro	1.2	2.7	} 3.4	} 1.9	} 1.3
Nuclear	-	-			

Notes: Indonesia 1974
(Except firewood etc. From a report of the Environment Seminar 1975, 2)

* As of 1973, World Energy Supplies 1975 (United Nations)

Consumption in Past 10 Years *

Unit: %/yr., 10^6 tons coal equivalent/yr.

U.S.A.	England	W. Germany	France	Italy	Japan	World Total
3.9	1.2	4.2	5.1	7.2	10.2	4.7
2,503.23	313.25	371.35	234.31	170.31	426.02	7,884.52
2,152.50	174.49	172.04	48.59	28.46	38.45	8,485.37

Resources *

Unit: %

W. Germany	France	Italy	Japan
53.5	68.7	76.0	76.7
12.4	9.3	13.6	1.8
32.8	18.9	7.0	18.9
} 1.3	} 3.1	} 3.4	} 2.6

Table 3 Self-Support Ratio of Energy * Unit: %

Indonesia	W. Malaysia	India	U.S.A.	England	W. Germany	France	Italy	Japan
544.0	2.7	84.7	86.0	55.7	46.3	20.7	16.7	9.0

* As of 1973, World Energy Supplies 1975 (United Nations)

As for other statistic to envision the characteristics of energy consumption, we have the index of 'per-capita' consumption as listed in Table 4. It is prominent that per-capita consumption in the U.S.A., showing equivalent coal tons, is by far the world's greatest, whereas its usage in other countries is around one-half or one-third that of the U.S.A. Per-capita consumption in developing countries is not much because industrialization probably has not yet reached a high level; however, it will come close to that used by other countries in the future.

Table 4 Energy Consumption per Capita * Unit: tce / yr.

Indonesia	W. Malaysia	India	Philippine	Iran	Brazil	U.S.A.	England	W. Germany	France	Italy	Japan
0.16	0.54	0.19	0.30	1.05	0.63	11.90	5.59	5.99	4.49	3.10	3.93

* As of 1973, World Energy Supplies 1975 (United Nations)

In viewing energy consumption based on the categories listed in Table 5, it is remarkable that the 'Living' consumption in Japan is less than 'Industry' compared with other countries.

In Indonesia, we could get no similar statistics unfortunately. If the commercial energy demands would be regarded as the sum of Industry, Transportation, and Energy and also a portion of kerosene in commercial energy would be regarded as Living, Living would display a remarkable percentage in those categories.

Table 5 Consumption Ratio in Sectors

Unit: %

	Indonesia	W. Malaysia	India	U.S.A.	England	W. Germany	France	Italy	Japan
Living	(74)	–	–	36.6	38.0	37.7	37.5	31.5	25.7
Industry	(26)	–	–	30.4	38.9	40.1	39.8	47.0	52.2
Transportation		–	–	22.9	14.8	15.0	16.6	16.1	13.8
Energy		–	–	10.1	8.3	7.2	6.1	5.4	5.3

Note: Indonesia 1974
Estimated from data written in a paper, The Indonesia Energy Demand in the Year 2000, Views and Comments; Dr. A. Arismunandar

Others 1972

2. Future Energy Demand and Resources in Indonesia

The history of oil exploration in Indonesia covers many years since the first discovery of oil, said to be in 1884. The major energy demand at present is dependent on oil. The 39.3% of oil usage is for the production of kerosene for household cooking and lighting use. Thus, oil usage in domestic industries is not so much at present. In the near future, however, as many of the mechanical and chemical industries progress, not only oil but other resources such as coal and natural gas will become increasingly necessary.

As for natural gas, in proportion to growing world demands, it's exploration is now in progress in many countries, including Indonesia.

Generally, world coal deposits are estimated to be more plentiful than oil, but the demand of oil has been so high over the past ten years that coal excavation has fallen into arrears. After the oil crisis, the value of coal was reappraised by many countries and became highlighted.

In Indonesia, where coal deposits are also estimated to be abundant, future coal demands not only for heat resources, but also for raw materials of many kinds of industries, can be expected. Then the composition ratio of primary resources will reach a percentage not greatly differing from that industrialized countries.

The latest forecast of the energy demand for Indonesia is shown in Table 6. There is expected to be an investigation of the reserve resources from the viewpoint of effective use of domestic energy resources.

Table 6 Energy Demand Forecast

Unit: 10^6 tce

Year	Demand
1979	27.9
1984	49.4
1989	79.6
1994	119.5
1999	169.5
2000	181.3

Note: From Hasil–hasil Seminar Energi Nasional 1974

3. Government Policy Concerning Coal Utilization

In past years, Indonesia had a record of 2,000,000 tons of coal production per annum in Java, Sumatera, and Kalimantan. The past production records of each mine are listed in Table 7.

Table 7 Coal Production Records in Indonesia

Unit: 10^3 t

Mine	1940	1970	1971	1972	1973
Ombillin	578	77	90	88	82
Bukit Asam	848	91	109	91	67
Mahakam	.162	4	-	-	-
Parapatan	303	-	-	-	-
Others	111	-	-	-	-
Total	2,002	172	199	179	149

Note: From Hasil–hasil Seminar Energi Nasional 1974

The Ministry of Mining, Indonesia, in considering the balance of supply and demand of energy in the future, has exerted efforts on a survey and redevelopment of domestic resources, especially taking into account coal mining which has declined because oil has been substituted for coal as an energy resource, and has established a policy for developing a coal mine in Sumatera.

Based on that policy, the Ministry of Mining set up a plan to rehabilitate the Bukit Asam coal mine in South Sumatera, and an agreement relating to the exploration of other coal deposits has been concluded between P.N. Batubara and Shell. Shell started a survey of coal in South Sumatera in 1974.

This primary stage survey will continue up to 1976, based on an agreement in 1973 and a revised agreement in 1975. Recently certain portions of the results of that survey were published by Shell.

According to that report, two final production levels --- 15 and 30 x 10^6 t/yr. --- are being considered for export, and more production for domestic use will be possible, they stated, if the demand increases.

Based on this report, the Ministry of Mining requested the Ministry of Public Works and Labor to use the greater part of the coal to be produced at the Shell mine for the field of electric power. Further, the Ministry of Public Works and Labor wants PLN to devise a plan for coal utilization for generating electricity.

4. Shell's Coal Exploration Report

(1) Contract between Batubara and Shell

An agreement relating to the exploration of coal was concluded between P.N. Batubara and Shell in October 1973. Based on that agreement, a related survey was executed, and the agreement was revised in October 1975.

Several items of the present agreement are as follows:

a. Agreement area: 7,144,980 ha

b. Shell Mijnbouw N.V. shall be and is the sole contractor.

c. Operation in the previous Agreement will continue from June 1, 1974 to June 1, 1976.

d. A feasibility study on commercial development of the coal will take 18 months.

e. After the feasibility study, the construction of mining facilities will consume 48 months.

f. The operating period shall continue for 30 years.

g. Profit coal share.

	Coal production 10^6 t/yr.	Share %	
		Batubara	Contractor
I	< 5	60	40
II	> 25	65	35

h. All coal shall be destined exclusively for export. No greater quantity shall be committed for export than one-third of reserve.

(2) **Rehabilitation Planning of the Tambang Arang Bukit Asam (TABA)**

(a) Demand

Coal exploration and assistance in the TABA of South Sumatera began from 1974. In parallel with this exploration, a survey on the future TABA coal market was conducted and Shell reported as follows:

i. General Industry Market

Table 8 Industry Market

Unit: 10^3 t

	1976	1977	1978	1979	1980	1981	1982	1983	1984
Railways	50	50	50	50	50	50	40	30	15
P.N. Timah	70	70	70	70	70	70	70	70	70
Baturaja (1)	-	-	100	150	150	150	150	150	150
(2)	-	-	-	-	100	150	150	150	150
Total	120	120	220	270	370	420	410	400	385

ii. Power Generation Market

In forecasting the demand for electric power, Shell surveyed the demand according to four groups. Namely, the first is the power demand in South Sumatera area which will be supplied by electricity from a mine-site, coal-fired power plant. The second is the demands of certain locations (e.g. Tl. Betung). The third is a certain portion of Java's power demand, and the fourth is for its own use necessary in the mining operation.

Those forecasts are as follows:

Table 9 Electric Power Market

Unit: 10^3 t

	1976	1977	1978	1979	1980	1981	1982	1983	1984
South Sumatera	-	-	-	150	300	300	450	450	600
Other Sumatera areas	-	-	-	-	150	150	225	225	300
Java (1)	-	-	-	-	100	300	300	300	300
(2)	-	-	-	-	-	100	100	200	200
Mining operation	40	40	50	50	50	50	50	50	50
Total	40	40	50	200	600	900	1,125	1,225	1,450

The demand in South Sumatera includes minimum coal requirements for electric power necessary for Shell's coal production.

This is as follows:

Coal production x 10^6 t/yr.	Electric power (MW)	
	Min.	Max.
15	41	91
30	84	200

iii. Summary of Coal Demand

Adding items i. and ii., and then considering the stockpile, the total demand will be as listed in Table 10, Shell explained.

Table 10 Total Demand

Unit: 10^3 t

	1976	1977	1978	1979	1980	1981	1982	1983	1984
i.	120	120	220	270	370	420	410	400	385
ii.	40	40	50	200	600	900	1,125	1,225	1,450
Stockpile	20	20	25	50	50	50	50	50	50
Total	180	180	295	520	1,020	1,370	1,585	1,675	1,885

(b) Production Planning for TABA

Based on the above demand forecast, Shell mentioned the next production planning.

Table 11 Installed Capacity and Production Planning

Unit: 10^3 t

	1976	1977	1978	1979	1980	1981	1982	1983	1984
Mine installed capacity	360	360	700	1,000	1,500	2,000	2,000	2,000	2,000
Coal production	180	180	295	520	1,030	1,370	1,585	1,675	1,885

Coal production planning is clear up to around 2,000,000 tons; however, further production estimation has not been clarified due to a lack of informations relating to the forecast.

(3) Shell Coal Project

Concurrent with the exploration by Shell for large deposits of coal in the Baturaja/ Gunung Maraksa/Tanjung Enim areas of South Sumatera, a preliminary study has been made on the possiblility of mining coal for export.

Final production levels in alternatives of 15 and 30 x 10^6 t/yr. are considered. Further, more production is expected if Indonesia requires coal for domestic use.

5. Coal Utilization Plan

(1) Export Plan

Shell has the responsibility for developing the coal market, but it is not clear what amount of coal production will be exported yearly.

(2) Domestic Utilization Plan

No definite plan has been formed by the Ministry of Industry related to the development program in South Sumatera, such as a plan for an industrial complex at Pandjung and Tanjung Karang. Thus, a coal market in those area is not expected.

As many kinds of industries in Indonesia continue to make progress, a larger utilization of coal will be expanded in those industries as a matter of course, although no information is available at present.

Therefore, the domestic utilization of coal will be limited to its usage for electric power if the price of coal is reasonable or less than that of fuel oil at power plants.

6. Possible Amount of Coal for Electric Power

If a future production schedule of coal is projected by Shell, the available amount of coal for electric power can be estimated. However, only 25 x 10^6 t/yr. production in 1985 for export is presently contained in the report.

7. Present Coal Prices and Transportation Costs

(1) Coal Prices

(a) Existing Prices

Unit: Rp / t

Location	Price	M.P.O.	P.P.N.	For scale
Bukit Asam	5,000 (US$12.05)	2%	5%	5,350 (US$12.89)
Kertapati (Palembang)	5,860 (US$14.12)	2%	5%	6,270 (US$15.11)

Notes: US$1 = Rp415 , From TABA (Dec. 20)

(b) Calculated Reasonable Price --- From Shell report

Inland fuel oil price at Jakarta
= US$7.3/bbl = US$32/t (Coal equivalent)

The coal price should be at least 20% below the prevailing fuel oil price.

Thus,

Coal price at Jakarta
= US$32 x (1 – 0.2) = US$25.6/t

This should be equivalent to an F.O.R. mine site price of approximately, US$25.6/t — US$11.7/t * = US$14/t (= 5,810 Rp/t)

* Transportation cost (Reference: (2) (b))

(2) Transportation Costs

(a) Existing Cost

Bukit Asam --------- Kertapati = 5,860 – 5,000
= 860 Rp (US$2.07)/t

(Reference: (1) (a))

(b) Estimated Costs --- From Shell report

Handling etc., Sumatera	US$ 1.7/t
Inland transportation, South Sumatera	US$ 3.0/t
Sea transportation, Palembang/Jakarta	US$ 4.5/t
Handling etc., Java	US$ 2.5/t
Total	US$11.7/t

II. UTILIZATION OF COAL FOR ELECTRIC POWER

1. Generation by Coal

As a means of utilizing coal for electric power, its use for thermal power generation based on present engineering techniques such as pulverized coal combustion is being considered.

The following will be available plans for the utilization of Bukit Asam coal and new Shell mine coal.

(1) To construct a coal-fired power plant at Bukit Asam, near the existing mine site, and transmit electricity to those places where power is needed. The power plant will be a so-called 'inland power plant,' thus limiting the scale of power capacity.

Hereinafter this type of power plant is referred to as a 'Mine site power plant.' No power plant at the Shell coal mine site is considered.

(2) To construct a large-scaled, coal-fired power plant at some location on the South Sumatera coast not far from the Shell coal mine site and also near to Java, and to transmit a major amount of generated electricity to Java. In this case, a trans-strait transmission line is necessary.

Hereinafter this type of power plant is termed the 'Lampung coastal site power plant.'

(3) To construct coal-fired power plants at suitable places in Java and to generate electricity from coal transported by land and sea from the Shell coal mine. In this case, the construction of ports (coal shipping ports on the Sumatera side and landing ports on the Java side) will be inevitable.

Hereinafter this type of power plant is called the 'Java coastal site power plant.'

(4) To construct coal-fired power plants in certain cities in Sumatera, including such places as Palembang, Tg. Karang, and Medan. In this case, the capacity of the power plant should correspond to city demands. The coal will be transported by land and sea from Bukit Asam or the Shell mine.

Hereinafter this type of power plant is termed a 'City power plant.'

(5) To construct power plants as a combination of the above-mentioned types.

2. Electric Power Demand

(1) The electric power demands cited by this study are limited only on the islands of Java and Sumatera.

(2) As for power demands on Java island, future power capacities for coal-fired power plants determined as optimum capacities through economic analysis by IAEA* are adopted as the corresponding necessary power based on a suggestion by Dr. A. Arismunandar, Director, Electric Power Research Institute. There are two kinds of total coal power capacities—high and low.

(3) As for the demands on Sumatera, first, demand forecasts of the Palembang system and the Tg. Karang area are fundamentally based on a power development study prepared for REPELITA III. Secondly, demands necessary for the Shell coal mining operation based on the Shell report are added to the demands of corresponding places, the Palembang system, and the Tg. Karang area respectively, in considering that power should be supplied by the PLN, whereas Shell might plan its own power plant. Thirdly, the demand of Medan was considered as "other Sumatera" demand.

(4) The above features are listed in Table 12 and shown in Fig. 1.

* International Atomic Energy Agency

3. Coal Quantity and Quality for Electric Power

Since the coal quantity which will be produced by Shell has not been clarified, except the export amount after 1984, the limitation will not be considered in this study.

Also, since the coal quality is uncertain as to whether or not, the coal is suitable for electric power generation, it is assumed that the coal will be acceptable for steam power plant fuel.

4. Mine Site Power Plant

(1) General

One of the characteristics of a thermal power plant is that the site for construction can be located near the power demand. This differs from a hydro-power plant.

In recent years, according to increases in fuel prices, it seems there is a tendency to alter thermal power plant construction sites in an effort to attain cheaper fuel. Especially, regarding the problem of coal transportation, generally speaking, coal-fired power plant construction is located nearer to the mine site.

Table 12 Electric Power Demand

Unit: MW

Fiscal Year	Java				Palembang Area	Mine Site Area	Shell Mine Site	Tg. Karang Area	Other Sumatera
	High Forecast		Low Forecast						
1975	(690)		(640)		22	0.9		6.2	21
76	(910)		(790)		27	1.1		7.5	22
77	(1,210)		(970)		37	1.3		8.7	39
78	1,603		1,187		45	1.5		10.2	45
79	2,119		1,401		50	1.7		11.6	51
1980	2,803	1,200	1,585		54	1.9	26	26.4	57
81	3,704	2,400	1,936	200	59	2.2	31	31.5	65
82	4,896	2,800	2,221		65	2.4	41	36.9	71
83	5,778		2,715	600	71	2.6	51	43.9	77
84	6,818		3,136		77	2.8	71	50.0	86
85	8,045		3,593		86	2.9	84	56.0	92
86	9,493		4,177	1,200	95	3.0	100	61.0	97
87	11,202		4,795		104	3.2	100	67.0	105
88	13,218		5,885		113	3.4	100	74.0	115
89	15,597		6,851	2,200	124	3.7	100	82.0	135
1990	18,405	3,600	8,139		135	4.0	100	90.0	137
91	21,718		9,491		146	4.4	110	94.0	150
92	25,627		10,915		160	4.6	120	99.0	163
93	28,189		12,750		175	5.0	130	105.0	178
94	31,008	4,200	14,665		191	5.4	140	110.0	195
95	34,109	6,400	16,861	2,800	209	5.8	150	117.0	213
96	37,520	7,800	19,371	3,400	229	6.2	160	124.0	232
97	41,272	8,600	23,238	4,800	251	6.7	170	133.0	254
98	(45,400)	(9,600)	(25,600)	(5,600)	275	7.2	180	142.0	277
99	(49,900)		(28,100)		301	7.8	190	152.0	303
2000	(54,900)		(30,900)		330	8.4	200	163.0	330

* Total optimum capacity of coal power plant in Java, calculated by IAEA.

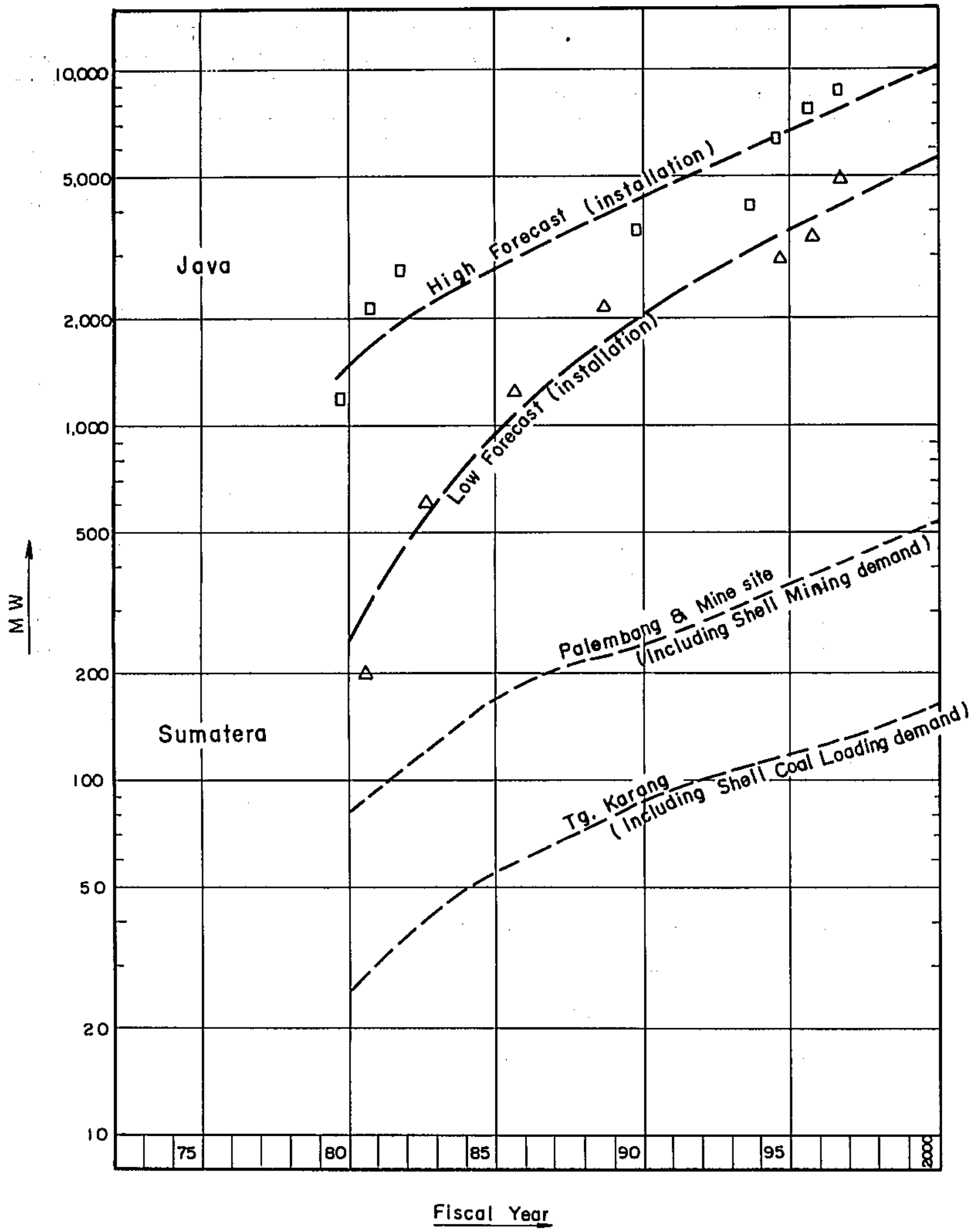
Shell Mine Site : Report on Electrical Power System Survey of South Sumatera by Shell.

( ) : Extrapolated or added to this study.

Tg. Karang Area : Including Shell coal handling load.

Other Sumatera : Demand of the Medan system.

Fig. 1 Optimum Capacity of Coal-fired Power Plant in Java and Peak Demand in Sumatera



(2) **Bukit Asam Coal Mine**

The Bukit Asam coal mine consists of two coal reserve areas of Air Laja (main mining area) and an other area. The present coal production is around 80,000 ton/yr.

Two rivers lie within a short distance of the Bukit Asam mine — the Enim River and the Lamatang River, into which the River Enim flows. There are two railway systems from the mine to Kertapati at Palembang and to Teluk Betung, the distance being about 160 and 250 km respectively.

(3) **Fundamental Conditions for Inland Thermal Power Plant**

In drawing up a plan for a large-scaled thermal power plant inland, certain special considerations must be given to points such as the following:

(i) Security of condenser cooling water
(ii) Assurance of fuel supply over a long period
(iii) Acquisition of land for power plant
(iv) Transport of construction materials and plant

(a) Condenser Cooling Water

i. The Enim River

Some reports contain records of the quantity of water flowing in the Enim River at the mine site. Those studies report that the minimum water flow of the Enim River is 30, 25, or 15 m^3/sec. average respectively in the dry season. But no data exists on long-term observation.

ii. The Lamatang River

There have been no studies conducted on this river, but many people say that the flow of the Lamatang River exceeds that of the Enim River. Consequently, at a location downstream from the junction of the two rivers, namely at the township of Muara Enim, the water flow will be double or more. Since cooling water for the condenser is the most important requirement in planning a mine site power plant, it is necessary to complete the survey as soon as possible to obtain more details on the flow data based on long-term observation.

(b) Assurance of Coal Supply

Coal production at Bukit Asam has sharply decreased in recent years, the present production being 80,000 ton/yr.

The property of the coal in this area is not uniform, and the calorific value of the coal varies from 5,900 to 7,900 kcal/kg. Prior to designing the boiler and its equipment, it is necessary to investigate the property of coal more minutely and to ensure good quality coal for generation.

(c) Land for Power Plant

Studies have already been conducted at the Tanjung Enim site, but not at the Muara Enim site. The Muara Enim site seems to be a more favorable site for power plant location, and the acquisition of land will have to be prepared.

The land area for a power plant must be considered from the viewpoint of the final scale of the power plant estimated by the power output and number of units. The land areas necessary for the power plant are:

Scale of power plant	Area
200 ∿ 300 MW 800 ∿ 900 MW	80,000 ∿ 90,000 m^2 280,000 ∿ 300,000 m^2

For a coal-fired power plant, an extra area is required for coal ash disposal over long years.

(d) Transport of Construction Materials and Plant

According to some reports on Bukit Asam, the road is kept rather well and bridges seemed to have been reinforced. However, the railway does not conform to this favorable situation because of its limitation in weight and dimensions; consequently, the power plant standard design might be partially modified to allow assembly at the site if necessary.

(4) Available Site and Scale of Power Plant

In duly considering all the points above mentioned, two sites are available. One is the Tanjung Enim site and the other is the Muara Enim site.

(a) Tanjung Enim Site

The scale of the power plant will be limited by the availability of cooling water and the maximum installation will be in the order of 300 MW at most.

(b) Muara Enim Site

The maximum plant scale might be in the order of 800 ∿ 900 MW at this site. But should an other plant at Tanjung Enim be planned, some problems will be created regarding cooling water.

5. Lampung Coastal Site Power Plant

(1) General

If the mine site conditions allow it, construction of a large-scaled power plant should be located at the Bukit Asam mine site, even if the economic study is not neglected as the matter of course. However, the scale of the power plant at the mine site might be limited to about 800 ∿ 900 MW depending on the availability of cooling water.

Therefore, if a huge power plant is taken into consideration, its site must be selected on the coast in South Sumatera, not so far from the Shell mine. Since Shell's future coal production will be more than the coal equivalent power demand in South Sumatera, a coal power plant to meet the power demand of other locations can be constructed. In such a case, the idea of a coal-fired power plant to fulfil Java's power demands is feasible. If trans-Sunda Strait power transmission becomes a possibility in the near future, electric power generated at the South Sumatera coastal site (the Lampung coastal site) can be transmitted to Java. But even if study on the trans-Sunda Strait power transmission line is started now, it will require eight or nine years for preparation. So, in this study, assumption is made that the commission time of that power transmission line will be the end of 1984.

Then, the Lampung coastal site power plant shall have been completed at least after the end of 1984.

(2) Transportation Cost of Coal

According to reports of P.N. Batubara and Shell, the inland transportation cost from Bukit Asam to Kertapati (160 km) is estimated as US$3.0/t. There might be different ways to transport the coal, but the transportation cost from the mine site to the Lampung coastal site (250 km) is assumed as US$4.7/t., proportional to the transit distance.

Location of the Shell mine site will differ from that of Bukit Asam, although the exact location is not clear at present. Thus, regarding the transportation cost from the Shell mine site to the Lampung coastal site, the same US$4.7/t. must inevitably be used temporarily. In the future, it is expected that the cost will drop if the transportation method is improved.

(3) Site and Scale

(a) Site

The coastal power plant can be installed at any location where the coal can be handled by land transport, and electricity generated by using coal can be supplied to the center of power demands from that power plant.

In the near future, the need for such electricity will be keenly felt in Java, based on the rapid power demand increase, so the plant site will be selected in the vicinity of the eastern side of Sumatera, near to Java --- for instance, the Lampung coastal site.

(b) Scale of the Power Plant

In mulling over the increase of Java's power demands, the scale of the Lampung coastal site power plant will be in the order of 2,500 MW between 1985 and 1990.

In the future, an even larger scaled power plant in this area might be considered if necessary.

(c) Unit Size

From economical and technical viewpoints, the unit size of the Lampung coastal site power plant should be considered in two steps. At the first step, a unit size of 500 MW class will be suitable for an interconnected power system between Java and Sumatera. And next, after 1990, 1,000 MW class units should be considered as additions.

In this study, it is not the purpose to select the optimum unit size of future coal-fired power plants, so the unit size has been defined under our direction.

6. Java Coastal Site Power Plant

(1) New Coastal Power Plant in Java

Rather than constructing the coal-fired power plant in South Sumatera, it is also worth considering construction of the power plants in Java from the start. In the case of Java coastal power plants, coal transportation will pose as the most important matter.

At present, coal is trnasported from Kertapati at Palembang to Java by using 6,000 ∿ 8,000 dwt. ships.

Even if the transportation system is revised to initiate slurry transportation, it will be necessary to consider the construction of a shipping port on the South Sumatera coast and a landing port on the Java side.

(2) Transportation Cost of Coal

According to Shell's report, the estimated transportation cost from Bukit Asam to Jakarta at present is US$11.7/t. This implies that the coal equivalent price of oil at Jakarta is US$25.6/tce, 20% below the prevailing fuel oil price; and as mentioned before, even the coal price at the mine site is US$14/t. The same price is considered for the Shell mining location.

Thus, the transportation system will have to be improved to attain a cheaper price if the coal-fired power plant is planned at another coastal site in Java. Otherwise, another subsidy will be necessary for coal utilization.

(3) **Scale of Java Coastal Site Power Plant**

The scale is the same as that of the South Sumatera coastal power plant.

(4) **Site**

The site will be West Java, and if necessary, also Central or East Java coast.

7. City Power Plant

The city power plant would be a type of coastal site power plant, if the city is located near the coast in Sumatera, except for the installed capacity. On the other hand, if the location is inland, it would be a type of inland power plant which will be restricted in the capacity of water availability.

8. Power Development Program

The power development program was prepared based upon the following premises:

(a) Estimate of power supply requirement was made based on power demand and required reserve capacity.

(b) For the power demand, the 'Electric power demand' in Chapter II-2 was employed.

(c) The required reserve capacity should be more than installed capacity of the largest unit in the system in anticipation of system capacity.
However, in case of a big power plant (for instance, Lampung coastal site power plant), the unit capacity was determined as 500 MW and 1,000 MW for simplification.

(d) The trans-Sunda Strait transmission line will be valid after 1984, inasmuch as eight or nine years will be necessary for preparing an engineering survey and construction. Since there are many patterns for the power development program in this study, the following patterns were assumed for the power development program.

(1) **Power Development Program to meet Demands of Palembang and Mine Site Area**

Both the Palembang and Mine site systems are considered as being interconnected in 1981, according to the economic study in the report of The Third Five Year Power Development Plan on Sumatera, June 1976.

The program is presented graphically in Fig. 2.

The total construction cost of power plants is US\$337 x 10^6.

(2) **Power Development Program to meet Demands of South Sumatera and Java**

(a) Palembang and Mine site interconnected system
Lampung and Java interconnected system

The development program is illustrated graphically in Fig. 2 for the Palembang and Mine site, and in Fig. 3 for the Lampung coastal site.

In this case, a 2,000 MW power plant installation should be constructed in Java before 1984, for the high demand forecast, or 600 MW for the low forecast.

Total construction costs of coal-fired power plants for the Lampung coastal site are US$3,480 x 10^6 and US$2,190 x 10^6 for the high and low forecasts of Java respectively.

(b) Palembang, Mine site, Lampung, and Java interconnected system

The development program of power plants is graphically illustrated in Fig. 4.

Total construction costs of the coal-fired power plants are US$4,720 x 10^6 and US$2,804 x 10^6 respectively for the high and low forecasts for Java.

(3) **Power Development Program to meet Demands of Java (No Interconnection between Mine Site and Lampung)**

(a) Interconnected system between Lampung coastal site and Java

This pattern is the same item (2)-(a), above.

(b) Java independent system

The development program is graphically illustrated in Fig. 2. The total construction costs of power plants are US$4,400 x 10^6 and US$2,484 x 10^6 respectively for the high and low forecasts for Java.

In these construction costs, the additional cost of a harbor is considered.

(4) **Power Development Program to meet Other Demands in Sumatera**

For other demands, Medan was considered as a 'City' power plant.

The total construction capacity for Medan is 475 MW and its construction cost is US$280 x 10^6.

(See Appendix I)

Fig. 2 Palembang – Mine Site / Tg. Karang / Java Independent System

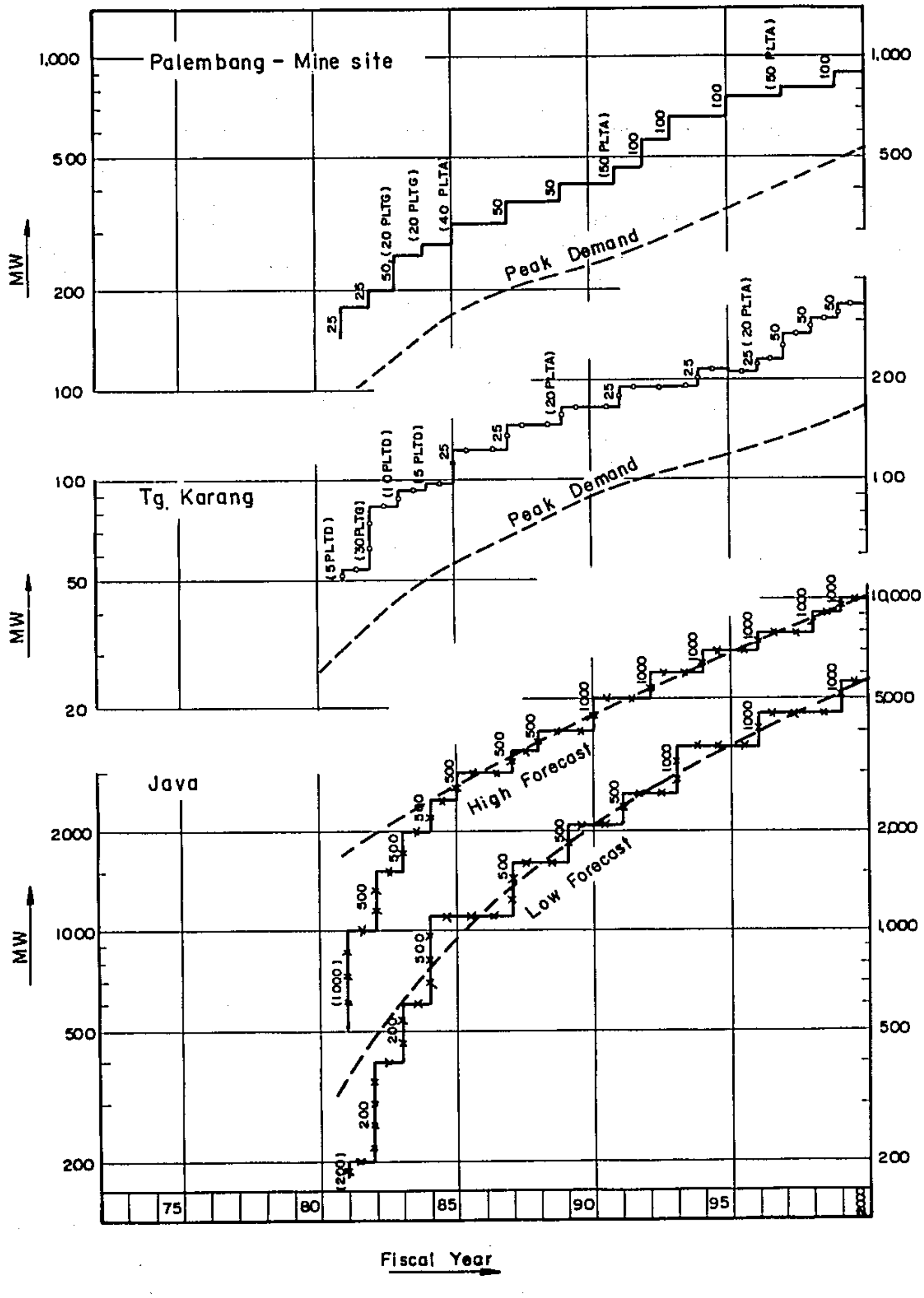


Fig. 3 Lampung Coastal Site – Java Interconnected System

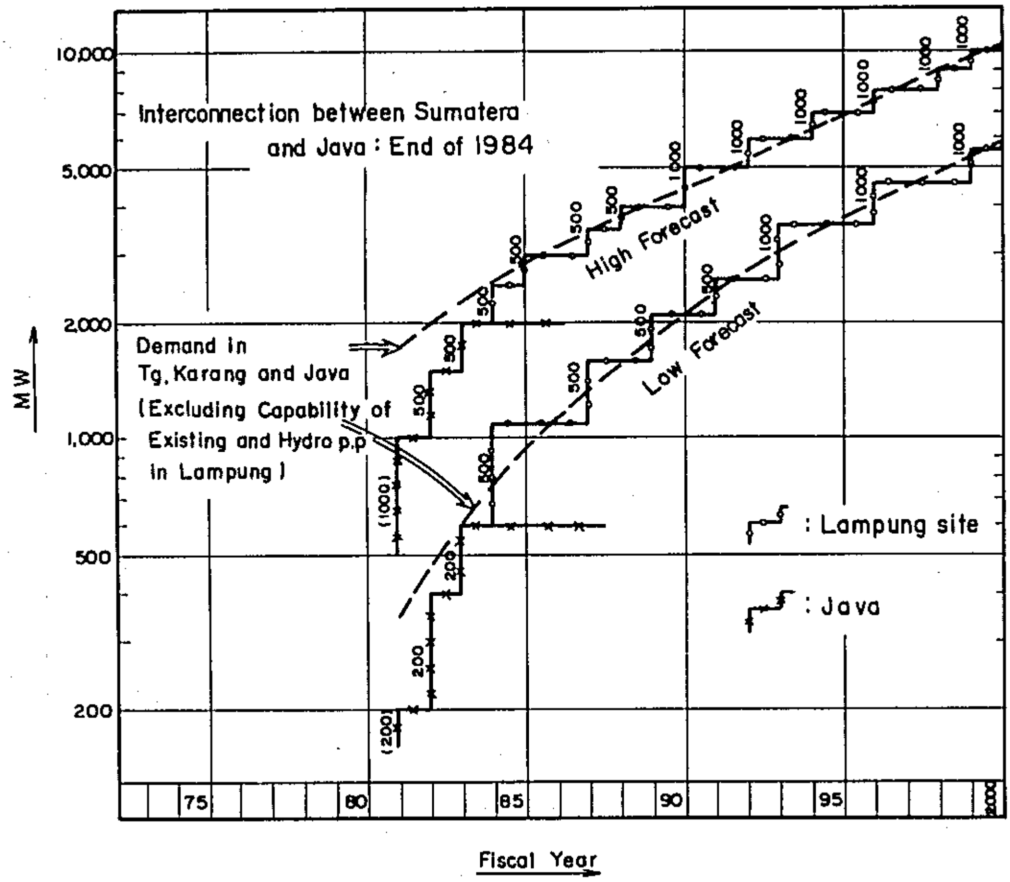
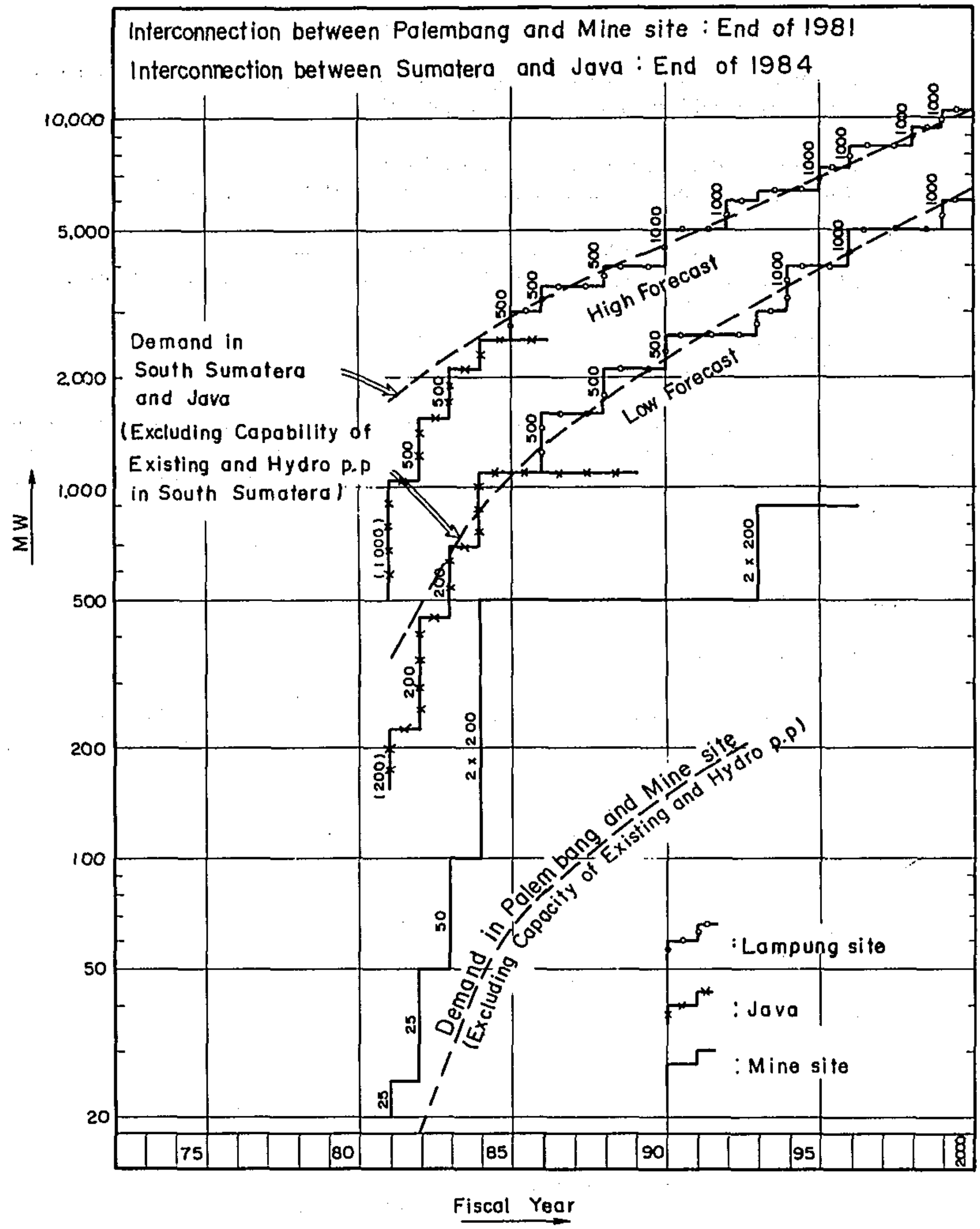


Fig. 4 Palembang – Mine Site – Lampung Coastal Site – Java Interconnected System



III. TRANSMISSION OF POWER

Transmission of power from the power plant (as mentioned in item II.8) to the load point can be accomplished with the following transmission lines:

(i) Transmission lines from Mine site to Palembang
(Palembang and Mine site interconnected system — II.8 (1), (2), (3) cf. —).

(ii) Transmission lines from Mine site to Lampung coastal site
(Palembang, Mine site, Lampung and Java interconnected system — II.8 (2) (b) cf. —).

(iii) Transmission lines from Lampung coastal site to Java
(Lampung coastal site and Java interconnected system — II.8 (2), (3) (a) cf. —).

The transmission capability, facilities construction cost estimate, and development program for the above-mentioned routes are explained in the following sections. It is assumed, that for each configuration, the reliability is such that, for one circuit failure, another circuit can still transmit normal power.

1. Mine Site – Palembang Transmission

(1) Transmission Capability

The capability required for the transmission of power will be approximately 210 MW in 1995, and 330 MW in 2000, as listed in Table 13, based on the load estimate for the Palembang area.

Table 13 Power Required for Transmission

Unit: MW

Fiscal Year		1980	1985	1990	1995	2000
Power	A	30	45	120	210	330
	B	30	85	135	210	330

Notes: A: The pattern for power development program of Palembang and Mine site interconnected system (II.8 (1) cf.)

B: The pattern of power development program for Palembang, Mine site, Lampung, and Java interconnected system (II.8 (2) (b) cf.)

(2) **Transmission Facilities**

The distance between Palembang and the Mine site is 160 km. Viewed from the stability limit, this will require a double-circuit transmission line of 150 kV, using ACSR 330 mm^2 x 2.

To cover the possibility of Sumatera–Java interconnection and load growth within the Palembang area, this voltage level will not be sufficient; a voltage level of 275 kV will have to be considered.

(3) **Development Program and Construction Cost**

150 kV ACSR 330 mm^2 x 2, 2 ccts 160 km .... US\$24 x 10^6 (1981)

2. **Mine Site – Lampung Coastal Site Transmission**

(1) **Transmission Capability**

Transmission lines from the Mine site to the Lampung coastal site as a part of the transmission to Java will require a capability of maximum 510 MW, as shown in Table 14.

Table 14 Power Required for Transmission

Unit: MW

Fiscal Year		1980	1985	1990	1995	2000
Power	B	—	330	260	510	330

Note: B: The pattern of power development program of Palembang, Mine site, Lampung, and Java interconnected system (II.8 (2) (b) cf.)

(2) **Transmission Facilities**

These transmission lines will also cover requirements in the Tanjung Karang area aside from the power to be transmitted to Java. The distance from the Mine site to the Lampung coastal site is 250 km, which will require at least AC 275 kV, ACSR 330 mm^2 x 2, double-circuit transmission lines.

Table 15 is a summary of comparisons among the alternatives to transmit power from the Mine site to Java, indicating AC 275 kV transmission as the most economical choice.

Table 15 Summary of Comparisons among the Alternatives to Transmit Power from Mine Site to Java

Location / System / Transmitting Power / Transmission Methods	MINE SITE POWER PLANT			Construction Cost (%)
	O.H.L. (OVERHEADLINE) ① BUKIT ASAM — 250 KM — ② TG. KARANG — 80KM — ③ S.C.(SUBMARINE CABLE) 30KM SUNDASTRAIT — ④ O.H.L. 100KM. — ⑤ JAKARTA			
	200 MW	400 MW	600 MW	
AC. 220kV	① ③ ④ ⑤ O.H.L: ACSR 410 MM² x 2 — 2ccts S. C: OF 800 MM² — 2ccts+1 * Sh.R: 160 MVA	① ②Ser.C ③ ④ ⑤ O.H.L: ACSR 410MM² x 2 — 2ccts * S. C: OF 800MM² — 3ccts+1 Sh. R: 230MVA Ser.C: 200MVA	① ②Ser.C ③ ④ ⑤ O.H.L: ACSR 410MM² x 2 — 2ccts * S. C: OF 800MM² — 3ccts+1 Sh.R: 230MVA Ser.C: 600MVA	110
AC. 275kV	① ③ ④ ⑤ O.H.L: ACSR 330MM² x 2 — 2ccts S. C: OF 600MM² — 2ccts+1 * Sh. R: 240MVA	① ②Ser.C ③ ④ ⑤ O.H.L: ACSR 330 MM² x 2 — 2ccts * S. C: OF 600MM² — 3ccts+1 Sh.R: 320MVA Ser.C: 30MVA	① ②Ser.C ③ ④ ⑤ O.H.L: ACSR 330 MM² x2 — 2ccts * S. C: OF 600MM² — 3ccts+1 Sh.R: 320 MVA Ser.C: 240 MVA	100
AC. 380kV	① ③ ④ ⑤ O.H.L: ACSR 240MM² x 4 — 2ccts S. C: OF 1200MM² — 2ccts+1 * Sh.R: 450 MVA	① ③ ④ ⑤ O.H.L: ACSR 240MM² x 4 — 2ccts * S. C: OF 1200MM² — 2ccts+1 Sh.R: 450MVA	① ③ ④ ⑤ O.H.L: ACSR 240MM² x 4 — 2ccts * S. C: OF 1200MM² — 2ccts+1 Sh.R: 450MVA	130
AC. 500kV	① ③ ④ ⑤ O.H.L: ACSR 240MM² x 4 — 2ccts S. C: OF 1000MM² — 2ccts+1 * Sh. R: 450MVA	① ③ ④ ⑤ THE SAME ON LEFT	① ③ ④ ⑤ THE SAME ON LEFT	140
DC± 250kV	CONVERTER ① ③ ④ ⑤ O.H.L: ACSR 610 MM² x 2 — 2ccts S. C: OF 600MM² — 2+1* lines	① ③ ④ ⑤ O.H.L: ACSR 610 MM² x2 — 2ccts S. C: OF 600MM² — 4+1* lines	① ③ ④ ⑤ THE SAME ON LEFT	140

* Spare cable　　Sh.R : Shunt Reactor　　Ser. C: Series Capacitor

(3) **Development Program and Construction Cost**

275 kV ACSR 330 mm^2 x 2, 2 ccts 250 km .... US$85 x 10^6 (1984)
500 kV/275 kV 500 MVA .... US$4 x 10^6 (1984)

3. Lampung Coastal Site – Java (Jakarta) Transmission

(1) Transmission Capability

To transmit power from the Lampung coastal site to Java island, power being originated from the Mine site power plant and the Lampung coastal power plant will require a capability of 280 ∿ 870 MW in 1985. In the year 2000, taking into account an expansion of the Lampung coastal site power plant, the capability required of these transmission lines will reach 4,300 ∿ 4,500 MW at low-load forecast and 7,100 ∿ 7,200 MW at high-load forecast for Java, as indicated in Table 16.

Table 16 Power Required for Transmission

Unit: MW

Fiscal Year			1980	1985	1990	1995	2000
Power	At low-load forecast	A	–	410	1,300	2,700	4,500
		B	–	280	1,600	2,700	4,300
	At high-load forecast	A	–	870	2,700	4,500	7,200
		B	–	740	2,500	4,600	7,100

Notes: A: Pattern of power development program of the Lampung coastal site and Java interconnected system (II.8 (3) (a) cf.)

B: Pattern of power development program of Palembang, the Mine site, Lampung, and Java interconnected system (II.8 (2) (b) cf.)

(2) Transmission Facilities

Transmission of power to Jakarta, including crossing of the Sunda-Strait, covering an overall distance of 210 km, will be AC 500 kV considering the stability limit and the construction cost.

Table 17 is a summary of comparisons among the alternatives for transmitting power from the Lampung coastal site to Java (Jakarta), indicating AC 500 kV transmission as the most economical choice.

Table 17 Summary of Comparisons among the Alternatives to Transmit Power from Lampung Coastal Site to Java

Location / System / Transmitting Power / Transmission Methods	LAMPUNG COASTAL POWER PLANT O.H.L. (OVERHEADLINE) ②—80 KM—③ S.C (SUBMARINE CABLE) —30 KM—④ O. H. L —100 KM—⑤ TG. KARANG — SUNDASTRAIT — JAKARTA 1,000 MW	5,000 MW	10,000 MW ※※	Construction Cost (%)
AC. 380kV	② ③ ④ ⑤ O.H.L : TACSR 240MM² x 4 — 2 ccts S. C : OF 1200MM² — 3 ccts + 1※ Sh. R : 680 MVA	② ③ ④ ⑤ O.H.L : TACSR 240MM² x4 — 4 ccts S. C : OF 1200 MM² — 9 ccts + 1※ Sh. R : 2040 MVA	② ③ ④ ⑤ O.H.L : TACSR 240 MM² x 4 — 6 ccts S. C : OF 1200MM² — 17 ccts + 1※ Sh. R : 3850 MVA Ser. C : 1300 MVA	110
AC. 500kV	② ③ ④ ⑤ O.H.L : TA 240MM² x4 — 2 ccts S. C : OF 1200 MM² — 3 ccts + 1※ Sh. R : 990 MVA	② ③ ④ ⑤ O.H.L : TACSR 240 MM² x 4 — 4 ccts S. C : OF 1200MM² — 8 ccts + 1※ Sh. R : 2600 MVA	② ③ ④ ⑤ O.H.L : TACSR 240 MM² x4 — 5 ccts S. C : OF 1200 MM² — 14 ccts + 1※ Sh. R : 4600 MVA	100
DC. ± 500 kV	CONVERTER ② ③ ④ ⑤ O.H.L : TACSR 810MM² x 6 — 1 ccts S. C : OF 1200 MM² — 2+1※ lines	② ③ ④ ⑤ O.H.L : TACSR 810MM² x 6 — 2 ccts S. C : OF 1200MM² — 9+1※ lines	② ③ ④ ⑤ O.H.L. : TACSR 810MM² x 6 — 2 ccts S. C : OF 1200MM² — 18+1※ lines	390

※ Spare cable　※※ at high-load forecast in Java

Sh. R : Shunt Reactor
Ser. C : Series Capacitor

The necessity of laying eleven circuits of submarine cables for transmitting 10,000 MW power is a big problem. It may be worth considering the planning of a transmission line of 750 kV voltage level to reduce the number of circuits, whereas the comparison in this study was omitted because the data concerned were insufficient.

At the low-load forecast in Java, this will consist of AC 500 kV TACSR 240 mm² x 4, three overhead line circuits; submarine cable of AC 500 kV OF 1,200 mm² 7 circuits, when the required capability reaches a level of about 4,500 MW.

At the high-load forecast in Java, this will consist of AC 500 kV TACSR 240 mm² x 4, four overhead line circuits; submarine cable of AC 500 kV OF 1,200 mm² 11 circuits, when the required capability reaches a level of about 7,200 MW.

(3) Development Program and Construction Cost

There are two kinds of demand high and low forecasts in Java. Thus, the development programs and construction costs are shown by the following alternatives (Power development program for Palembang and Mine site interconnected system/Lampung coastal site and Java interconnected system).

(a) Development Program and Construction Cost (low forecast)

500 kV TACSR 240 mm² x 4	2 ccts	180 km	US$222 x 10^6 (1984)
500 kV OF 1,200 mm²	2 ccts	30 km	
500 kV/150 kV transformer		200 MVA	
500 kV OF 1,200 mm²	2 ccts	30 km	US$112 x 10^6 (1987)
Switching stations			
500 kV TACSR 240 mm² x 4	1 cct	180 km	US$220 x 10^6 (1996)
500 kV OF 1,200 mm²	3 ccts	30 km	
Total			US$554 x 10^6

(b) Development Program and Construction Cost (high forecast)

500 kV TACSR 240 mm² x 4	2 ccts	180 km	US$290 x 10^6 (1984)
500 kV OF 1,200 mm²	3 ccts	30 km	
Switching stations			
500 kV/150 kV Transformer		200 MVA	
500 kV OF 1,200 mm²	1 cct	30 km	US$ 39 x 10^6 (1987)
500 kV TACSR 240 mm² x 4	2 ccts	180 km	US$232 x 10^6 (1992)
500 kV OF 1,200 mm²	2 ccts	30 km	

500 kV OF 1,200 mm^2	2 ccts	30 km	US\$ 79 x 10^6 (1994)
500 kV OF 1,200 mm^2	3 ccts	30 km	US\$118 x 10^6 (1998)
Total			US\$758 x 10^6

4. Power System Development Program and Power Flow Diagram

Power system development programs corresponding to the power development programs of Palembang – Mine site interconnected system, Lampung – Java interconnected system, and Palembang – Mine site – Lampung – Java interconnected system are shown in Figs. 5 and 6.

Electric power flow diagrams are shown in Figs. 7 and 8.

5. Reinforcement of the Power Interconnection in Java

It will be necessary to reinforce the trunk transmission lines for the interconnection between West and East Java according to an increase of the transmitting capacity from Sumatera; however, this has been omitted in this study.

But the reinforcement of power interconnection for the purpose of power transmission is not always preferable based on power supply reliability of each system in West, Central, and East Java.

Fig. 5 Power System Development Program for Palembang and Mine Site Interconnected System
Lampung and Java Interconnected System

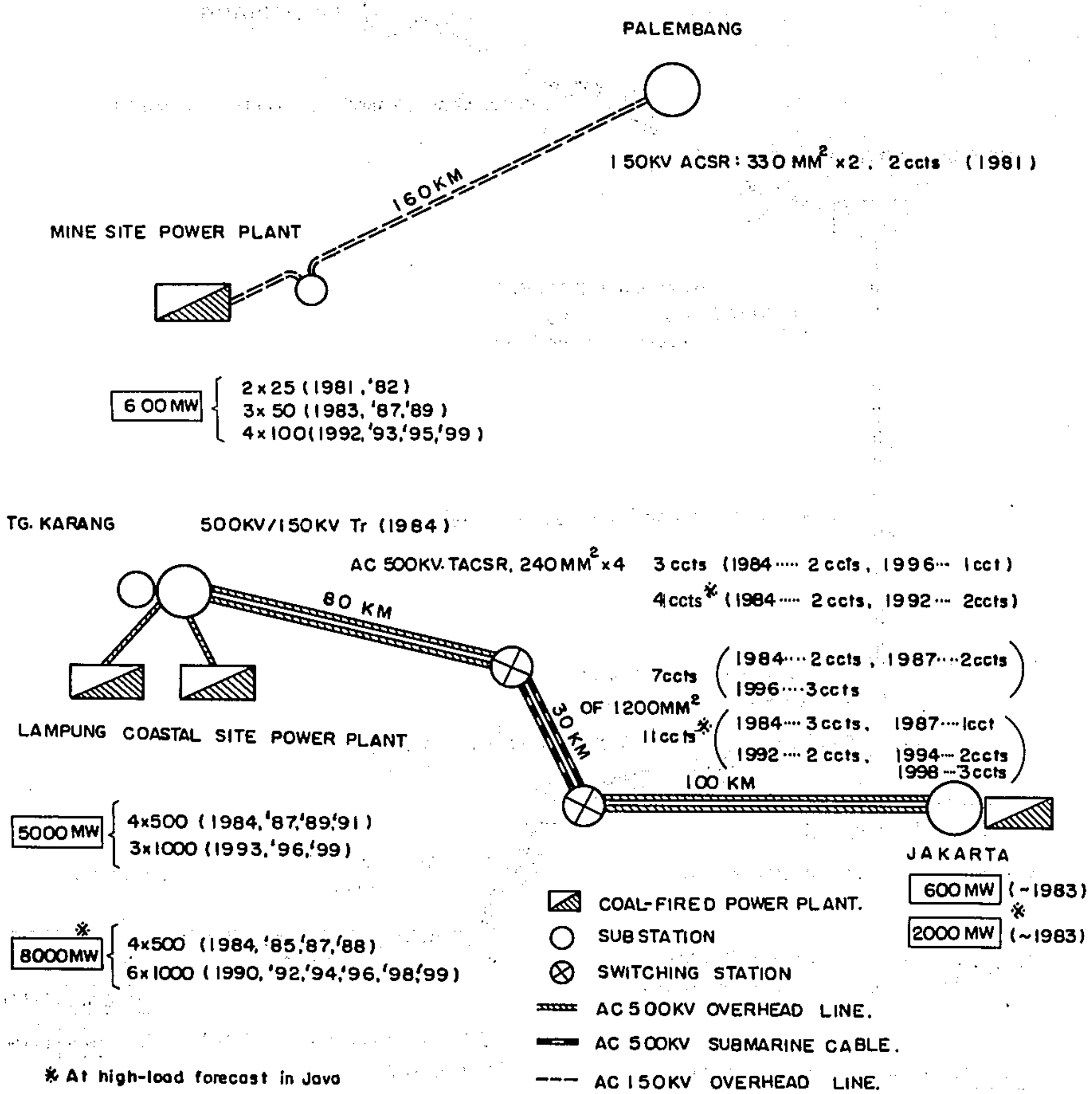


Fig. 6 Power System Development Program for Palembang, Mine Site, Lampung and Java Interconnected System

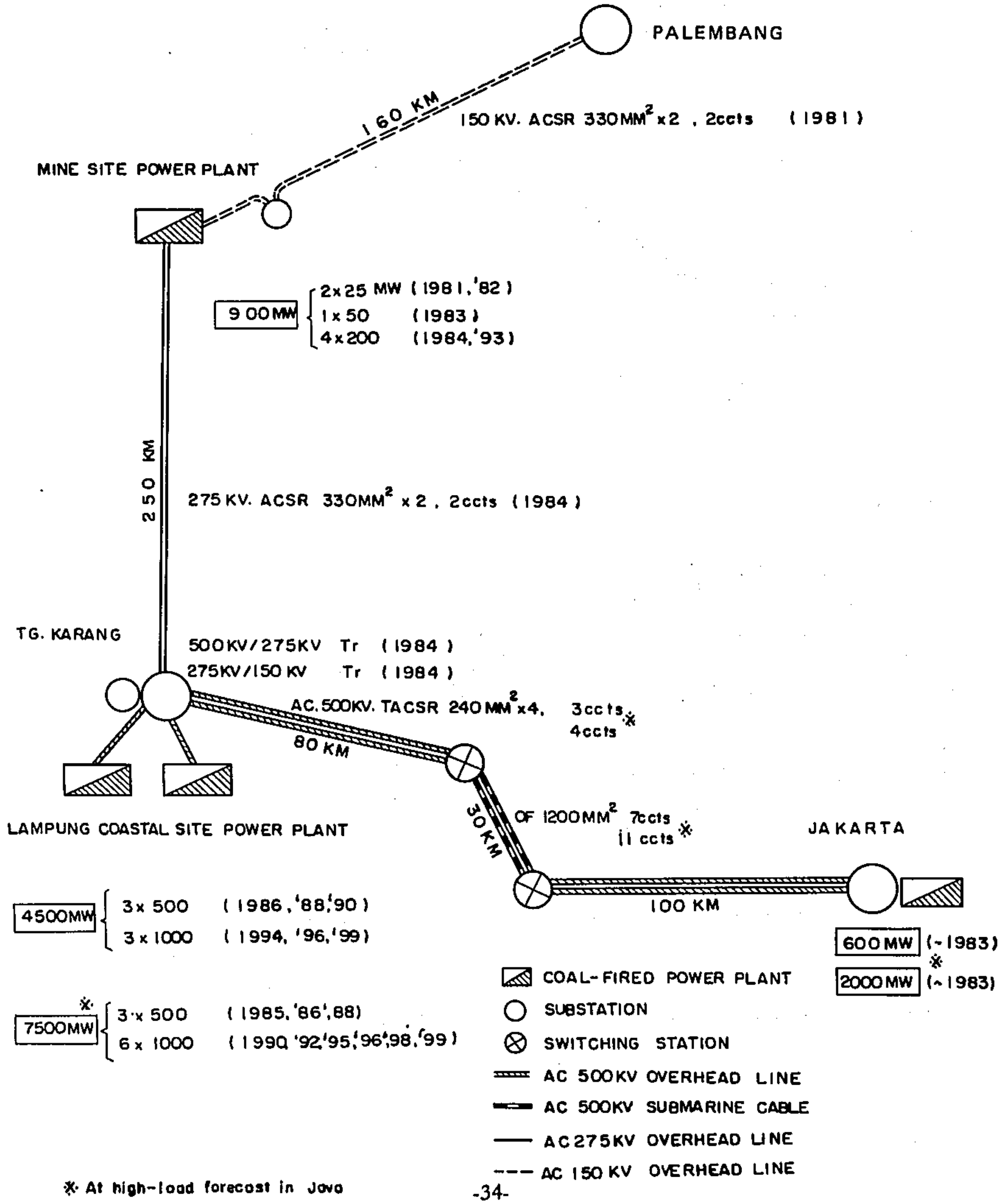
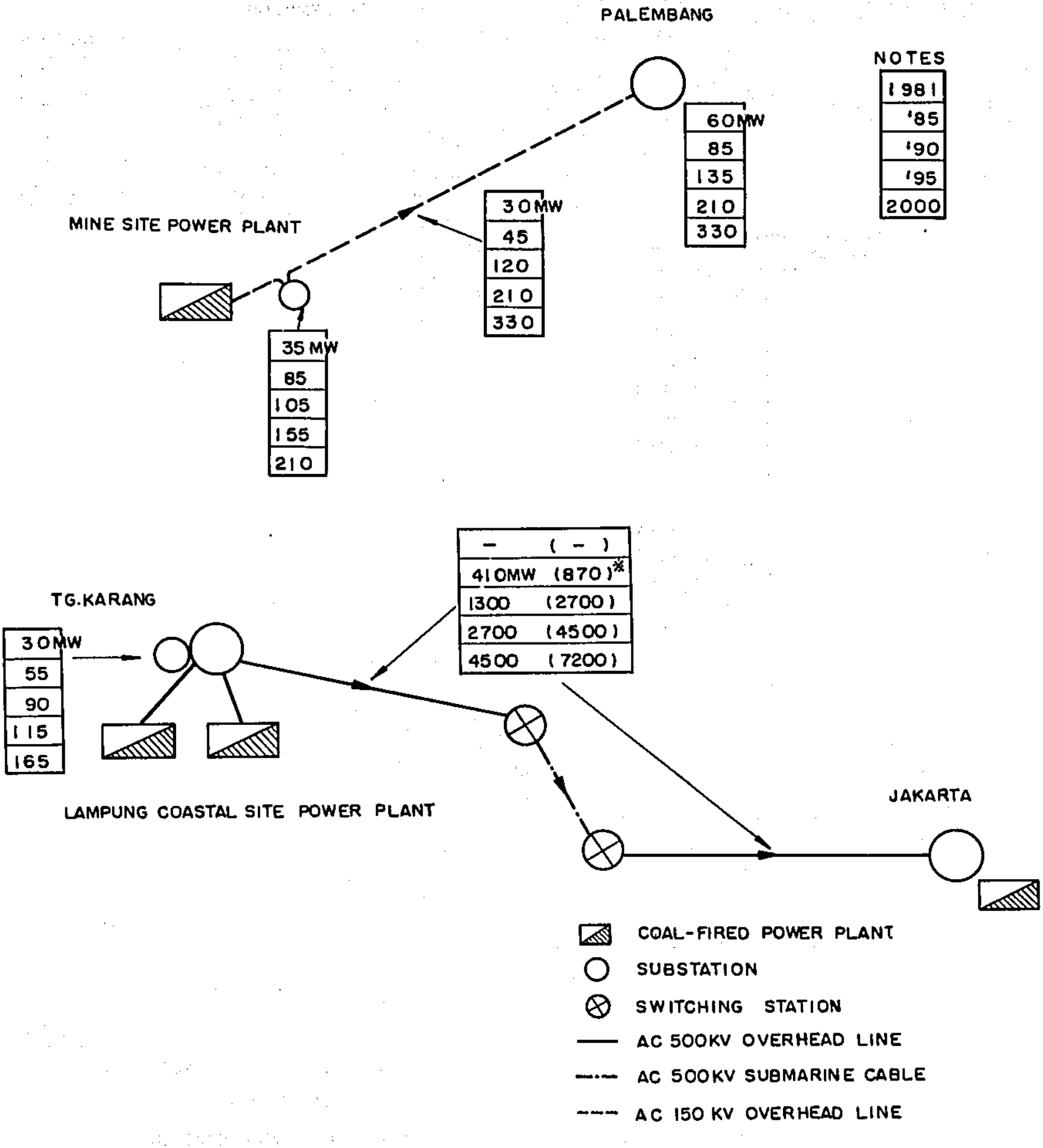


Fig. 7 Power Flow Diagram for Palembang and Mine Site Interconnected System
Lampung and Java Interconnected System

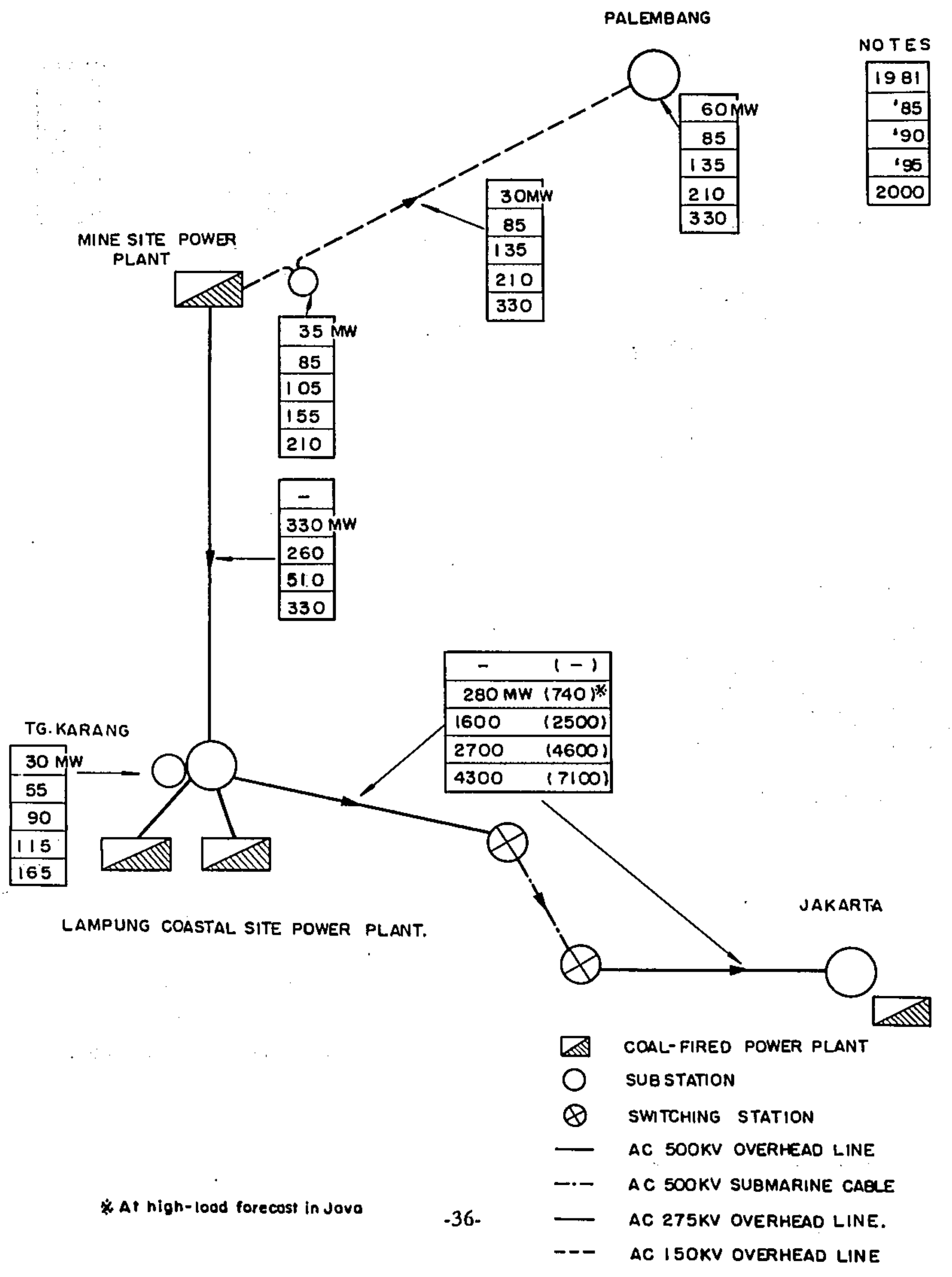
Unit : MW



※ At high-load forecast in Java

Fig. 8 Power Flow Diagram for Palembang, Mine Site, Lampung and Java Interconnected System

Unit : MW



※ At high-load forecast in Java

IV. ECONOMIC STUDY

1. Basic Criteria of Study

All economic studies were conducted on the basis of the low forecast in Java. Basically, the comparison by present worth of annual cost is used in this study.

The development planning period and the economic evaluation period are considered up to the years 1995 and 2010, 15 years after the planning period respectively.

The annual fixed cost of such facilities will be calculated by using the annual cost factor for construction cost, as listed in Tables 18 and 19.

Assumption of the quantitative characteristics of the coal-fired power plant is based on that the calorific value of coal is 6,000 kcal/kg, the plant designed efficiencies are 35% for a small unit and 40% for a large unit, and plant service is 8% of installed capacity. Also the plant factor is assumed as 50% when the plant is connected to the Java system.

As for an oil-fired power plant, plant service is assumed to be 5% of installed capacity.

Actually, there may be some differences in ordinary operation of existing plants between systems, depending on whether or not they are interconnected; however, their energy production and cost are assumed to be the same in this study.

Fuel costs are listed in Table 20 (see item I.7).

Table 18 Annual Cost Factor at 7% Interest Rate

Unit: %

	Coal-fired Power Plant	Oil-fired Power Plant	Transmission Line
Service Life (years)	20	20	25
Capital Recovery Factor	9.2	9.2	8.4
Operational and Maintenance Cost	3.0	2.5	1.5
Total	12.2	11.7	9.9

Table 19 Annual Cost Factor at 12% Interest Rate

Unit: %

	Coal-fired Power Plant	Oil-fired Power Plant	Transmission Line
Service Life (years)	20	20	25
Capital Recovery Factor	13.2	13.2	12.7
Operational and Maintenance Cost	3.0	2.5	1.5
Total	16.2	15.7	14.2

Table 20 Fuel Cost at Sending End (Coal equivalent)

Location	Fuel Price	Fuel Consumption	Fuel Cost
	US$/ton	kg/kWh	mill/kWh
Mine Site	14.0	0.48	6.7
Palembang	18.7	0.48	9.0
Lampung Coastal Site	20.4	0.42	8.6
Java	25.6	0.42	10.8
Java (Oil)	32.0	0.41	13.1

As already mentioned in Chapter II, there are many developing patterns of coal-fired power plants. Thus, for preliminary economic study, certain types of models are used for the purpose.

2. Interconnection between Mine Site and Lampung Coastal Site

In this study, it is assumed that the transmission line between the Lampung coastal site and Java will be commissioned at the end of 1984, and the interconnection between Palembang and Mine site is already accomplished.

This is an economic comparative study of the following two cases.

Case ML-1: To construct a coastal site power plant in the vicinity of Lampung bay. It is necessary to transport coal from the Mine site to the Lampung coastal site.

Case ML-2: To construct the Mine site power plant in 1984 instead of installing an equivalent unit at the Lampung coastal site power plant, and to construct a transmission line between the Mine site and Lampung coast.

The reserve capacity of the Palembang - Mine site system will be the same level as that of the Java system. It is assumed to be 25% of the system peak demand.

Alternative plans are indicated in Table 21 (see Figs. 2 and 4).

It is assumed that hydro, diesel, and gas turbine power plants are the same in both cases.

Table 21. Alternative Plans

Fiscal Year	ML–1			ML–2		
		US$	US$ x 10^6		US$	US$ x 10^6
1984				Mine Site P.P	2 x 200 MW	192
				Transmission Line 275 kV 2 ccts x 250 km		85
				Transformer Tg. Karang S.S. .500/275 kV 500 MVA		4
1987	Mine Site P.P	1 x 50 MW	30			
1989	Mine Site P.P	1 x 50 MW	30			
1992	Mine Site P.P	1 x 100 MW	53			
1993	Mine Site P.P	1 x 100 MW	53	Mine Site P.P	2 x 200 MW	192
1995	Mine Site P.P	1 x 100 MW	53			
1984∿1995	* Apportionment of Lampung P.P	570 MW	257			
Total	Power Plants	970 MW	476	Power Plants Transmission Lines	800 MW	384 89

Notes: P.P: Power Plant
S.S: Sub-station
* See Appendix II.

Comparison between the present worth of each case is as follows (see Appendix IV):

(1) Case ML–1

Fixed cost of power plants:

Total present worth of fixed cost of 219 million US dollars for 400 MW at Mine site is 173/125 (Interest rate i = 7/12%) in millions of US dollars.

Cost of coal transportation:

In the case ML-2, generated power at the Mine site power plant will be transmitted to Palembang and the excess will be transmitted to Java via the Lampung coast. Power transmitted to the Lampung coast will vary from 368 MW (1985) to 540 MW (1996). Transmission loss between the Mine site and the Lampung coast is estimated as approximately 3% of the electricity.

The plant factor is assumed as 50% because of interconnection to the Java system.

Then, the total present worth of coal transportation cost, equivalent to the corresponding power capability, is 45/30 (i = 7/12%) in millions of US dollars.

(2) Case ML–2

Fixed cost of power plants:

After 1984, the reserve capacity of the Palembang – Mine site system can be decreased to the same level in Java. In this case, power plants totaling 400 MW will be constructed at the Mine site on 1984 and 1993 respectively, and excess power will be transmitted to Java. Thus, for economic study, a portion of construction cost of the Mine site power plant must be allocated to the Palembang – Mine site system.

The transmission loss should also be counted.

Then, the resultant cost allocation for this system varies from 17 (1985) to 127 (1996) in millions of US dollars, according to the growth of power demand.

Total present worth of fixed cost of the power plant is 107/81 (i = 7/12%) in millions of US dollars.

Cost of transmission line between Mine site and Lampung coast:

Total present worth of the annual cost of transmission line is 111/112 (i = 7/12%) in millions of US dollars.

(3) Comparison between ML–1 and ML–2

Difference of present worth of annual costs between case ML-1 and ML-2 is shown in Table 22.

Table 22 Present Worth of Case ML–2 minus ML–1

Unit: US$ x 10^6

Item \ Interest Rate	7%	12%
Fixed Cost of Power Plants	-66	-44
Cost of Coal Transportation	-45	-30
Cost of Transmission Line	+111	+112
Total	±0	+38

Notes: + : Case ML–2 is not economical compared with case ML–1.
– : Case ML–2 is economical compared with case ML–1.

This Table reveals that the alternative plan should be chosen based on the interest rate.

If the interest rate is not too high, the construction of a transmission line can be considered from an economical viewpoint.

For caution's sake, this analysis is conducted based on completion of an interconnection between Sumatera and Java.

3. Interconnection between Lampung Coastal Site and Java

This is economic comparative study of the following three cases:

Case LJ–1: The coal-fired power plants are located in Java to meet the demand of Java. Some small units will be planned at Tg. Karang to meet its demand.

Coal for the power plant in West Java will be shipped from South Sumatera to the power site. In this case, the conditions of the existing harbor and certain other facilities for coal transportation must be checked. In this paper, it is taken for granted that a harbor should be constructed for unloading coal.

Case LJ–2: The coal-fired power plants are located in South Sumatera, mainly at the Lampung coastal site, instead of installing power plants on Java island.

Transmission lines between Sumatera and Java are necessary, and also a submarine cable will have to be laid across the Sunda strait. A major distance of 210 km between the power plant and Jakarta will be connected by overhead transmission lines, while about 30 km will be submarine cables.

In this case, a part of the Tg. Karang area power demand will be supplied by a large unit plant, so the reserve capacity can be decreased.

Case LJ–3: To construct an oil-fired power plant in Java instead of a coal-fired power plant. Construction cost of an oil-fired power plant is estimated to be approximately 15% cheaper than a coal-fired power plant.

These alternative plans are listed in Table 23 (see Figs. 2 and 3).

Table 23 Alter-

Fiscal Year	LJ–1			
			US$ x 10^6	
1984	Tg. Karang PLTD	1 x 5 MW	3	
1985	Tg. Karang P.P	1 x 25 MW	18	
1987	Tg. Karang P.P	1 x 25 MW	18	
1989				
1991	Tg. Karang P.P	1 x 25 MW	18	
1993				
1994	Tg. Karang P.P	1 x 25 MW	18	
1984∿1995	Apportionment of Java (Including Harbor Cost US$10/kW)	2,892 MW	1,311	
Total	Power Plants	2,997 MW	1,386	

Notes: P.P: Power Plant
* See Appendix III.

native Plans

LJ−2				LJ−3		
			US$ x 10^6			US$ x 10^6
Lampung Coastal P.P	1 x	500 MW	225			
Transmission Line and Submarine Cable			220			
500 kV 2 cct x 210 km						
Transformer			2			
500 / 150 kV 200 MVA						
−						
Lampung Coastal P.P	1 x	500 MW	225	Same as case LJ-1	105 MW	75
Submarine Cable			112			
500 kV 2 cct x 30 km						
Lampung Coastal P.P	1 x	500 MW	225			
Lampung Coastal P.P	1 x	500 MW	225			
Lampung Coastal P.P	1 x	1,000 MW	430			
Transformer			1			
500 / 150 kV 100 MVA						
−						
				* Apportionment of Java Oil P.P	2,800 MW	1,073
Power Plants		3,000 MW	1,330	Power Plants	2,905 MW	1,148
Transmission Lines			335			

Comparison between the present worth of annual costs during the economic evaluation period of each case is as follows (see Appendix IV):

(1) Case LJ–1

Fixed cost of power plants:

Total present worth of fixed cost of 75 million US dollars for 105 MW coal-fired power plant at Tg. Karang (including 5 MW diesel power plant in 1984) is 78/63 (i = 7/12%) in millions of US dollars.

Cost of coal transportation:

In the case LJ-2, power generated at the Lampung coastal site power plant will be transmitted to Java varying from 460 MW in 1985 to 2,687 MW in 1996. The coal transportation cost equivalent to the above power flow should be counted in case LJ-1, considering a 1% loss of transmitting power for economic comparison.

Total present worth of coal transportation cost from the Lampung coast to Java is 210/126 (i = 7/12%) in millions of US dollars. This is the difference between case LJ-1 and LJ-2.

(2) Case LJ–2

Fixed cost of power plants:

Subtracting the demand of electricity in the Tg. Karang area from the generated power, the transmitting power from Sumatera to Java varies from 460 MW (1985) to 2,687 MW (1996). Thus, a portion of the construction cost of the Lampung coastal site power plant must be allocated to the Tg. Karang area. The allocated cost varies from 0 (zero) (1985) to 19 (1996) in millions of US dollars.

Total present worth of the fixed cost of the power plant for demand of the Tg. Karang area will be 14/10 (i = 7/12%) in millions of US dollars. Namely, the difference of present worth from LJ-1 is 64/53 (i = 7/12%) in millions of US dollars.

Cost of transmission lines between Lampung and Java:

Total present worth of the annual cost of transmission line is 388/377 (i = 7/12%) in millions of US dollars.

(3) Case LJ–3

Fixed cost of power plants:

The cost of the local power plant at Tg. Karang is the same as case LJ-1.

The difference of the total present worth between case LJ-1 and LJ-3 will be obtained as follows:

$$US\$1,317 / 1,048 \times 10^6 - US\$1,035 / 832 \times 10^6$$

$$= US\$282 / 216 \times 10^6 \quad (i = 7/12\%)$$

Difference of fuel cost:

The difference of total present worth of fuel cost between case LJ-1 and LJ-3 is 220/131 (i = 7/12%) in millions of US dollars.

(4) Comparison between LJ–1, LJ–2, and LJ–3

Difference of the present worth of annual costs between the three cases are listed in Table 24.

Table 24 Present Worth of LJ-2 minus LJ-1 and LJ-3 minus LJ-1

Unit: US$ x 10^6

Interest Rate / Case / Item	7%		12%	
	LJ–2	LJ–3	LJ–2	LJ–3
Fixed Cost of Power Plant	-64	-282	-53	-216
Fuel Cost	-210	+220	-126	+131
Cost of Transmission Line	+388	-	+377	-
Total	+114	-62	+198	-85

Notes: + : Not economical compared with case LJ–1.
- : Economical compared with case LJ–1.

Table 24 shows that the profitable power development pattern viewed from economic analysis is that for constructing the power plants in Java.

4. Result of Economic Analysis and Amount of Coal Utilization

The power development program resulting from the economic study is shown in Table 25.

Table 25 Power Development Program

Unit: MW

Fiscal Year	Location					Installed Capacity	
	Java		Mine Site	Tg. Karang	Other Sumatera	Java High	Java Low
	High	Low					
1980	500					500	0
81	500	200	25			1,025	225
82	500	200	25			1,550	450
83	500	200	50		50	2,150	750
84	500	500				2,650	1,250
85	500			25		3,175	1,275
86						3,175	1,275
87	500	500	50	25		3,750	1,850
88	500				25	4,275	1,875
89		500	50			4,325	2,425
1990	1,000				50	5,375	2,475
91		500		25	100	5,500	3,100
92	1,000		100			6,600	3,200
93		1,000	100		50	6,750	4,350
94	1,000			25		7,775	4,375
95			100			7,875	4,475
96	1,000	1,000		25		8,900	5,500
97				50	100	9,050	5,650
98	1,000			50		10,100	5,700
99	1,000	1,000	100	50	100	11,350	6,950
2000						11,350	6,950
Construction Cost of Power Plants (US$ x 10^6)	4,480*	2,534*	337	178	280	5,275	3,329

Notes: See Fig. 2.
Planning period is from 1984 to 1995.
* Including harbor cost at US$10/kW.

As for coal consumption in the economic analysis, it is assumed that the plant factor is 50%.

The IAEA report describes annual coal consumption as one ton per installation kW capacity after 1990, as shown in Fig. 9. This Figure shows that the plant factor will decrease rapidly in the future and drop to approximately 30% after 1990, according to the generating share of the load curve.

The annual amount of coal utilization is shown in Fig. 10.

Fig. 9 Plant Factor of Cool-fired Plant in Java (from IAEA report)

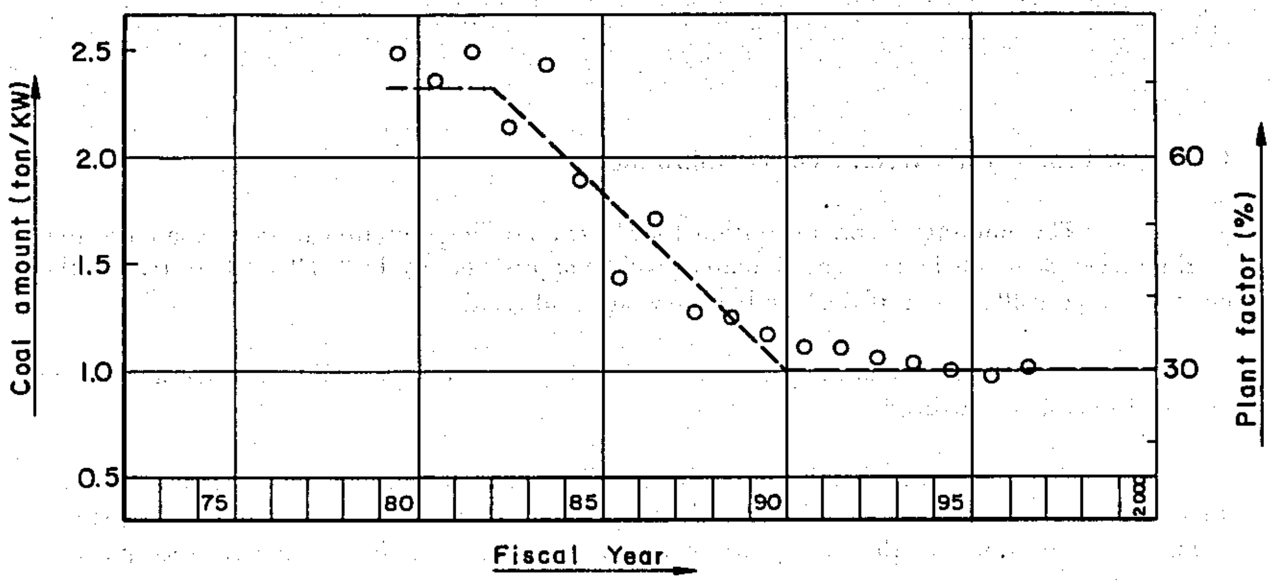
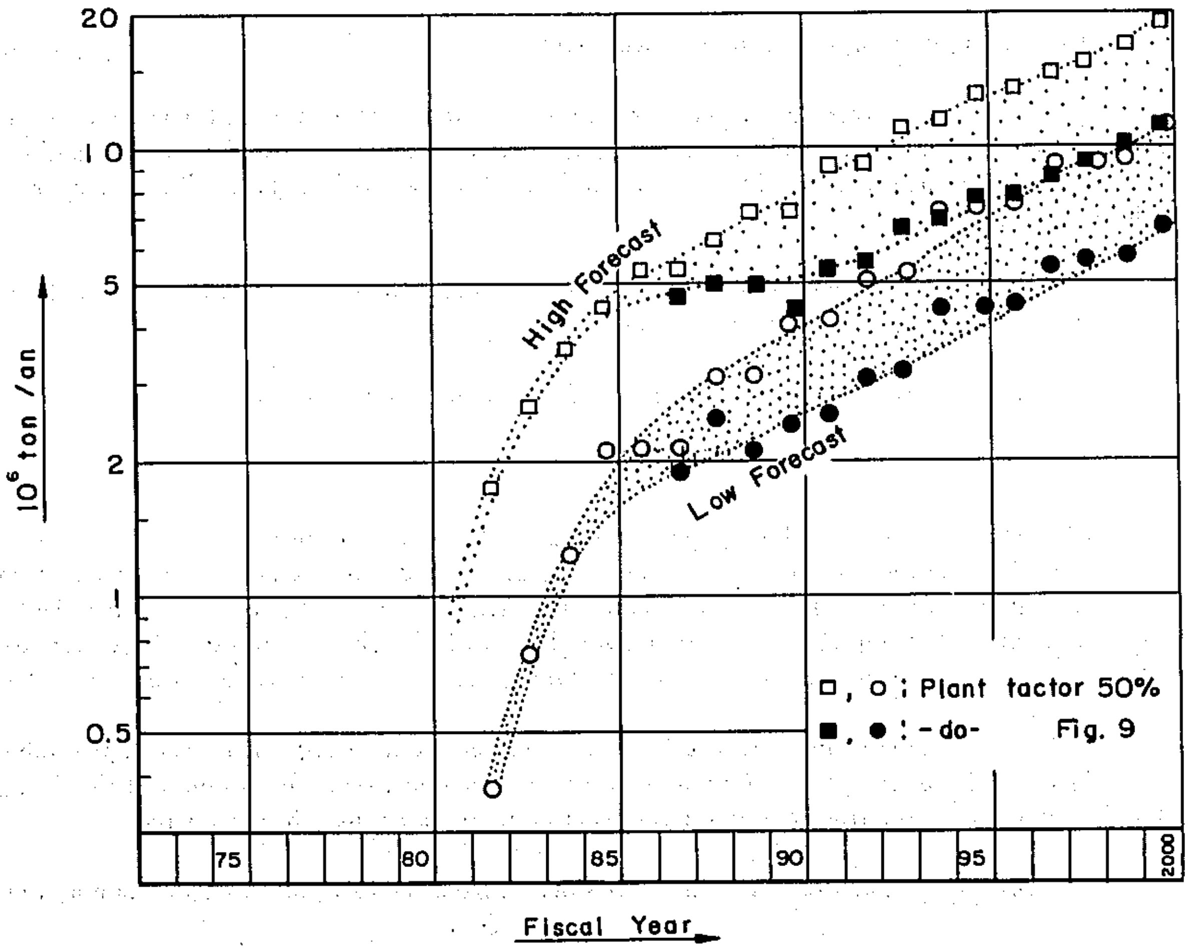


Fig. 10 Annual Amount of Cool Utilization



V. CONCLUSION AND MATTERS REQUIRING ATTENTION

1. Coal Amount for Electric Power Utilization

The amount of coal utilization for electric power generation to meet some portion of the power demands in Java and Sumatera will be approximately 11 $\sim$ 19 x 10^6 ton/yr. at the most in the year 2000, even if the high load forecast is adopted.

On the other hand, approximately 7 $\sim$ 11 x 10^6 ton/yr. will be considerable when the low forecast is actualized.

The minimum of each figure above will result if the nuclear power plants are commissioned in the system in accordance with the plan and their share reaches two-thirds (which seems to be enormous) of the total power capacity; then the plant factor may drop to approximately 30%.

2. Developing Pattern of Coal-fired Power Plant (See Appendix V)

(1) The first pattern is to plan a combination of the Mine site and Java coastal site power plants not only in the vicinity of Bukit Asam to meet the demands of Palembang and the Mine site area, but also in Java will be considered. In this case, coal for Java will be transported both by land and sea.

This will be considerable, whereas a more detailed study will have to be made on transportation costs and port construction costs.

The annual expenses at receiving point, representatively at Jakarta, will be

Rp.10.2/12.1/kWh (i = 7/12%)

(2) The second pattern is to plan the major objective of transmitting electricity from Sumatera to Java, besides the Mine site – Palembang interconnected system. Namely installation of the Mine site power plant and transmission line to Palembang should be accomplished on 1981, and subsequently the Lampung coastal site power plant, with the object of transmitting electricity to Java, should be commissioned in 1984, also including the supply to Tg. Karang area after 1984.

This planning can be realized if the present environment of Jakarta is not profitable to install large-scaled power plants. And in the future, interconnection of the system to Palembang, related to planning of the trans-region interconnection in Sumatera may be considered.

Assuming that this plan will be considered, from the viewpoint of power supply reliability in Java, it is not desirable to transmit a large amount of electricity to Java across the Sunda Strait. Namely, the maximum amount of electricity transmitted will be limited to around 20∿30% of Java's demand. Otherwise, restricting Java's power supply in the event some damage occurs at the trans-Sunda Strait transmission system will be unavoidable. Also, the same condition will exist in East Java should the interconnection between West and East Java suffer from some accident.

Thus, the maximum power from Sumatera to Java must be limited to a certain amount, and other necessary electricity for Java should be supplied by Java coastal site power plants.

Annual expenses at the receiving point, representatively at Jakarta, will be

Rp.10.9/13.8/kWh (i = 7/12%)

(3) The third pattern is to plan the entire interconnected system from the beginning. Namely, the plan is to initially install the Mine site power plant in 1981 at the Bukit Asam area and transmit electricity to the Palembang area, and then to install the transmission line from Bukit Asam to Java in 1984, and also to install the large-scaled Lampung coastal site power plant after 1984 or 1985 due to Java's demand. For one or two years after 1984, power transmitted to Java will be only from Bukit Asam.

The limitation on sending the amount of electricity to Java should be the same as item (2).

Annual expenses at the receiving point, representatively at Jakarta, will be

Rp.10.9/14.1/kWh (i = 7/12%)

3. Necessity of Feasibility Study Relating to the Trans-Sunda Strait Transmission Line

It seems that there is some difference between the above-described three patterns from an economic viewpoint, referring to the average annual expenses shown in the previous chapter.

The approval of a comparison of these planning patterns depends on the possibility of realization of the trans-Sunda Strait transmission line whether the power will be transmitted by an AC or DC system. If the trans-Sunda Strait transmission line presents difficult problems, there may be no variety in the utilization of coal.

Thus, the most necessary task today is to begin a feasibility study on the trans-Sunda Strait transmission line as soon as possible.

4. Matters Requiring Attention for Utilization of Coal

(1) World Market Price of Energy Resources in the Future

The price of energy resources should be determined basically by the interrelation between supply and demand. After the oil crisis, most countries who required an amount of energy resources changed their lean-to-one-side policy of depending on oil and are now planning to have a variety of energy resources. Also, they are making efforts to develop new energy resources. Nuclear energy is already in practical use, and in near future, development of the utilization of energy such as hydrogen and solar energy will become applicable toward the year 2000.

Considering these conditions, today's energy resources will not be the only ones in the future. Thus, great precautions will have to be observed regarding the future utility value of energy resources.

(2) Advancement of Utilization Form of Coal

The utilization form as heat energy has been a very old, changing form from block coal to pulverized coal. Now the conversion to liquid and also gasfication at mine sites are being experimented with or tested in several countries.

In considering developing progress like that mentioned above, it is very risky and rash to determine a long range plan -- toward the year 2000 -- of generation based only on present engineering techniques.

So it is important that planning should be promoted by steadily recognizing the degree of engineering progress.

(3) Utilization of Coal for Other Industries

Present coal utilization fields are not only for heat energy as a substitute for oil, but also for many uses such as raw materials in the heavy and chemical industries. Whereas heavy and chemical industrialization is not the only way to attain prosperity in Indonesia, it is important to make more utilization of coal worth. For this purpose, the authorities concerned should cooperate to utilize coal for other sectors.

(4) Utilization for Electric Power

(a) Electric Power Demand Forecast

The electric power demand forecast in Java used in this study is based on demand forecasts reported in an IAEA paper. In this report, there are two kinds of forecasts – high and low forecast. However, this study is mainly executed based on the low forecast in Java, because the high forecast seemed to be difficult to realize even though the present growth of demand is rapid.

High demand would be realized due to the excessive development of many kinds of heavy industries, but such a symptom is scarcely feasible in Indonesia at present. However, it is important to pay attention to the tendency of demand growth, taking care of progress of the Five Year Plan.

(b) Efforts to Improve the Load Curve

Present electric energy demands in Indonesia are fed half and half by the PLN and by privately owned plants. The reasons are: (1) although efforts have been made to add to the generating capacity of electric power and repairs have been effected together with an addition to the supply capacity of the transmission and distribution network, shortages are still felt, since no balance has yet been reached between the supply and demand of electric power; (2) certain tariff categories are somewhat undesirable to find new customers; and (3) since customers can barely get the electricity they want, most industries (especially outside of Java) have been obliged to install private power plants.

Consequently, consumers of the PLN are mainly composed of household consumers and small industries which causes a situation where the focus of peak demand centers on certain evening hours.

The absorption of the electric demand by these industries which operate in the day-time, therefore, not only contributes to an improvement of the load curve of the system, but also to more efficient operation of the generators; as a result, the PLN can expect more profits through increased income.

(c) Planning the Trans-region Interconnection in Sumatera

This study is examined for the time being only in the case of transmitting electricity from Sumatera to Java island against the subject of coal utilization in South Sumatera.

Yet, today, since planning of the dissolution of population from populous Java to other islands is being hastened step by step, future development on Sumatera should constitute a big problem. Therefore, study of the trans-region interconnection system in Sumatera will be important in the future.

(d) Mine Site Conditions

To obtain the site of inland thermal power stations, the following surveys should be executed in more detail:

i. Accurate observation study of the river flow which is to be used for condenser cooling
ii. Suitable site for power station
iii. Acquisition of the land for power plant
iv. Preparation of an area for coal ash disposal

v. Transportation of the construction materials and plant
vi. Detailed qualitative and quantitative analysis of coal

(e) Lampung Coastal Site Conditions

i. Stable supply of coal
ii. Suitable site for large-scaled power station
iii. Acquisition of land for the power station

(f) Java Coastal Site Conditions

i. Stable supply of coal
ii. Suitable site for large-scaled power station
iii. Aquisition of land for power station
iv. Possibility of coal landing port

(g) Overhead Transmission Route Conditions

i. Transmission route crossing mountainous region between the Mine site and Lampung coastal site
ii. Acquisition of route in Sumatera and Java
iii. Weather conditions along the transmission route

(h) Sunda Strait Conditions

The nearest distance between the islands of Java and Sumatera is about 30 kilometers. Study has conducted on the assumption that a submarine power cable could be laid between the two islands. No problems will exist as to the distance, but as far planning the laying of submarine cable, the following should be investigated:

i. Most suitable location for cable laying
ii. Conditions of the sea bottom
iii. Conditions of the strait current
iv. Conditions of the strait tide
v. Conditions of ship navigation
vi. Conditions of the submarine volcano (Eruption in 1886 was reported.)

APPENDICES

Coal-fired Power Plant Construction Cost

MW	US$ / kW
25	700
50	600
100	530
200	480
500	450
1,000	430

Necessary Capacity of Lampung Coastal Site Power Plant

Necessary additional capacity of case ML-1 in the Lampung coastal site compared with case ML-2 is as follows:

$$I = P \times 1 / (1 - S) \times (1 - L) \quad \text{...} \quad (1)$$

I : Necessary capacity

P : Power flow from Mine site to Lampung in case ML-2, varies from 368 MW to 540 MW (see Appendix IV, Table 1, column 13).

S : Plant service (8%)

L : Transmission loss between Mine site and Lampung (3%)

Thus, the necessary capacity (I) varies from 388 MW (1985) to 570 MW (1996) year by year. The construction cost is 257 million US dollars in the case of 570 MW, using a unit price of US$450/kW.

Necessary Capacity of Java Power Plant

The necessary additional capacity of case LJ-1 and LJ-3 at the Java coastal site compared with case LJ-2 is calculated by using the formula (1) in Appendix II.

Where P : Power from Lampung to Java in case ML-2 varies from 460 MW to 2,687 MW (see Appendix IV, Table 2, column 13).

S : 8% for coal and 5% for oil power plant

L : 1%

In case LJ-1, the necessary capacity varies from 495 MW (1985) to 2,892 MW (1996) year by year. The construction cost is US$1,311 million for 2,892 MW, including harbor cost of US$10 per installation kW capacity.

In case LJ-3, the differences between LJ-1 are the plant service and the unit price. Installed capacity is 2,800 MW and the cost is US$1,073 million in 1996.

Table 1 Present Worth

					1985	1986
	Year			(1)	1985	1986
	Present Worth Factor (P.W.F)		i = 7%	(2)	1.000	0.935
			i = 12%	(3)	1.000	0.893
Case ML-1	Fixed Cost of Power Plant	Demand in Palembang and Mine Site (Including Reserve Capacity: Largest 2 units) (MW)		(4)	242	267
		Available Capacity of Existing and New Hydro P.P (MW)		(5)	254	285
		Available Capacity of Additional Coal P.P in Mine Site (MW)		(6)		
		Construction Cost of Coal P.P (US$ x 10^6)		(7)		
		Present Worth (P.W) of Fixed Cost	i = 7%	(8)		
		(US$ x 10^6)	i = 12%	(9)		
	Coal Transportation Cost	Demand in Palembang and Mine Site (Including Reserve Capacity: 25% of Demand) (MW)		(10)	216	248
		Necessary Capacity of Coal P.P for Palembang and Mine Site ((10) – (5)) (MW)		(11)	-	-
		Available Capacity of Additional Coal P.P in Mine Site in Case ML-2 (MW)		(12)	368	368
		Power from Mine Site to Lampung in Case ML-2 ((12) – (11)) (MW)		(13)	368	368
		P.W of Coal Transportation	i = 7%	(14)	3.0	2.7
		(US$ x 10^6)	i = 12%	(15)	3.0	2.7
Case ML-2	Fixed Cost of Power Plant	Construction Cost of Coal P.P in Mine Site (US$ x 10^6)		(16)	192	192
		Cost Allocation for Lampung (US$ x 10^6)		(17)	175	175
		Cost Allocation for Palembang and Mine Site ((16) – (17)) (US$ x 10^6)		(18)	17	17
		P.W of Fixed Cost	i = 7%	(19)	2.1	1.9
		(US$ x 10^6)	i = 12%	(20)	2.8	2.5
	Cost of Transmission Line	Cost of Transmission Line (US$ x 10^6)		(21)	89	....
		P.W of Transmission Line Cost	i = 7%	(22)		
		(US$ x 10^6)	i = 12%	(23)		

Notes: (8) (9), (19) (20) and (22) (23) : (7), (18) and (21) x Annual Cost Factor x P.W.F, See Tables 18 and 19.

(14) (15) : (13) x 8,760 x 0.5 x (1 – 0.03) x mill (8.6 – 6.7)/kWh x P.W.F.F, See Table 20.

(17) : (13) x US$450/kW x 1/(1 – 0.08) x (1 – 0.03)

of Each Case

of Each Case ML–1 and ML–2

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	....	2010	Total
0.873	0.816	0.763	0.713	0.666	0.623	0.582	0.544	0.508	0.475	....	0.184	12.654
0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361	0.322	0.287	....	0.059	8.843
276	308	320	331	352	377	448	520	549	569	....	569	
283	282	281	280	279	304	303	287	286	285	....	285	
	46	46	92	92	92	184	276	276	368	....	368	
	30	30	60	60	60	113	166	166	219	....	219	
	3.0	2.8	5.2	4.9	4.6	8.0	11.0	10.3		123.7		173
	3.5	3.1	5.5	4.9	4.4	7.4	9.7	8.7		77.8		125
259	270	285	299	325	356	388	420	456	481	....	481	
-	-	4	19	46	52	85	133	170	196	....	196	
368	368	368	368	368	368	368	736	736	736	....	736	
368	368	364	349	322	316	283	603	566	540	....	540	
2.6	2.4	2.2	2.0	1.7	1.6	1.3	2.7	2.3		20.2		45
2.3	2.5	1.8	1.6	1.3	1.2	0.9	1.7	1.5		9.6		30
192	192	192	192	192	192	192	384	384	384	....	384	
175	175	172	166	153	150	134	286	269	257	....	257	
17	17	20	26	39	42	58	98	115	127	....	127	
1.8	1.7	1.9	2.3	3.2	3.2	4.1	6.5	7.1		71.7		107
2.2	2.0	2.1	2.4	3.2	3.1	3.8	5.7	6.0		45.1		81
....	....	....	....	....	....	....	....	89	89	....	89	
												111
												112

Table 2 Present Worth

					1985	1986
	Year			(1)	1985	1986
	Present Worth Factor (P.W.F)		i = 7%	(2)	1.000	0.935
			i = 12%	(3)	1.000	0.893
Case LJ-1	Fixed Cost of Power Plant	Demand in Tg. Karang (Including Reserve Capacity: Largest 2 units) (MW)		(4)	85	99
		Available Capacity of Existing and New Hydro P.P (MW)		(5)	82	81
		Available Capacity of Additional Coal P.P in Tg. Karang (MW)		(6)	5 *	28
		Construction Cost of Coal P.P (US$ x 10^6)		(7)	3	21
		Present Worth (P.W) of Fixed Cost (US$ x 10^6)	i = 7%	(8)	0.4	2.4
			i = 12%	(9)	0.5	3.0
	Coal Transportation Cost	Demand in Tg. Karang (Including Reserve Capacity: 25% of Demand) (MW)		(10)	70	76
		Necessary Capacity of Coal P.P for Tg. Karang ((10) – (5)) (MW)		(11)	-	-
		Available Capacity of Coal P.P in Lampung Site in Case LJ-2 (MW)		(12)	460	460
		Power from Lampung to Java in Case LJ-2 ((12) – (11)) (MW)		(13)	460	460
		P.W of Coal Transportation (US$ x 10^6)	i = 7%	(14)	4.4	4.1
			i = 12%	(15)	4.4	3.9
Case LJ-2	Fixed Cost of Power Plant	Construction Cost of Coal P.P in Lampung Site (US$ x 10^6)		(16)	225	225
		Cost Allocation for Java (US$ x 10^6)		(17)	228	228
		Cost Allocation for Tg. Karang ((16) – (17)) (US$ x 10^6)		(18)	-3	-3
		P.W of Fixed Cost (US$ x 10^6)	i = 7%	(19)	-0.4	-0.3
			i = 12%	(20)	-0.5	-0.4
	Cost of Transmission Line	Cost of Transmission Line (US$ x 10^6)		(21)	222	....
		P.W of Transmission Line Cost (US$ x 10^6)	i = 7%	(22)		61.7
			i = 12%	(23)		84.8

Notes:

(8) (9), (19) (20) and (22) (23) : (7), (8) and (21) x Annual Cost Factor x P.W.F, See Tables 18 and 19.

(14) (15) : (13) x 8,760 x 0.5 x (1 – 0.01) x mill (10.8 – 8.6)/kWh x P.W.F, See Table 20.

(17) : (13) x US$450 or 440/kW x 1/(1 – 0.08) x (1 – 0.01) plus Harbor Cost

* Diesel P.P, Characteristics of this plant are assumed to the same as those of coal-fired P.P.

of Case LJ–1 and LJ–2

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	....	2010	Total
0.873 0.797	0.816 0.712	0.763 0.636	0.713 0.567	0.666 0.507	0.623 0.452	0.582 0.404	0.544 0.361	0.508 0.322	0.475 0.287	....	0.184 0.059	12.654 8.843
105	120	126	136	140	145	151	156	163	170	....	170	
80	78	77	90	89	88	87	86	85	82	....	82	
28	51	51	51	51	74	74	74	97	97	....	97	
21	39	39	39	39	57	57	57	75	75	....	75	
2.2 2.7	3.9 4.5	3.6 4.0	3.4 3.6	3.2 3.2	4.3 4.2	4.0 3.7	3.8 3.3	4.6 3.9		42.4 26.6		78 63
84	93	103	113	118	124	131	138	146	155	....	155	
4	15	26	23	29	36	44	52	61	73	....	73	
460	920	920	1,380	1,380	1,840	1,840	2,760	2,760	2,760	....	2,760	
456	905	894	1,357	1,351	1,804	1,796	2,708	2,699	2,687	....	2,687	
3.8 3.5	7.0 6.1	6.5 5.4	9.2 7.3	8.6 6.5	10.7 7.8	10.0 6.9	14.1 9.3	13.1 8.3		118.7 56.2		210 126
225	450	450	675	675	900	900	1,330	1,330	1,330	....	1,330	
226	448	443	672	669	893	889	1,321	1,317	1,311	....	1,311	
-1	2	7	3	6	7	11	9	13	19	....	19	
-0.1 -0.1	0.2 0.2	0.7 0.7	0.3 0.3	0.5 0.5	0.5 0.5	0.8 0.7	0.6 0.5	0.8 0.7		10.7 6.7		14 10
222	334	....	....	....	....	334	335	335	335	....	335	
				137.7 155.5						188.4 136.8		388 377

Table 3 Present

	Year			(1)	1985	1986
Case LJ-3	Fixed Cost of P.P in Tg. Karang (US$ x 10^6)		i = 7%	(24)		
			i = 12%	(25)		
	Difference of Fixed Cost of P.P in Java	Construction Cost of Oil P.P in Java (US$ x 10^6)		(26)	187	187
		P.W of Fixed Cost of Coal P.P (US$ x 10^6)	i = 7%	(27)	27.8	26.0
			i = 12%	(28)	36.9	33.0
		P.W of Fixed Cost of Oil P.P (US$ x 10^6)	i = 7%	(29)	21.9	20.5
			i = 12%	(30)	29.4	26.2
	Difference of Fuel Cost between LJ-1 and LJ-3 (US$ x 10^6)		i = 7%	(31)	4.6	4.3
			i = 12%	(32)	4.6	4.7

Notes:

(26) : (13) x US$390 or 370/kW x 1/(1 – 0.05) x (1 – 0.01)

(27) (28) and (29) (30) : (17) and (26) x Annual Cost Factor x P.W.F, See Tables 18 and 19.

(31) (32) : (13) x 8,760 x 0.5 x (1 – 0.01) x mill (13.1 – 10.8)/kWh x P.W.F, See Table 20.

No. is continued from Table 2 on p.60-61.

Worth of Case LJ–3

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	....	2010	Total
Same as Case LJ–1												78
												63
185	368	363	552	549	733	730	1,082	1,078	1,073	....	1,073	
24.1	44.6	41.2	58.5	54.4	67.9	63.1	87.7	81.6		740.5		1,317
29.2	51.7	45.6	61.7	54.9	65.4	58.2	77.3	68.7		465.5		1,048
18.9	35.1	32.4	46.0	42.8	53.4	49.7	68.9	64.1		581.3		1,035
23.1	41.1	36.2	49.1	43.7	52.0	46.3	61.3	54.5		369.3		832
4.0	7.4	6.8	9.7	8.9	11.2	10.4	14.7	13.6		124.0		220
3.6	6.4	5.7	7.7	6.8	8.1	7.2	9.8	8.6		58.7		131

Annual Expenses of Each Developing Pattern

1. Java Coal-fired Power Plant

(1) Energy Production of Coal-fired Power Plants in Java

When the interconnection between Sumatera and Java is considered, electric power from Sumatera to Java varies from 460 MW (1985) to 2,687 MW (1996) in case LJ-2; then the average power will be 1,741/1,490 MW (Interest rate = 7/12%) (see Table 1). Therefore, the capacity of Java power plants should be considered as corresponding capacity for expense evaluation.

Thus, the energy production is;

1,741/1,490 MW x 8,760 hr. x 0.5 x (1−0.01)
= 7,549/6,461 GWh/yr. (i = 7/12%)

(2) Fixed Cost of Java Coal-fired Power Plant

Total present worth of fixed cost during the period of economic analysis is 1,317/1,048 (i = 7/12%) in millions of US dollars (see Appendix IV, Table 3, Columns 27 and 28).

Thus, the fixed costs are;

US\$1,317 x 10^6/12.654/7,549 GWh = 13.8 mill/kWh
US\$1,048 x 10^6/8.843/6,461 GWh = 18.3 mill/kWh

(3) Fuel Cost

10.8 mill/kWh (see Text, Table 20)

(4) Annual Expenses

(13.8 + 10.8) mill/kWh = 24.6 mill/kWh = 10.2 Rp/kWh (i = 7%)
(18.3 + 10.8) mill/kWh = 29.1 mill/kWh = 12.1 Rp/kWh (i = 12%)

2. Lampung Coastal Site Coal-fired Power Plant

(1) Receiving Energy in Java

Receiving energy in Java from Lampung coastal power plants is 7,549/6,461 (i = 7/12%) GWh/yr. (see 1. (1)).

(2) Fixed Cost of Lampung Coastal Site Power Plant

Allocation of construction cost of Lampung power plant for Java is calculated as follows:

Allocation for Java

$$= \text{Construction Cost of Power Plants} \times \frac{\text{Power from Lampung to Java}}{\text{Available Capacity of Lampung Power Plant}}$$

The average value of annual cost allocated for Java is 103/117 (i = 7/12%) in millions of US dollars (see Table 1).

Thus, the fixed costs are:

US$103/7,549 GWh = 13.6 mill/kWh
US$117/6,461 GWh = 18.1 mill/kWh

(3) Fuel Cost

8.6 mill/kWh (see Text, Table 20)

(4) Cost of Transmission Line

Total present worth of annual cost of the transmission line from Lampung to Java is 388/377 (i = 7/12%) in millions of US dollars (see Appendix IV, Table 2, Columns 22 and 23).

Thus, the costs are:

US$388 x 10^6/12.654/7,549 GWh = 4.1 mill/kWh
US$377 x 10^6/8.843/6,461 GWh = 6.6 mill/kWh

(5) Annual Expenses

(13.6 + 8.6 + 4.1) mill/kWh = 26.3 mill/kWh = 10.9 Rp/kWh (i = 7%)
(18.1 + 8.6 + 6.6) mill/kWh = 33.3 mill/kWh = 13.8 Rp/kWh (i = 12%)

3. Mine Site and Lampung Coastal Site Coal-fired Power Plants

As a matter of course, power from the Mine site is expensive, running about US$0/38 x 10^6 (i = 7/12%) in total present worth more than the Lampung coastal power plant (see Text, Table 22). Therefore, following extra cost should be added to the expenses of item 2, above.

US$0/12.654/7,549 GWh = 0 mill/kWh
US$38/8.843/6,461 GWh = 0.7 mill/kWh

Thus, annual expenses are:

26.3 mill/kWh = 10.9 Rp/kWh (i = 7%)
34.0 mill/kWh = 14.1 Rp/kWh (i = 12%)

Table 1 Power from Lampung to

				Year (1)	1985	1986
Present Worth Factor (P.W.F)		i = 7%	(2)		1.000	0.935
		i = 12%	(3)		1.000	0.893
Average Power	Power from Lampung to Java (MW)		(4)		460	460
	Present Worth (P.W)	i = 7%	(5)		460	430
		i = 12%	(6)		460	411
Average Cost	Cost Allocation for Java		(7)		225	225
	Present Worth of Annual Cost	i = 7%	(8)		27.5	25.6
		i = 12%	(9)		36.5	32.5

Notes: (4) : See Appendix IV, Table 1, Column 13

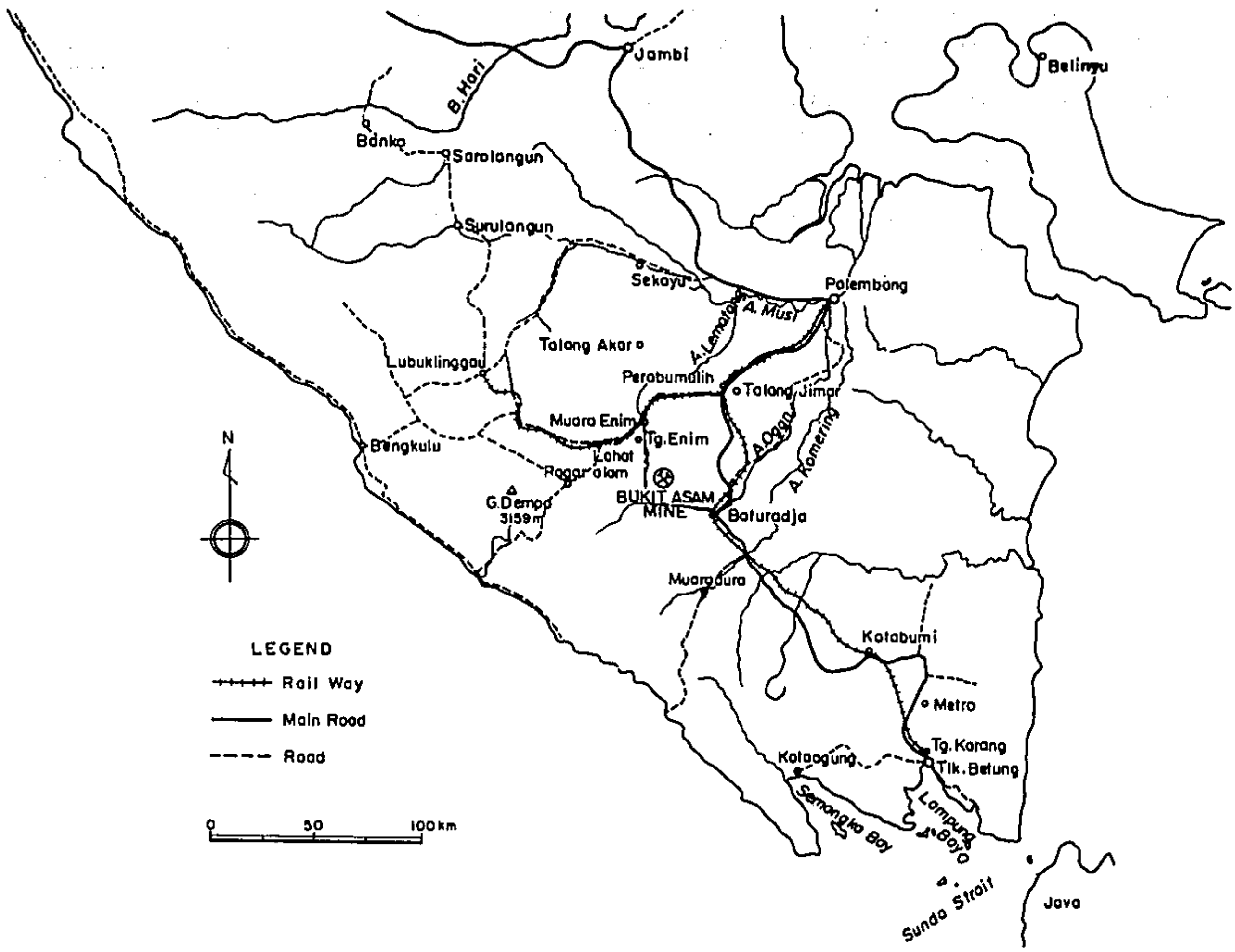
(7) : Appendix IV, Column (16) x $\frac{\text{Column (13)}}{\text{Column (12)}}$

(8), (9) : (7) x Annual Cost Factor x P.W.F, See Tables 18 and 19

Java and Cost Allocation for Java

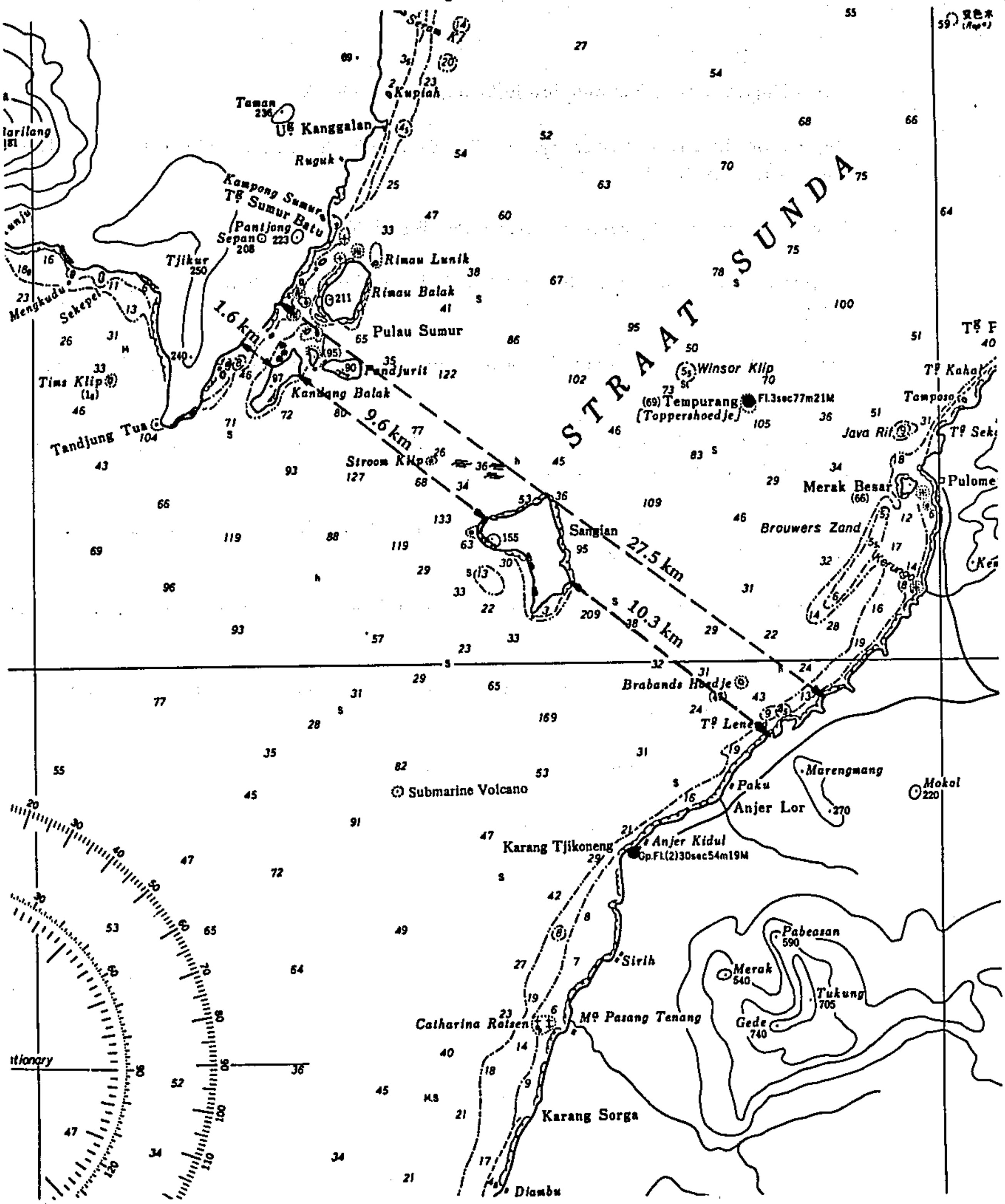
1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	....	2010	Average
0.873	0.816	0.763	0.713	0.666	0.623	0.582	0.544	0.508	0.475	....	0.184	12.654
0.797	0.712	0.636	0.567	0.507	0.452	0.404	0.361	0.322	0.287	....	0.059	8.843
456	905	894	1,357	1,351	1,804	1,796	2,708	2,699	2,687	....	2,687	
398	738	682	968	900	1,124	1,045	1,473	1,371		12,441		1,741
363	644	569	769	685	815	726	977	869		5,890		1,490
223	443	437	664	661	882	878	1,305	1,301	1,295	....	1,295	
23.8	44.0	40.6	57.7	53.7	67.0	62.3	86.6	80.6		731.5		103
28.8	51.1	45.0	61.0	54.3	64.6	57.5	76.3	67.9		459.9		117

General Map of South Sumatera



Appendix VII.

General Map of Sunda Strait



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