Table 5-40 Price forecast of Charcoal with Small Bag

	Actual		Forecast (Based on Constant Price)			
	1989	1990	1995	2000	2005	2010
Probable Case						
Bahts/kg	5.0	5.5	7.4	7.6	7.9	8.3
Bahts/MMBTU	182.6	200.2	270.0	278.2	290.0	304.0

5-5 Evaluation of Market for Lignite Briquettes

5-5-1 Retail Price of Lignite Briquettes

(1) Rationale for Consumers' Price of Lignite Briquettes

In a market economy, the price of a commodity is not the price at which the manufacturer or retailer wishes to sell it, but the price the buyer is willing to pay for it.

In Thailand, the lignite briquettes are not meant for exploring a virgin market but for substituting for existing fuels being sold in the existing market. Without regard to the price competitiveness of lignite briquettes, it is technically possible that the lignite briquettes could substitute for portions of natural gas, certain petroleum products, electricity, coal, lignite, charcoal, firewood, bagasse and rice husks. Historically, energy has evolved in the form from solid through liquid to gas and electricity prompted by, or conversely promoting, the advancement of technology and economy. In a free market economy, the economically and technically right form of energy -- solid, liquid, gas and electricity -- is used in the right place. Such an allocation of energy by an invisible hand is reasonable in most cases and would not alter significantly unless there is a drastic change in the economic environment or supply situation of energy. Therefore, the possible target for substitution by the lignite briquettes is not liquid or gaseous fuels nor electricity but solid fuels.

The lower the price of lignite briquettes is, the more they are acceptable to the consumers. If lignite briquettes are cheaper than coal or lignite, their existing markets will accept lignite briquettes; however, the lignite briquettes will be produced from lignite through a series of processes and their price will naturally be higher than that of lignite itself. Therefore, the present consumers of lignite would have no economic incentive to use lignite briquettes in place of lignite. Besides, desulfurization to the extent of nearly 70 percent achievable when burned in ordinary cooking stoves, an important advantage of the lignite briquettes, does not occur at high temperatures encountered in industrial furnaces.

Technically, lignite briquettes could be a substitute for firewood, bagasse or even rice husks. However, lignite briquettes must be cheaper than these fuel in order to substitute for them, which is practically an impossibility. It follows therefore that the target for substitution will be cooking fuels in the residential and commercial sector, relatively high-priced charcoal, in particular.

(2) Market Trends from Retail Price of Lignite Briquettes

Table 5-41 shows the result of an opinion survey on the acceptable price of lignite briquettes by region conducted during the monitoring survey. The demand for lignite briquettes is expressed as a function of the ratio of the price of lignite briquettes to that of charcoal. The table indicates that if lignite briquettes are made available at 60 percent of the price of charcoal, for example, about 63 percent of charcoal may be substituted for by lignite briquettes.

If a prospective market is defined as the market where more than 50 percent of charcoal could be replaced by lignite briquettes, any region of the kingdom could be broadly regarded as prospective if lignite briquettes are supplied at 60 percent of the price of charcoal. With the penetration of more than 50 percent into the charcoal market, the 60 percent of the price of charcoal may be considered as a reasonable price level at consumers' end.

Table 5-41 Substitution Rate of Charcoal by Lignite Briquettes

(Unit: percentage by weight)

LB Price/CC Price, percent	80	60	40	20	0
Nakhon Si Thammarat	0.2	56.6	100.0	100.0	100.0
Ratchaburi	24.2	60.4	90.0	92.8	92.8
Ubon Ratchatani	35.3	55.9	75.9	86.7	94.4
Mahasarakham	37.4	86.1	88.0	99.5	99.5
Phitsanulok	7.3	51.9	80.5	91.4	100.0
Chiang Mai	51.9	65.7	81.7	89.8	89.8
Average	25.5	62.7	84.1	92.8	96.9

(3) Price Forecast of Charcoal

The lignite briquettes will be in a position to compete with charcoal in price with their purposes, methods of handling and distribution systems largely in common with those of charcoal. Therefore, the forecast price of charcoal is discussed before evaluating the price of lignite briquettes.

LPG is priced higher than charcoal because LPG is more convenient to use and to ignite, and cleaner than charcoal. LPG will not tarnish cocking utensils nor dirties the kitchen as charcoal does. Therefore, LPG is priced higher than charcoal. The price of LPG and that of charcoal in large bags were found to be in a ratio of 10:3 on weight basis and 2:1 on the basis of heat content, at the time of field survey. The price of LPG to that of charcoal in one-kilogram bag were 2:1 on weight basis.

In view of the decrease of the wood resources and the ban on cutting down of trees it is expected that the difference in price on thermal basis between LPG and charcoal will decrease in the future; charcoal will never be more expensive than LPG except for charcoal for special purposes, if any. Therefore, it is forecast in this study that the price of charcoal sold in a large bag containing 35 kilograms will reach 70 percent of that of LPG on thermal basis by 1995, in consideration of the thermal efficiency of the common Thai charcoal stoves being about 70 percent of that of LPG stoves. This price is forecast to hold after 1995. Table 5-42 shows the forecast price of charcoal in 35-kilogram bag.

Table 5-42 Price Forecast of Charcoal with Large Bag

	Actual		Forecast (constant price)			
	1989	1990	1995	2000	2005	2010
Charcoal in Large Bag						
Bahts/35 kg Bag	100	110	162	167	174	183
Bahts/kg	2.86	3.14	4.63	4.77	4.97	5.23
Bahts/MMBTU	104.3	114.8	169.1	174.9	182.3	191.1
Price of LPG (Bahts/MMBTU)	209.8	206.8	241.5	249.9	260.4	273.0

Note: Heating value, kcal/kg Charcoal: 6,900 LPG: 12,000

(4) Forecast Price of Lignite Briquettes

If the price of lignite briquettes is considered to be 60 percent of the forecast price of charcoal, then the forecast retail price of lignite briquettes will be as shown in Table 5-43.

Table 5-43 Price Evaluation of Lignite Briquettes (Large Bag)
(Unit: Bahts/kg, Based on Constant Price)

	1995	2000	2005	2010
Charcoal Price	4.63	4.77	4.97	5.23
Lignite Briquette Price	2.78	2.86	2.98	3.14

5-5-2 Pricing of the Lignite Briquettes

(1) Pricing from Production to Consumption

It is quite likely that the first several commercial plants will be located in the northern Thailand where lignite is produced. The lignite briquettes produced at the plants will be transported through wholesalers to retailers who will be selling lignite briquettes to consumers in 35-kilogram or one-kilogram bags. Some lignite briquettes will be sold directly from the plants to consumers living in the vicinity but the amount thus sold will be negligible.

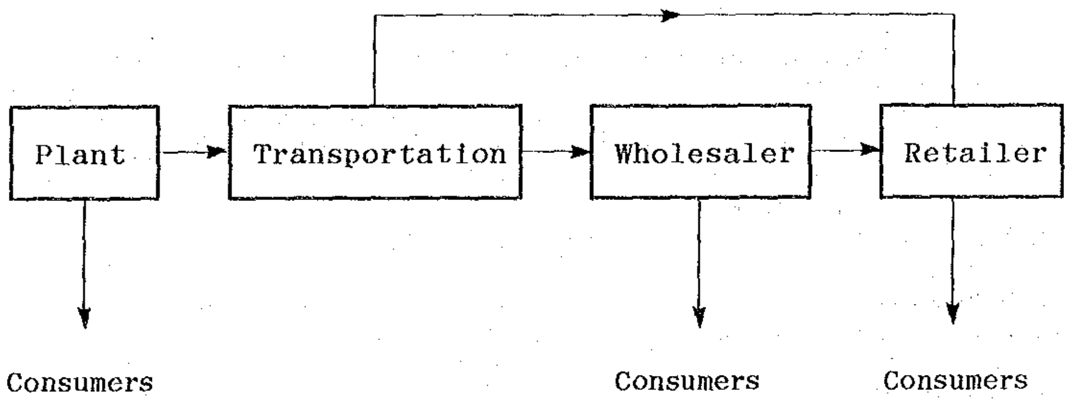


Figure 5-4 Distribution Route of Lignite Briquettes

The transportation cost from the plants in Northern Region to Bangkok and its suburbs is estimated at about 300 Bahts per ton. An attractive margin is necessary to encourage sales. From five to 15 percent of the sales price would be needed for sales in large bags and somewhat more for sales in smaller bags to pay for the trouble of packaging. Table 5-44 presents the ex-factory price of the lignite briquettes calculated on the above assumptions.

Table 5-44 Ex-factory Price of Lignite Briquettes

(Unit: Bahts/kg, Constant Price Base)

	1995	2000	2005	2010
Sales Price in 35 kg Bag	2.78	2.86	2.98	3.14
Margin	-0.46	-0.48	-0.50	-0.52
Transportation Cost	-0.30	-0.30	-0.30	-0.30
Ex-factory Price	2.02	2.08	2.18	2.32

5-5-3 Demand for Charcoal

(1) Demand for Charcoal in Thailand

The consumption of charcoal in the residential and commercial sector has been rapidly replaced by LPG, especially in the urban and suburban areas, though in some areas the demand for charcoal has increased substituting for firewood.

The consumption of charcoal in this sector decreased from 2,227 KTOE in 1982 to 2,008 KTOE in 1989 at an average rate of minus 1.5 percent per year. The consumption of charcoal in 1989 accounted for 37.8 percent on the total energy consumption for cooking. The demand for charcoal will decrease to 1,699 KTOE by 2000. The average annual rate of decrease will be minus 1.5 percent, and its share in the total energy demand for cooking will be 28.2 percent in 2000. The demand for charcoal will continuously decrease after 2000, because of the replacement by LPG and other fuels. Table 5-45 summarizes the result of the demand forecast of charcoal.

Table 5-45 Demand Forecast of Charcoal

	Actual		Growth rate	Forecast				Growth rate
	1982	1989	%	1995	2000	2005	2010	%
	2,227	2,008	-1.5	1,822	1,699	1,596	1,508	-1.5

(2) Estimates of Charcoal Consumption by District

Table 5-46 summarizes estimates of charcoal consumption by region based on the statistics on population and energy by region. The assumption for forecasting are stated in 5-1-4.

Table 5-46 Demand of Charcoal by Region

(Unit: KTOE)

	1989	1995	2000	2005	2010
Bangkok Metropolitan	50	45	41	38	35
Central	391	355	331	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

5-5-4 Demand for Lignite Briquettes

(1) Total Demand for Lignite Briquettes

Section 5-1-6 estimates the supply demand balance of charcoal and the results are summarized in Table 5-24. The shortage of charcoal shown in the table may be considered to represent the ultimate demand for lignite briquettes but all the shortage will not be filled by lignite briquettes. Section 5-3-3 discusses how much charcoal will be replaced by lignite briquettes if the supply of charcoal is short and summarizes the results in Table 5-28. The comparison of these two table leads to the ultimate demand for lignite briquettes. Table 5-47 shows the estimated demand for lignite briquettes with the ratio of the price of lignite briquettes to that of charcoal as parameter.

Table 5-47 Estimated Market Size of Lignite Briquettes

(Unit: KTOE)

LB Price/CC Price, % (Weight Basis)	80	60	40	20	0
1995	93	229	307	339	354
2000	211	518	695	767	800
2005	289	711	954	1,052	1,099
2010	338	831	1,114	1,230	1,284

As indicated by the table, the forecast demand of lignite briquettes is 230 KTOE and 830 KTOE in 1995 and 2010, respectively, if the consumers' price of lignite briquettes is 60 percent of that of charcoal.

(2) Demand for Lignite Briquettes by Region

Table 5-48 summarized the potential demand for lignite briquettes by region estimated for the price of lignite briquettes assumed at 60 percent of the price of charcoal.

Table 5-48 Lignite Briquette Demand 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

The estimated demands shown above were calculated on the assumption that lignite briquettes will be supplied at the same price in every region. However, the sales prices should be different with region, if lignite briquettes are sold at legitimate prices reflecting the manufacturing cost, transportation and a fair margin. If the plant is constructed in Northern Region near the coal mines, for example, sales prices in Northeastern and Southern Regions should naturally be higher than those in Northern or Central Regions. In other words, the rates of replacement of charcoal by lignite briquettes in Northeastern and Southern Regions would be lower than those in other regions.

Chapter 6 Quality of Lignite Briquettes

Chapter 6 Quality of Lignite Briquettes

This chapter discusses the quality lignite briquettes that will be a substitute for charcoal, firewood and lignite, and also discusses the quality design of lignite briquettes for this project.

6-1 Basic Principle

The quality design was done by the first-stage study. The principal objective of the first-stage study was to assess the market feasibility of the lignite briquettes that will be a substitute for charcoal and firewood, the most important cooking fuels in Thailand. If the lignite briquettes are to be a substitute for charcoal and firewood for household cooking, the lignite briquettes must be so easy to use and so safe that common housewives, or even children, can use them without any special training, just as they burn charcoal and firewood. Therefore, this feasibility study sets forth as the basic principle of the quality design that the present consumers of charcoal and firewood can use lignite briquettes without having to change their lifestyles or cooking habits. Particularly important about the quality design are the generation of smoke, strength and length of the flame and ease of ignition. The generation of smoke, and the irritating odor stemming from the sulfur contained in lignite, which have sometimes made lignite unpopular, were given particular attention. It is also very important to make the lignite briquettes available to consumers at cheap prices; therefore, the quality design should be achievable by simple and inexpensive manufacturing processes.

The basic principle for the quality design of lignite briquettes for industrial consumption is that the lignite briquettes can be burned without significant modifications to the present furnaces now used for lignite or firewood.

This feasibility study presumes that the feed is the high-quality lignite or low-quality lignite from the Ban Pa Kha Mine of NEA. If the ash and sulfur contents of the feed are high, the lignite may have to be washed to increase the heating value and to lower the sulfur content.

There are cases where the additional cost for washing is offset by the saving in the transportation cost per unit heating value, because of the increased heating value brought about by washing; in other words, the consumer price may be reduced by washing. The lignites from the Ban Pa Kha Mine do not need washing, because the ash and sulfur contents are low. For biomass, bagasse, rice husks and rice straws are considered as candidates. Bagasse and rice straws are good as binders. Rice husks, if used alone, would produce briquettes of insufficient breaking strength, but could produce briquettes of sufficient strength if used together with bagasse or rice straws. This feasibility study prefers rice straws and rice husks to bagasse for the following reasons:

(1) Rice straws and rice husks are available at low cost in Thailand.

(2) There is not enough excess bagasse in sugar mills in Thailand.

(3) Bagasse is used effectively for other purposes like a raw material for paper making. The supply of bagasse may be unreliable.

As a desulfurizing agent, the slaked lime generally available in Thailand is used.

6-2 Quality Design of Lignite Briquettes for Household Use

The purpose of the lignite briquettes for household consumption to be developed by this study is substitution for charcoal. Charcoal is a clean fuel which does not produce smoke or soot. Charcoal is superior to firewood except when long flames are needed. However, the price of charcoal per unit heat is significantly higher than that of firewood. Accordingly, lignite briquettes that can be a substitute for charcoal could also be a substitute for firewood for most uses, if the lignite briquettes are competitive in price. The latter, however, is not the case in Thailand.

6-2-1 Quality Item

As mentioned previously, the basic principle of the quality design is that the present consumers of charcoal can use lignite briquettes without significantly changing their current lifestyles, cooking habits, and thus their cooking utensils. Based upon this principle, the following items of quality must be satisfied when the lignite briquettes are burned in the common clay cooking stoves of Thailand.

(1) Ease of Ignition

The study team closely observed the way people use fire for cooking. In a typical instance, charcoal is lit very easily with a small quantity of wood sticks as kindlings and a match. Within five minutes of ignition, the fire reaches a steady burning state. Therefore, the lignite briquettes to be developed in this project should desirably be able to reach a steady burning state within five minutes from ignition.

(2) Strength of Fire, Heating Value

The strength of fire is important for cooking. In order for the lignite briquettes to be accepted by the consumers of charcoal, the lignite briquettes should burn as strongly as charcoal, so that consumers can cook with lignite briquettes just as with charcoal. In this regard, the lignite briquettes should have higher heating values. If the lignite briquettes are transported over a long distance, they would be more economical if they have higher heating values. However, since the heating value of lignite is lower than that of charcoal, it is simply impossible to produce lignite briquettes with heating values comparable to charcoal. During the first-phase field survey, the target heating value of the lignite briquettes was tentatively set at 5,000 kcal/kg or higher.

A long flame length is not needed since the purpose of the lignite briquettes is substitution for charcoal that burns without a flame. The cooking places of common Thai houses are of wood and stoves are generally placed close to the wall; a long flame is therefore not desirable from the viewpoint of safety.

One charge of charcoal in a stove normally keeps burning steadily for more than 30 minutes without additional supplies. One charge of lignite briquettes in a stove should be able to burn steadily for more than 30 minutes without a further charge.

(3) Smokeless Lignite Briquettes

The lignite briquettes for household uses are a substitute for charcoal and therefore should ideally burn without a flame and without smoke. However, the feed lignite should be carbonized in order to manufacture completely smokeless lignite briquettes. The process of carbonization, in spite of its ability to completely eliminate flames and smoke, has drawbacks. One notable drawback is that carbonization loses the volatile matter contained in the feed which normally constitutes a significant portion of the energy of the feed. The second drawback is that the application of carbonization increases the investment and operation costs.

The houses of common Thai people are normally not of a closed structure, which tolerates the generation of smoke to a certain extent. Therefore, this feasibility study aims to produce lignite briquettes which would generate only a practically tolerable amount of smoke limited to during the initial period of combustion when the fire is still weak. Generally, smoke is generated as a result the of incomplete combustion of fuel. It would be effective to give the briquettes a shape that would assist combustion. It is also important that stoves induce sufficient air. The lignite briquettes should have a uniform composition of lignite and biomass; the latter helps the lignite burn well to the center.

(4) Odorless Lignite Briquettes

Smoke and odor are closely associated. The smoke generated as a result of incomplete combustion normally has a disagreeable odor. Measures to eliminate the smoke are effective for reducing the odor.

However, the irritating odor of sulfur dioxide stemming from the sulfur originally contained in lignite needs to be reduced to a tolerable level, or a level not perceptible by the human senses.

(5) Safety

Lignite briquettes are a stable solid fuel. Unlike gaseous or liquid fuel, lignite briquettes are free from any dangers associated with the ignition of gas or vapor by hidden sources or sparks, leaks or explosions. The following five items are the only safety measures required of lignite briquettes.

(1) The inherent tendency for the auto-ignition of lignite should be eliminated during the manufacturing process.

(2) The generation of sulfur dioxide from the combustion of the sulfur contained in the feed should be reduced.

(3) The acidity of the lignite briquettes should be neutralized to make the ashes remaining after combustion harmless to animals and plants.

(4) The heavy metals contained in the feed should not remain in the ash in water-soluble forms.

(5) The smoke and soot should be reduced to levels considered not constituting health hazards to persons routinely exposed to cooking environment.

(6) Control of the Strength of Fire

With household fuels, it should be easy to start a fire, control the strength of the fire, and put it out. The fire should be strong when frying, but should be weak, as well as long-lasting, when boiling noodles. In these ways, different dishes require a different strength of fire. The strength of fire should be easy to control with lignite briquettes just as with charcoal and firewood. The strength of fire is normally controlled by the amount of fuel put in the stove and the amount of primary air. The control of these variables should not lead to the generation of heavy smoke or the extinguishing of the fire. In addition, the stove should have a structure to allow the control of these variables.

(7) Water Repellence

There are many chances that the lignite briquettes may get wet along the way from the manufacturing plant to consumers. Consumers store fuels under an elevated floor or eaves where they may get wet. The lignite briquettes become difficult to burn or even lose strength and collapse if they get wet. Lignite briquettes are sold by weight, so it will be disadvantageous to consumers if the briquettes absorb moisture and become heavier per unit heat.

(8) Physical Strength

Lignite briquettes would undergo rough handling as they go down from the manufacturing plant to the end users. At the plant, they will be thrown into storage silos and dropped onto trucks; at the depots, they will be dumped from the trucks onto the floor; at the wholesalers and retailers, they will be shoveled onto pickups and into bags. Lignite briquettes should have enough physical strength to withstand all such handling without becoming broken or worn.

(9) Others

The shape and size of the lignite briquettes should be determined so as to offer the best convenience to consumers.

6-2-2 Tentative Quality Design

The quality design of the lignite briquettes was tentatively set during the closing stage of the first-phase field survey from November to December 1989 based on the premise that the lignite briquettes will be burned in common Thai stoves. The tentative quality design is given below.

(1) Ease of Ignition

The lignite briquettes should reach a steady burning state within five minutes of ignition.

(2) Strength of Fire

The strength of fire should be equal to that of burning firewood. The heating value should be more than 5,000 kcal/kg. One charge of lignite briquettes in a stove should burn steadily for more than 30 minutes. The flame should be short enough to be safe.

(3) Generation of Smoke

The smoke should not exceed the tolerable level in common Thai cooking places.

(4) Generation of Odor

The odor should not exceed the tolerable level in common Thai cooking places.

(5) Safety

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

(6) Control of Fire

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

(7) Water-repellence

The lignite briquettes should be water-repellent and should not allow water to permeate to the inside.

(8) Physical Strength

The lignite briquettes should have enough physical strength to withstand rough handling; specifically, they should have a breaking strength of 150 kilograms or more.

(9) Others, Shape and Size

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

6-2-3 Revision of the Tentative Quality Design

The tentative quality design was reviewed in the light of the results of the monitoring survey and the experimental production of lignite briquettes. It was found that the ease of starting a fire, the strength of fire, water-repellence and physical strength had to be revised. The revisions and rationales are explained below.

(1) Ease of Ignition

The tentative quality design called for five minutes from ignition until the fire became strong. The five minutes are relaxed to between eight and 10 minutes. Charcoal is a soft, porous fuel and can reach a steady burning condition ready for cooking within five minutes, whereas lignite briquettes are a hard and dense fuel. Naturally, lignite briquettes take longer than charcoal for the fire to become strong enough. This drawback could be considered to be partly offset by the longer burning time of lignite briquettes, this attribute also stemming from the hardness of lignite briquettes.

(2) Strength of Fire

The heating value set for the tentative quality design, 5,000 kcal/kg, is revised to 4,000 kcal/kg. The primary concern of the tentative quality design in setting the heating value at 5,000 kcal/kg was that the lignite briquettes should not be greatly handicapped as compared with charcoal which has a heating value of about 7,000 kcal/kg. The higher the heating value is, the more favorable will it be for the project at the stages of manufacture, transportation, distribution and marketing, as well as from the standpoint of consumers' acceptance. However, the heating value of lignite briquettes is determined solely by the heating values of their components and blending ratios which often have to be determined by other factors. There is almost no room to adjust the blending ratios to control the heating value of the product. As long as this project uses Ban Pa Kha lignite whose heating value ranges between 4,000 and 5,000 kcal/kg, it will simply be impossible to manufacture lignite briquettes of heating values higher than 5,000 kcal/kg. The lignite briquettes the study team used for the monitoring survey had a heating value of 4,300 kcal/kg; they fared well against charcoal. As long as this project uses Ban Pa Kha lignite, the quality standard for the heating value should be relaxed to 4,000 kcal/kg minimum.

(3) Water-repellence

The lignite briquettes absorb moisture from the atmosphere and lose their physical strength. As far as the study team could observe the way charcoal was distributed and stored, charcoal was not protected from absorbing moisture. Based on the assumption that lignite would be treated like charcoal, the study team considered it necessary to coat the lignite briquettes with wax to give them water-repellence. It was experimentally confirmed that the lignite briquettes with a wax coating do not absorb moisture, nor do they allow water to permeate to the inside even when they are dipped in water. However, it was found by the experimental production on the bench-scale plant and burning tests done in Japan that the wax coating had a drawback which would outweigh its advantages; the lignite briquettes with a wax coating generate considerably more smoke and odor upon combustion, and the production cost is significantly higher. It was found, on the other hand, as a result of the monitoring survey, that smoke and odor have a great impact upon consumers' acceptance.

From the above, the study team has decided not to recommend a wax coating. Therefore, practical and inexpensive measures to prevent the lignite briquettes from absorbing moisture are necessary. Perhaps the following would be most practical:

Manufacturing:	Storage in closed vessels
Transportation from the plant to depot:	In covered trucks
Retail side:	Packing in plastic bags

(4) Physical Strength

The standard is relaxed from the 150 kilograms set for the tentative quality design to 100 kilograms for the following reasons:

(1) The physical strength of 150 kilograms was found to be more than necessary for practical purposes.

(2) It is technically possible to produce lignite briquettes with a physical strength of 150 kilograms, but this would put restrictions on the selection of raw materials, blending ratios and operating conditions.

(5) Safety

The combustion gas, smoke and soot, and ash should be safe to humans, animals and plants. Smoke and soot can contain a number of organic chemicals that could constitute health hazards if inhaled or orally taken. Smoke and soot should be reduced to the levels that would not constitute health hazards in ordinary Thai cooking conditions. In addition to the items set forth in the tentative quality design, the above statement is important.

6-2-4 Final Quality Design

The quality design ultimately decided upon is given below:

(1) Ease of Ignition

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

(2) Strength of Fire

The strength of 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 short enough to be safe.

(3) Generation of Smoke

The smoke should not exceed the tolerable level in common Thai cooking places.

(4) Generation of Odor

The odor should not exceed the tolerable level in common Thai cooking places.

(5) Safety

The combustion gas, smoke and soot, and ash should be safe to humans, animals and plants.

(6) Control of Fire

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

(7) Water-repellence

The plan to provide lignite briquettes with water repellence by a wax coating has been abandoned.

(8) 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.

(9) Others, Shape and Size

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

6-3 Quality Design of Lignite Briquettes for Industrial Consumption

The purpose of the lignite briquettes for industrial consumption is substitution for firewood and lignite as industrial fuel. Unlike charcoal, both firewood and lignite generate smoke when they burn. Therefore, industrial lignite briquettes could generate smoke, provided that the amount of smoke is less than that from charcoal and lignite, and that the facility is not close to residential areas. The quality requirements for industrial lignite briquettes would be less strict than those for household consumption. Different users have different facilities, so the ideal quality may vary from one installation to another. This means that a large number of products have to be manufactured in order to satisfy every consumer.

The prices of firewood and lignite are much lower than that of charcoal. Therefore, the first thing required of industrial lignite briquettes is a low price. If only one type of lignite briquettes of a quality much lower than that for household consumption is produced in a larger scale, the manufacturing cost would be lower than that for household lignite briquettes. If a variety of industrial lignite briquettes are produced in small quantities in addition to household lignite briquettes, no reduction in the manufacturing cost can be expected. Therefore, it is more desirable, at least during the bench-scale or pilot-plant stage, to provide for industrial consumption lignite briquettes of a quality equal to that for household consumption.

Although it is possible that, in the future, a number of lignite briquettes will be needed to satisfy the varying demands of consumers, this feasibility study applies the quality design for household use to industrial consumption for the above reasons.

6-4 De-smoking

During the survey to obtain information about promotion of lignite briquettes, it was pointed out that the reduction, or elimination if possible, of the smoke and soot would facilitate promotion of lignite briquettes. 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 lignite briquettes which may, strictly speaking, vary from one lot to another. Therefore, there is no denying the possibility of the smoke or soot containing one or more substances that are known to have adverse effects upon the health. This question of the effect of the smoke and soot upon the health would be very elusive, because the entire range of the composition of smoke and soot can hardly be represented by several runs of experiments.

The best solution to this problem is to make the lignite briquettes smokeless and this could only be done at the manufacturing stage. Accordingly, reduction of smoke has been added to the required quality of the lignite briquettes.

The operation conditions for reducing smoke were successfully found by an additional series of experimental production. The results of the experiments are incorporated in the manufacturing scheme.

6-5 Issue of Lignite Briquette Quality

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 by measures recommended in 6-2-3 (3).

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 will be explained in Chapter 7, 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 7 Raw Materials for Lignite Briquettes

Chapter 7 Raw Materials for Lignite Briquettes

7-1 Coal Resources in Thailand

7-1-1 Coal Reserve in Thailand

The total reserves of coal in Thailand are estimated at 2.4 billion tons, or 490 million TOE, as geological reserve. Coal is regarded as a precious indigenous energy source, with the natural gas resource anticipated to be exhausted not in the remote future. Recently, the indigenous coal resources have been vigorously explored by the Department of Mineral Resources, DMR. As a result, the details of coal resources are being clarified. Tables 7-1 and 7-2 indicate the outlines of coal mines in Thailand under operation and under investigation, respectively. Figure 7-1 shows the locations of coal mines. As shown in these tables and figure, the total mineable reserves of the operating coal mines are 950 million tons and the total proven reserves of the coal mines under development, including those to be developed, are 200 million tons. About 90 percent of the coal resources are located in the Northern Region.

7-1-2 Use of Coal in Thailand

(1) Quality of Coal

To establish an optimum use of a given coal resource, the characteristics of the coal must be known, because its characteristics could put restrictions on the uses of the coal.

It is generally recognized that coal was formed from the ancient plant substances, accumulated under the ground, which were transformed into coal over a long period of time by the combined effects of the geothermal heat and the pressure. Therefore, the quality of the coal is determined principally by the environment in which the process of coalification took place, namely, temperature, pressure and duration, but not so much by the properties of the original plant substances.

Table 7-1 Coal Production Areas in Thailand

Name of Basin	Location District	Location Province	Reserve MM tons	Production MM tons	Heating Value Kcal/kg	Proprietor
North						
Mae Chaem	Mse Chaem	Chaing Mai	1.20	0.138	4800-5300	Private
Mae Teep	Ngao	Lampang	11.00	0.519	2400-8200	Private
Mae Mo	Mae Mo	Lampang	820.90	36.398	1900-4600	EGAT
Mae Than	Sop Prap	Lampang	1.2	0.097	3600-5800	Private
Li	Li	Lamphun	28.00	6.289	2800-6600	NEA/Pr
Mae Tuen	Mae Ramat	Tak	1.23	0.323	1700-8200	Private
Mae Lamao	Mae Ramat	Tak	1.63	0.137	3300-5200	Private
Central						
Nong Ya Plong	Nong Ya Plong	Phetcha-buri	1.40	0.465	2400-7800	Private
South						
Krabi	Muang	Krabi	83.60	6.631	1600-4700	EGAT
Kan Tang	Kan Tang	Trang	N.A.	0.0004	2500-3900	Private
Northeast						
Na Duang	Naduang	Loei	N.A.	0.062	4700-7700	Private
Na Klang	Naklang	U-don Thani	N.A.	0.006	4800-6400	Private

Note: (1) Reserve: Mineable Reserve
(2) Production Data: As of end of May 1990
(3) Heating Value: As determined basis
(4) Pr stands for "Private."

Table 7-2 Quality of Coal from Various Basins investigated by DMR during 1987-1990

Name	F.C. %	V.M. %	M %	A %	S %	H.V. Kcal/kg	d,mmf V.M. %	d,mmf H.V. Kcal/kg	Reserve MMtons	OP
Chae Hom	11.93	24.98	14.29	48.87	3.70	2,044	76.07	4,458	15.78	DMR
Chiang Muan	20.03	30.40	22.96	26.62	3.11	3,213	59.27	4,557	25.27	DMR/NEA
Khian Sa	31.40	31.76	13.84	22.99	6.91	3,936	48.57	5,296	15.41	DMR
Mae Tha	23.08	26.49	20.07	30.35	4.04	3,068	50.45	4,632	N.A.	DMR
Muang Pan	7.16	21.75	16.96	54.13	2.97	1,580	69.22	3,943	0.51	DMR
Ngao	11.66	27.44	15.94	45.00	5.19	2,099	67.04	4,161	48.40	EGAT
Pong	21.30	25.49	34.50	18.72	5.28	2,628	52.71	3,382	N.A.	DMR
Pua	24.80	27.33	31.95	15.92	5.94	3,120	46.84	3,885	N.A.	DMR
Serm Ngam	30.83	32.57	22.22	14.38	2.39	4,128	50.66	4,927	6.19	DMR
Sin Pun	24.28	32.84	24.35	18.53	6.12	3,534	55.25	4,512	N.A.	EGAT
Wang Nua	19.18	28.00	16.86	35.96	2.45	2,980	58.78	4,874	9.01	DMR
Wiang Haeng	20.05	23.51	24.25	32.19	0.92	2,883	51.14	4,246	93.02	EGAT

Note: All figures except amount of reserve are averages of collected samples. F.C.: Fixed Carbon, V.M.: Volatile Matter, M: Moisture, A: Ash, S: Sulfur, H.V.: Heating Value as received basis, d,mmf: dried, mineral matter free, Reserve: as measured basis, OP: Operator

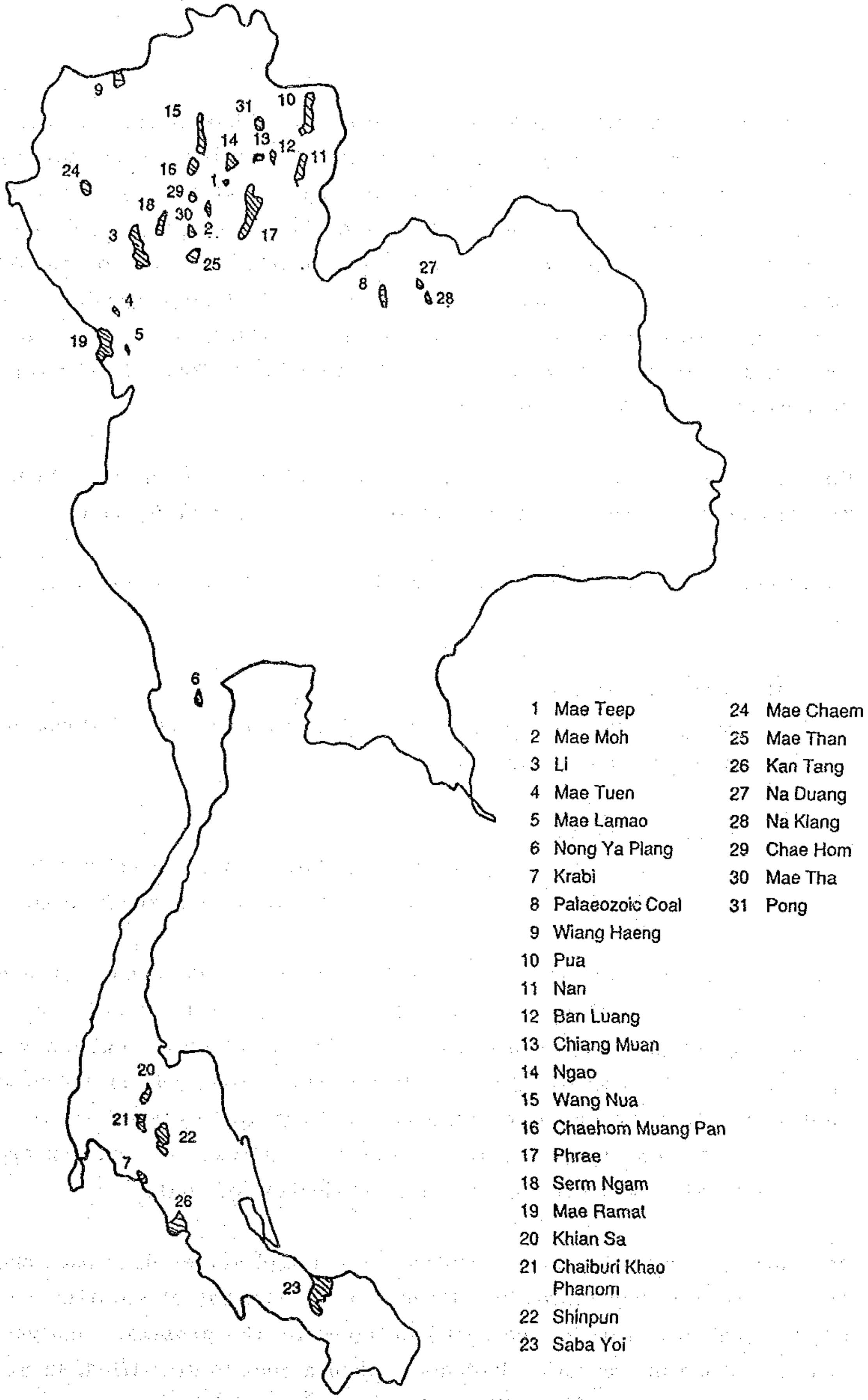


Figure 7-1 Location of Coal Deposit in Thailand

The origin of coal dates back to the geological period ranging from the Carboniferous period in the Palaeozonic era, 300 million years ago, to the Tertiary period in the Cainozoic era, 65 million years ago. Generally, the older the coal is, the better is the quality; the carbon content increases with the progress of coalification and the content of impurities decreases along with it. Coals of the best grade were generally formed in the Carboniferous period as the name of the period implies; most major coal resources in the world were found in the formations of the Carboniferous period.

Coal is generally classified into lignite, sub-bituminous coal, bituminous coal and anthracite according to the rank of coalification.

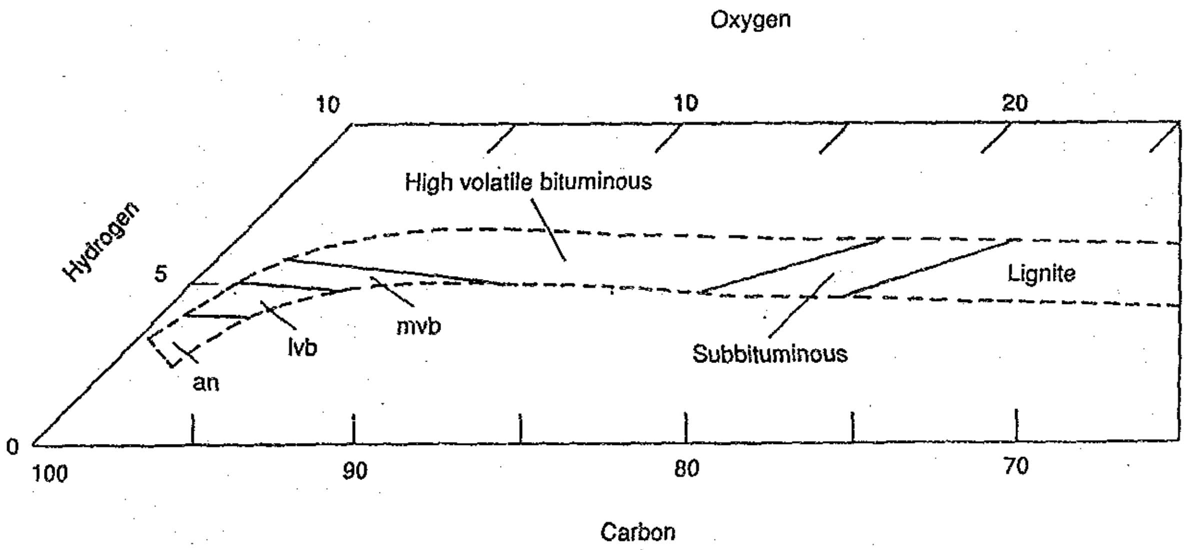
The following two methods are universally applied to the analysis of coal.

(1) Ultimate analysis
Measurement of the contents of carbon, oxygen, hydrogen, nitrogen and sulfur of coal

(2) Proximate analysis
Measurement of the contents of moisture, ash, volatile matter and fixed carbon of coal, plus measurement of heating value

The rank of coalification is determined based on the result of the above analyses, but the universal method is not yet established for it. In the beginning, carbon content obtained by the ultimate analysis was used as the only indicator for classifying coal. Today, it is accepted that use of carbon content alone is not adequate to classify coal as may be noted from Figure 7-2; the contents of hydrogen and oxygen are also taken into consideration in the classification of coal.

As coalification proceeds, the content of volatile matter decreases and that of fixed carbon increases. Therefore, the content of volatile matter (dry, mineral matter-free basis) obtained by the proximate analysis is used as one of the major indicators when a coal is classified. In addition, heating value (dry, mineral matter-free basis) is also used as a reliable indicator in the classification of coal. Table 7-3 shows the methods for coal classification specified by the American Society for Testing and Materials (ASTM).



an: anthracite
lvb: low volatile bituminous
mvb: medium volatile bituminous

Figure 7-2 Triangular Diagram of Coal Composition, wt%

Table 7-3 Classification of Coal by Rank[a] (ASTM)

Class	Group	Fixed Carbon Limits, % (dry, mineral matter-free basis) Equal to or Greater Than	Fixed Carbon Less Than	Volatile Matter Limits, % (dry, mineral matter-free basis) Greater Than	Volatile Matter Equal to or Less Than	Calorific Value Limits, Kcal/kg (moist.[b] mineral matter-free basis) Equal to or Greater Than	Calorific Value Less Than	Agglomerating Character
1. Anthracitic	1. Meta-anthracite	98			2			
	2. Anthracite	92	98	2	8			
	3. Semianthracite	86	92	8	14			Nonagglomerating[c]
2. Bituminous	1. Low volatile bituminous coal	78	86	14	22			
	2. Med volatile bituminous coal	69	78	22	31			
	3. High volatile A bituminous coal		69	31		7,780[d]		Commonly agglomerating[e]
	4. High volatile B bituminous coal					7,220[d]	7,780	
						6,390	7,220	
	5. High volatile C bituminous coal					5,830	6,390	Agglomerating
3. Subbituminous	1. Subbituminous A coal					5,830	6,390	Nonagglomerating
	2. Subbituminous B coal					5,280	5,830	
	3. Subbituminous C coal					4,610	5,280	
4. Lignite	1. Lignite A					3,500	4,610	
	2. Lignite B						3,500	

Note :
(a) This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties, and which come within the limits of the fixed carbon or calorific values of the high volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral matter-free fixed carbon or have more than 8,610 moist. mineral matter-free Kcal/kg.
(b) "Moist" refers to coal containing its natural inherent moisture, but not including visible water on the surface of the coal.
(c) If agglomerating, shall be classified in the low volatile group of the bituminous class.
(d) Coals having 69 percent or more fixed carbon on a dry, mineral matter-free basis shall be classified according to fixed carbon, regardless of calorific value.
(e) It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in the high volatile C bituminous group.

Most coal deposits in Thailand exist in the formations of the Tertiary period in the Cainozoic era, indicating that Thai coal is generally very young and their degrees of coalification are low. Judging from volatile matter contents as well as heating values, Thai coal is classified into sub-bituminous coal or lignite, having inferior quality as fuel. Moreover, the majority of Thai coals are ranked as low-quality lignite with heating values below 3,000 kcal/kg.

(2) Use of Thai Coal

The use of lignite is rather limited by the following drawbacks stemming from its high moisture and high volatile matter contents and low heating value.

(1) Possibility of autogenous ignition when dried due to its high reactivity,

(2) Generation of a large amount of smoke during ignition stage due to its high volatile matter content, and

(3) High transportation cost due to its low heating value

Although lignite accounts for 34 percent of the total coal reserves in the world, it has not been utilized effectively except for fueling at mine-mouth power plants.

In Thailand, power generation is also given priority in the use of lignite; large-scale lignite deposits of over 15 million tons are allocated preferentially to the Electricity Generating Authority of Thailand (EGAT). Medium and small-sized mines are open to the private sector and their lignite is used for other purposes such as cement production, fuel for boilers and tobacco curing.

In 1989, 8.9 million tons of lignite was produced, of which approximately 76 percent was used for power generation. This quantity far exceeded the forecast coal demand for 1989 estimated in 1987, as shown in Table 7-4. This is because the demand for fuel expanded as a result of the remarkable economic growth, and moreover, because of the cheaper price of lignite compared with those of other fuels, as shown in Table 7-5. DMR has been intensively conducting exploration work over the prospective coal areas, and transferring the concessions of the coal mines to the private sector. The companies obtaining a concession shall pay royalty to the government, the amount of which was 20 Bahts/ton in 1990 based on the average lignite selling price of 500 Bahts/ton. According to the forecast coal demand shown in Table 7-4, the production of lignite will reach 20 million tons per year in 1995. Based on this production rate, the reserve production ratio of Thai lignite is as long as 50 years. For this reason, lignite is considered as a precious energy resource that could be counted on and should be effectively utilized over the future.

Table 7-4 Forecast of Coal Demand in Thailand

(Unit: thousand tons)

	1988	1989	1990	1991	1995	2000
Lignite						
Power Plant	5,898	6,414	7,512	8,736	18,859	19,374
Cement Industry	763	797	833	870	1,070	1,341
Tobacco Curing	80	80	80	80	82	85
Others	203	249	305	375	436	530
Sub-total	6,944	7,540	8,730	10,061	20,447	21,330
Imported Coal						
Power Plant	0	0	0	0	0	4,447
Others	297	315	334	354	461	675
Sub-total	297	315	334	354	461	5,122
Total	7,241	7,855	9,064	10,415	20,908	26,452

Sources: "REPORT OF THE FIFTH MEETING OF THE ASIAN EXPERTS GROUP ON COAL", 28-29 January, 1988

1. Demand for Power plant - Power Development Plan, EGAT, Nov. 1987
2. Demand for Cement, Tobacco and Other Industries - Seminar on Lignite-Substituted Fuel for Industry, Nov. 1987
3. Imported Coal for Industries - Report submitted to Energy Demand and Production Study Sub-Committee, Dec. 1987

Table 7-5 Energy Price in Thailand

(as of Nov. 1, 1990)

Item	Unit	Retail Price (Bahts/unit)	Heating Value (kcal/unit)	Energy Price (US$/MMBTU)
Electricity	kWh	1.23	860	14.42
LPG	kg	11.05	11,000	10.13
Kerosene	liter	8.72	8,250	10.65
Fuel Oil	liter	3.90	9,500	4.14
Charcoal	kg	3.10	6,900	4.53
Lignite	kg	0.80*	4,400	1.83

Note: Exchange Rate = 25 Bahts/US$
 * Lignite Price = Ex-mine price + Transportation cost
 (0.55 Bahts/kg) (0.25 Bahts/kg)

7-1-3 Thai Lignite for Briquette Production

The quality of lignite briquettes is determined largely by the properties of the feed lignite, particularly with the high-pressure compression process employed in this project. In order to produce high-quality lignite briquettes, lignite having the following properties shall be used as feedstock.

(1) High heating value (affecting heating value of the lignite briquettes)

(2) Low ash content (affecting heating value of the lignite briquettes)

(3) Low sulfur content (affecting required amount of slaked lime and hence the heating value and ash content of the lignite briquettes)

(4) Low volatile matter content (affecting smoke generation)

(5) Low moisture content (affecting drying cost in briquette production)

Among the above properties, the heating value of the feedstock is the critical item when selecting lignite, and use of a lignite with a higher heating value, so-called high-quality lignite, is desirable. If lignite of a high heating value is not available, installation of a washing plant should be considered. A washing plant removes ash and sulfur from the lignite and improves the heating value. Moreover, if lignite briquettes generates excessive smoke, pretreating the lignite with heat in order to reduce the volatile matter content should be considered.

7-2 Lignite from Ban Pa Kha Coal Mine

7-2-1 Outline of Ban Pa Kha Coal Mine

The Ban Pa Kha coal mine, designated to supply lignite to the project, is located in Li District, Lamphun Province in Northern Region of Thailand. In Li District, there are two other coal mines, named Ban Na Sai coal mine and Ban Pu coal mine, and they both produce lignite of higher quality.

The Ban Pa Kha coal mine had been operated by NEA, but was transferred in 1986 to a private sector company named Lanna Lignite Co., Ltd. in accordance with a change in the policy of the government. As the geological columnar section on Figure 7-3 indicates, there are two coal seams in the Ban Pa Kha coal mine, upper and lower layers, and the lower layer is divided further into the massive seam having an accumulated coal deposit and the split seam where the coal deposit is dispersed. The coal quality of each seam is shown in Table 7-6. High-quality lignite having a heating value of 6,500 kcal/kg (dry basis) could be produced from the lower massive seam, but lignites from other two seams have lower heating values.

Zone	Lithology	Thickness (M.)	Lithologic Description
Overburden		0–10	Overburden Quarternary deposit : Unconsolidated sand, silt, clay and rock fragments, yellowish to reddish brown, lateritic subrounded to rounded gravels and boulders in the bottom' portion.
		20–150	Semiconsolidated claystone, gray to brown, laminated and highly compaction, thin bedded of oil shale interbedded in some portion, and common leaves remains interbedded with sandstone, gray to brownish gray, fine to medium grained, common laminated with very small coal fragment, moderately sorted, rather loose, poorly cement with clay cement.
Upper Coal Zone		10–15	Upper coal zone : Composed of coal, brown to black, hard, dull and bright interbanded, commonly interbedded with ligneous claystone and claystone.
Interburden		15–40	Interburden : Composed of claystone and sandstone. Sandstone is light gray, fine grained, semiconsolidated, mainly found in upper portion. Claystone is gray to brown, well compacted, laminated, well bedded, common leaves remains. Thin bedded of oil shale interbedded in the lower portion.
Lower Coal Zone		15–20	Lower coal zone : Coal, black, hard, bright, subconchoidal fracture, massive in the upper part. Ligneous claystone and claystone interbedded in the bottom part.
Underburden		2–3 M. UP TO > 30	Underburden : Claystone and sandstone interbedded. Claystone is light gray to gray, compact, poorly bedded. Sandstone is gray, low compact, poorly sorted. The bottom part is gradational to pebbly sandstone and conglomerate with some fragments of basement rock that remainly quartzite and greenish gray sandstone.

Figure 7-3 Typical Columnar Section, Ban Pa Kha Coal Mine

Table 7-6 Coal Quality of Ban Pa Kha Coal Mine

	As-received Basis Moisture (%)	Ash (%)	Heating Value (kcal/kg)	Dry Basis Ash (%)	Heating Value (kcal/kg)	Remarks
Run of Mine						
Upper Seam	25.12	23.65	3,547	31.58	4,737	V.M. 35-40%
Lower Massive Seam	28.70	6.10	4,649	8.56	6,520	F.C. 40-45%
Lower Split Seam	25.81	20.25	3,742	27.29	5,044	S 0.5-1.5%
Average	27.03	14.27	4,132	19.56	5,663	
Finished Coal						
Washed Coal	28.00	10.80	4,238	15.00	5,886	
Lower Massive	28.70	6.10	4,649	8.56	6,520	
Average	28.43	7.88	4,493	11.01	6,278	Average for sale

Note: Reserves, million tons
- Mineable Reserve: 18
- Upper Coal Seam: 5
- Lower Massive Seam: 9
- Lower Split Seam: 4

Lignite is produced by the open cut mining using power shovels. The run-of-mine lignite is crushed into particles of under two inches and transported to users by dump truck. Figure 7-4 shows the flow scheme of coal crushing and screening system employed in the Ban Pa Kha coal mine.

Lanna Lignite Co., Ltd. has two selling prices for lignite in accordance with the heating value as shown below. The price of low-quality lignite for tobacco curing factory is under control by the government.

High-quality lignite: 550 Bahts/ton

Low-quality lignite: 260 Bahts/ton

The marketing and production plan of Lanna Lignite Co., Ltd. for lignite is shown in Table 7-7.

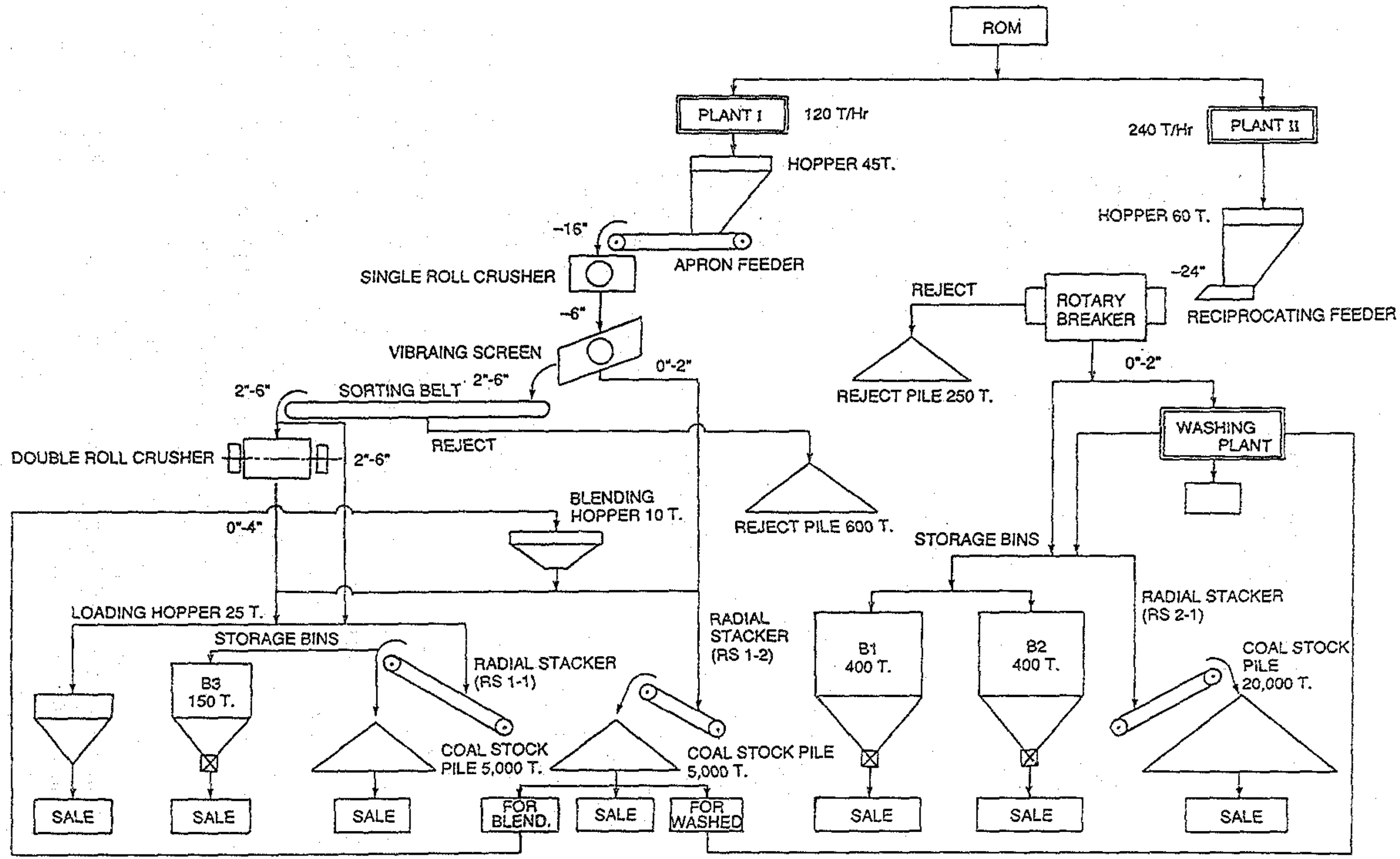


Figure 7-4 Lignite Production Flow Scheme, Ban Pa Kha Coal Mine

Table 7-7 Marketing and Production Plan of Lanna Lignite Co., Ltd.

Marketing Plan

Year	Marketing Volume (tons/year)
1986	37,000
1987	275,000
1988	410,000
1989	690,000
1990	1,000,000
1991 - 2004 (planned)	1,000,000

Detail of Marketing Plan

User	(tons/year)
Cement Factory	720,000
Lime Kiln and others	180,000
Tobacco Curing	100,000
Total	1,000,000

Production Plan

Grade	(tons/year)
High-quality Lignite	400,000
Washed Lignite	700,000
Low-quality Lignite	100,000
Total	1,200,000

According to the plan, 900,000 tons per year of high-quality lignite will be sold to cement factories, lime kilns and other industries. The shortage of high-quality lignite will be made up for by the washed lignite treated by the washing plant, which has been in operation since February 1991. In the process of washing, ash contained in low-quality lignite is removed and consequently the heating value of lignite is improved. The capacity of the washing plant and the cost for lignite washing are as follows:

Capacity of the washing plant, tons/hour	240
Washing cost, Bahts/ton	150

7-2-2 Supply of Lignite to the Lignite Briquette Project

The pilot plant and the commercial plant of 50,000-ton-per-year capacity envisaged by this project will require the following quality and quantity of lignite:

Quality of lignite

Heating value (dry base), kcal/kg:	4,639 minimum
Moisture content: wt % max.	30
Particle size, mm max.	50

Required quantity (based on the moisture content of 30 wt%)

Pilot plant, tons/year:	3,176
Commercial plant, tons/year:	52,940

According to the marketing and production plan of Lanna Lignite Co., Ltd., 200,000 tons per year of high-quality lignite and/or washed lignite could be produced beyond the planned marketable quantity.

Therefore, it seems possible to supply the required quality and quantity of lignite to the pilot plant as well as to the commercial plant until the end of the year 2004 when the company will terminate the mining operation there.

Since the availability of high-quality lignite from the Ban Pa Kha coal mine is limited, it seems more practical to feed to the project other than the high-quality lignite. As shown in Table 7-6, the quality of run-of-mine lignite from each seam meets the minimum requirement for briquette production. Therefore, the crushed lignite produced from any coal seam could be fed to the plants without further treatment. However, to produce briquettes of higher quality as well as to reduce the crushing cost in the production process, use of washed lignite is preferable, because the washed lignite has a heating value almost equal to that of the high-quality lignite and has smaller particle sizes.

7-3 Lignite from Other Mines

After the termination of production at the Ban Pa Kha coal mine expected for 2004, the project will need other sources for the supply of lignite. In such a case, Ban Na Sai and Ban Pu coal mines are the candidates to substitute for Ban Pa Kha coal mine, since the both mines are located close to the plant site. In the case that the demand for lignite briquette expands as a results of a number of lignite briquette plants being constructed throughout the country, lignite must be supplied from other mines.

7-3-1 Lignite Supply to the Project

(1) Ban Na Sai Coal Mine

The Ban Na Sai coal mine located in Li District is under development, with the start of production scheduled for 1994. The outline of the mine is as follows:

Lignite reserve, million tons	11
Lignite quality	
Heating value (dry base), kcal/kg	4,265
Sulfur content, wt%	2.06
Proprietor:	NEA
Development plan:	Commencement of operation in 1994
Lignite user:	Cement factories, lime kilns, tobacco curing

The heating value is slightly lower than the requirement for briquette production, or about 4,750 kcal/kg on dry base. In order to supply lignite of the heating value meeting the requirement, either of the following two measures should be adopted.

(1) Lignite solely from specific seams containing lignite of higher heating values will be supplied to the lignite briquette plants, if there are any such seams.

(2) A washing plant will be installed and washed lignite will be

supplied.

(2) Ban Pu Coal Mine

The Ban Pu coal mine is under operation by Ban Pu Coal Mine Co., Ltd. The company has been operating coal mines other than Ban Pu, and the total output in fiscal 1989/1990 reached one million tons per year. The outlines of coal mines being operated by the company are shown in Table 7-8. As shown in the table, the quality of lignite from each coal mine surpasses the requirement for briquette production. Furthermore, washing plants will be installed. Consequently, the company is a prospective supplier of lignite to the project after the termination of the Ban Pa Kha coal mine.

Table 7-8 Outline of Deposits Operated by Ban Pu Coal Mine

	Deposits' Name				
	BP1	BP2	BP3	LP1	LP2
Deposit Size, km^2	0.146	0.88	0.6	0.58	0.81
Drilling, m	1,450	8,148	6,426	6,232	-
Performance holes	30	109	82	153	-
Geological, mmton	2.788	5.80	3.577	1.390	12.00
Recovery, x:1	1,433	3.3	6.54	13.61	-
Quality					
Moisture (AR), %	30.00	30.23	36.06	24.71	30.88
Ash, %	19.49	19.41	15.88	25.50	14.60
V.M., %	42.59	42.30	44.52	39.80	44.64
F.C., %	39.00	36.82	39.58	34.80	40.76
Heating Value, kcal/kg (dry)	5,516	5,186	5,560	5,008	5,662
Sulfur, %	1.71	1.33	0.58	1.50	1.43

Note:
(1) All quality values are on dry-basis, except for moisture which is on as received basis.
(2) Among BP1, BP2, BP3 and LP1, some coal reserves have been mined out.
(3) BP1 is under exploration for mine project expansion.

7-3-2 Lignite Supply in Case for Large-Scale Briquette Production

According to the forecast demand developed in Chapter 5, there is possibility of the demand for lignite briquettes reaching 800,000 TOE per year in 2010. In order to meet such a great demand, more than two million tons per year of lignite will be needed. This amount is equivalent to 10 percent of the forecast total lignite output in Thailand for the year 2010. Considering the limited availability of high-quality lignite in Thailand, it is required to use washed lignite as feedstock for lignite briquette production.

After washing plants have been sufficiently installed, powder coal and/or low-quality lignite awaiting effective utilization could be used as feedstock for lignite briquette production after treatment by the washing plants.

Powder coal, the yields of which are between 20 and 40 percent on product coal, is a very troublesome material when it is being handled in one way or another or transported. It remains unused in most cases. For some of the coal mines producing high-quality lignite, it would be possible to produce washed lignite of a high-heating value by treating the powder coal at the washing plant, designed to be able to treat powder coal. However, majority of coal resources in Thailand is low-quality lignite, and it is essential that these low-quality lignites be used as feedstock for briquette production in order to supply lignite of over two million tons per year. Therefore, it is required to install washing plants to improve the heating value of low-quality lignite.

Test of washability of subject lignite is essential to the determination of the applicability of washing. As far as the information obtained suggests, however, the Thai lignites appear amenable to washing; it would probably possible to reduce ash content and to increase considerably heating value by the application of washing.

7-4 Biomass

In the process of producing lignite briquettes by means of the high-pressure compression process with biomass, the biomass acts as a binder to hold the particles of lignite and slaked lime together. The biomass also works as a combustion improver to facilitate ignition as well as to promote combustion. Although any kind of biomass could be used as feedstock, use of agricultural wastes is practical. As agriculture is the key industry in Thailand, various agricultural wastes are available as feedstock for the production of lignite briquettes. However, to select the biomass feedstock best suited to this project, the candidates should be examined from the three aspects; namely, availability, cost and quality.

(1) Availability

The required quantity can be calculated from the unit consumption rate of biomass in the lignite briquette production, which is approximately 0.25 kilograms per kilogram of lignite briquettes. To produce two million tons per year of lignite briquettes, 0.5 million tons per year of biomass feedstock is required.

(2) Cost

The following items will be criteria for selecting the best agricultural waste in terms of minimizing the cost for biomass feedstock; namely, procurement, transportation, storage and processing costs.

- high production rate without effective utilization
- availability throughout a year by season-free cultivation
- availability around the plant site
- low moisture content

(3) Quality

The moldability varies with the kind of biomass. The moldability must be examined by the experimental production of briquettes using the subject biomass. At the beginning of this feasibility study, rice straws, rice husks and bagasse were selected as candidate feedstocks and their moldability was actually examined by means of experimental production of lignite briquettes. The result indicates that bagasse and rice straws have good moldability but rice husk has an inferior moldability; rice husks cannot be used for briquette production unless rice husks are mixed with rice straws or bagasse.

The production rate as well as the current use of potential biomass feedstocks are explained below. However, it should be noted that the moldability of biomass except rice straws, rice husks and bagasse are not examined by this feasibility study. Their moldability should be tested when they are planned to be used.

7-4-1 Rice Straws

(1) Rice Production in Thailand

Rice is the most important crop for Thailand and is cultivated throughout the country. Rice straws, a refuse from rice production, are available throughout the country. The region-wise rice production in 1990 is shown below.

(Unit: 1,000 tons/year)

Region	Major rice	Second rice	total
Northern	5,471	807	6,278
Northeastern	7,106	197	7,303
Central	4,581	1,080	5,661
Southern	894	41	935
Total	18,052	2,125	20,177

The climate of Thailand is suited to the production of rice, which requires plenty of water. Rice is planted in the rainy season and harvested in the dry season. In Central Region of Thailand where irrigation facilities are well provided, double cropping of rice is a common practice.

Since about two kilograms of rice straws are obtained for each one kilogram of rice harvested, the total production of rice straws in Thailand is estimated at 40 million tons per year. Use of rice straws is rather limited to animal fodder, to sheltering young plants against heat, to mushroom growing beds; rice straws are mostly burned on the paddy field to be used as a fertilizer. If two percent of rice straws produced in Thailand are used for the production of lignite briquettes, they would meet the requirement for the production of two million tons per year of lignite briquettes. In this sense, rice straws are the most promising biomass feedstock in terms of availability.

(2) Supply of Rice Straws to the Project

The production of rice in Lamphun Province in 1990, where the plants are to be installed, 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

Then, the production of rice straws is estimated at about 250 thousand tons per year, which is equivalent to the requirement of biomass for the production of one million tons per year of lignite briquettes. To operate both the pilot plant and the commercial plant, with a combined capacity of 53,000 tons per year of lignite briquettes, the supply of five percent of the rice straws produced in Lamphun Province would suffice.

In Lamphun Province, most farmers raise two different crops a year, namely, major rice and vegetables such as onion and garlic or tobacco, because irrigation facilities are not well provided there to enable them to grow rice twice a year. Only nine percent of rice field is used for double cropping of rice. The cultivation period for the major rice is between June and November to January. During the rest of the year, vegetables or second rice is cultivated. Farmers raising two crops utilize their rice straws as animal fodder, for sheltering young plants against heat and for making mushroom growing beds. If there is demand, they sell surplus rice straws; otherwise, they burn them out. The selling price of rice straws in a small lot is two Bahts per a bundle of two kilograms. The price would be discounted to 500 Bahts per ton if purchased in a large lot. If a purchase contract is secured with this project, farmers will store their rice straws during the dry season. There is no effective way of using rice straws for farmers doing double cropping of rice; they sell or burn their rice straws immediately after the harvest.

In Lamphun Province, in February and during the period from August to October, rice is not harvested. In addition, as it is in the rainy season from August to October, the farmers do not store rice straws on their own fields. Therefore, to insure supply of rice straws during this period, one of the following means must be adopted.

(1) to procure and to transport rice straws from other areas where rice harvesting season is different from Northern Region,

(2) to install a rice straws storage facility having a capacity corresponding to three months' briquette production,

(3) to utilize this period for maintenance of the plant scheduled two months a year. The capacity of rice storage would be of one month briquette production.

There is no insurmountable difficulty in supplying rice straws to the project. But, since there are no dealers and/or collectors of rice straws in this area, rice straws must be purchased directly from farmers. To obtain rice straws at a reasonable price, the project must have an appropriate procurement schedule of rice straws based on the information on harvesting schedule of rice and selling price of rice straws by areas and/or by major farmers.

7-4-2 Bagasse

Bagasse is the crushed residue of the sugarcanes discharged from sugar mills. Bagasse is used mostly as a fuel for their own boilers, and only the surplus is available to other uses. Although bagasse has a draw-back of having a high moisture content, bagasse is one of the best binders for the production of lignite briquettes from the viewpoint of quality of lignite briquettes, because bagasse has a high heating value and lignite briquettes made with bagasse have a good appearance and a high breaking strength, comparable to those made with rice straws.

The region-wise production of sugarcanes is shown below.

	(Unit: 1,000 tons/year)
Northern	6,779
Northeastern	5,879
Central	20,903
Southern	-
Total	33,561

As indicated above, sugarcanes is cultivated primarily in Central Region of Thailand, and its harvesting season is from December to March.

In modern sugar mills, 700 kilograms of sugar juice and 300 kilograms of bagasse containing 50 percent of moisture are produced from one ton of sugarcanes. About 75 percent of the bagasse produced is consumed as fuel for the mill and the remaining about 25 percent of the total would be discharged from the mill. Based on the above material balance, the total availability of bagasse in Thailand is estimated at 2.5 million tons per year based on 50 percent moisture content, which would suffice for the requirement of biomass for the production of approximately five million tons per year of lignite briquettes.

The surplus bagasse is usually used as animal fodder, fuel and a source of cellulose for paper making; but because of the high transportation cost associated with the high moisture content, its use is limited to the areas surrounding the sugar mills. In the Central Region of Thailand most of the surplus bagasse is utilized for paper production. The purchase price of bagasse at paper mills ranges from 100 to 150 Bahts per ton excluding the transportation cost. In Northern Region there is no paper mill consuming a large quantity of bagasse. A liquor distillery uses the surplus bagasse, together with a waste fluid from their process, to produce an organic fertilizer.

There are following advantages to the use of bagasse as binder for the production of lignite briquettes,

(1) The quality of the lignite briquettes is good.

(2) The crushing cost in the manufacturing process could be reduced, because bagasse is supplied in a crushed form from sugar mills.
(3) The purchase price could be lower than that of rice straws.
(4) The purchase will be easier, because the supply sources are not scattered;

while the following drawbacks are anticipated:

(1) A huge capacity would be required for storage of bagasse in order to maintain a continuous operation of the plant for one year, because the operation of sugar mills and hence the supply of surplus bagasse is limited to the harvesting season of sugarcanes.
(2) The bagasse price may rise when competing with the existing uses.
(3) Additional costs for the equipment and operation for drying bagasse of a high moisture content would be incurred.

If a sugar mills is located close to the lignite briquette plant, bagasse is worth considering as a biomass feedstock. In that case, the following points should be studied:

(1) current uses of bagasse,
(2) selling price of bagasse,
(3) transportation cost from the sugar mill to the lignite briquette plant,
(4) availability in terms of quantity and period,
(5) costs for storage and drying of bagasse.

7-4-3 Other Biomass

In Thailand there are several agricultural residues considered to be available and applicable to the production of lignite briquettes other than rice straws and bagasse; stalks of maize and cassava and old rubber trees, for example.

The estimated amounts of residues and current uses are shown below.

	Production Rate (1,000 tons/year)	Amount of Residue (1,000 tons/year)	Use of residue
Maize	4,393	10,983	Fertilizer
Cassava	20,701	3,337	Fuel
Rubber	936	N.A.	Furniture, Charcoal

If lignite briquettes are produced in Southern Region where neither rice nor sugarcanes is the major crop, but rubber plantation prospers, old rubber trees could be a good biomass feedstock. A large number of old rubber trees will be available to the production of lignite briquettes, because rubber trees are replanted in every 25 years or so to maintain the productivity of latex. Barks are used as biomass feedstock in a coal briquette plant in Japan; therefore, barks as well as wood itself will be good biomass feedstocks for briquette production. Old rubber trees are now utilized for furniture production and charcoal making. The purchase price of old rubber trees for the above uses is 300 Bahts per ton. Recently, some charcoal producers have suspended production, because of the sluggish price of charcoal made from rubber trees. This could possibly lower the price of old rubber trees in the future.

7-5 Slaked Lime

Slaked lime, with calcium hydroxide as the principal component, is added to lignite briquettes to capture sulfur oxides discharged when lignite briquettes are burned.

7-5-1 Slaked Lime Production in Thailand

Slaked lime is made from limestone. The reserves of limestone are abundant and the deposits are spread in the whole Thailand as shown in Figure 7-5. The production of limestone was 14.26 million tons in 1988, 99 percent of which was used for cement production and one percent for other purposes. If one percent of the total limestone mined in 1988 had been used for the production of slaked lime, the production of slaked lime in 1988 would have been at 90,000 tons.

Limestone is calcined at temperatures above 900 degrees Centigrade in a lime kiln to make quick lime, and then, quick lime is slaked by adding water. Slaked lime and/or quick lime are used in steel plants, zinc plants and sugar mills as a chemical, a neutralizing agent and an agent for waste water treatment. Firewood or lignite is used as fuel for lime kilns in Thailand. Fuel oil is also used in large-scale lime kilns.

7-5-2 Supply of Slaked Lime

The pilot plant and the 50,000-ton-per-year commercial plant envisaged in this feasibility study will consume the following amounts of slaked lime.

Pilot Plant	276 tons/year
Commercial Plant	4,595 tons/year

The capacities of lime kilns in Thailand are rather small compared with those of cement plants. Even in Saraburi Province where major lime kilns are located, the production capacities of 22 manufacturers are from nine to 900 tons per month, or an average of 214 tons per month. In other places, the capacities are much smaller, or so-called cottage industry scale. The quality of slaked lime is determined largely by the calcining temperature. When the temperature is not high enough, the conversion of calcium carbonate to calcium hydroxide is incomplete and consequently the product contains a high content of calcium carbonate remaining unconverted. The sample of slaked lime sent to Japan for the experimental production of lignite briquettes scarcely contained calcium hydroxide. If the content of calcium hydroxide is low in the slaked lime, it will lower the effect of desulfurization of the lignite briquettes. Therefore, it is important to procure slaked lime of good quality from reliable suppliers.

According to one of the major manufacturers of slaked lime, it would be better to obtain slaked lime from Tak Province than from Saraburi Province if such large amounts are necessary. There will be enough supply capacity in Tak Province and the transportation cost to Ban Pa Kha would be lower from Tak Province than from Saraburi Province. The price of slaked lime is quoted at 2,500 Bahts per ton including transportation cost to the plant. The slaked lime will be supplied to the plant in 25 kilogram plastic bags or in bulk by tank truck. It would also be possible that a lime kiln be constructed in a place near the lignite briquette plants if a deposit of high-quality limestone should be discovered there.

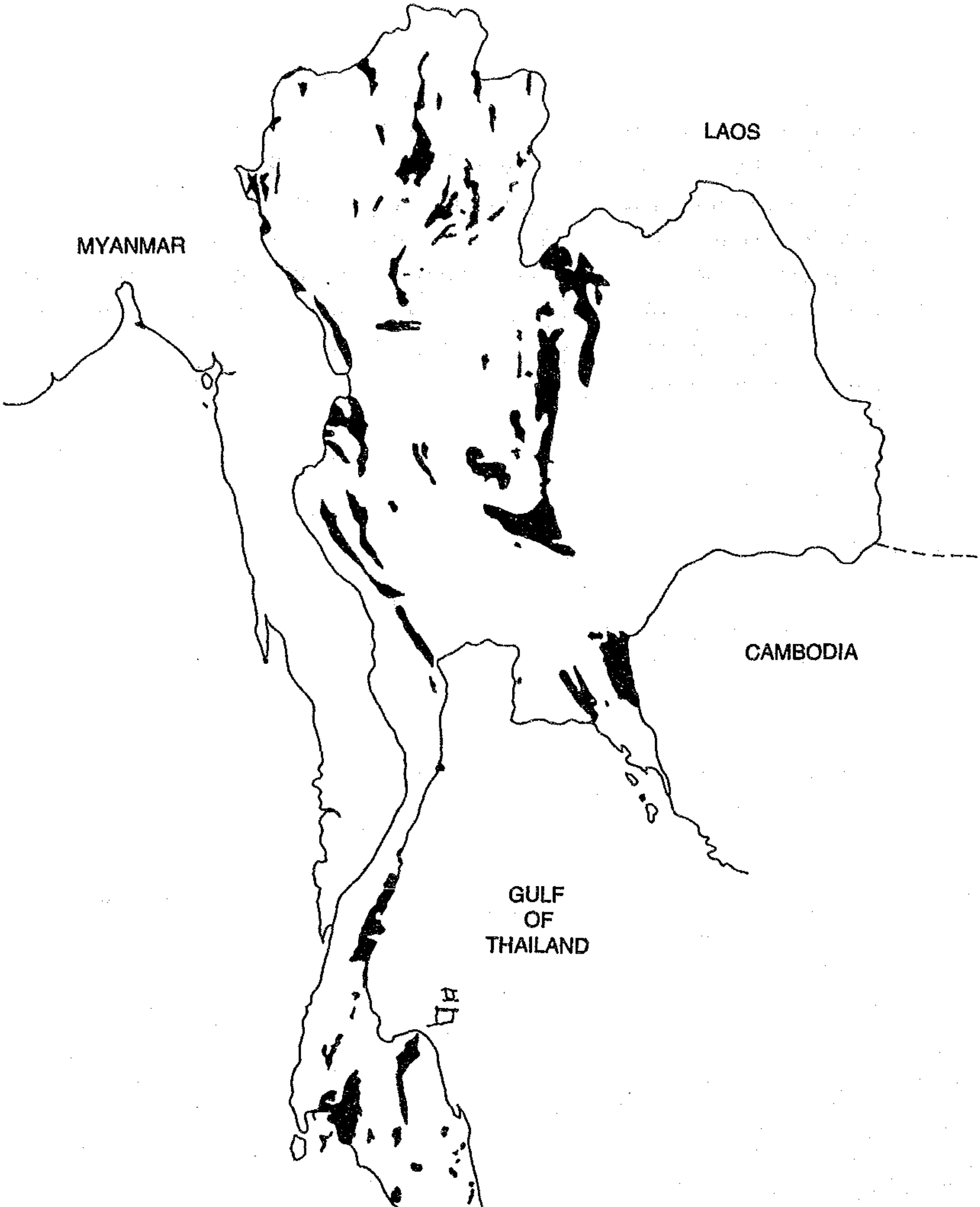


Figure 7-5 Location of Limestone Deposit

Chapter 8 Infrastructure and Utility

Chapter 8 Infrastructure and Utility

8-1 General Condition of Infrastructure

8-1-1 Transportation

(1) Road

The highway network of Thailand is well developed as shown in Figure 8-1. The Asian Highway which stretches to Singapore through Malaysia constitutes a portion of the highway network of Thailand. Major inter-regional highways connect the important provincial cities to Bangkok. The highways are classified into seven categories, with responsibility for their construction, improvement and maintenance resting with the different government offices as indicated below.

Department of Highway
- (1) Special highway
- (2) National highway
- (3) Provincial highway
- (4) Conceded highway, rural highway

Changwat (Provincial) Administrative Organization
- (5) Rural highway

Municipal Public Works
- (6) Municipal highway
- (7) Sanitary highway

As the conditions of transportation significantly affect social and economic development of the country, construction of new roads, improvement and maintenance of the existing ones are naturally an important government prerogative. As shown in Table 8-1 the total length of roads has been increasing at a rate of five percent a year as the road network has been expanded. Under the Sixth National Economic Development Plan (1987-1992), the Department of Highway will construct 436 kilometers of new roads, 330 kilometers of main highways and 106 kilometers of provincial roads.

Table 8-1 also shows that the number of registered vehicles has been increasing, indicating the ever increasing importance of the road in the inland transportation. Actually, the road transportation is considered by far the most advanced and efficient transportation system Thailand has.

(2) Railways

The State Railway of Thailand (SRT) operates a total of 3,825 kilometers of railway tracks, almost all of which, or 3,644 kilometers, is of single tracks and the rest, or only 181 kilometers, is of double tracks. The SRT has 623 stations, most of which with buildings for passengers, others only for cargo and workshops. The rail gauge is one meter. As the railways have not been electrified, steam and diesel locomotives are used.

The railway routes are shown in Figure 8-1. There are four main routes emanating from Hualampong, the main station in Bangkok: one going to Chiang Mai in Northern Region, another to Nong Khai and Ubon Ratchathani in Northeast Region, the third to Prachinburi Province to the east and the fourth down southward to Malaysia connecting with the Malaysia Railway which goes as far as Singapore. The SRT is extending the rail route from Bangkok to the Sattahip Deep Sea Port and other eastern industrial complexes.

Recently, there have been almost no increase in the passenger and freight volumes carried by the railways. There is a severe competition with the road transportation. Table 8-3 shows recent status of railway passengers and freights. Major commodities carried by rail are crude oil, petroleum products and cement. Special containers are provided by the railways for these cargos.

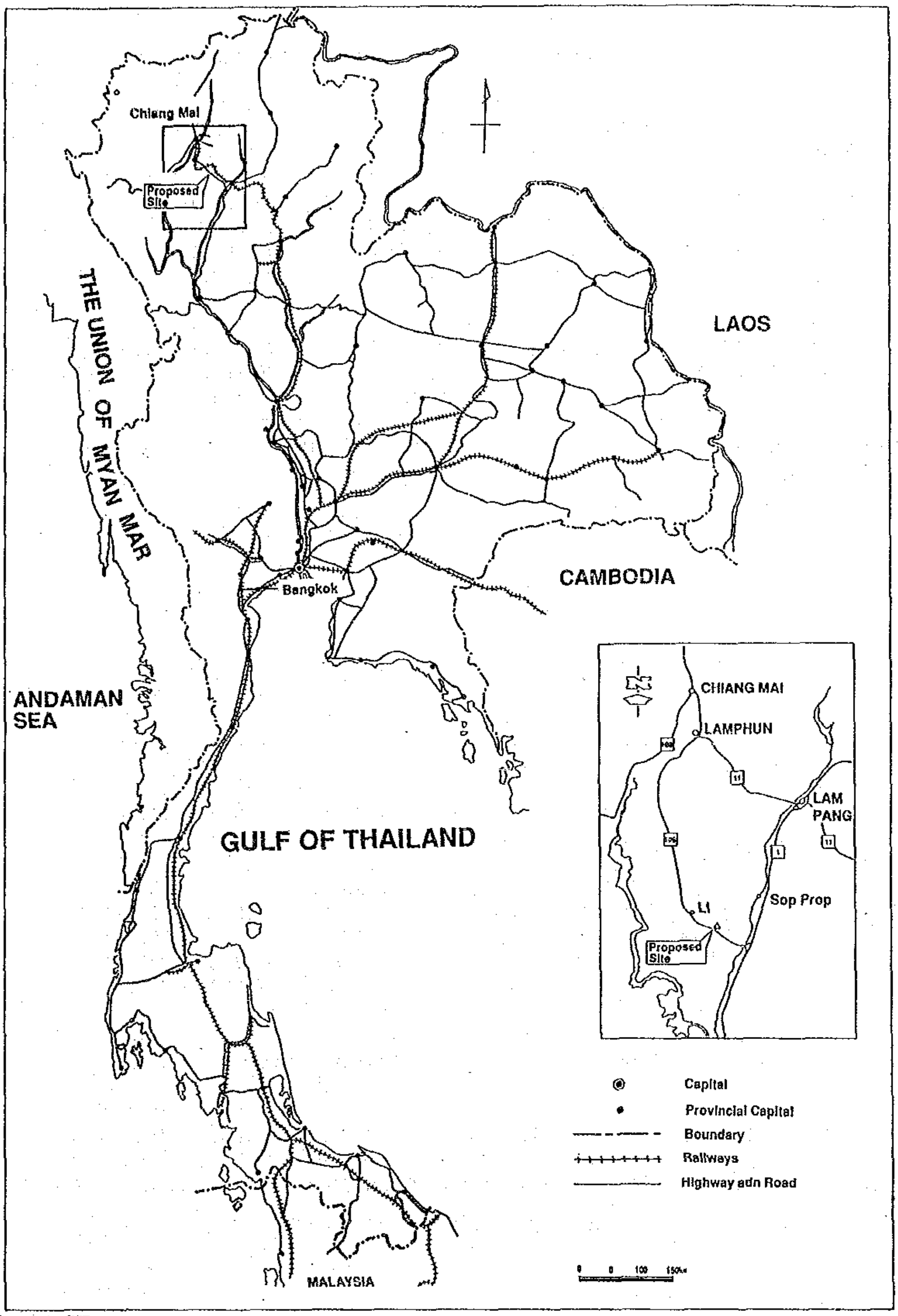


Figure 8-1 Highway Network and Railways

Table 8-1 Length of Main Highways and Roads

(Unit: Kilometer)

Fiscal Year	State Highway Primary	State Highway Secondary	Provincial Highway	Total Length
1980	6,632.7	7,260.5	14,257.4	28,150.6
1981	6,797.7	7,377.8	15,840.7	30,016.2
1982	6,805.9	7,542.6	16,652.9	31,001.4
1983	7,225.5	7,846.9	18,075.7	33,148.1
1984	7,252.1	7,907.6	19,542.0	34,701.7
1985	7,304.5	7,913.3	21,016.7	36,234.5
1986	7,272.0	8,114.1	22,338.5	37,724.6
1987	7,278.3	8,385.8	24,500.1	40,164.2
1988	7,314.1	8,585.2	25,894.9	41,794.2

Source: Department of Highways, Ministry of Transport and Communications

Table 8-2 Number of Motor Vehicle Registration

(Unit: Number)

Fiscal Year	Personal Car	Taxi & Bus	Van & Truck	Motor Cycle	Other Vehicle	Total
1970	188,327	44,116	126,590	337,708	20,382	717,123
1975	248,562	39,629	224,142	456,467	65,528	1,034,328
1980	390,394	66,512	299,946	919,928	60,540	1,737,320
1981	432,312	68,701	469,305	1,168,824	66,160	2,205,302
1982	493,654	73,327	537,498	1,422,971	72,987	2,600,437
1983	540,554	72,429	564,906	1,737,210	80,716	2,995,815
1984	671,446	74,399	600,336	1,916,921	84,788	3,347,890
1985	715,131	76,294	608,198	1,826,290	86,993	3,312,906
	Passenger Car	Taxi & Services Car	Van & Truck	Motor Cycle	Other Vehicle	Total
1988	1,146,512	65,399	1,061,348	3,894,824	214,857	6,382,940

Source: Department of Land Transport (Data from 1970 to 1986)
Department of Highways (Data for the year 1988)

Table 8-3 Railways Passenger and Freight Summary

Description	Unit	1985	1986	1987	1988
Passenger Carried	(1,000 Numbers)	78,013	76,702	77,931	81,618
First Class	(1,000 Numbers)	69	65	64	45
Second Class	(1,000 Numbers)	1,757	2,344	2,368	2,140
Third Class	(1,000 Numbers)	76,187	74,293	75,499	79,433
Passenger-Kms	(1,000,000)	9,140	9,274	9,583	10,301
Freight Ton-Kms	(1,000,000)	2,718	2,583	2,729	2,867
Goods Wagon-Kms	(1,000,000)	334	306	333	333
Loaded Wagon-Kms	(1,000,000)	199	183	194	207
Empty Wagon-Kms	(1,000,000)	135	123	139	126

Source: The State Railway of Thailand

8-1-2 Electric Power Supply

Public electricity is generated almost entirely by the Electricity Generating Authority of Thailand (EGAT) and distributed by the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA). There are currently twelve hydroelectric, seven thermal and four gas-turbine plants throughout the country. In addition, EGAT has plans to construct additional plants in Northern and Southern Regions. The installed capacity and electricity generation are shown in Table 8-4 by type of power plant. Electricity generation has recently been increasing at rates higher than ten percent a year. Even with such an increase of capacity, abrupt increases of consumption often cause power failures.

Energy sources for electricity generation are hydro power, fuel oil, diesel oil, lignite and natural gas. In 1988, natural gas accounted for 58 percent of all the energy sources. The consumption of natural gas has steadily increased as more natural gas resources were found and developed in the Gulf of Thailand.

As shown in Figure 8-2, the residential areas have almost been electrified. The total consumption of electricity was 28,000 GWh and that per capita was 598 kilowatt-hours in 1988, The consumption has been increasing at a high rate of nearly 10 percent per year. The shares of consumption by sector were 22 percent for residential, 31 percent for commercial, 46 percent for industrial and one percent for agriculture and others. The consumption by the commercial sector has been increasing recently. The standard voltages are 230, 115 and 69 kilovolts for power transmission and 33, 22 and 11 kilovolts for distribution. The frequency is 50 Hertz.

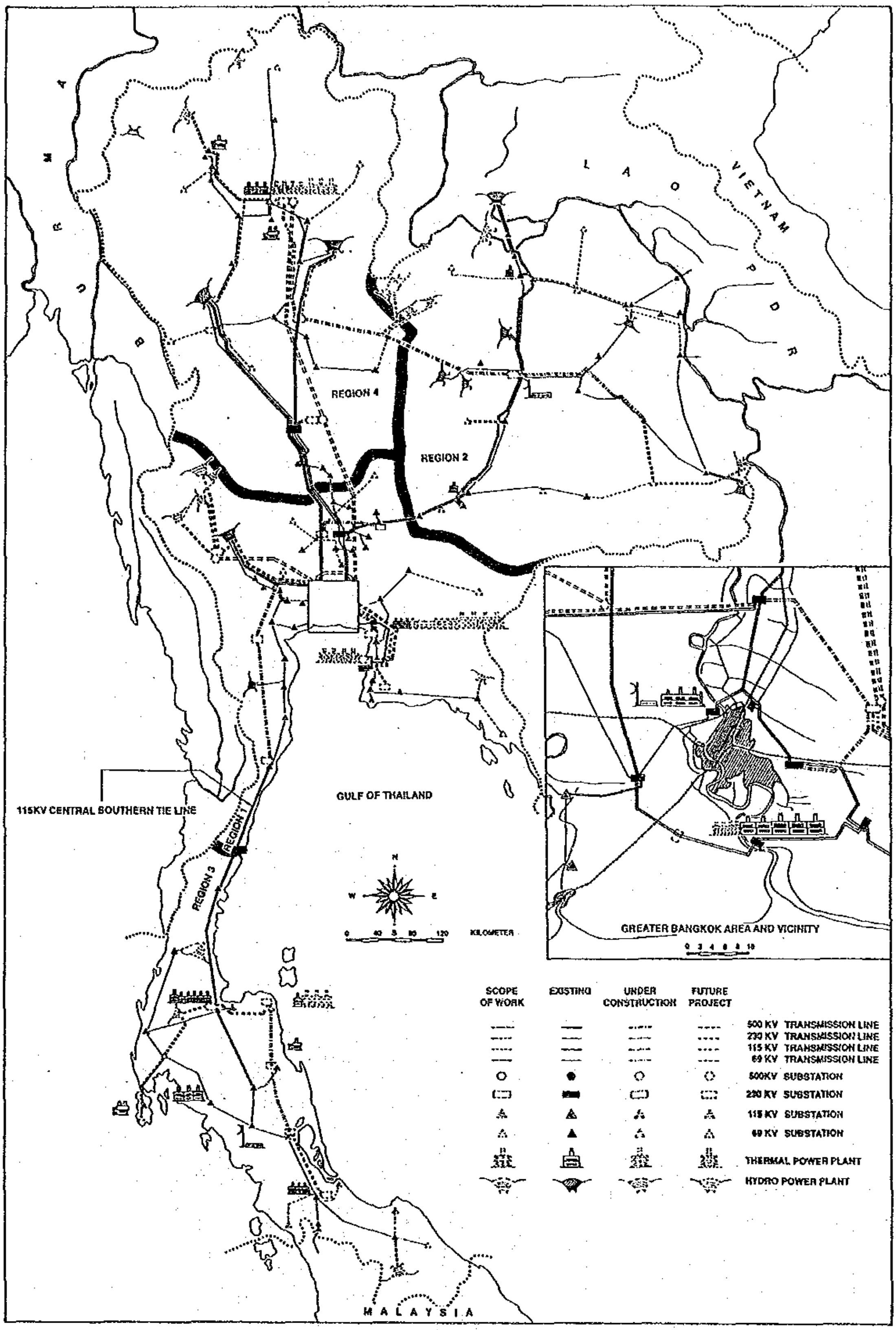


Figure 8-2 Location Map of Electricity Power System

Table 8-4 Installed Generation Capacity and Electricity Generation by Type of Power Plants

Year	Utility Installed Capacity (MW)						Utility Electricity Generation (Gwh)					
	Hydro	Steam	Gas Turbine	Diesel	Combined Cycle	Total	Hydro	Steam	Gas Turbine	Diesel	Combined Cycle	Total
1980	1,270	1,778	285	115	-	3,448	1,273.0	12,762.4	259.4	131.2	-	14,426.0
1981	1,361	1,928	610	109	-	4,008	2,974.3	11,972.7	383.5	46.8	-	15,377.3
1982	1,519	1,928	490	106	360	4,403	3,836.5	11,907.1	847.3	23.6	5.4	16,619.9
1983	1,501	2,477	250	84	720	5,032	3,659.8	12,077.9	162.8	38.3	2,917.8	18,856.6
1984	1,714	3,327	265	102	720	6,128	4,081.4	14,703.9	346.2	20.8	1,872.3	21,024.6
1985	2,004	3,628	265	88	720	6,705	3,692.2	16,935.2	554.0	18.9	1,874.1	23,074.4
1986	2,096	3,608	265	96	720	6,785	5,554.4	16,082.5	706.3	25.2	2,348.4	24,716.8
1987	2,256	3,608	267	82	772	6,985	4,075.3	20,507.7	754.5	64.7	3,250.0	28,652.2
1988	2,268	3,608	267	82	772	6,997	3,779.0	22,966.8	763.7	20.9	4,934.0	32,464.4

Source: EGAT, PEA, NEA, POF

Table 8-5 Electricity Consumption by Categories of Consumers and Per Capita

(Unit:GWh)

Year	Residential	Commercial	Industrial	Agricultural	Street Lighting	Other	Total	khW Per Capita
1980	3,005.3	3,561.0	6,454.5	22.5	71.2	34.7	13,149.2	323
1981	3,168.0	3,468.2	7,064.2	20.1	83.2	33.5	13,837.2	337
1982	3,630.3	3,862.4	7,389.0	32.5	90.5	28.0	15,033.0	355
1983	4,187.7	4,530.0	8,013.6	41.2	103.2	30.6	16,906.3	395
1984	4,731.5	4,912.5	8,723.5	47.8	118.3	38.6	18,572.2	429
1985	5,164.7	5,344.1	9,298.0	55.0	127.9	42.2	20,031.9	459
1986	5,795.1	5,847.8	10,162.7	56.7	140.9	31.2	22,034.4	481
1987	6,135.5	7,331.2	11,319.4	61.3	-	46.8	24,894.2	539
1988	6,253.5	8,847.6	12,951.8	67.4	-	132.4	28,252.4	598

Source:EGAT, PEA, MEA, POF

8-1-3 Telecommunication

The telecommunication services in Thailand are provided by two government agencies; namely, the Telephone Organization of Thailand (TOT) and the Communications Authority of Thailand (CAT). The former operates domestically and and also provides international trunk services but only with Malaysia and Laos; the latter provides the international telephone, telegraph, telex and facsimile services.

In 1988, the telephone density was 1.83 units per 100 persons. TOT maintains about one million active lines, 60 percent of which are located in Bangkok. However, the conditions of telecommunication leaves much to be desired even in Bangkok. According to TOT's Fifth Development Plan (1984-1991), two million telephone lines will be installed.

Recently, in the metropolitan area and the surrounding provinces, mobile telephones are popular. Radio telephone and leased telephone lines are also available. International telephone, facsimile, telegraph facilities are available in urban areas throughout the country operated via satellite and submarine cable system.

8-1-4 Postal Service

Postal service is provided by the Communications Authority of Thailand (CAT) covering 72 percent of the total territorial area of the country. The postal network has 21,284 mail boxes, 5,941 postage stamp agencies and 4,004 post and telegraph offices including CAT-operated, district-licensed, private-licensed and rural delivery offices.

8-1-5 Mass Media

(1) Broadcasting

There are five television stations based in Bangkok and six stations in other areas. One of them is the Army Television Station (Channel 5) covering the whole country. There were about two million TV receivers in Thailand in 1986. It is estimated from this number that about 50 percent of households in the country have TV receivers. As this figure has been increasing rapidly, the TV broadcasting has grown to be the largest mass media comparable to newspapers.

There are 298 radio stations for FM and AM broadcasting in the country. There were estimated 7,350,000 radio sets in 1983, or 14.9 sets per 100 persons.

(2) Newspaper

A total of 69 daily newspapers are published; of 43 major newspapers, 35 are in Thai, six in Chinese and two in English. The total circulation is about three millions.

8-2 Infrastructure and Utility around the Selected Plant Site

8-2-1 Road Condition

(1) Condition of Existing Road

As shown in Figure 8-3, the Highway Route 106, running about three kilometers from the selected plant site, links the site with Chiang Mai and other major cities across the country. The highway is asphalt-paved with two lanes. Guard rails and side sewers are not provided. The traffic load is not heavy. The highway is well maintained. There is no bridge or tunnel that may hinder transportation of heavy construction materials for the project. By comparison, even the nearest railway station to the site is located in Lampang, about 70 kilometers from the plant site. It is not practical to transport the raw materials and product by rail.

The plant site is directly accessible by the main laterite road to the mine branched from the highway. This road is used for the transportation of lignite. The conditions of the road are considered good enough for the purpose of this project even in the rainy season; the road is elevated above the surrounding paddy fields. There is no need to improve the road specifically for the purpose of this project.

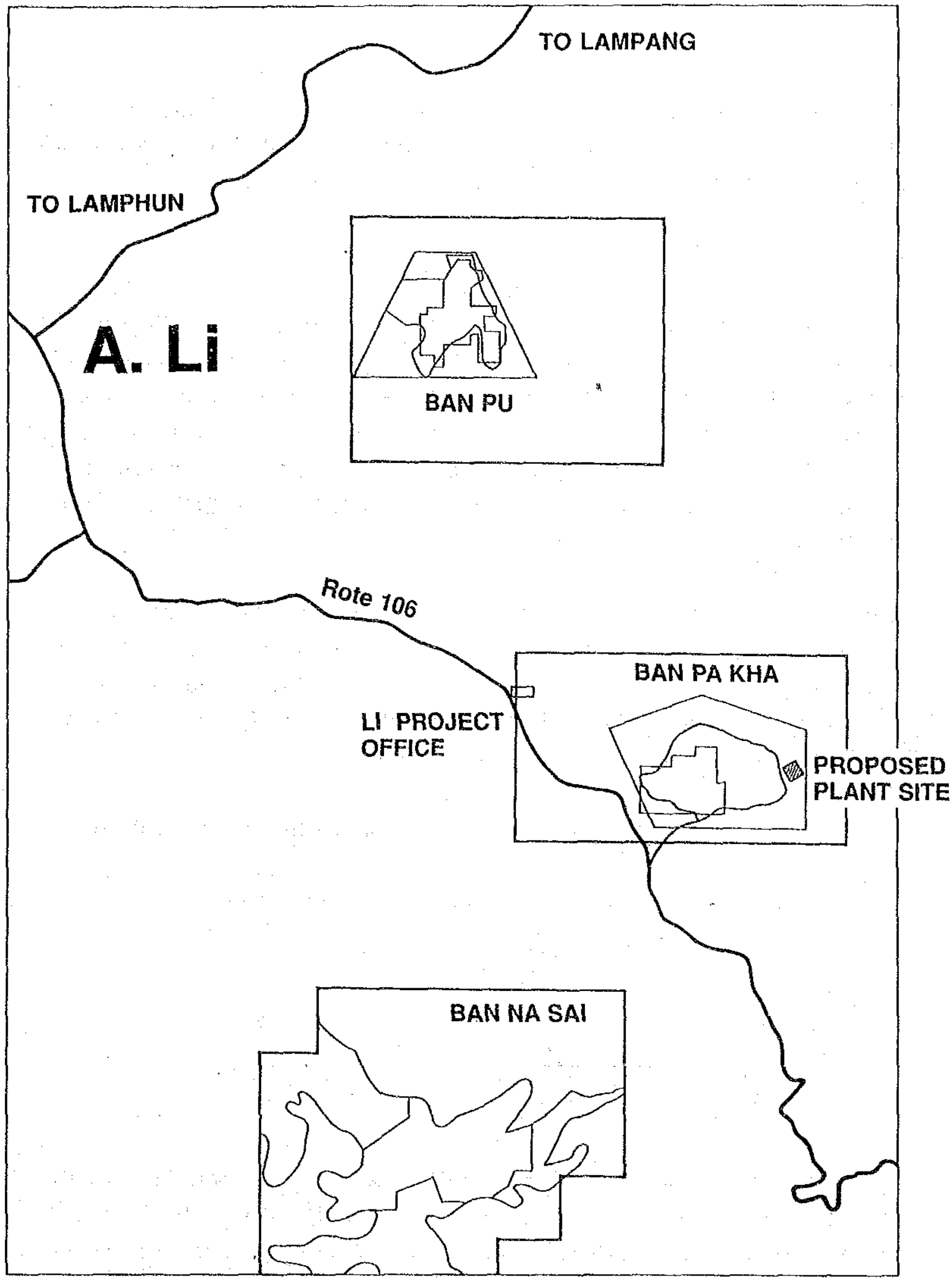


Figure 8-3 Location Map of Plant Site and Surrounding Area

The road running by the selected site is also an unpaved laterite road. This road is well maintained by the mine operator and will not pose any problem to the transportation of lignite to the plants.

(2) Traffic Load

The traffic loads added to the road by this project are delivery of construction materials, machines and equipment for the construction period, collection of the raw materials and delivery of lignite briquettes, the latter two on a routine base. The construction materials, machines and equipment may be brought to the site from Bangkok and other cities without any difficulty on the highway system and the main road to the mine.

The highway system, the main road to the mine, and the access road to the project site to be built will be used for transporting all the raw materials and product except lignite. As described in the Chapter 9, the transportation volume and the required number of vehicles for the commercial plant are summarized in Table 8-6.

Table 8-6 Transportation Volume and Required Number of Vehicles

Description	Required Volume of Material (Tons/day)	Required No. of Vehicle (Number)
Lignite briquettes	177	15
Rice Straws	38	3
Slaked Lime	18	2
Sub total	233	20
Lignite	215	18

The traffic will reach the maximum at 20 trucks per day when the 50,000-tons/year commercial plant starts. The traffic load added by this project to the load of lignite transportation is not large; improvement of the road is not considered necessary.

The road in the premises of Ban Pa Kha Mine next to the plant site is not paved but well maintained by the mining contractor. As the additional traffic load by this project is only 17 trucks per day, the transportation of coal will not be disrupted and improvement of the road is not necessary.

8-2-2 Electric Power Supply

A public power line is running along the Highway Route 106 as shown in Figure 8-1. The capacity of the power line is 500 amperes at 22 kilovolts, which is sufficient to accommodate the additional consumptions by the pilot plant and the commercial plant together. Under the present conditions of power supply, the voltage drops during the hours of peak consumption, which would affect the planned round-the-clock operation of the plants. However, this problem will be resolved by installation of a new automatic stabilizer in the existing sub-station scheduled for 1992, according to the Provincial Electricity Authority (PEA). In addition, PEA will construct a new sub-station of 13 MVA at a distance of 50 kilometers from the plant site. This will improve the conditions of power supply to the plant site.

The contract operator of Ban Pa Kha Mine has laid on their own cost a branch line of a capacity of 1,000 kilowatts from the public power line to the mine along the main road. The branch line does not have enough capacity for the additional consumptions by the pilot plant and commercial plants. Accordingly, it is required to install a new branch line from the public power line to the plant site for a distance of 3 kilometers. The installation cost is estimated as below:

Installation of line, Bahts/km:	400,000
Installation of pole, Bahts/unit:	5,000
(Average pole spacing: 80 meters)	
Transformer, Bahts/unit:	437,500
Inspection, Bahts:	50,000

The electricity charges for the plant (medium manufacturing and mining 500-1,999 kW) are as follows:

Demand charge, Bahts/kW/month:	174.00
Energy charge, Bahts/kWh:	1.23

8-2-3 Water Supply and Sewage

There is no water supply and sewage system around the plant site. The Ban Pa Kha Mine receives water from the river beside the mining place through a pipe for coal washing and office use. This project can obtain 10 m^3/hour of water from the mine. As the briquetting process dose not require process water, water is used mainly for fire fighting and sanitation. One person requires about 100 liters per day for living. Therefore, the above volume is enough for the project. The fire hydrants are installed at strategic points, the plant yard and the stockyard for rice straws. Water is stored in the elevated water tank.

The sanitary waste water is treated by a simple septic tank. The sewage system has a detention basin at the outlet of the plant.

8-2-4 Telecommunication

Main cable of telephone is running along the Highway Route 106. The Ban Pa Kha Mine has a branch telephone line to the mining office along the main road to the mine like the electric line. This project can tap from this branch line. Telephone charges are as follows:

Installation of telephone, Bahts: (Including 300-meter line)	3,700
Installation of telephone line Bahts/50 meters:	350

8-2-5 Accommodation

There is no accommodation facility around the plant site except cheap self-made shacks for mining workers beside the Ban Pa Kha Mine. However, the project staff members can commute from the neighboring villages.

Chapter 9 Transportation

chapter 9 Transportation

As described in Chapter 8, the road transportation is the most advanced transportation system in Thailand. In addition, the conditions around the plant site are satisfactory; there is no need to improve the existing infrastructure to enable this project to use the road transportation system. This view was confirmed by the observation by the study team on conditions surrounding the plant site. The result of the field survey and the subsequent study have further confirmed that all the raw materials and lignite briquettes could be transported best by truck.

9-1 Transportation of Raw Materials

The following three materials have been selected as raw materials for lignite briquettes: (1) Lignite, (2) Rice straws, and (3) Slaked lime.

The transportation of the raw materials is divided into the following two kinds:

(1) The transportation of the raw materials from the places of procurement to the stockyard in the plant site,

(2) The transportation of the raw materials from the stockyard to the respective feeders of the briquetting plant, this type of transportation being hereinafter referred to as "Site Transportation."

9-1-1 Lignite

(1) Transportation from Mine

Lignite will be supplied from the Ban Pa Kha Mine, an open-cut mine adjacent to the plant site. The mine is of a capacity of 200,000 tons per year, equipped with the mining facilities well maintained by the mining contractor. The distance from the mine to the stockyard is about 0.5 kilometers. The mine may be considered as a very dependable source of lignite.

The pilot plant will feed 3,177 tons of lignite per year and the commercial plant 52,950 tons. Lignite is usually transported by the buyers' trucks, because the mining contractor does not provide transportation. Therefore, this project needs to own a dump truck for transporting lignite, one each for the pilot plant and for the commercial plant. As the dump trucks can use the existing facility of the mine for quick loading of lignite and can unload it quickly without using manual labor, a 12-ton dump truck can make 15 to 20 shuttle trips between the mine and the plant in a day. Table 9-1 shows the amounts of lignite to be transported.

Table 9-1 Transportation of Lignite

	Pilot Plant	Commercial Plant
Required Lignite, tons/year	3,177	52,950
Transportation Volume, tons/day/truck	216	216
Required Transportation Period, day	15	245

Note:	Operation days for transportation, days/year	300
	Loading capacity of a truck, tons	12
	Number of shuttles by a truck, times/day	18

The pilot plant and commercial plant will require 15 and 245 days per year respectively for transportation of lignite using one dump truck. Therefore, one dump truck, Dump Truck (A), will be purchased at the start of the pilot plant and another, Dump Truck (B), at the start of the commercial plant. The dump truck (A) can also be used for the transportation of rice straws and lignite briquettes to the wholesalers or depots.

(2) Site Transportation

The pilot plant and the commercial plant feed about 450 kilograms and 7.3 tons per hour of lignite. Assuming that unskilled labor and hand carts are used, the time required for transportation is obtained under the following conditions.

Bases	
Loading speed, tons/hour/man:	1.0
Carriage:	
Weight transported, tons/trip:	0.25
Distance from stockyard to feeder, kms:	0.1
Average speed, kms/hour:	2.0
Operation and number of workers	
Loading worker, persons:	1
Carrier, persons:	1
Working hour, hours/day:	8
Shift, shifts:	3

As one trip transporting 250 kilograms of lignite to the plant mouth takes 20 minute -- 15 minutes for loading and 5 minutes for transportation --, it takes one two-man team 40 minutes to transport about 450 kilograms, the feed for one hour of operation. Therefore, manual labor will be used for the pilot plant. The commercial plant will use a wheel loader, because the volume of transportation would require a team of 9 persons if unskilled manual labor is used.

9-1-2 Rice Straws

(1) Transportation from Paddy Field

Rice straws will be obtained mainly from farmers in Lamphun Province. The pilot plant and the commercial plant will consume 738 tons per year and 12,300 tons per year, respectively. Rice straws are harvested in two seasons; once from May to June from the second crop and again from November to December from the major crop. In this area, single cropping growing only during the rainy season is the rule except for the limited places where irrigation is provided. Rice straws can be stored on the paddy fields during the dry season of nine months starting from November to July when the paddy field should be ready for planting. Therefore, they can be procured and transported to the plant site during these 9-month period. The bulk density of rice straws is 123 kg/m^3. A six-wheel truck with a loading capacity of 12 tons can load an average of two tons of rice straws. Temporary workers living around the places of collection of rice straws are employed for loading. As an average distance of transportation is about 50 kilometers, it is possible to transport 4 tons of rice straws by making two trips a day. The transportation of rice straws is summarized below.

Table 9-2 Transportation of Rice Straws

	Pilot Plant	Commercial Plant
Required Rice Straws, tons/year	738	12,300
Transportation Volume, tons/day/truck	4	4
Required Transportation Period, day	185	3,075
Required Number of Trucks, number	1	14

Note: Operation days for transportation, days/year 225
Loading capacity of a truck, tons 15 m^3

Under the above conditions, the pilot plant needs 185 days per year for transportation of rice straws by the truck, the Truck (A) mentioned before. For the commercial plant; however, it is not economical to possess and operate 14 trucks, because they will be used only for nine months a year. Therefore, transportation is consigned to local freighters.

(2) Site Transportation

The pilot plant and the commercial plant will require 103 kilograms and 1.7 tons per hour of rice straws, respectively. Rice straws are cut on arrival at the plant into several centimeters long by primary crushers placed on the stockyard. The time required to transport the cut rice straws to the plant mouth by manual labor is obtained as shown below.

Bases
Loading speed, tons/hour/man: 1.0
Carriage
Weight transported, tons/trip: 0.1
Distance from stockyard to feeder, kms 0.1
Average speed, kilometers/hour: 2.0
Operation and number of workers
Loading worker, persons: 1

Carrier, persons:	1
Working hour, hours/day:	8
Shift:	3

One trip carrying 0.1 tons of rice straws takes 6 minutes for loading and 6 minutes for carriage, or totally 12 minutes. As the pilot plant needs 1.03 tons per hour of rice straws, one trip an hour is enough. Therefore, the labors working for the transportation of lignite could transport rice straws, too. For the commercial plant, the wheel loader utilized for lignite is used.

9-1-3 Slaked Lime

(1) Transportation from Lime Kilns

As described in Chapter 7, slaked lime can be obtained from a couple of lime kilns located in Tak Province. The pilot plant and the commercial plant will require 0.92 and 15.32 tons per day, respectively. Therefore, the pilot plant will need one truck-load of slaked lime every 13 days. As slaked lime is sold as a commercial commodity and shipped by lime kilns, the plant needs not to provide transportation. The transportation cost is included in the selling price. The transportation of slaked lime is summarized in Table 9-3.

Table 9-3 Transportation of Slaked Lime

	Pilot Plant	Commercial Plant
Required Slaked Lime, tons/year	276	4,600
Transportation Volume, tons/day/truck	12	12
Required Transportation Period, day	23	383
Required Number of Trucks, number	0.08	1.3

Note: Operation days for transportation, days/year 300

(2) Site Transportation

The pilot plant and the commercial plant need 38.3 and 638 kilograms per hour of slaked lime, respectively. For the pilot plant, One two-man team, Team (A), will be occupied for 52 minutes -- 40 minutes for lignite and 12 minutes for rice straws -- per hour. Therefore, Team (A) can hardly handle additional load. Another two-man team, Team (B), will be assigned to the site transportation of slaked lime. Team (B) will also be used for miscellaneous works. At the commercial stage, Team (B) will be fully employed for the site transportation of slaked lime.

9-2 Lignite Briquettes

As will be discussed in Chapter 17, the principal role of the pilot plant is to produce lignite briquettes in a small quantity to be used for the development of the market. The target market area is located in Central Region, with Bangkok in the center, where deforestation is in its worst state. Lignite briquettes may partly be sold in Northern Region near the plant site whenever demanded. The product lignite briquettes will mainly be transported in bulk by truck from the plant to the target market in Central Region at the pilot plant stage, and to the Regional Energy Centers of NEA and wholesalers at various places at the stage of commercial plant. The lignite briquettes will be re-packed in small bags by the wholesalers or retailers.

Lignite briquettes are stored in storage silos and dumped directly into the trucks. The pilot plant project has a truck of its own for transporting a portion of lignite briquettes in order to facilitate the development of the market and for transporting the raw materials as described in 9-1. The transportation of the rest of lignite briquettes will be consigned to local transportation companies. It takes two days to make a round trip from the plant site to the market in Central Region near Bangkok, a distance of about 1,400 kilometers. As Truck (A) mentioned before will be used for the transportation of the raw materials for 200 days a year, the truck will transport lignite briquettes for the remaining 100 working days. The transportation of lignite briquettes for the pilot plant is summarized below.

Own transportation	12 tons x 100/2 trips =	600 tons
Consignment	12 tons x 200 trips =	2,400 tons
Total		3,000 tons

For the commercial plant, transportation of the entire product will be consigned to local transportation companies. The target market area will be decided as a result of the market promotion activities. Figure 9-1 shows hauling distances from the plant site to major cities.

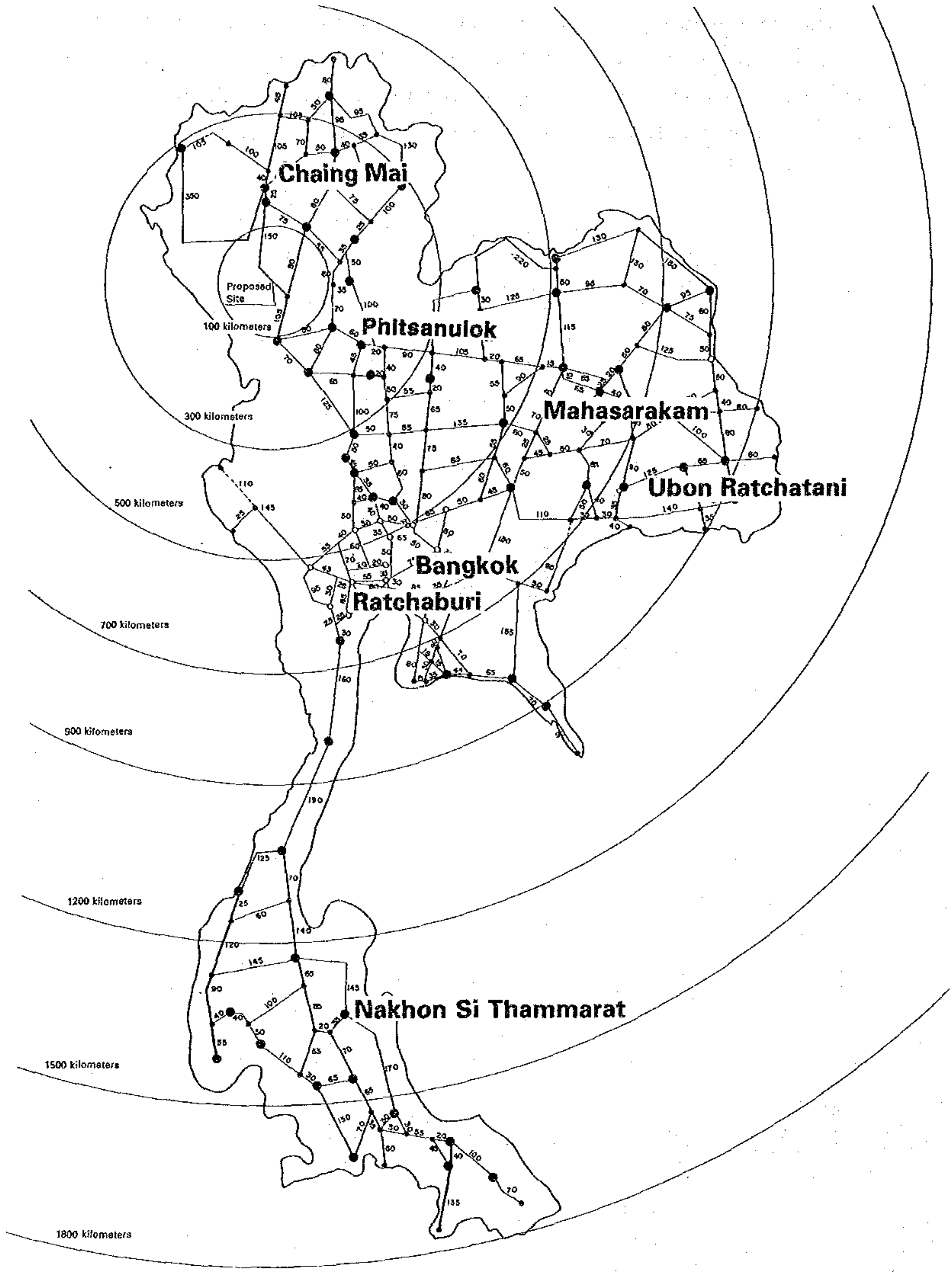


Figure 9-1 Hauling Distance

9-3 Summary of Transportation

Table 9-4 summarizes the modes of transportation obtained as a result of the analysis for the pilot plant and the commercial plant.

Table 9-4 Summary of Transportation

	Pilot Plant	Commercial Plant
Lignite Rise Straws Slaked Lime	Truck (A) Truck (A) Contract	Truck (B) Contract Contract
Lignite Briquettes	Truck (A) and Contract	Contract

Truck (A) will serve on the schedule shown below:

	(days)
Lignite	15
Rice straws	185
Lignite Briquettes	100
Total	300

9-4 Transportation Cost

9-4-1 Pilot Plant

(1) Lignite and Rice Straws

In the case of the pilot plant, lignite and rice straws are transported by the above-mentioned Truck (A). Loading and unloading works for rice straws need to employ ten labors. The transportation costs are estimated as below.

Annual Transportation Cost for Lignite (Unit: Bahts/year)

Dump truck (A)		
	BT 1,784,000 /6 years x 15/300 =	14,867
Driver	BT 4,500 x 1 person x 12 months x 15/300 =	2,700
Fuel	BT 8.2/lit x 1km /5 km/lit x 18 trips/day x 15 days =	443
Total		18,010

Annual Transportation Cost for Rice Straws (Unit: Bahts/year)

Dump truck (A)		
	BT 1,784,000 /6 years x 185/300 =	183,356
Driver	BT 4,500 x 1 person x 12 months x 185/300 =	33,300
Fuel	BT 8.2/lit x 100km /5 km/lit x 2 trips/day	
	x 185 days =	60,680
Loading and unloading		
	BT 100 x 10 persons x 185 days =	185,000
Total		462,336

Note: (1) Truck
Depreciation: 6 years
Fuel consumption: 5 kilometers/liter

(2) Distance and frequency of transportation
Lignite: 1 kilometer, 15 days/year
Rice straws: 100 kilometers, 185 days/year

Therefore, transportation costs per one ton of products are 6.0 Bahts for lignite and 154.1 Bahts for rice straws.

(2) Slaked Lime

As the selling price of slaked lime includes the transportation cost from lime kilns to the project site except for the cost of unloading work, calculation of the transportation cost is not necessary here. The cost for unloading is given in 9-4-3, Site Transportation.

9-4-2 Commercial Plant

(1) Lignite

In the case of the commercial plant, lignite is transported by the above-mentioned dump truck (B). The transportation cost is calculated as shown below.

Annual Transportation Cost for Lignite (Unit: Bahts/year)

Dump truck (B)		
	BT 1,784,000 /6 year =	297,333
Driver	BT 4,500 x 1 person x 12 months =	54,000
Fuel	BT 8.2/lit x 1km /5 km/lit x 18 trips/day	
	x 245 days =	7,232
Total		358,565

Note: Depreciation of the truck: 6 years
Fuel consumption: 5 kilometers/liter

(2) Rice Straws

As rice straws will be collected locally and brought to the site during the nine months from January through to July and November to December, local freighters will be used. The cost for transportation for short distance within Lamphun Province is 1,000 Bahts per one trip. Annual transportation cost is calculated below.

Annual Transportation Cost for Rice Straws (Unit: Bahts/year)

Consigned cost		
	BT 1,000 x 3,075 days x 2 trips/day =	6,150,000
Loading/unloading cost		
	BT 100 x 10 persons x 3,075 =	3,075,000
Total		9,225,000

Unit transportation cost per one ton of product is estimated at 184.5 Bahts.

(3) Slaked Lime

As the selling price of slaked lime includes the transportation cost, it is not necessary to calculate the transportation cost here.

9-4-3 Site Transportation

Lignite and rice straws will be transported from the stockyard to the plant inlet by manpower, Team (A), and a wheel loader in the case of the pilot plant and the commercial plant, respectively, as explained before. Slaked lime is transported by Team (B). Each team will consist of two workers. The mode of site transportation is summarized in Table 9-5.

Table 9-5 Summary of Site Transportation

	Pilot Plant	Commercial Plant
Lignite	Team (A)	Wheel Loader (A)
Rise Straws	Team (A)	Wheel Loader (A)
Slaked Lime	Team (B)	Team (B)

Annual costs of site transportation are estimated as shown below.

Annual Transportation Cost for Rice Straws	(Unit: Bahts/year)
Pilot Plant	
Lignite and Rice Straws	
BT 2,500 x 2 person x 12 months =	60,000
Slaked Lime	
BT 2,500 x 2 person x 12 months =	60,000
Total	120,000
Commercial Plant	
Lignite and Rice Straws	
Wheel Loader	
BT 2,800,000 / 6 year =	466,667
Operator	
BT 4,500 x 12 months =	54,000
Total	520,667

9-4-4 Lignite Briquettes

(1) Pilot Plant

The target market for the pilot plant will be located in Central Region, with Bangkok in its center, where deforestation is in its worst state. Lignite briquettes will be transported partly by Truck (A) and partly by consignment to local transportation companies. The distance from the plant site to Bangkok is about 1,400 kilometers for a round trip, it takes two days for one trip. As transportation cost of lignite from the Ban Pa Kha mine to Central Region by local transportation companies is 300 Bahts per ton. The annual transportation cost for lignite briquettes for pilot plant is estimated as below.

Annual Transportation Cost for Lignite Briquettes

(Unit: Bahts/year)

1. Own Transportation		
Dump Truck		
	BT 1,784,000 / 6 years x 100/300 days =	99,111
Driver	BT 4,500 x 2 persons x 12 months x 100/300 days =	36,000
Fuel	BT 8.2/lit x 1,400 km/ 5 km/lit x 50 trips =	114,800
Sub-total		249,911
2. Consignment		
	BT 300/ton x 12 ton x 200 trips =	720,000

(2) Commercial Plant

The lignite briquettes produced by the commercial plant will be transported entirely by consignment to local transportation companies. Annual transportation cost to Bangkok is estimated as below.

BT 300/ton x 50,000 tons = BT 15,000,000

The transportation costs from the plant site to the Regional Energy

Centers of NEA and local wholesalers at various places by local transportation companies are estimated as given below. These figures are not based on actual records but estimates given by a local transportation company in Chiang Mai, because of the transportation of lignite to these destinations being not actually done.

Destination	Bahts/ton
Nakhon Si Thammarat	900
Chaing Mai	160
Ratchaburi	380
Rangsit	350

Chapter 10 Project Shceme

Chapter 10 Project Scheme

10-1 Purpose of the Project Scheme

The project scheme defines the project in terms of capacity of the pilot plant, plant site, kinds of the raw materials used, quality of the product, process scheme and facilities, kinds of utility 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. 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 and also of 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 second-stage studies.

10-2 Capacity of the Pilot Plant

The nominal capacity of the pilot plant is set at 3,000 tons per year based on the operation days of 300 per year and 24 hours a day on a three-shift operation. The 3,000-ton-per-year capacity is considered sufficient for the purpose of market development. The pilot plant itself is not financially feasible; in other words, the pilot plant will not produce a profit but incur a loss. The larger is the capacity, the larger is the loss. Naturally, a larger capacity and hence larger investment in the pilot plant would put a heavier financial burden on the subsequent commercial plant to pay for it. For a smaller capacity of around 1,000 tons per year or less, the modification of the existing bench-scale plant at Rangsit mentioned in Chapter 17 would meet the purpose.

10-3 Selection of the Plant Site

It is recommended that the pilot plant be located on a relatively flat piece of land on a corner of the premises of the Ban Pa Kha Mine of NEA, at the opposite side of the planned pits across the main road connecting the mine to the main highway. This is the only vacant lot available in the premises of the Ban Pa Kha mine. The site has attributes required of the plant site.

The proposed site is not used now; according to NEA, there is no specific plan for the use of this area. The site is a low mound with an elevation of less than five meters, bordered by a ditch along the road, a brook on the mountain side, a paddy field and what seems a temporary playground on the other sides. The site has an area in excess of 40,000 square meters considered necessary for the pilot plant and a commercial plant with a capacity of 50,000 tons per year, including an area needed for stockpiling the raw materials. Trees grow sparsely with undergrowth covering the soil.

The selected site is immediately accessible from the main road to the mine. The electricity needed for the pilot plant and one commercial plant may be tapped from the existing 22 KVA line laid overhead along the Highway Route 106. The branch line to the plant will be installed for a distance of about three kilometers along the existing line to the mine. The existing line along the highway has an enough capacity for the forecast consumption by the future operation of the mine plus those for the pilot plant and the commercial plant. Presently, the mine suffers from a drop of voltage during the hours of peak consumption in the evening which necessitates use of its own generator. It was confirmed with the Provincial Electricity Authority that this problem will be resolved in 1992 by installation of an automatic voltage stabilizer in the existing sub-station. In addition, according to PEA, a new sub-station will be constructed at a distance of 50 kilometers from the proposed site. A telephone line could also be branched from the existing one at the plant gate. A maximum of ten cubic meters per hour of water could be supplied from the mine. The process of manufacturing lignite briquettes is essentially a dry process and this amount of water will be enough.

This area is normally free from typhoons and earthquakes. The brook and ditch bordering the site and the few meters of elevation above the surroundings would make the site immune to inundation even in case of heavy downpours.

The soil is apparently of hard laterite with a high bearing strength. The coal washing plant which started in 1991 close to the selected site did not need piling for the foundations of the heaviest pieces of equipment; this may be considered to attest to the rigidity of the formations. Although digging to a certain depth is necessary, dispensing with piling works would be a great economic advantage.

The raw materials and products, and construction materials and equipment, will be transported by truck on the main road to the site. There is no such things as bridge or tunnel which may restrict traffic of heavy or long vehicles.

From the point of view of pollution prevention, the proposed site is ideally located. The site is well apart from the residential area. The noise that the machines would generate and the smoke from the furnace would not be a nuisance to any third party. The plant will not produce industrial waste water.

There is one farm house on the edge of the selected site. This house needs to be relocated.

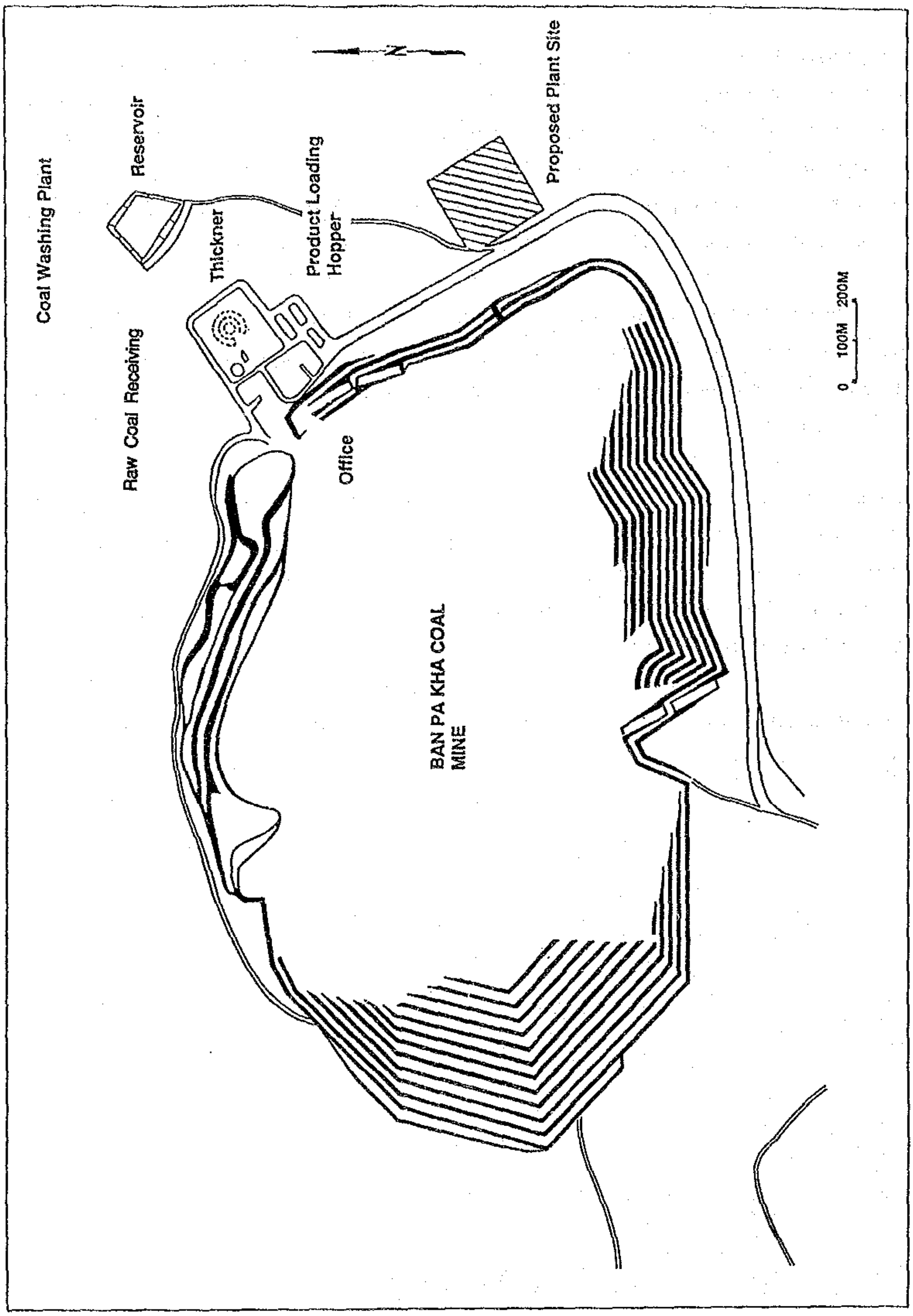


Figure 10-1 Location of the Plant

10-4 Raw Material

The raw materials to the pilot plant will be the high-quality lignite of the Ban Pa Kha mine, rice straws and slaked lime. At the stage of pilot plant when the consumption of biomass is not very large, the pilot plant would be able to obtain a portion of bagasse which is presently effectively used as fuel for the sugar mill, raw material for paper manufacture and that for an organic fertilizer. Since the pilot plant is to be a precursor to a number of commercial plants to follow in the future, the biomass raw material should be the one considered standard for these commercial plants, which is rice straws with its large resource and ready availability.

The conceptual design of the pilot plant calls for the following amounts of raw materials:

Table 10-1 Raw Material Requirement

(Unit: tons per ton of lignite briquettes)

Raw material	Raw material base	Feed base	Ratio
Lignite	1.059	0.682	75.0
Rice straws	0.246	0.227	25.0
Slaked lime	0.092	0.091	10.0
Total	1.397	1.000	

Assumptions on moisture contents, wt%, used for the calculation.

Lignite	30.0
Rice straws	15.0
Slaked lime	1.0

The rice straws are normally well dry with a moisture content close to 10 percent. A shelter will be provided to house rice straws to prevent them from wetting during the rainy season.

As Chapter 7 explains, there will expected to be sufficient supplies of lignite, rice straws and slaked lime. The minimum heat content of lignite meeting the requirement of the product higher than 4,000 kcal/kg is calculated to be 4,639 Kcal/kg.

10-5 Quality of Product

The quality standard of the lignite briquettes, or quality design, was first tentatively set up at the closing stage of the first-phase field survey of the first-stage study reflecting the lifestyles and cooking habits of the ordinary Thai people. This quality design was modified during the second-phase field survey of the first-stage study, or monitoring survey, in consideration of the responses of the potential consumers obtained during the demonstration of the experimentally produced lignite briquettes and also of the performance of the bench-scale plant. The revised quality design was achievable by the operation of the bench-scale plant using the the Thai raw materials: the Ban Pa Kha lignite, rice straws and slaked lime.

However, during the survey to obtain information about promotion of lignite briquettes, it was pointed out that the reduction, or elimination if possible, of the smoke and soot would facilitate promotion of lignite briquettes. 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 lignite briquettes which may, strictly speaking, vary from one lot to another. Therefore, there is no denying the possibility of the smoke or soot containing one or more substances that are known to have adverse effects upon the health. This question of the effect of the smoke and soot upon the health would be very elusive, because the entire range of the composition of smoke and soot can hardly be represented by several runs of experiments.

The best solution to this problem is to make the lignite briquettes smokeless and this could only be done at the manufacturing stage. Accordingly, reduction of smoke has been added to the required quality of the lignite briquettes.

The operation conditions for reducing smoke were successfully found by an additional series of experimental production. The results of the experiments are incorporated in the manufacturing scheme.

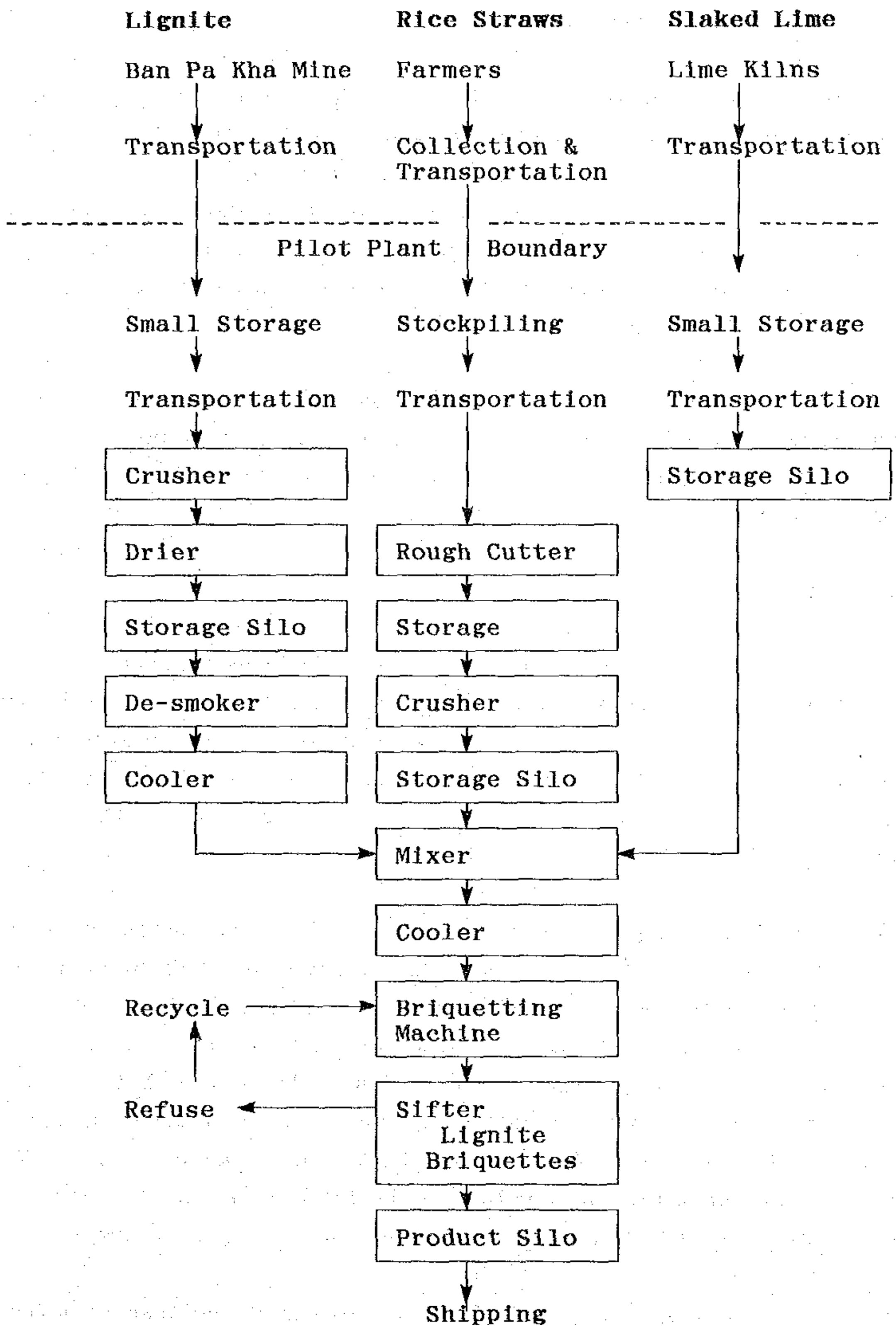


Figure 10-2 Manufacturing Flow

10-6 Manufacturing Scheme and Facility

A simplified manufacturing flow is schematically shown in Figure 10-2 omitting such facilities as conveyers, hoppers, bag filters, hot air generators, devices to control the flows, etc. The manufacturing flow consists of three flows: lignite, rice straws and slaked lime flows, down to the mixer. A facility to remove smoke from lignite, de-smoker, is installed. The gas generated from the de-smoker is used as fuel for de-smoker; the exhaust heat is utilized to dry lignite.

There will be shelters on manufacturing facilities and storage area of rice straws. An office room will be provided. There will be a control room where instruments and meters for essential operating conditions and simple pieces of testing equipment are provided.

10-7 Infrastructure and Utility

There is no need to improve infrastructure for the construction or operation of the pilot plant, or subsequent commercial plant. All the project will have to do is to lay an access road from the main road leading to the mine and build a small bridge over the ditch along the main road, and to branch a telephone line from the existing line running along the road.

The conceptual designs of the pilot plant and the 50,000-ton-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. A receiving unit will be installed at the plant gate. A power line will be laid between the branch on the main and the receiving unit, over a distance of 3,000 meters. The main along Highway Route 106 has a capacity of 22 KVA which is sufficient for the supplies to the pilot plant and the commercial plant. The plants will not have their own power generators.

The consumption of water is limited to cooling of the bearing boxes, fire-fighting, drinking, hygienic use and cleaning. The process for manufacturing lignite briquettes is a dry process and does not use process water. Bottled water will be purchased for drinking purpose. A cistern of 10 cubic meters will be provided in the site to maintain pressure. A pipe will be installed from the mine to the pilot plant for receiving water.

Pneumatic air will be provided by running a compressor as required. Compressed nitrogen gas will be purchased if required. The de-smoking uses its own gas as heat source and the effluent from the furnace is used for drying the lignite.

10-8 Organization

It is assumed that a public corporation will be created under NEA to own and operate the pilot plant, and perhaps, one or two 50,000-ton-per-year commercial plants to be built subsequent to the pilot plant. The organization for the operation of the pilot plant is proposed as follows:

Table 10-2 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 10-3. The plant manager and the 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.

Table 10-3 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	4	
Guard	Contract	0	
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	

10-9 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 will be incorporated to facilitate small onstream maintenance works.

10-10 Inventory of Raw Material and Product

The inventories of the raw materials, product and spareparts represent fixation of capital and therefore a financial burden; however, without appropriate amounts of the inventories smooth operation of the plant is not possible. Because of the immediate proximity of the pilot plant to the mine, the inventory of lignite can be minimized.

In the area near the pilot plant, single cropping of rice is a rule except where irrigation and drainage facilities are well provided. The production of rice straws In Lamphun Province and Northern Region in 1990 is estimated as shown in Table 10-4. These amounts are well in excess of the requirements by the pilot plant and a 50,000-tons-per-year commercial plant. However, the collection of rice straws would become difficult when the rice fields begin to be used for growing; therefore, 30 days are allowed for rice straws.

Table 10-4 Harvest of Rice Straws (1990)

(Unit: 1,000 tons)

	Rice Production	Rice Straws Production
Lamphun Province		
Major Rice	114	227
Second Rice	14	28
Total	128	255
Northern Region		
Major Rice	5,471	10,944
Second Rice	807	1,613
Total	6,278	12,557

For slaked lime, steady supply throughout the year is possible; therefore, a working inventory is enough. The following inventories are proposed:

Table 10-5 Inventory of the Raw Materials

(Unit: days)

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

10-11 Transportation

The transportation of the raw materials to the stock area in the pilot plant premises -- lignite, rice straws and slaked lime -- and that of the product to the market will be by truck. The railroad will not be used. The railway system of Thailand does not cover the nation well enough; uneconomical transshipment would be unavoidable if the railways are used. At the pilot plant stage, the raw materials will be transported from the stock yard to the plant mouth by manual labor with handcart. A truck loader will be used for this purpose for the commercial plant.

10-12 Commercial Plant

As is mentioned in Chapter 2 and explained more in detail in Chapter 15, the investment in the pilot plant is justified in part in terms of possibility of being paid out by a commercial plant. It is assumed therefore that a typical commercial plant of a minimum viable capacity will be installed following the pilot plant. The commercial plant is defined as follows:

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

10-13 Project Schedule

The following overall schedule is proposed for the pilot plant.

Table 10-6 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

Before the construction actually can start, NEA will need some time to study the project, establish the public corporation, go through the government proceedings to get the project approved, and to procure the funds.

Figure 10-3 Overall Project Schedule