FEASIBILITY STUDY
ON
LIGNITE BRIQUETTE DEVELOPMENT
IN
THE KINGDOM OF THAILAND

(SUMMARY)

NOVEMBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

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CONTENT

Chapter 1 Introduction

This is a summary of the feasibility study report on LIGNITE BRIQUETTE DEVELOPMENT IN THE KINGDOM OF THAILAND. This feasibility study was conducted in accordance with the Scope of Work agreed upon in Bangkok on July 26, 1989 by the representatives of the National Energy Administration (NEA), of the Ministry of Science, Technology and Energy, the Kingdom of Thailand and the Japan International Cooperation Agency (JICA). This report presents the summary of the contents of the feasibility study. For further details, the readers are requested to refer to the main report submitted to NEA.

The purpose of this study is to examine and evaluate the feasibility of the Thai government plan for establishing a pilot plant for the production of lignite briquettes that could be a substitute for wood fuel, and to make recommendations for the implementation of the project, as well as for the dissemination of lignite briquettes for popular use, provided that the project is found feasible.

The Sixth Five Year Plan specifically mentions promotion of lignite utilization for industrial and household uses in rural areas as part of its policy to intensify the development and utilization of lignite. This project conforms to this policy by expanding the use of lignite.

This project is of particular importance in the context of environmental conservation. A large number of trees are cut down to produce firewood and charcoal, the most important cooking fuels for most Thai people, and this is chiefly attributable to the destruction of the nation's forest. In 1961, forests constituted about 53 percent of the total area of the kingdom; the forest area had declined to about 28 percent of the total area by 1988. Today, deforestation is still under way at an alarming rate. Deforestation has made many places, including those remote from, and seemingly unrelated to the sites of deforestation, vulnerable to floods, landslides or droughts which give rise to serious social problems. The use of lignite briquettes in place of firewood and charcoal would help save the nation's endangered forest, and conserve the environment before it is too late.

This study was conducted in two stages as specified by the Scope of Work. In the first stage, lasting from November 1989 to March 1991, study is made mainly of the market potential of lignite briquettes. The study on the market potential included assessment of the possibility of using lignite briquettes as a substitute for firewood and charcoal for household and industrial uses, and that for lignite now used by small industries, and identification of the prospective market.

The second-stage study, which immediately followed the completion of the first-stage study, consisted of a techno-economic analysis and the formulation of strategies for the dissemination of lignite briquettes for popular use.

As a result of the first-stage study, the prospective markets for lignite briquettes and the potential demands were identified. Charcoal for cooking purpose was identified as the most prospective target of substitution by lignite briquettes. It was found difficult, however, to use lignite briquettes as a substitute for firewood. The estimated price of lignite briquettes is not competitive with firewood for both household and industrial uses. In addition, many industrial furnaces have to be modified before they can burn lignite briquettes. Ironically, if such modifications are made, they can burn lignite rather than lignite briquettes, the former being much cheaper than the latter. Besides, the temperature could be so high in the industrial furnaces that slaked lime, blended into lignite briquettes as desulfurization agent, would not be effective enough in catching sulfur oxides. Regarding substitution for lignite in industrial applications, there is not a great merit in the use of lignite briquettes in place of lignite, if desulfurization is not expected.

As part of the first-stage study, lignite briquettes were experimentally produced from the domestic raw materials both in Japan and in Thailand. Burning tests were conducted to evaluate the performance of the experimentally produced briquettes. The burning tests also led to the development of the designs of cooking stoves suited to burning lignite briquettes. A bench-scale plant was installed at the Fuel Test Center of NEA in Rangsit near Bangkok. The study team of JICA assisted NEA in

the installation and startup of the bench-scale plant, thereby transferring the related technologies to NEA.

JICA invited three engineers of NEA to Japan to study technologies of coal briquette production at a coal briquette plant, as part of its programs to ensure transfer of technology.

A large amount of lignite briquettes produced by this bench-scale plant enabled demonstrations to be conducted at various locations and a number of samples to be distributed among the potential users of lignite briquettes. Their opinions on the quality of the lignite briquettes were polled. Although charcoal is more convenient than lignite briquettes as cooking fuel, about 60 percent of the respondents said they would accept lignite briquettes on conditions that the price would be 60 percent of that of charcoal, and that charcoal would become hard to obtain. It was also discovered that the nation's already diminished forest will no longer be able to provide charcoal and firewood as much as to meet the forecast demand without becoming exhausted in a matter of only two decades. This is where lignite briquettes will have important roles to play. The results of the first-stage study were reported in the interim report submitted in February 1991.

In the second stage, techno-economic analyses were conducted. These include studies on the raw materials, production technology of lignite briquettes, sites, conceptual design, estimation of the cost, construction, utility and infrastructure, construction schedule, organization for operation, financial, economic and social evaluations; and strategies for the dissemination of lignite briquettes were recommended.

The Scope of Work defined the framework of this study and specified that the Ban Pa Kha lignite would be the main raw material and (an) appropriate kind(s) of biomass would be blended. Within the framework, this study specifies in detail the capacity of the pilot plant; the quality of the product; the kinds of raw materials and their blending ratios; the processing scheme; the location of the plant. To evaluate

possibility of recovering the investment in the pilot plant during the subsequent commercial stage, a commercial plant is assumed to start following the pilot plant. The study also recommends an appropriate system of the project management. As will be explained later, this study recommends that the capacity of the pilot plant be 3,000 tons per year and that of the commercial plant be 50,000 tons per year; the raw materials be Ban Pa Kha lignite, rice straws and slaked lime; and the site be on the premises of Ban Pa Kha mine.

The results of the financial analysis indicate that the pilot plant project is worth implementing. The investment to be made in the pilot plant will be recovered by the commercial plants assumed to follow the pilot plant. The pilot plant is expected to play a vital role in the dissemination of lignite briquettes among people who are now using charcoal as cooking fuel, and thereby paving the way for the commercial production and ensured marketing of lignite briquettes.

The commercial plant that will follow the pilot plant is found financially feasible. Commercialization of lignite briquettes on a large scale will have a significant effect upon conservation of the nation's forest, in addition to bringing about a variety of benefits, as explained in Chapter 12. This project is evaluated as worth implementing.

The first stage of this study started in November 1989 and completed in March 1991. The second stage started immediately after completion of the first stage. The experts assigned to this study are Koji TANAKA, Yoshitaka IMAEDA, Akinori HASHIMOTO, Kunio KAWADA, Ryu-ichi HIRAIWA, Kiyoji DEGUCHI, Masumi KURIBAYASHI, Yukio MIYAMOTO and Shizuo KAMIKURA. The successful completion of this study owes a great deal to the devoted support by NEA and cooperation extended by the concerned offices of the government of Thailand.

Chapter 2 Summary of Results

2-1 Background - Justification

The proposed project well addresses the important elements of the backgrounds: the policy of the government to increase the degree of self-sufficiency with respect to the supply of energy; the serious deforestation; the endowment of lignite resources; and the lifestyles and cooking habits of most Thai people. The Thai lifestyles and cooking habits will accommodate lignite briquettes as cooking fuel; or conversely, the quality of lignite briquettes is designed to fit the lifestyles and cooking habits of most Thai people. The impact of dissemination of lignite briquettes as cooking fuel is great, because the most important cooking fuels for the Thai people are charcoal and firewood, accounting collectively for about 80 percent of the consumption of cooking fuels.

2-2 Market

The lignite briquettes to be produced by this project are found to be competitive in price with charcoal but not with firewood; lignite briquettes could therefore take the place of a significant portion of the forecast demand for charcoal. Thailand suffers from severe deforestation, for which the production of firewood and charcoal is largely responsible; deforestation restricts the supply of charcoal and firewood. A case study conducted as part of this study indicates that during the period from 1995 to the year 2010, the supply of charcoal will fall short of the demand by 0.4 to 1.3 million tons oil equivalent. Such shortfalls in supply must be filled by other cooking fuels; lignite briquettes will certainly be one of them.

Lignite briquettes are a promising substitute for charcoal, although they are not suitable as a substitution for modern energy like petroleum products and natural gas, because lignite briquettes are not suited to the uses in which efficiency is pursued or as transportation fuel. Lignite briquettes are also not suited as a substitute for the small amount of firewood consumed by industry. The price of firewood

is much lower than the estimated price of lignite briquettes. The furnaces now burning firewood need substantial modification before they can burn lignite briquettes. Desulfurization, one of the merits of lignite briquettes, is not expected in the case of industrial furnaces where temperatures are rather high compared with cooking stoves. If desulfurization is not expected, there is little merit in using lignite briquettes as a substitute for lignite in industrial applications.

The results of the opinion surveys on the potential consumers of lignite briquettes, namely, the present consumers of charcoal, conducted in and around major local cities and Bangkok indicate that most consumers will accept lignite briquettes if the prices are less than that of charcoal; 60 percent of those surveyed said that they would accept lignite briquettes if they are priced at 60 percent of that of charcoal, for example. This implies a large potential market for lignite briquettes.

2-3 Experimental Production and Burning Tests

By means of experimental production and burning tests, this study has ascertained the technical feasibility of producing lignite briquettes that would meet the quality design by using domestic raw materials alone: the Ban Pa Kha high-quality lignite, rice straws and slaked lime. To improve the burning performance of lignite briquettes, a design of cooking stoves better suited than the well-accepted Thai clay stoves to burning lignite briquettes has been developed.

2-4 Raw Material

The Ban Pa Kha mine will be able to support production of the 190,000 tons of lignite briquettes per year. There are enough rice straws in Northern Region. Thailand has vast resources of limestone from which a sufficient amount of slaked lime could be produced.

2-5 Plant Site

The site for the pilot plant was selected at a location on the premises

of the Ban Pa Kha mine. The site has an area large enough to accommodate a commercial plant with a capacity of 50,000 tons per year in addition to the pilot plant, including an area needed for the stockpiling of the raw materials. The selected site is adequate in terms of accessibility, the transportation of the raw materials and the product, safety and security, firmness of the soil, and the availability of public utilities.

2-6 Financial Feasibility

The capacity of the pilot plant is 3,000 tons per year. This pilot plant, per se, is not feasible as far as financial profitability is concerned. However, the investment and loss incurred by the pilot plant will be repaid by a 50,000-ton-per-year commercial plant assumed to start five years after the start of the pilot plant. The purpose of the pilot plant is, by its very nature, not to make a profit but to explore the technology or market for the sake of commercialization that will follow; therefore, the pilot plant can be considered to be justifiable.

The cash flow for the commercial plant gives a return of discounted cash flow on investment of 11.6 and 10.0 percent before and after tax, and that on equity of 14.3 and 11.7 percent before and after tax, respectively.

2-7 Benefits

The socio-economic benefits that may result from the extensive use of lignite briquettes in place of charcoal are very great and versatile. First and foremost, it will help reduce deforestation; it could therefore curb many of the adverse effects attributable to deforestation: floods, droughts or an insufficient supply of water for agriculture, landslides, salt attacks, etc. The saving in the planting costs by realization of a large-scale commercialization of lignite briquettes could amount to about 40,000 million Bahts by 2010 as described in Chapter 12. Burning lignite in the form of briquettes could arrest a great portion, or about 70 percent, of the sulfur contained in the lignite that would otherwise be discharged into the atmosphere. As is

described also in Chapter 12, commercialization of lignite briquettes could save the cost of desulfurization, amounting to 350 million Bahts per year, that would otherwise have to be done by flue gas desulfurization. The production of lignite briquettes on a large scale would help ensure a stable supply of household cooking fuel, which would otherwise have to depend upon LPG, a commodity susceptible to fluctuation in price in the international market. The construction and operation of briquetting plants in rural areas would increase the number of employment opportunities in such job-scarce areas. Furthermore, the commercialization of lignite briquette production will promote the introduction of foreign technology and stimulate the domestic machine industry.

2-8 Recommendations

Based upon the preceding conclusions of this study, recommendations given in Chapter 16 are presented.

Chapter 3 Background of the Project

The policy of the government, the pattern of energy consumption, the seriousness of deforestation, the endowment of lignite resources, and the lifestyles and cooking habits of the ordinary Thai people constitute important aspects of the background to this project.

The policy of the government has been to increase the degree of self-sufficiency and to diversify the sources with respect to the supply of energy. In line with this policy, the government has been encouraging the use of lignite. Table 3-1 shows a remarkable increase in the use of lignite.

Table 3-1 Lignite Consumption in Thailand

(Unit: Thousand tons)

Year	Electricity	Tobacco	Cement	Others	Total
1980	1,321	80	4	43	1,448
1981	1,534	100	50	12	1,695
1982	1,687	122	203	30	2,042
1983	1,573	99	196	52	1,920
1984	1,945	76	224	61	2,305
1985	4,597	92	387	56	5,132
1986	4,685	80	532	129	5,426
1987	5,727	78	658	360	6,823
1988	5,896	60	874	369	7,199
1989	6,780	110	1,265	418	8,573

Source: Thailand Energy Situation, NEA

The probable reserves of coal, including lignite, are estimated at about 440 million TOE, or tons oil equivalent, the largest of all domestic energy resources. The government also encourages research and development into new technologies for expanded use of lignite, particularly lignite briquettes as a substitute for charcoal and firewood used as household and industrial fuels.

Energy consumption in Thailand is characterized, as explained in the next chapter, by heavy dependence on imported fuel, petroleum in particular, as well as on charcoal and firewood for household fuels. Modern energy like coal, petroleum products, natural gas and

electricity meets approximately two-thirds of the total energy requirement, with renewable energy like charcoal, firewood and rice husks, about one-third of the requirement.

The consumption of charcoal and firewood combined amounts to about five million TOE, and 8.5 million TOE of trees are cut down to supply this amount of charcoal and firewood. The eight and a half million TOE of wood corresponds to between 45 and 50 million cubic meters of wood. This amount far exceeds the sustainable supply capability of the entire existing forests of Thailand. The production of charcoal and firewood has been recognized as a major cause of deforestation.

The problem of deforestation is very serious as Table 3-2 explains itself. In 1961, more than half the area of the nation was covered by forests; now the forest area represents only about a quarter of the total land area.

Table 3-2 Forest Area in Thailand, 1961-1988

(Unit: %)

Area	1961	1973	1976	1978	1982	1985	1988
North	68.54	66.96	60.32	55.96	51.75	49.59	47.37
Northeast	41.90	30.01	24.57	18.49	15.33	15.15	14.03
South	41.89	26.07	28.46	24.89	23.25	21.90	20.69
Central	52.91	35.50	32.38	30.31	27.47	26.24	25.59
East	57.98	41.19	34.00	30.24	21.92	21.89	21.46
Whole Kingdom	53.33	43.21	38.07	34.15	30.52	29.05	28.03

Source: Royal Forestry Department

Viewed from the angle of consumption, charcoal and firewood now supply about 80 percent of cooking fuel consumed in Thailand; while electricity and LPG supply only small portions of the cooking fuel. Charcoal and firewood are important cooking fuels for the overwhelming majority of Thai people, far outweighing in importance and consumption LPG and electricity.

The consumption of charcoal and firewood is, however, a major factor causing deforestation. Thailand cannot afford to lose any of the

remaining scarce forests. However, the consumption of charcoal and firewood cannot be banned without an appropriate substitute made available to consumers. This is where lignite briquettes will have an important role to play.

The lifestyles and cooking habits of ordinary Thai people would accept lignite briquettes as cooking fuel. Charcoal and firewood generate smoke, the former during the ignition period when the kindling burns and the latter almost throughout the whole of the burning period. The lignite briquettes of this project would generate a small amount of smoke during the initial period of ignition. The structure of most houses allows natural ventilation and accordingly is able to tolerate a small amount of smoke. Most people use fire in that part of the house where there is sufficient ventilation. Therefore, lignite briquettes are acceptable to Thai people in general, although it would be difficult for the small fraction of the population who live in western-style houses to accept the use of lignite briquettes; these people now use LPG.

Chapter 4 Energy Supply and Demand

Table 4-1 well explains the total supply and demand of energy in Thailand. Modern energy like coal, petroleum, natural gas and electricity accounts for about 70 percent of the total consumption; renewable energy like charcoal, firewood and agricultural wastes constitutes the remaining 30 percent. Lignite, natural gas and renewable energy are domestically produced; 70 percent of petroleum is imported. Natural gas and lignite are mostly converted into electricity. Renewable energy is burned as fuel. Charcoal is used almost entirely for household cooking; firewood is also used chiefly for cooking, except for a small amount used by small-scale industries. About 70 percent of rice husks for fuel are used as industrial fuel, and 30 percent, for household fuel. Bagasse is consumed chiefly by sugarmills.

Table 4-1 Primary Energy Supply & Final Energy Consumption: 1989

	Primary Energy Supply		Final Energy Consumption	
	Volume (KTOE)	Share (%)	Volume (KTOE)	Share (%)
MODERN ENERGY	25,726	69.1	19,196	71.7
Coal/Coke	300	0.8	300	1.1
Lignite	2,463	6.6	782	2.9
Petroleum/Petroleum Prod.	16,482	44.2	15,168	56.6
Natural Gas	5,194	13.9	114	0.4
Electricity	1,234	3.3	2,798	10.5
RENEWABLE ENERGY	11,529	30.9	7,579	28.3
Firewood	8,496	22.8	2,798	10.5
Charcoal	-50	-0.1	2,008	7.5
Rice Husks	1,194	3.2	884	3.3
Bagasse	1,889	5.1	1,889	7.1
TOTAL ENERGY	37,255	100.0	26,775	100.0

Source: Thailand Energy Situation, NEA

Table 4-2 shows the estimated consumption of energy for the Residential and Commercial Sector. The consumption is mainly for cooking. It may be noted, first of all, from the table that charcoal and firewood assume overwhelming importance as cooking fuel, 80 percent in 1989 for example, while LPG meets only about 15 percent of the requirement, although the latter has recently been increasing very rapidly. The per-

capita consumption of around 95 KgOE is quite normal for a country which is situated in a tropical or sub-tropical zone and in which the household consumption of energy is chiefly for cooking.

Table 4-2 Estimated Energy Consumption for Cooking in the Residential and Commercial Sector

(Unit: KTOE)

	1982	1983	1984	1985	1986	1987	1988	1989
Charcoal	2,227	2,183	2,161	2,138	2,103	2,103	2,066	2,008
Firewood	2,169	2,189	2,237	2,294	2,313	2,270	2,267	2,241
Paddy Husks	99	131	179	247	254	261	267	266
LPG	199	230	232	366	453	541	687	801
Electricity	nil	nil	nil	nil	nil	nil	nil	nil
Total	4,694	4,733	4,809	5,045	5,123	5,175	5,287	5,316
Per Capita (KgOE)	96.2	95.7	95.1	97.4	96.7	96.1	96.2	95.1

This study forecasts the demands for charcoal and firewood up to the year 2010. Table 4-3 summarizes the results of the forecast. The decreasing demands reflect the general tendency of the people toward using LPG instead of wood fuel.

Table 4-3 Demands for Wood Fuel by Area

(Unit: KTOE)

	1989	1995	2000	2005	2010
Charcoal					
Bangkok Metropolitan	50	45	41	38	35
Central	391	355	333	311	293
North	512	465	435	409	386
Northeast	879	798	744	699	658
South	175	159	148	139	131
Whole Kingdom	2,008	1,822	1,699	1,596	1,503
Firewood					
Bangkok Metropolitan	34	29	26	22	18
Central	352	326	307	288	267
North	598	556	525	494	462
Northeast	1,502	1,391	1,310	1,228	1,141
South	312	289	272	255	237
Whole Kingdom	2,798	2,590	2,439	2,287	2,125

The supply of charcoal and firewood is by no means easy; deforestation

severely limits the supply of these important household fuels. Table 4-4 simulates the depletion of the forests in relation to the production of charcoal and firewood. The two lines at the bottom of Table 4-4 show the forecast demands for firewood and charcoal, respectively. By this simulation, forest area will almost disappear by the year 2010 if the demands are to be met. It is hardly conceivable that this situation will actually be allowed to happen; in other words, the supply of charcoal and firewood will be severely limited and will not meet the demand.

Table 4-4 Forest Area versus Supply of Wood Fuel (Case-A)

	1989	1995	2000	2005	2010
Forest Area, km^2					
Natural Forest	137,684	100,851	69,484	36,519	1,598
Planted Forest					
Protective Forest	280	1,960	3,360	4,760	6,160
Productive Forest	120	840	1,440	2,040	2,640
Total Forest Area	138,084	103,651	74,284	43,319	10,398
Forest Volume, million m^3	524.0	383.8	264.4	139.0	6.1
Sustainable Supply Vol., million m^3					
Natural Forest	13.83	10.13	6.98	3.67	0.16
Planted Forest	--	0.38	0.75	1.13	1.50
Total	13.83	10.51	7.73	4.79	1.66
Supply Volume					
Total Supply, million m^3	37.4	33.7	31.5	29.6	27.8
Total Supply, KTOE	8,496	7,651	7,158	7,720	6,300
Firewood, KTOE	2,798	2,590	2,439	2,287	2,125
Charcoal, KTOE	2,008	1,822	1,699	1,596	1,503

Table 4-5 gives a more realistic simulation where the cutting down of trees is more restricted and the supply of charcoal is limited. This simulation assumes that the volume of trees cut down will decrease by six percent per year as a result of the regulations by the government. The trees cut down are consumed as firewood in preference to charcoal, because firewood is more thermally efficient than charcoal; the overall thermal efficiency of charcoal production in Thailand is as low as 35 percent. The use of wood as firewood instead of charcoal represents maximum national efficiency. This simulation represents a compromise between the conservation of the forests and the supply of wood fuel.

Table 4-5 Forest Area versus Supply of Wood Fuel (Case-B)

	1989	1995	2000	2005	2010
Forest Area, km^2					
Natural Forest	137,684	101,451	79,691	64,396	53,943
Planted Forest					
Protective Forest	280	1,960	3,360	4,760	6,160
Productive Forest	120	840	1,440	2,040	2,640
Total Forest Area	138,084	104,251	84,491	71,169	62,743
Forest Volume, million m^3	524.0	386.1	303.3	245.0	205.3
Sustainable Supply Vol., million m^3					
Natural Forest	13.83	10.19	8.01	6.47	5.42
Planted Forest	--	0.38	0.75	1.13	1.50
Total	13.83	10.57	8.76	7.59	6.92
Supply Volume					
Total Supply, million m^3	37.4	29.2	21.4	15.7	11.5
Total Supply, KTOE	8,496	6,628	4,865	3,570	2,620
Firewood, KTOE	2,798	2,590	2,439	2,287	2,125
Charcoal, KTOE	2,008	1,454	873	462	178

If the supply of wood fuel is controlled as shown by the above simulation, there will be shortages of supplies as given in Table 4-6.

Table 4-6 Supply Demand Balance of Wood Fuel

(Unit: KTOE)

		1995	2000	2005	2010
Supply	Charcoal	1,454	873	462	178
	Firewood	2,590	2,439	2,287	2,125
Demand	Charcoal	1,822	1,699	1,596	1,503
	Firewood	2,590	2,439	2,287	2,125
Balance	Charcoal	-368	-826	-1,134	-1,325
	Firewood	0	0	0	0

The forecast shortages of supply of charcoal are very large. Lignite briquettes are one of very promising candidates to fill a significant portion of such shortages.

Chapter 5 Market for Lignite Briquettes

The lignite briquettes to be produced by this project will serve as a substitute for charcoal, the most important household cooking fuel along with firewood. Technically, the lignite briquettes could be a substitute for firewood for cooking; however, the estimated price of lignite briquettes is not competitive with that of firewood. The same is true of the substitution of firewood as an industrial fuel. In addition, in many industrial applications where firewood is burned, it is not technically possible to burn lignite briquettes without first making substantial modifications to the existing facilities. If such modifications are made, the furnace can burn lignite rather than lignite briquettes, the former being much cheaper than the latter. As explained in Chapter 1, the ability of lignite briquettes to remove sulfur would be lost in the industrial furnaces because of the high temperatures in the industrial furnaces. The ceramic industry is an example of such industries. There is no economic nor technical merit in using lignite briquettes in place of lignite. Lignite briquettes will not serve as a substitute for petroleum products.

The price of charcoal varies from one place to another, while also depending upon the size of the sales lot. Charcoal is priced higher in and around major cities. The most promising markets are the places where the price of charcoal is high. There is also the question of the preference of consumers. The study team conducted two rounds of opinion survey along with public demonstrations of lignite briquettes in and around such rural centers as Nakhon Si Thammarat, Ratchaburi, Ubon Ratchatani, Mahasarakham, Phitsanulok and Chiang Mai. Opinion surveys and demonstrations were also conducted in Bangkok. The results of the monitoring survey are summarized in Table 5-1.

Table 5-1 shows the relationship between the rates of acceptance of lignite briquettes by the potential consumers and the ratio of the price of lignite briquettes to that of charcoal. The rates of acceptance at the price ratio of 60 percent are particularly important, because this is the lowest price at which lignite briquettes could be sold to the consumers, if all the costs of raw materials, investment in and

operation of the manufacturing facilities, transportation of the raw materials and product, and the sales margins for the dealers are included in the price. It is noted that there is no appreciable difference by the survey area in the rates of acceptance at the price ratio of 60 percent.

Table 5-1 Substitution Rate of Charcoal by Lignite Briquettes

(Unit: percentage of households)

Price ratio, % Lig. briq'tes/charcoal	80.0	60.0	40.0	20.0	0.0
From the questionnaires recovered					
Nakhon Si Thammarat	10.4	56.3	97.9	100.0	100.0
Ratchaburi	39.4	63.6	90.9	97.0	97.0
Ubon Ratchatani	33.3	51.1	71.1	82.2	97.8
Mahasarakham	38.9	63.9	77.8	97.2	97.2
Phitsanulok	16.9	46.2	69.2	84.6	93.8
Chiang Mai	47.9	69.0	87.3	97.2	98.6
Average	30.9	58.1	81.9	92.6	97.3
Bangkok	35.1	56.8	70.3	83.8	91.9

Using the acceptance ratio of 60 percent, the demands for lignite briquettes are forecast as shown in Table 5-2.

Table 5-2 Demands for Lignite Briquettes by Region

(Unit: KTOE)

	1995	2000	2005	2010
Bangkok Metropolitan	6	13	17	19
Central	45	101	139	163
North	58	133	182	213
Northeast	100	226	311	364
South	20	45	62	72
Whole Kingdom	229	518	711	831

Chapter 6 Raw Materials

The total reserves of coal in Thailand are estimated at about 440 million TOE, and coal is regarded as a precious indigenous energy source. However, Thai coal is mostly classified into sub-bituminous coal or lignite, having inferior quality as fuel, and thus, it has not been utilized effectively except for fueling at mine-mouth power plants. The production of lignite briquettes will be a promising means to extend the use of lignite as household fuel, since it could redress the inherent drawbacks of lignite to some extent.

Although it is possible to treat a wide range of coal in the lignite briquette production process employed in this project, selection of feed coal needs particular attention, since the quality of briquette is determined largely by the properties of the feedstock. In the case of using lignite, the heating value of the feedstock is the critical item when selecting feed lignite, and use of a lignite with a higher heating value, so-called high-quality lignite, is desirable. However, the reserves of high-quality lignite are rather scarce in Thailand, and moreover, the deposits are concentrated in a certain area. Therefore, when in the future a number of lignite briquette plants are to be constructed throughout the nation, the low-quality quality lignite will have to be used as feedstock, because the reserve of low-quality lignite is abundant and the deposits are spread throughout Thailand. The heating value of low-quality lignite should, however, be improved through processing at washing plants prior to feeding to lignite briquette plants. After washing plants have been installed in sufficient numbers, the powder coal could be used as feedstock for briquette production. The yields of the powder coal on product coal are between 20 and 40 percent but the use of which is quite limited.

According to the forecast supply of lignite, the production of lignite will reach 20 million tons per year in 2000, and if 10 percent of which is used for briquette production, it would meet the requirement of lignite for the production of approximately two million tons per year of lignite briquettes. The total lignite production capacity in Ban Pa Kha coal mine, designated to supply lignite to the project, is 1.2 million

tons per year as shown below.

Production Capacity of High-quality Lignite	400,000 tons/year
Production Capacity of Washed Lignite	700,000 tons/year
Production Capacity of Low-quality Lignite	100,000 tons/year
Total	1,200,000 tons/year

According to the marketing plan of the Ban Pa Kha mine, one million tons per year of lignite will be sold to firm users, and thus, 200,000 tons per year of lignite could be produced beyond the planned marketable quantity. Therefore, it seems possible to supply high-quality and/or washed lignite of 56,000 tons per year required by the pilot plant of 3,000-ton-per-year capacity and the commercial plant of 50,000-ton-per-year capacity until the end of the year 2004 when the mining operation will be terminated. In and after 2005, lignite could be supplied to the project from the neighboring coal mines.

In the lignite briquette production process, other raw materials than lignite are required; biomass acts as a binder as well as a combustion improver and slaked lime acts as desulfurization agent.

Because agriculture is the key sector in Thailand, various agricultural wastes are available as feedstock for the production of lignite briquettes. When utilizing biomass, major inconveniences may be encountered in transportation and storage, and thus, biomass available around plant site and throughout a year is to be chosen. Having studied the availability, cost and quality of candidate biomass feedstocks, rice straws are found as the most promising feedstock. If two percent of rice straws produced in Thailand is used for the production of lignite briquettes, it will meet the requirement for the biomass for the production of two million tons per year of lignite briquettes.

In Lamphun Province, where the plants are to be installed, most farmers raise two different crops a year, namely, major rice and vegetables. Double cropping of rice is not predominant but a small fraction of farmers are doing it. Rice straws should be available almost

throughout a year, except for a certain short period. The 1990 production of rice in Lamphun Province is shown below.

Major rice	113,735 tons/year (harvesting season: November - January)
Second rice	14,128 tons/year (harvesting season: March - July)
Total	127,863 tons/year

The production of rice straws is about two times that of rice; the production of rice straws is estimated at about 250 thousand tons per year. This amount is equivalent to the requirement of biomass for the production of one million tons per year of lignite briquettes. It seems therefore possible to procure rice straws of the required quantity for the project from the adjacent area of the plant site. To minimize the storage capacity of rice straws on the plant site, it is required to establish an appropriate procurement schedule of rice straws and to utilize the off-harvesting season for maintenance of the plants, scheduled two months a year.

When a number of briquette plants are installed throughout Thailand, in addition to rice straws, bagasse would be a possible biomass feedstock in Central Region and old rubber trees in Southern Region.

Slaked lime is made from limestone. As the deposits of limestone are spread across the country, there seem to be no obvious obstacles to supplying slaked lime to the project. Today, the production of limestone is 14 million tons per year, 99 percent of which is used for cement production. Most of slaked lime is produced in a small quantity in the so-called cottage industries. The quality of slaked lime is determined largely by the calcining temperature. Therefore, it is important to procure slaked lime of good quality from reliable suppliers.

A total of 5,000 tons per year of slaked lime will be required for the production of lignite briquettes by the pilot plant of 3,000-ton-per-year capacity as well as by the commercial plant of 50,000-ton-per-year capacity. To supply such a large quantity of slaked lime to the plants

at Ban Pa Kha, the existing lime kiln in Tak Province would be a proper supplier. It is also possible that a lime kiln be constructed in a place near the lignite briquette plants if a deposit of high-quality limestone is discovered there.

In short, all the raw materials required will be supplied not only to the pilot plant but also to commercial plants; the total capacity of the commercial plants will be two million tons per year in the future.

Following are the prices of the raw materials as of today.

High-quality Lignite (ex-mine)	550 Bahts/ton
Rice Straws (at rice field)	500 Bahts/ton
Slaked Lime (at the briquette plant)	2,500 Bahts/ton

Chapter 7 Quality of Lignite Briquettes

This study is oriented towards achieving the quality target set to meet the requirements of consumers. The quality target is referred to as quality design throughout this study, because the quality target is one of the most important bases for the design of the manufacturing process. In the design of quality, consumers always come first, while the role of the manufacturing technology is to realize the degree of quality that will satisfy consumers.

The quality design was to be the target of the experimental production of lignite briquettes conducted immediately after the first-phase field survey of the first-stage study. A tentative quality design was therefore set before the experimental production started, or towards the closing stage of the first-phase field survey. Based on the intensive observations during the field survey, the tentative quality design was made in such a way that it reflects the lifestyles and cooking habits of ordinary Thai people using charcoal for cooking; in other words, the quality design was intended to enable lignite briquettes to serve as a substitute for charcoal. The ease with which a fire could be started and the strength of the fire comparable to charcoal when burned in traditional Thai clay cooking stoves, safety in handling, and strength to withstand rough handling were the important points that determined the tentative quality design. The quality level set by the tentative quality design was achieved by the experimental production conducted in Japan using Ban Pa Kha lignite, Japanese rice straws and Thai slaked lime. The quality design was tentative, because it was subject to revisions as a result of the later study.

Monitoring surveys were then conducted. At its initial stage, a bench-scale plant was installed at the Fuel Test Center of NEA in Rangsit. The bench-scale plant produced lignite briquettes from all Thai raw materials in accordance with the blending formula established as a result of the experimental production in Japan. These lignite briquettes were used for the monitoring survey to obtain the responses of the potential consumers with respect to the acceptability of lignite briquettes. As a result of the monitoring survey, minor modifications

to the quality design were made so as to better meet the requirements of consumers and accommodate the constraints arising from the nature of the raw materials.

At this stage, the generation of a small amount of smoke, and hence soot and odor accompanying the smoke, was tolerated, limited only to the initial short period of combustion when the fire is still weak. This is because, firstly, the elimination of smoke would require the expensive process of removing the volatile matter from the feed lignite which represents a significant portion of the heat content of the lignite and, secondly, the fireplaces of ordinary Thai houses do not have a closed structure, and thereby allowing sufficient ventilation to dissipate the smoke. However, during the second-stage field survey, the study team came to realize that the elimination of smoke would facilitate the dissemination of lignite briquettes among Thai people.

Smoke and soot should contain a large number of chemical compounds produced during the process of combustion, incomplete combustion in particular; and the kinds of such combustion products may vary depending upon the conditions of combustion and the constitution of the lignite briquettes, which may, strictly speaking, also vary from one lot to another. There is therefore no denying the possibility of the smoke or soot containing one or more substances that are known to have adverse effects upon human health. It was therefore decided at the second-stage study to pursue the technology of manufacturing smoke-reduced lignite briquettes in a way that would not greatly affect the economic viability of the project. After a series of laboratory tests, the conditions for manufacturing smoke-reduced lignite briquettes were established. This study, the conceptual design in particular, incorporates the results of such endeavors.

Finally, the quality design of lignite briquettes was established as follows:

(1) Ease of Ignition

The lignite briquettes should reach a steady burning state within eight to 10 minutes of ignition.

(2) Strength of the Fire

The fire should be strong enough for cooking. The heating value should be more than 4,000 kcal/kg. One charge of lignite briquettes in a stove should burn steadily for more than 30 minutes. The flame should be low enough in height to be safe.

(3) Generation of Smoke

Smoke should not be generated in a notable amount under the normal conditions of burning in typical Thai clay stoves.

(4) Generation of Odor

No disagreeable odor should be generated under the normal conditions of burning in typical Thai clay stoves.

(5) Safety

The combustion gas and ash should be safe for human beings, animals and plants.

(6) Control of the Fire

The strength of the fire should be easily controllable by adjusting the amount of primary air.

(7) Physical Strength

The lignite briquettes should have enough physical strength to withstand rough handling; specifically, they should have a breaking strength of 100 kilograms or more.

(8) Others, Shape and Size

The lignite briquettes should have a shape and size convenient for actual use.

The lignite briquettes of this project emulate charcoal in many aspects; however, it it not possible, within the limit of commercial practicality, to make them comparable to charcoal in certain aspects. These constraints, or drawbacks in comparison with charcoal, should be accepted and kept in mind in the use of lignite briquettes.

The lignite briquettes of this project is not water-repellent. Lignite briquettes should be kept from absorbing moisture.

Lignite briquettes leave a considerably more ash than charcoal does. When lignite briquettes are used in a large amount, the disposal of ash may become a problem. It is recommended that each household dispose ash in a manner that would not cause a social problem, burying in the yard for example.

Although the generation of smoke and odor will be significantly reduced by the addition of a de-smoking facility to the processing scheme, the production of completely smokeless lignite briquettes is not intended. Making lignite briquettes completely smokeless is expensive in terms of the loss of the volatile matter contained in the feed lignite as well as in terms of the investment and operation cost required for such an operation.

As explained in Chapter 6, lignite of inferior quality may have to be used after washing when lignite briquettes are produced in a large amount. Washability can vary from one lignite to another; therefore, washability test must be conducted before use of a lignite is decided.

Chapter 8 Experimental Production and Burning Tests

The purpose of the experimental production of lignite briquettes was to confirm by experiments the technical feasibility of producing lignite briquettes of the quality satisfying the quality design from the Thai raw materials under consideration: Ban Pa Kha lignite, biomass -- Thai rice straws, rice husks, bagasse at the time of the experiments -- and Thai slaked lime, and at the same time to establish the appropriate manufacturing conditions. The experiments were carried out in a laboratory and a coal briquette manufacturing plant in Japan. Actually, Japanese rice straws and Japanese rice husks were used in place of their Thai counterparts, because the Japanese law controlling agricultural pests and diseases does not allow them to be imported into Japan.

A number of experiments were done in search of the best blending formula in a progressively increasing scale; from the scale of the tablets at first through the bench-scale size, and finally to the commercial plant. Concurrent with the briquetting experiments, burning tests were carried out so as to evaluate the quality of the experimentally produced lots. The experimental production finally arrived at the best blending formula as shown in Table 8-1.

Table 8-1 Recommended Formula for Lignite Briquettes

Ingredient	Ratio by Weight
De-smoked Ban Pa Kha lignite	75.0
Rice straws	25.0
Slaked lime	10 to 30

The blending ratio of slaked lime should vary depending upon the sulfur content of the lignite used; in the case of Ban Pa Kha lignite, slaked lime of about 10 percent is sufficient. After a blending formula had been established by experiments on small scales, the operation conditions including the blending formula were reproduced on the commercial plant; thus, the applicability of the blending formula for a commercial installation was confirmed. As explained in Chapter 7, an

additional series of experimental production was conducted in order to establish the conditions for producing smoke-reduced lignite briquettes. For the de-smoked lignite, the above blending formula has been found to be recommendable.

There is an important objective for the burning tests, that is, the development of cooking stoves suited to burning lignite briquettes. In Thailand, clay stoves of good designs are in extensive use. These clay stoves come in various sizes and are sold at 30 to 80 Bahts per piece. The lignite briquettes of this project could burn rather well in these clay stoves; however, the stoves of improved design developed by this study provide a better burning properties with reduced smoke and improved thermal efficiency. Stoves of improved design have been presented to NEA.

Chapter 9 Project Scheme

The project scheme defines the project in terms of the capacity of the pilot plant, plant site, kinds of raw material to be used, quality of the product, process scheme and facilities, kinds of utility to be used, modifications to the infrastructure, organization, operation rate, inventory of the raw materials and product, and methods of transportation of the raw materials and product.

The mission of this study is to work out the details of the project in such a way as to ensure the maximum benefits of the project. At the closing stage of the second-stage field survey, a tentative project scheme was worked out as a result of the first-stage study, as well as the second-stage field survey, and was recorded in the progress report. The project scheme has been finalized as follows, incorporating the results of the home-office work of the second-stage studies.

9-1 Capacities of the Pilot Plant and the Commercial Plant

The nominal capacity of the pilot plant is set at 3,000 tons per year, based on the operation days of 300 days per year and 24 hours a day on a three-shift operation. The production of 3,000 tons per year would be sufficient for the development of market for lignite briquettes. However, a pilot plant with this capacity is not financially feasible. Under the Thai conditions, a plant producing lignite briquettes as a substitute for charcoal could be financially feasible only when the capacity is close to 50,000 tons per year or larger. The capacity of the commercial plant is set at 50,000 tons per year on the same conditions. This plant was studied for feasibility.

9-2 Selection of the Plant Site

The pilot plant will be located in the premises of the Ban Pa Kha mine of NEA. The exact location of the site is shown on Figure 9-1. The site is very conveniently located for obtaining electric power, telephone communications and water. The area is normally free from typhoons and earthquakes.

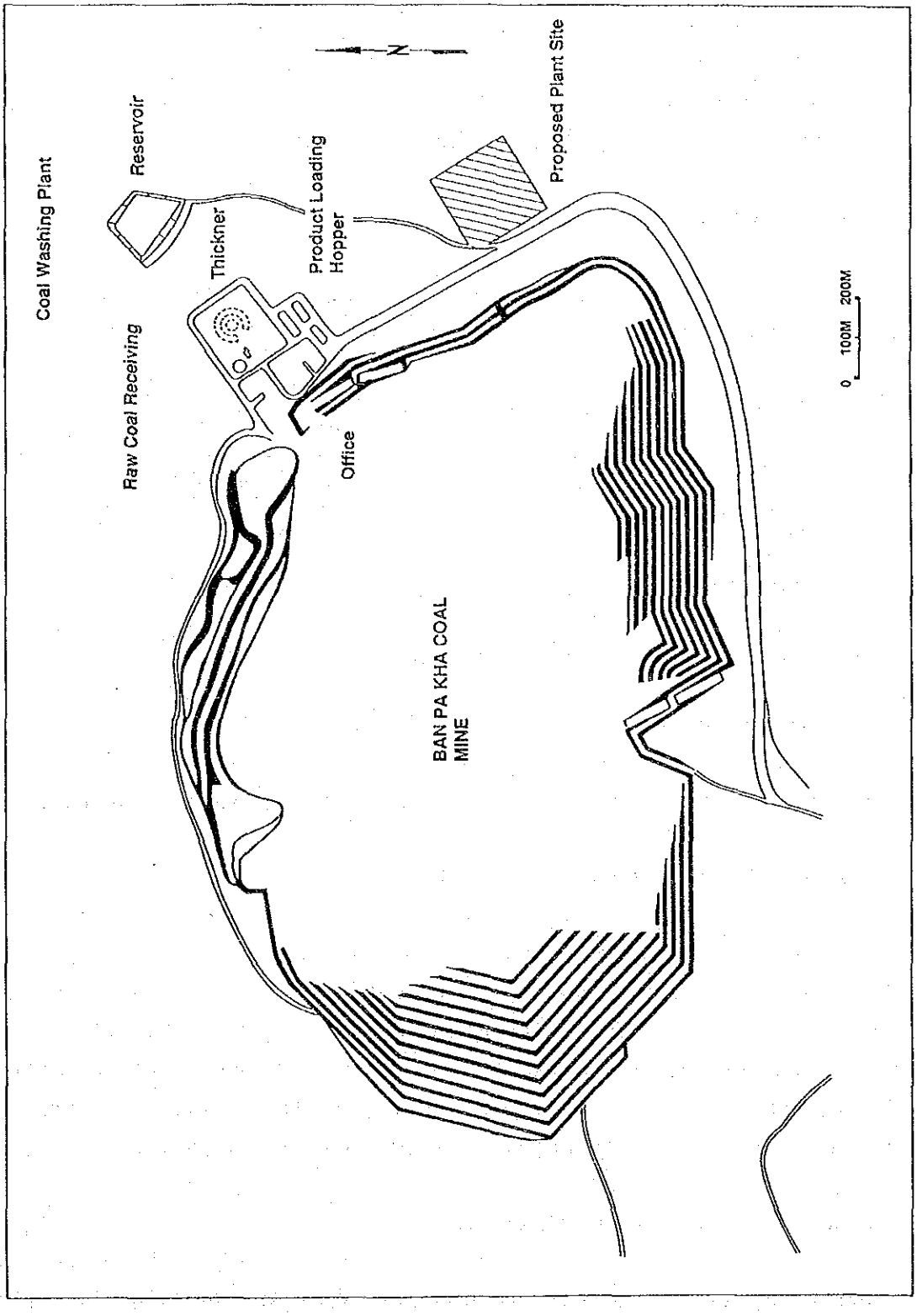


Figure 9-1 Location of the Plant Site

The site is immune to inundation even in the case of heavy downpours. The soil is very solid. The site is at a sufficient distance from the residential area. The raw materials and product, as well as construction materials and equipment, will be transported by truck.

9-3 Raw Material

According to the conceptual design of the pilot plant, the following amounts of raw materials are required.

Table 9-1 Raw Material Requirement
(Unit: tons per ton of lignite briquettes)

Raw material	Raw material base	Feed base	Ratio
Lignite	1.059	0.682	75
Rice straws	0.246	0.227	25
Slaked lime	0.092	0.091	10
Total	1.397	1.000	110

9-4 Quality of Product

The quality of the lignite briquettes is as per explained in Chapter 7.

9-5 Manufacturing Scheme and Facilities

The manufacturing scheme and major facilities are shown in Figure 9-2. Equipment to remove smoke is provided. The gas generated in this equipment is used as fuel. There are shelters over the manufacturing facilities and storage area of rice straws. There will be a control room provided with instruments and meters for measuring essential operating conditions and pieces of simple testing equipment.

9-6 Infrastructure and Utilities

There is no need to improve the infrastructure for the construction or operation of the pilot plant, or subsequent commercial plant.

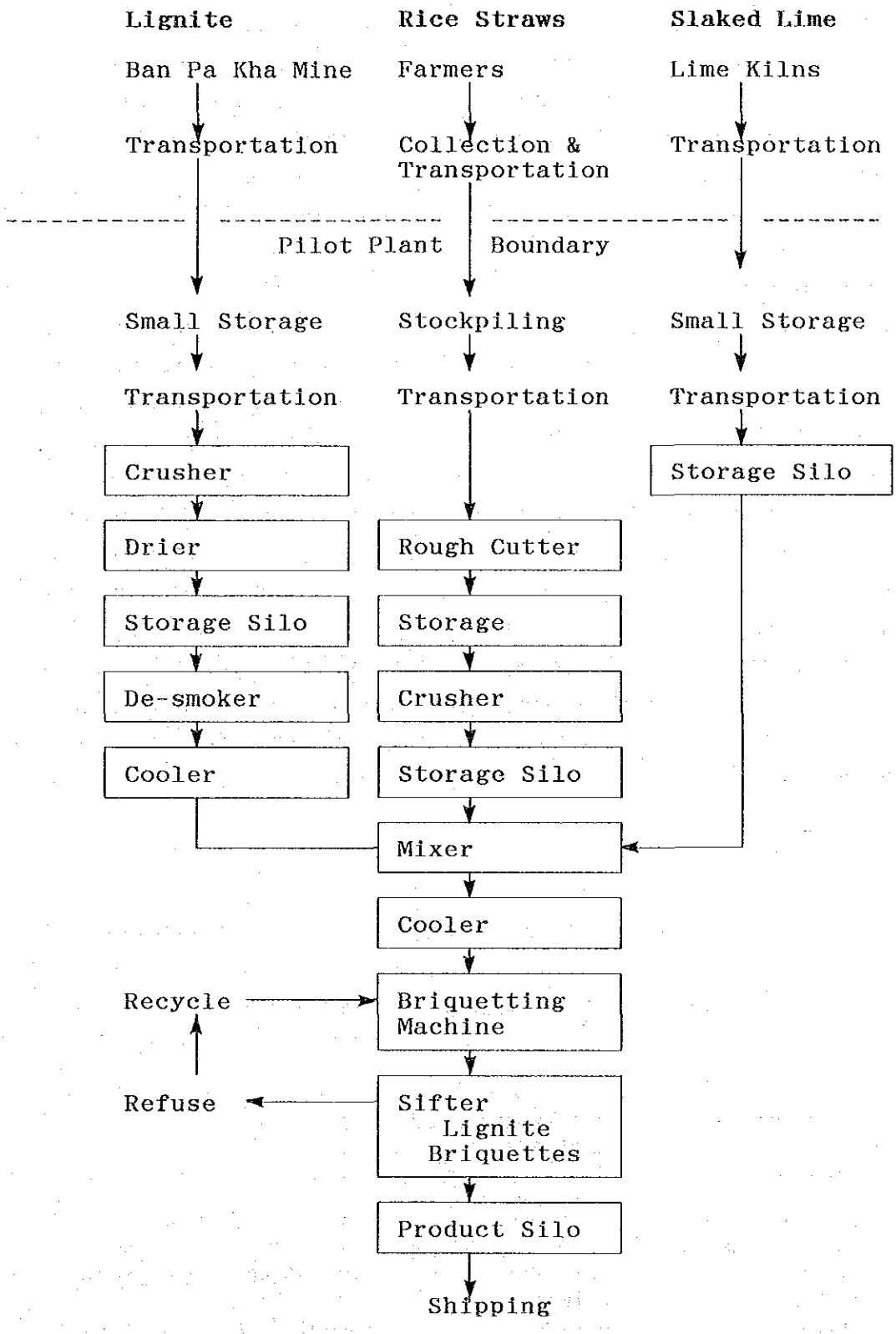


Figure 9-2 Manufacturing Flow

As part of this project, an access road has to be built to connect with the road leading to the mine. It is also necessary to build a small bridge over the ditch bordering the site. A telephone line will be branched from the existing one running along the site. The conceptual designs of the pilot plant and the 50,000-tons-per-year commercial plant call for supplies of 122 kilowatts and 652 kilowatts of electricity, respectively. Electricity will be tapped from the existing power line running along Highway Route 106. The power main has a capacity of 22 KVA, sufficient for both the pilot plant and the commercial plant. A branch line will be laid between the main and the receiving unit at the gate of the plant over a distance of 3,000 meters. The consumption of water is limited to drinking, hygienic use and cleaning. The process of manufacturing lignite briquettes is a dry process and does not use water. Bottled water will be purchased for drinking purposes. A cistern of 10 cubic meters will be provided on the site to maintain pressure. Water is not consumed continuously; however, a pipeline will be installed from the mine to the pilot plant in order to receive water. Pneumatic air will be provided by running a compressor as required. Compressed nitrogen gas will be purchased if required. The de-smoking equipment uses its own gas as the heat source and the effluent from the furnace is used for drying the feed lignite.

9-7 Organization

The organization for operating the pilot plant is shown in Table 9-2.

Table 9-2 Organization for the Pilot Plant

Position	Rank	Number	
Plant Manager	Department Head	1	
Engineer	Engineer	1	
Technician	Supervisor	1	
Foreman	Foreman	1	
Staff accountant	Staff accountant	1	
Secretary & clerk	Secretary & clerk	1	
Operator	Operator	20	(5/shift x 4 groups)
Driver	Driver	2	
Guard	Contract	4	(1/shift x 4 groups)
Unskilled Labor	Contract	14	

The organization for operating the commercial plant is shown in Table 9-3.

Table 9-3 Organization for the Commercial Plant

Position	Rank	Number	
Plant			
Plant Manager	Department Head	0	
Engineer	Engineer	1	
Technician	Supervisor	1	
Foreman	Foreman	1	
Staff Accountant	Staff Accountant	1	
Secretary & Clerk	Secretary & Clerk	1	
Operator	Operator	20	(5/shift x 4 groups)
Driver	Driver	2	
Guard	Contract	0	(1/shift x 4 groups)
Unskilled Labor	Contract	18	
Head Office			
General Manager	General Manager	1	
Department Head	Department Head	2	
Engineer	Engineer	2	
Staff	Staff Accountant	2	
Secretary & Clerk	Secretary & Clerk	1	

The plant manager and engineer will take care of both the pilot plant and the commercial plant. The head office is installed in the headquarters of NEA at the commercial plant stage.

9-8 Operation Rate

For both the pilot plant and the commercial plant, 24-hours-per-day operations under three shifts are planned. The operation days are 300 per year; in other words, 65 days are available to maintenance and repairs. Intermediate storage capacities between major facilities will be incorporated to facilitate minor onstream maintenance works.

9-9 Inventory of Raw Material and Product

The following capacities for inventories are planned for both the pilot plant and the commercial plant.

Table 9-4 Inventory of the Raw Materials

Item	Pilot Plant	Commercial Plant
Lignite, days	20	3
Rice straws, months	1	1
Slaked lime, days	10	10
Lignite briquettes, days	15	15

9-10 Transportation

The transportation of the raw materials to the stockyard on the premises of the pilot plant -- lignite, rice straws and slaked lime -- and that of the product to the market will be by truck. At the pilot plant stage, the raw materials will be transported from the stockyard to the plant mouth manually by means of handcarts. A truck loader will be used for this purpose for the commercial plant.

9-11 Commercial Plant

The commercial plant is defined as follows:

Location:	Adjacent to the pilot plant
Capacity:	50,000 tons per year
Feed:	Same as those for the pilot plant
Quality of product:	Same as those for the pilot plant
Startup:	5 years after the start of the pilot plant
Owner:	NEA or the public corporation running the pilot plant

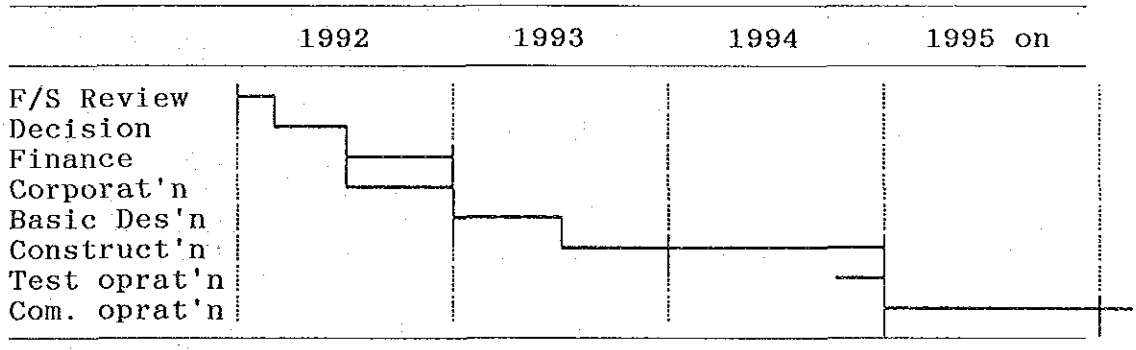
9-12 Project Schedule

Before construction can actually start, a certain period of time will be required for NEA to obtain the final approval on the project, establishment of a public corporation, government proceedings to have the project approved, acquisition of funds, etc. The following table shows the schedule for the implementation of the pilot plant.

Table 9-5 Schedule for Implementation

Item	Duration (month)
(1) Review of the feasibility study	3
(2) Decision making	3
(3) Arrangement for financing, and simultaneously	6
(4) Establishment of public corporation	6
(5) Basic design and preparation for bidding	6
(6) Construction	17
(7) Test operation	1
(8) Commercial operation, year	20

Figure 9-3 Overall Project Schedule



The material balance and energy balance were developed for the process scheme already introduced in Chapter 9. The process flow diagram was drawn up based on the material and energy balances. The process specifications were derived from the material and energy balance for the major facilities.

10-1 Material and Energy Balances

Table 10-1 represents the overall material balance of the pilot plant.

Table 10-1 Overall Material Balance

(Unit: kilograms/hour)

	Input to System	Drier		De-smoker			Mixer		Brq. Mac.
		Moist	Lig	Moist	Gas	Lig	Moist	Blend	Briq't
Lignite									
Moist	132.4	118.8	13.6	13.6	-	-	-	-	-
Ash	37.6	-	37.6	-	-	37.6	-	37.6	37.6
VM	139.6	-	139.6	-	24.7	114.9	-	114.9	114.9
FC	131.6	-	131.6	-	-	131.6	-	131.6	131.6
Total	441.2	118.8	322.4	13.6	24.7	284.1	-	284.1	284.1
R. straws									
Moist	15.3	-	-	-	-	-	7.8	7.5	7.5
Ash	14.8	-	-	-	-	-	-	14.8	14.8
VM	59.6	-	-	-	-	-	-	59.6	59.6
FC	12.8	-	-	-	-	-	-	12.8	12.8
Total	102.5	-	-	-	-	-	7.8	94.7	94.7
S. Lime									
Moist	0.4	-	-	-	-	-	0.4	-	-
DSL	37.9	-	-	-	-	-	-	37.9	37.9
Total	38.3	-	-	-	-	-	0.4	37.9	37.9
G. Total	582.0	118.8	322.4	13.6	24.7	284.1	8.2	416.7	416.7

Note: Moist, Lig, Briq't, VM, FC, and DSL stand respectively for moisture, lignite, briquettes, volatile matter, fixed carbon, and dry slaked lime.

Table 10-2 gives the overall energy balance for the pilot plant.

Table 10-2 Overall Energy Balance

(Unit: 10^3 Kcal/hour)

Input		Output	
Feed		Drier vent	133.6
Lignite	0.0	Heat of decomposition	20.8
Rice straws	0.0	Mixer vent	5.0
Slaked lime	0.0	Cooler-1 vent	4.2
Heat of combustion	104.8	Cooler-2 vent	6.2
Hot air generator		Lignite briquettes	11.7
Heat of combustion			
De-smoker gas	23.4		
Diesel fuel	49.6		
Heat of compression	3.7		
Air to the furnace	0.0		
Total	181.5		181.5

Table 10-3 indicates the analyses used as a base for the development of the material and energy balances; the conditions given in the process flow diagram are also used as bases.

Table 10-3 Analyses Used for Material and Energy Balance

(Unit: weight percent)

	Lignite		Rice	Slaked	Lignite
	ROM	Dry base	straws	lime	briquettes
Moist.	30.0	-	14.9	1.0	1.8
Ash	8.5	12.2	14.4	-	21.7
VM	31.7	45.2	58.2	-	41.8
FC	29.8	42.6	12.5	-	34.7
Dry lime	-	-	-	99.0	-
Total	100.0	100.0	100.0	100.0	100.0

Note: ROM, Moist, VM, and FC stand respectively for run of the mine, moisture, volatile matter and fixed carbon.

10-2 Fuel Balance

Normally, the de-smoker gas is burned in the de-smoker furnace to heat the lignite. The excess de-smoker gas and the furnace effluent are used to generate hot gas for drying lignite feed; however, the heat obtainable from these two sources is insufficient for the purpose. Diesel fuel is burned in the hot air generator to make up the balance. In ad-

dition, during the processes of startup and shutdown when gas is not sufficiently generated, diesel fuel is used.

Table 10-4 De-smoker Gas Material Balance

(Unit: kilograms/hour)

	Generation			Consumption	
	Moist	Gas	Total	Furn.	Hot gas ge'tor
De-smoker					
Carbon	-	17.2	17.2	14.0	3.2
Hydrogen	-	3.0	3.0	2.5	0.5
Oxygen	-	4.0	4.0	3.3	0.7
Nitrogen	-	0.5	0.5	0.4	0.1
Moisture	13.6	-	13.6	-	-
Total	13.6	24.7	38.3	20.2	4.5
Diesel fuel					5.2
Total	13.6	24.7	38.3	20.2	9.7

Note: Moist, Furn and ge'tor stand for moisture, furnace and generator, respectively.

10-3 Utility Balance

Electricity is the only process utility used by the lignite briquette plants. Water is used for cleaning, fire-fighting, sanitation, and in a very small amount for cooling bearing boxes. Pneumatic air is generated as needed by running a compressor. Table 10-5 shows the overall utility balance.

Table 10-5 Overall Utility Balance

(Unit: Average kw)

Input		Output	
Electricity	122	Power	112
		Lighting & others	10
Water	Normally none	Cooling	Normally none

10-4 Organization for Construction of the Plant

For the purpose of implementing as smoothly as possible the construction of the pilot plant and the effective transfer of technology to

Thailand, the organization shown in Figure 10-1 is recommended.

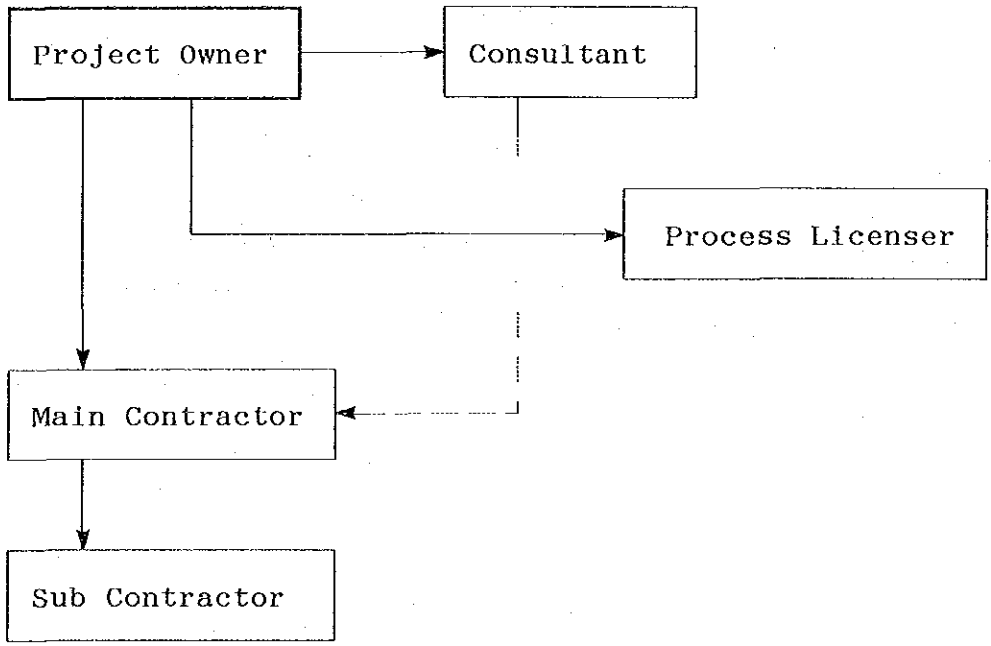


Figure 10-1 Recommended Contractual Scheme for Plant Construction

The project owner will be either NEA or a public corporation to be established under the auspices of NEA. The consultant will assist the project owner in selecting and controlling the main contractor. The process licenser will prepare the basic design of the plant under contract with the project owner. The main contractor will draw up the detailed designs, procure the equipment and machines, undertake construction works, and manage the entire construction works. The main contractor will use subcontractors as needed.

The lump-sum type of contract is more recommendable than the cost-plus-fee type of contract for the effective implementation of the construction work, mainly because the total cost for the construction can be determined at the time of awarding the contract and the responsibility of the main contractor can be clearly defined, by the former type of contract.

10-5 Estimation of the Plant Costs

The costs of the plants are estimated as shown in Table 10-6.

Table 10-6 Estimated Plant Cost

(Unit: 1,000 Bahts)

Pilot Plant	56,987
Commercial Plant	185,403

Note: The cost of the commercial plant excludes the cost for leveling the site which is included in the cost of the pilot plant. This explains the difference in the cost of the commercial plant between Tables 10-6 and 11-1.

Chapter 11 Financial Analysis

11-1 Total Capital Requirements

Table 11-1 shows the total capital requirements for the pilot plant and the commercial plant.

Table 11-1 Total Capital Requirement

(Unit: 1,000 Bahts)

	Pilot Plant	Commercial Plant
Plant cost	56,987	186,445
Interest during construction	2,684	8,346
Preoperating cost	6,255	7,399
Working capital investment	2,117	8,346
Total	68,043	208,182

Note: (1) The plant costs are estimated using cost levels for 1990.

(2) The interest during the construction period is calculated using 9.0 percent per year.

(3) The preoperating costs consist of the estimated costs for basic design fee, consultant fee and test run cost.

(4) The working capital investments represent investments in the inventories of raw materials and product, inventory of spareparts, accounts receivable, accounts payable and cash in hand.

(5) The rate of exchange is 5.5 yen per Baht.

11-2 Financial Rates of Return

The rates of return of the discounted cash flows on investment and equity before and after tax are obtained as shown in Table 11-2.

Table 11-2 Financial Rates of Return

(Unit: percent)

	Pilot Plant	Commercial Plant	Combined
ROI before tax	Negative	11.6	5.7
ROI after tax	Negative	10.0	4.6
ROE before tax	Negative	14.3	2.4
ROE after tax	Negative	11.7	Negative

Note: (1) ROI and ROE represent respectively the rate of return of the discounted cash flow on investment and that on equity.

11-3 Evaluation

(1) The pilot plant gives negative returns, meaning that the pilot plant, per se, is not financially feasible.

(2) The commercial plant shows acceptable returns, indicating that the commercial plant is financially feasible.

(3) The combined cash flow gives positive returns. This means that, although the pilot plant is not financially feasible, the investment in the pilot plant will be paid out by the commercial plant, giving profits as indicated by the rates of return.

For the other parameters of the financial evaluations, the main report should be referred to.

Chapter 12 Socio-economic Analysis

12-1 Economic Internal Rates of Return

Economic cash flows are developed for the pilot plant and a commercial plant of 50,000 tons per year; economic internal rates of returns, EIRR's, are calculated for these two cases. The methods of developing economic cash flows and calculating EIRR's are explained in the main report.

The EIRR of the pilot plant is negative, meaning that the pilot plant itself is not justifiable in terms of economic price and economic cost. The EIRR obtained for a commercial plant of 50,000 tons per year is 14.5, a value high enough to justify the subject project in economic terms. How high EIRR should be varies depending upon the nature of the project; however, it is generally accepted that the borderline range is between 8 and 12.

12-2 Qualitative Analysis

The merits of the lignite briquettes are discussed from the viewpoints of their effects upon the nation and society. The effects of the pilot plant itself, or even one or two commercial plants, would be too small to be evaluated in such terms. The pilot plant would be a small, but one definite step forward towards realization of large-scale production of lignite briquettes. Therefore, the socio-economic impacts of large-scale production of lignite briquettes are evaluated here. In other words, the socio-economic value of the pilot plant is evaluated in terms of future prospect of lignite briquettes to which the pilot plant acts as a precursor.

12-2-1 Conservation of Forests

The difference in the forest area between Table 4-4 and Table 4-5, 52,345 square kilometers in 2010, is the area of forest to be saved by substitute fuels for charcoal, of which 60 percent, or 31,407 square kilometers would be credited to lignite briquettes. The value of this

area of forest defies any attempt to express it in terms of monetary value, given serious effects of deforestation: floods, droughts, land slides, salt attacks, etc. The forest area of 31,407 square kilometers represent 23 percent of the total forest area of 1989. Just a small portion of the total benefit of the forest saved, the cost of replantation saved on account of 31,407 square kilometer is calculated to be 39,300 million Bahts by using a unit cost of 2,000 Bahts per rai.

12-2-2 Desulfurization

Supposing that 831,000 TOE of lignite briquettes, or 1.6 million tons are consumed in 2010 as forecast by the market study and that the raw material lignite contains two percent sulfur on dry base, the amount of sulfur to be caught by the desulfurization agent blended into lignite briquettes is 16,600 tons. The average cost of desulfurization by means of flue gas desulfurization is about 42,000 Bahts per ton sulfur; therefore, the cost of desulfurization saved will be 700 million Bahts. The cost of desulfurization agent, or slaked lime, is estimated at about 350 million Bahts; there will still be saved 350 million Bahts after deduction of the cost of desulfurization agent.

12-2-3 Cost of LPG

Should there not be lignite briquettes, LPG would be the only practical alternative to make up for the forecast demand of lignite briquettes, supposing the wood fuel is not allowed to be used any more than the forecast consumption of this study. In 2010, 831,000 tons more LPG would have to be imported, the total cost of which would be 125 million US dollars at an assumed price 150 US dollars per ton of LPG. Lignite briquettes would save the foreign currency cost of LPG that would have to be imported without lignite briquettes.

12-2-4 Social Benefits

Besides protection of the forest and preventions of the hazards directly and indirectly attributable to deforestation, lignite briquettes would have the following benefits.

(1) Diversification of the sources of energy supply,
(2) Effective utilization of lignite briquettes, or low-quality coal,
(3) Effective utilization of unused domestic resources: rice straws and slaked lime,
(4) Creation of job opportunities in job-scarce rural areas as a results of construction of lignite briquettes plants,
(5) Transfer of technology relative to the manufacture of lignite briquettes and to the design and fabrication of machines needed by the lignite briquette plants.

12-3 Economic Comparison with Other Fuels

Lignite briquettes are not meant for substituting for modern fuels like natural gas, gasoline, diesel fuel, LPG, and electricity. Technically, lignite briquettes could be a substitute for firewood, charcoal and lignite. Lignite briquettes, however, cannot economically compete with firewood and lignite. Moreover, the furnaces now burning firewood or lignite need substantial modifications in order to be able to burn lignite briquettes. In economical terms, lignite briquettes can compete only with charcoal and LPG for cooking purpose. The retail price of charcoal is about 7 US$/MMBTU in small bags, 4 US$/MMBTU in large bags, and that of LPG is 9 US$/MMBTU. The price of lignite briquettes is set to be competitive with charcoal both at wholesale and retail stages. At the same time, manufacturing of lignite briquettes is made financially and economically feasible at the commercial stage. Lignite briquettes are naturally competitive with LPG as far as the price is concerned. However, the conditions in which LPG is burned are significantly different from the conditions in which lignite briquettes will be burned, and therefore not a target for substitution.

12-4 Environmental Consideration on Production and Utilization

The conceptual design of the pilot plant as well as that of the commercial plant incorporate provisions for environmental conservation. First and foremost, the site is selected at a sufficient distance from the residential area. The possible causes for environmental disruption

are dust of lignite and gas from the de-smoker. Bag filters are installed where dusts could be generated to catch them. The gas generated from the de-smoker is burned in the furnace of the de-smoker and also in the hot gas generator for drying lignite. The above provisions will prevent pollutants from escaping the plant and also conserve the working conditions for the operators. The process of manufacturing lignite briquettes is a dry process and does not produce a foul effluent stream. However, in order to prevent lubricating oil or tar from leaving the site with rain water, a detention pond is provided at the outlet of the sewage system.

In consideration of the environmental aspects associated with utilization of lignite briquettes, the conceptual design incorporates a provision for reducing generation of smoke when lignite briquettes are burned. By this, generation of smoke could be reduced markedly. An analysis of the ash of lignite briquettes indicates that the content of cadmium is lower than 5 ppm, the standard set for Japanese fertilizers. Chromium VI was not detected by the analysis of ash. Lignite briquettes generate carbon monoxide when they burn but not more than charcoal does. Sulfur originally contained in lignite is converted into sulfur oxides and find its way in the combustion gas. By addition of slaked lime in the lignite briquettes, about 70 percent of sulfur oxides is caught before they can be released in the combustion gas. With this, smell of sulfur oxides is hardly recognizable by the human senses. Anyhow, smoke, soot, sulfur oxides and carbon monoxide are generated during combustion; therefore, lignite briquettes are not suited to be burned in a closed quarter. The houses of ordinary Thai people are of a structure which allows ventilation; and cooking is usually done in a place where ventilation is particularly good. In modern houses of a closed structure, LPG and electricity are used. This study gives consideration as explained above to the environmental aspects of the utilization of lignite briquettes.

Chapter 13 Strategy for the Dissemination of Lignite Briquettes

13-1 Premises for Study

The government of Thailand fully realizes the seriousness of deforestation, for which consumption of charcoal and firewood has been greatly responsible, as explained in Chapter 1 and Chapter 3, as well as the importance of the dissemination of lignite briquettes as a means of ameliorating the ever-worsening situation of deforestation. In concluding this study, it is recommended that concrete measures be taken to disseminate lignite briquettes among the people of Thailand. As will be explained, the government has very important roles to play, without which the successful dissemination of lignite briquettes would hardly be conceivable.

13-2 Lignite Briquettes as a New Commodity

Lignite briquettes are intended chiefly to be a substitute for charcoal as cooking fuel. The potential consumers of lignite briquettes are therefore those who now purchase and consume charcoal for cooking. The upper thin layer of socially and economically privileged people consume LPG and electricity only. In 1989, LPG accounted for only 15 percent of the total cooking fuel consumed in Thailand. The residents of western-style houses in Bangkok and Chiang Mai use exclusively LPG and electricity. However, many other LPG users also use charcoal and electricity depending on the purpose, together with LPG. In 1989, charcoal accounted for 37.8 percent of the total consumption of cooking fuel, a significant share along with firewood which accounted for 42.1 percent. Charcoal users represent the majority of the population, while they also use LPG, electricity and firewood depending upon the purpose, income level and where they live.

Compared to charcoal, lignite briquettes have drawbacks stemming from the quality of the raw materials: lower heating values, slower ignition, and the generation of smoke. To compensate for such drawbacks, lignite briquettes should be priced lower than charcoal. The results of the monitoring survey indicate that about 60 percent of the consumption of

charcoal could be replaced by lignite briquettes, provided that the price of lignite briquettes is 60 percent of that of charcoal. In line with this result, this study sets the consumer price of lignite briquettes at 60 percent of that of charcoal. Furthermore, the quality of lignite briquettes is designed in such a way that they may be used without forcing consumers to change their lifestyles or cooking habits.

This does not mean in the least, however, that lignite briquettes will sell well automatically. In Thailand, lignite briquettes are a new commodity known only to very few people. Among the very few who know of lignite briquettes, there is the preconceived idea that lignite briquettes generate so much smoke and odor that they can hardly be used as cooking fuel. Since lignite briquettes are a new commodity, everything has to start from scratch. Firstly, consumers have to be informed of the existence of lignite briquettes, how to use them and their advantages. All incorrect and misguided preoccupations have to be corrected. Secondly, as lignite briquettes are a new commodity, there is no established distribution and marketing channel for them. Thirdly, since they are a new commodity without an established reputation, lignite briquettes will be very vulnerable to earning a bad reputation. Fourthly, and conversely because lignite briquettes are a new commodity, they will be very responsive to the strenuous efforts made to disseminate them; in other words, efforts well made will be well rewarded. The resources and skills the government has among the related ministries and departments, should therefore be rallied so that concerted efforts may be made for the promotion of lignite briquettes; these efforts should include the allocation of necessary budgets.

13-3 Essence of Efforts toward Dissemination

The efforts toward dissemination should correspond well to the four characteristics of lignite briquettes mentioned above while they should also be properly scheduled. The dissemination efforts to be made before the start of the pilot plant, after the start of the pilot plant but before the start of the commercial plant, and after the commercial production, should be distinguished and adequately timed.

The dissemination efforts should be timed according to the following three periods:

(1) Before the start of the pilot plant (1st Period),

(2) After the start of the pilot plant but before the start of the commercial plant (2nd Period),

(3) Commercial stage (3rd Period).

13-3-1 *Efforts toward Dissemination for the 1st Period*

The recommendations here apply to the period before the start of the pilot plant. It is recommended first of all that a policy committee and an executive committee be created consisting of the representatives of the related ministries and departments. The bench-scale plant installed at the Fuel Test Center should be modified to enable continuous operation. The continuous operation of the bench-scale plant would produce a maximum of 1,000 tons of lignite briquettes a year; an amount corresponding nearly to the total cooking fuel consumed by 5,000 persons a year. However, the bench-scale plant would also have to be used for the purpose of research and development; the maximum amount the plant could produce would therefore be about 500 tons a year, equivalent to the cooking fuel for about 2,500 persons.

At the beginning of the dissemination activities, lignite briquettes must be distributed free of charge among potential consumers. During this period, the available amount of lignite briquettes will be small; therefore, dissemination efforts should be focused on a designated area in order to be effective. The designated area, referred to as the "model market" for the sake of convenience, would be a local community with a population of about 25,000, consuming 10 times as much cooking fuel as the bench-scale plant will be producing.

The model market should preferably be identified in Central Region, the most prospective market because of the scarcity of forests, among the communities where the dependence on charcoal is high and the penetra-

tion of LPG is not significant.

The dissemination activities will be done chiefly by a task force. In addition to the staff of NEA, the officers of the Department of Agricultural Extension and the Cooperative Promotion Department, the Ministry of Agriculture and Co-operatives should be the members of the task force. As is detailed in the main report, the Department of Agricultural Extension has done a marvelous job in promoting biogas among farming societies in addition to popularizing new varieties of crops, agricultural chemicals, fertilizers, and new agricultural technology. The Cooperative Promotion Department works closely with farmers.

When it comes close to the start of the pilot plant, say, six months before the start, the bench-scale plant should increase production so as to expand the promotion activities to the communities surrounding the model market.

13-3-2 Efforts toward Dissemination for the 2nd Period

The dissemination efforts in this period represent the preparations necessary for the commercialization of lignite briquettes. In a way, this period is crucial to the success of the dissemination of lignite briquettes. The pilot plant will produce 3,000 tons of lignite briquettes, an amount equivalent to the total cooking fuel consumed by about 15,000 persons. The model market, with a population of 25,000, could absorb a good portion of the amount produced by the pilot plant, provided that the dissemination efforts in the 1st period have been successfully carried out. However, the efforts during this period should be concentrated rather on the geographical expansion of the consumers of lignite briquettes in preparation for commercialization. The media, such as television and radio, should be made good use of.

The distribution and marketing network must be established and strengthened during this period. Building an entirely new distribution and marketing channel reaching the end consumers, specifically to lignite briquettes, would not be a realistic option, because this option would need too much economic and human resources to be justifiable.

As mentioned in Chapter 5 of the main report, lignite briquettes should ride on the existing distribution and marketing channels for charcoal from wholesalers down to retailers. Free distribution by the Department of Agricultural Extension officers should continue on the one hand, while commercial marketing on the charcoal distribution and marketing channel should be promoted on the other; the volume for commercial distribution and marketing should be expanded. This would serve as a form of compensation to the charcoal dealers for the diminishing sales of charcoal. The charcoal dealers should be given enough incentive to make them keen on lignite briquettes by affording them the same margin of profit as they obtain from charcoal.

13-3-3 Commercial Stage (3rd Period)

The dissemination efforts during this period should be oriented toward a quantitative and geographical expansion of the market on the one hand, and perhaps more importantly on the other hand, toward creating an environment in which the business of lignite briquettes becomes self-sustainable, or financially feasible. If a fair margin of profit can be expected from the lignite briquette business, there will be private entrepreneurs entering this business. This is the only way that lignite briquettes will take off as a sound business. The production of lignite briquettes will increase whereby the substitution of charcoal will proceed so as to achieve the objective of curbing the destruction of the forests.

The role of the government lies in helping create an environment where the lignite briquette business can stand on its own feet financially rather than supporting it indefinitely as a dependent industry, mainly by the following provisions.

(1) The electric power generation and cement have taken priority in the proration of lignite. Lignite briquettes should take priority in the proration of high-quality lignite.

	1st Period			2nd Period					3rd Period		
Year	1	2	3	4	5	6	7	8	9	10	11 and on
Promoter	National Energy Administration supported by Policy Committee										
Plant in Operation	BS Plant	Modified BS Plant		Pilot Plant					Commercial Plant		
Organization	.Policy committee .Executive committee .Task force .Model market			.More task forces .More model markets							
Major Activity	.Establish policy committee .Establish executive committee .Form task force .Start mass education .Select model market .Prepare model market .Start modified BS Plant .Expand dissemination activity around the model market .Intensify dissemination activity .Intensify mass education .Start intensifying geographical expansion .Intensify marketing on the charcoal marketing channel .Establish Thai quality standards of lignite briquettes .Form more task forces .Select more model markets										
Incentive				.Tax exemption for replantation cost .Tax exemption for machines							

Figure 13-1 Sequence of Activities for Dissemination of Lignite Briquettes

(2) The lignite briquette industry should have its income tax reduced by the amount equivalent to the contribution made to the savings in replantation costs realized by the lignite briquettes it produces.

(3) The domestic machine industry should be fostered so that future plants may be constructed using mainly domestic machines. The machines to be used for such lignite briquette plants should be exempted from the 3.3 percent sales tax.

(4) The manufacturers of lignite briquettes should be guided so as to maintain the quality of lignite briquettes at the level proposed by this study as a standard.

(5) Controls on the production and sales of charcoal should be intensified in keeping pace with the production of lignite briquettes, without straining the supply of cooking fuel.

13-4 Roles of the Government

This study sets the consumer price of lignite briquettes at a level competitive with that of charcoal in conformity with the results of the monitoring survey. However, although the size of the potential market is large, it must be remembered that the market is still only a potential one, not a real one. So that the market for lignite briquettes may become a real one and grow to an economical size, the development of the market under the minute care of the government is indispensable. The lignite briquette development project has so many versatile aspects that the concerted efforts of a number of government offices are essential for its successful realization. The nation needs this industry to help protect the environment, so this project deserves attentive care by the government until it can stand on its own feet.

At the central administration, the policy committee and the executive committee should be established to coordinate government works. In the field, task forces should be set up. The administrative authorities at the levels of province, district, and village must support the dis-

semination activities.

13-4-1 Government Committee

NEA and the Ministry of Science, Technology and Energy should coordinate with other ministries to establish a policy committee and an executive committee consisting of the representatives of the related offices of the government. The following organizations may be considered to have roles to play and should therefore be represented in the committees. NEA, the promoter of this pilot plant project; the Ministry of Science, Technology and Energy to which NEA belongs; the Office of the National Environmental Board; the Ministry of Agriculture and Cooperatives and its important executive arms, the Department of Agricultural Extension and the Cooperative Promotion Department; the Royal Forestry Department; the Ministry of Industry; the Department of Mineral Resources; the Ministry of Interior; the Office of the Prime Minister, and two of its functional arms, the National Economic and Social Development Board and the Department of Technical and Economic Cooperation.

The policy committee will have the following roles to play:

(1) To appoint the members of the executive committee; the committee members should be capable officers with practical experience and knowledge,

(2) To approve the expenditure recommended by the executive committee and applications of budget to the Ministry of Finance,

(3) To review periodically the dissemination activities and make corrections if necessary,

(4) To conduct PR activities to educate the people on a wide scale,

(5) To appraise the capabilities available in Thailand and decide

on the necessity of assistances from abroad,

(6) To mobilize the capabilities of the organization to which each committee member belongs for the sake of promoting lignite briquettes.

The executive committee will have the following functions:

(1) To support the activities of NEA for the promotion of lignite briquettes,

(2) To analyze and resolve any problems that may occur in the procurement and transportation of the raw materials, production, storage and transportation of the product lignite briquettes, distribution, marketing, quality, consumer behavior, financial status of the project, and all other problems that may hinder smooth dissemination,

(3) To keep the policy committee well informed so that the policy committee may be able to respond adequately.

13-4-2 Cooperation from Other Ministries

This project is so versatile in nature that the Ministry of Science, Technology and Energy cannot cover everything. For a successful realization, cooperation from other ministries and departments is needed. At the initial stage, lignite briquettes must be distributed among potential consumers free of charge. Arrangements must be made to cover the cost of production and transportation. In this connection, the understanding of the Ministry of Finance will be necessary. The public must be educated about the seriousness of deforestation. The mass media, TV and radio, owned by the government must work in this direction. The administrative channels through the provinces, districts and down to the villages must be effectively utilized. The Department of Agricultural Extension and the Cooperative Promotion Department of the Ministry of Agriculture and Co-operatives would be the only effective organizations that could work directly with poten-

tial customers in rural communities. The Royal Forestry Department should put an effective ban on the production of charcoal and firewood, and is in a position to support this project in a positive manner for the purpose of protecting the forests.

13-4-3 Budget

The following budgets will be necessary for this project.

	(Unit: Bahts)
(1) 1st Period	
1. Modification of the bench-scale plant	32,000,000
2. Distribution of lignite briquettes	4,500,000
(2) 2nd Period	
1. Investment in the pilot plant	68,043,000
2. Distribution of lignite briquettes	15,000,000
3. Compensation for the loss by the pilot plant	64,771,000
(3) 3rd Period	
1. Investment in the commercial plant	270,066,000

The loss by the pilot plant will be recovered by the commercial plant. The costs incurred by the media owned by the government and the services of the government officers are not included.

13-4-4 Mass Education

As a result of the monitoring survey, it was learned that ordinary people are not fully aware of the seriousness of deforestation and the adverse effects the deforestation could have on the nation and the people. Ordinary people must be educated about these points, as well

as about lignite briquettes. Visual presentations would be most impressive, so television should be made full use of. Nearly 50 percent of the households own television sets which means that television would prove to be very effective.

The organization recommended for the dissemination of lignite briquettes is shown on Figure 13-2.

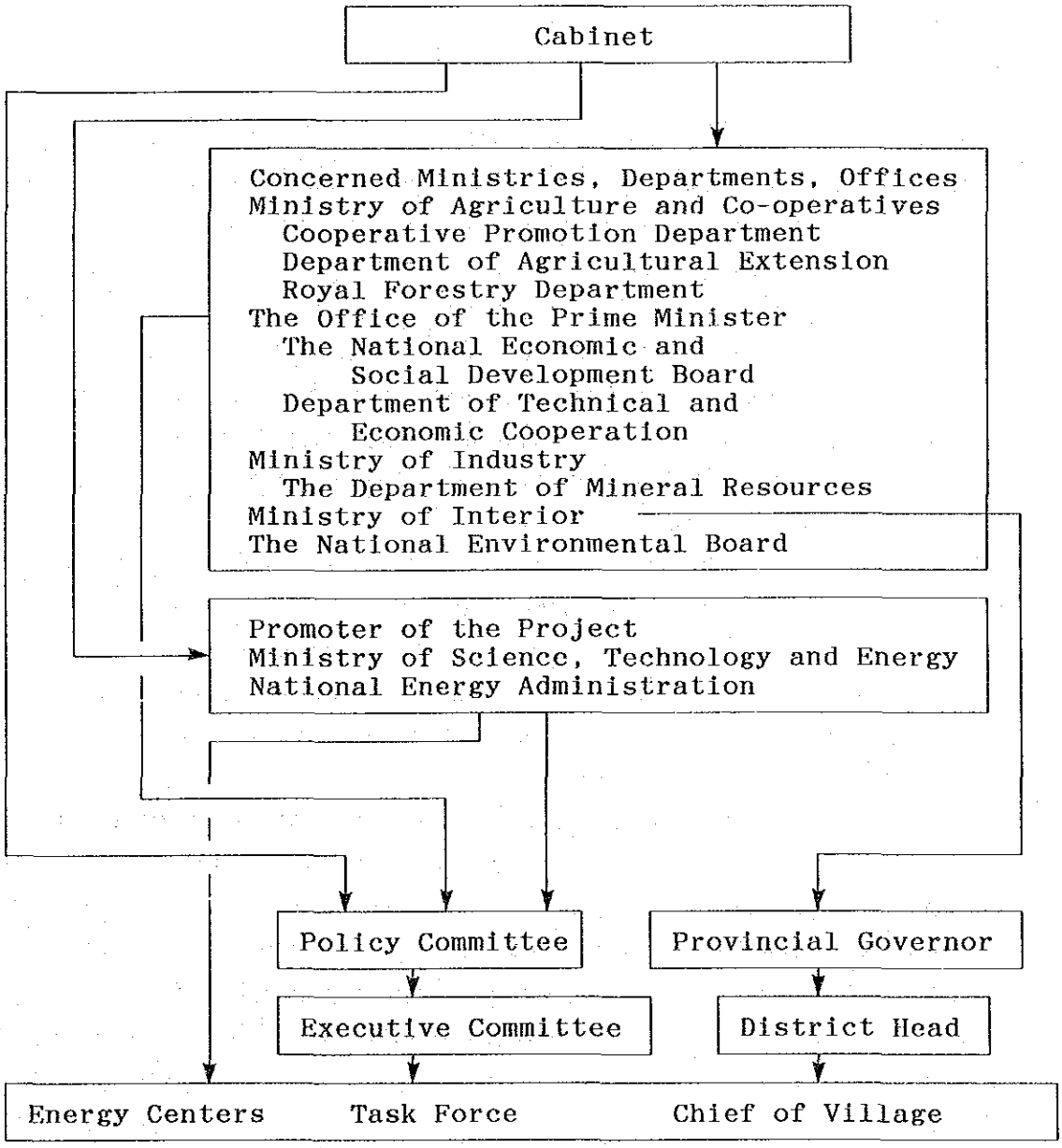


Figure 13-2 Organization for Promotion of Lignite Briquettes

Chapter 14 Bench-scale Plant

As a part of the feasibility study, a bench-scale plant was installed in the premises of the Fuel Test Center at Rangsit near Bangkok. The bench-scale plant confirmed the technical feasibility of manufacturing lignite briquettes of the quality meeting the quality design from the Thai domestic raw materials: the Ban Pa Kha lignite, Thai rice straws and slaked lime. The bench-scale plant also produced the lignite briquettes used for the monitoring survey. The bench-scale plant consists of the machines shown in Table 14-1.

The bench-scale plant helped familiarize the staff of NEA with the operation of the plant. To ensure that the technology for the operation and maintenance of the bench-scale plant is duly transferred to NEA, the study team prepared a booklet entitled, "Standard Operation Practice" describing the basic principles for the operation and maintenance of the plant, and presented it to NEA. Each procedure of the Standard Operation Practice was confirmed with NEA and the study team at the plant. Furthermore, the Standard Operation Practice was translated into Thai by NEA in order to ensure its effective utilization.

NEA has been using this bench-scale plant for research and development purposes. The plant is not designed for continuous operation; therefore, the plant cannot produce lignite briquettes at the rated capacity of the briquetting machine. With the addition of some items of equipment and a modification to the layout, the bench-scale plant could be operated on a continuous basis at the rated capacity of the briquetting machine. In other words, the plant could produce several hundred tons up to one thousand tons of lignite briquettes which could be effectively used for market development, along with the research and development work. It is therefore recommended that the bench-scale plant be streamlined to continuously produce lignite briquettes that could be used for market development before the pilot plant comes on stream.

Table 14-1 Machine List

Item	Machine Name	Specifications
Coal Crusher	Roll Jaw Crusher	Coal: 200 to 300 kg/h Particles: 100 to 5 mm
Coal Pulverizer	Hammer Crusher	Coal: 100 to 150 kg/h Particles: 5 to 2 mm
Biomass Pulverizer	Pin Mill Machine	Biomass: 50 kg Particles: 10 to 2 mm
Vibrating Screen	Vibrating Screen	3 Decks, Closed Screen Area: 0.31 m^2/deck
Mixer	Mixer	Coal, Biomass: 100 to 150 kg/h Ribbon spiral, barrel type, batch mixer with heater
Briquetting Machine	Briquetting Machine	Briquettes: 150 to 200 kg/h Single-shaft drive, double-roll type with cantilever
Vibrating Sifter	Vibrating Sifter	Screen mesh: 14 mm Total screen area: 0.524 m^2
Belt Conveyer	Belt Conveyer	Belt width: 350 mm, length: 5 m
Platform Scale	Platform Scale	Max. capacity: 100 kg Reading: 10 gr.
Tablet Tester	Tablet Tester	Max. Pressure: 4 tons/cm^2 Tablet size: 25 mm dia.
Unconformity Compression Tester	Compression Tester	Max. Capacity: 200 Kg-force
Vernier Caliper	Vernier Caliper	L 200 mm x 0.05 mm
Dust Collector	Dust Collector	Static pressure: 110 mm Aq. Capacity: 28 m^3/min.
Air Compressor	Air Compressor	Max. pressure: 7 Kg/cm^2g Air tank: 38 liters Filling up time: 5 min.
Oil Burner Combustion Test Kit	Combustion Test Kit	1. MFZ draft, 2. Thermometer, 3. Smoke tester, 4. CO_2 Detector
Gas Detector	Gas Detector	Detector tube: CO, CO_2, NO_2, SO_2

Note: One each item was provided.

Chapter 15 Past Studies on Lignite Briquettes

The government of Thailand declared in the Sixth Five-year Plan (1987 to 1992) a policy of promoting the use of domestic lignite for small industries and rural households as a means of improving self-sufficiency in energy supply, as well as for protecting the diminishing forests. In line with this policy, the government has been encouraging the research into development of lignite briquettes that could meet these purposes.

Over the last 20 years, a considerable amount of research work has been conducted by a number of research institutes and universities. These research works aimed at development of metallurgical briquettes, carbonized briquettes, non-carbonized briquettes, mixed briquettes of biomass and lignite, etc. Coal tar, asphalt, starch, clay, and black liquor -- a waste stream from pulp production -- were tried as the binders. These binders either produced too much smoke upon combustion or did not have adequate binding effects. These research works have not met with success.

In Thailand, the technology for producing lignite briquettes of satisfactory quality using biomass as the binder has not been developed. The technology provided by this study would therefore open up a new field of technology that would correspond well with the conditions of Thailand.

Chapter 16 Conclusion and Recommendations

In concluding this study, the following conclusion and recommendations are presented.

16-1 Conclusion

Although the pilot plant, per se, is not financially feasible, the pilot plant is worth realizing for the following reasons:

(1) There exists in Thailand an environment ideally favorable to the realization of lignite briquette projects: the policy of the government committed to protecting the forests from further destruction, diversification of the sources of energy supply, and effective utilization of the lignite resources; lifestyle and cooking habits of most Thai people that could accommodate lignite briquettes; availability of raw materials -- lignite, biomass and limestone; serious deforestation that cannot afford to supply wood fuel as demanded.

(2) Charcoal and firewood are the most important cooking fuels in Thailand, collectively accounting for about 80 percent of the cooking fuel consumption. Use of charcoal and firewood as cooking fuel is a major cause of deforestation. The simulation conducted by the study indicates that the Thai forest cannot supply charcoal and firewood as much as to meet their forecast demands without being exhausted in a matter of two decades. This means that restriction of cutting down of trees must be intensified in order to preserve the forest. This will result in shortfalls of the supply of cooking fuels. If the volume of trees cut down is decreased by six percent per year as a reasonable compromise between the supply of wood fuel and preservation of the forest, the nation' forest will be saved from extinction. In this case, the supply of charcoal will fall short of the demand by 0.4 to 1.3 million TOE from 1995 to 2010. Such shortfalls in the supply of cooking fuel must be filled by appropriate substitutes, of which lignite briquettes will be a

promising candidate.

(3) Charcoal for cooking purpose was identified as the most promising candidate for substitution by lignite briquettes. It was found difficult to burn lignite briquettes as a substitute for firewood either for cooking purpose or industrial purpose. The estimated price of lignite briquettes is not competitive with that of firewood for both household and industrial uses.

Many industrial furnaces have to be modified before they can burn lignite briquettes. If such modifications are made, they will become able to burn lignite rather than lignite briquettes. Lignite is much cheaper than lignite briquettes; therefore, consumers will naturally choose lignite. One advantage of lignite briquettes over lignite is the ability to reduce emission of sulfur oxides generated from the combustion of sulfur originally contained in lignite. However, this ability is suppressed at high temperatures prevailing in most industrial furnaces. There is not a great merit in the use of lignite briquettes in place of lignite for industrial applications, if desulfurization is not expected.

(4) On the bases of the foregoing conclusion, the quality of lignite briquettes are designed to be a substitute for charcoal for cooking purpose. Lignite briquettes meeting such a quality requirement were experimentally produced from Thai lignite, rice straws and slaked lime, all abundantly available in Thailand. The experiments were done initially on a tablet scale, then on a bench-scale plant, and finally by a commercial plant. The technical feasibility of producing lignite briquettes meeting the quality target and the best blending ratio were confirmed.

(5) A bench-scale plant was installed at the Fuel Test Center in Rangsit. A large amount of lignite briquettes was produced by this plant and used for opinion surveys on the potential consumers, namely the present charcoal consumers, in and around

major local cities and Bangkok. The result of the opinion survey indicates that 60 percent of the potential consumers will accept, provided that the price of lignite briquettes is 60 percent of that of charcoal and that charcoal becomes difficult to obtain.

(6) Assuming that lignite briquettes will fill 60 percent of the forecast shortfalls in the supply of charcoal, the demand for lignite briquettes is forecast as below.

(Unit: KTOE)

Year	1995	2000	2005	2010
Forecast demand	229	518	711	831

(7) The capacity and other details of the pilot plant, and the commercial plant that would recover the investment in the pilot plant, were developed as a result of this study as indicated in Chapter 9.

(8) The investment in and the loss incurred by the pilot plant is recoverable by one or two of the commercial plants.

(9) Lignite briquettes are a new commodity unknown to most Thai people; therefore, it would be too adventurous to attempt to manufacture and sell lignite briquettes on a commercial scale, without first developing the market on a pilot plant scale.

(10) The knowledge to be learned about the market and technology at the pilot plant stage will prove to be valuable and worth laboring for at the commercial stage.

(11) The socio-economic benefits that could be brought about by large-scale commercialization of lignite briquettes are very versatile and great, although many of the benefits are not

quantifiable in monetary terms. The pilot plant project is the first step forward to large-scale commercialization and should therefore be evaluated in terms of the socio-economic benefits of the large-scale commercialization of lignite briquettes.

1) Contribution to conservation of environment
   Lignite briquettes will help conserve the ever-diminishing forests. The forests of Thailand are destined to become extinct unless appropriate substitute fuels for charcoal and firewood are made available to most Thai people. Lignite briquettes are certainly one of very promising candidate substitute fuels. Deforestation causes, directly and indirectly as well, floods, droughts, salt attacks, land slides, abnormal climates and is endangering the very foundation on which agriculture is based. On a global scale, deforestation is now acknowledged as an important cause of atmospheric warming. Lignite briquettes will also save the nation the cost of replantation.

2) Desulfurization
   A good portion of sulfur originally contained in lignite could be caught in ash when lignite briquettes burn, that would otherwise escape into atmosphere and cause a series of health hazards like asthma and environmental disruptions: acid rains, destruction of ecosystems of rivers and lakes, and damage the sound conditions on which livelihood of people the world over depends. The cost associated with affording lignite briquettes ability to catch sulfur is very low in comparison with other methods of desulfurization.

3) Saving of foreign currency
   The only conceivable substitute fuel along with lignite briquettes is LPG. Should there not be lignite briquettes, more LPG would have to be imported at the expense of foreign currency that could be spent for importation of capital goods effectively usable to the betterment of the living standard of the people and for further development

of economy.

4) Creation of employment opportunities
Installation of lignite briquettes plants in rural areas will generate employment opportunities in the job-scarce rural areas. Lignite briquettes will also give some compensation to charcoal dealers throughout the countries for diminishing sales of charcoal.

5) Transfer of technology and stimulation of industries
Realization of lignite briquettes industries will promote transfer of new technology to Thailand not only of that related to the manufacture of lignite briquettes but also of that related to design and fabrication of machines and equipment used by lignite briquette plants.

16-2 Recommendations

Based upon the preceding conclusions of this study, the following recommendations are made.

(1) The construction of the pilot plant is worth realizing in order to facilitate the commercialization of lignite briquettes, thereby bringing about all the benefits mentioned above to the nation and people.

(2) All the procedures for the construction of the plant should conform to the recommended schemes for the construction so as to ensure smooth implementation of the project.

(3) In parallel with such implementation, the recommendations for the strategy for the dissemination of lignite briquettes given in Chapter 13 should be adopted to develop the market for lignite briquettes, from the standpoint of preserving the endangered Thai forest.

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