# FEASIBILITY STUDY REPORT ON THE SMOKELESS COAL BRIQUETTES DEVELOPMENT PROJECT IN THE ISLAMIC REPUBLIC OF PAKISTAN

## (SUMMARY)

JANUARY, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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# CONTENT

## INTRODUCTION

This is the summary version of the feasibility study report on the SMOKELESS COAL BRIQUETTES PROJECT IN THE ISLAMIC REPUBLIC OF PAKISTAN. The purpose of this summary version is to give a concise outline of the feasibility study report without going into details. For details the readers are requested to refer to the full report submitted to Pakistan Mineral Development Corporation, PMDC, together with this summary version.

The purpose of this feasibility study is to investigate the feasibility of a government-sponsored plan for establishing a coal briquette plant at Lakhra to produce coal briquettes of good quality that could substitute for kerosene and, if possible, firewood, and to present appropriate recommendations regarding implementation if the project is found feasible. This project has particular importance in the context of balance of payments problem, because a large sum of foreign exchange is spent for the importation of kerosene and the consumption of kerosene is forecast to increase.

Broadly speaking, the study consists of a market study, social study, technical study and financial and economic evaluations. The market study played an instrumental role in determining the capacity of the plant and the price of coal briquettes. The social study looked into the availability and prices of the main and subordinate raw materials, and conditions of infrastructure and public utility. The technical study covered process and mechanical aspects. The process study included experimental production of coal briquettes from the local raw materials and their burning test to determine the optimum blending ratios of the raw materials and the process best suited to the planned coal briquettes. The study on the mechanical aspect included, in addition to the design of the manufacturing facilities and estimation of the cost, evaluation of the capability of promising local constructors, machine manufacturers and engineers. As part of the technical study, designs of stoves ideal for burning the coal briquettes were developed. The financial and economic evaluations assessed the project regarding the financial feasibility and economic feasibility of the the project, the latter being a national and social benefits and costs analysis.

In accordance with the agreement between Pakistan Mineral Development Corporation (PMDC) and the Japan International Cooperation Agency (JICA), this feasibility study was executed in two stages: the first-stage study from March to June and the second-stage from June to December 1988. The first-stage study examined the market aspect and was completed with the presentation of Interim Report to PMDC in June; the second-stage study immediately succeeded the first-stage study given that good prospect of market feasibility was confirmed. The second-stage study was a techno-economic study comprising all aspects, with the exception of the market study, which normally make up an industrial feasibility study. This feasibility study report includes not only the results of the second-stage study but the market study, with some corrections made to the previous submission.

The scope of work did not define the project except that the main raw material would be the Lakhra coal and (an) appropriate kind(s) of biomass would be blended. It was up to this feasibility study to make recommendations as to the size of the project, i.e., initial capacity of the manufacturing plant and subsequent expansions, quality of the product, kinds of raw materials and their blending ratios, processing scheme, location of the plant, strategy for marketing the product, the system of management, and the price structure. The first-stage study, or market study, determined the desired quality of the coal briquettes, forecast the demand of the coal briquettes, and developed the price of the coal briquettes. The second-stage investigated all techno-economic aspects of the project. The results of the first-stage study were reviewed and corrected as necessary in the light of the results obtained from the second-stage study.

Three cases of the capacity were developed: Case 1, Case 2 and Case 3. Case 1 supposes that the plant will always be run at 100 percent capacity. Case 2 will be run not at full capacity but with some allowance for increasing production in case the demand suddenly increases. Case 3 assumes continuation of the present subsidy on kerosene. Cases 1, 2 and 3 are further divided into Cases 1A, 2A and 3A and Cases 1B, 2B and 3B; Cases with A presume use of imported washing and mixing/briquetting facilities for the initial plant while Cases with B will use all domestically produced machines. Case 1A shows sound financial feasibility; therefore, this feasibility study evaluates Case 1A of this project as worth promoting and presents recommendations regarding the effective methods of its implementation.

# CHAPTER 1 PROJECT SUMMARY

The major findings of this feasibility study are as follows:

1. The following cases were established for study.

| | Capacity, tons/year | | Facility | |
|---|---|---|---|---|
| Case | Initial | Ultimate | Washing plant Mixing/Briquetting | Others |
| Case 1A | 50,000 | 300,000 | imported | domestic |
| Case 1B | 50,000 | 300,000 | domestic | domestic |
| Case 2A | 100,000 | 300,000 | imported | domestic |
| Case 2B | 100,000 | 300,000 | domestic | domestic |
| Case 3A | 50,000 | 300,000 | imported | domestic |
| Case 3B | 50,000 | 300,000 | domestic | domestic |

2. Plant location

A flat piece of land close to the mine office near the operating shafts located about 1.5 kilometers from the main road running through Lakhra Coal Mine, 80 kilometers to the northwest of Hyderabad, Sind Province. The site is in Lease No. 88. The exact location is indicated in Figure 1-1.

3. Raw material requirement

The following materials are finally selected; the requirement of the raw materials per ton of coal briquettes are also indicated.

| | |
|---|---|
| Lakhra coal | |
| Feed | 1.250 |
| Fuel | 0.373 |
| Bagasse | 0.325 |
| Slaked lime | 0.0625 |
| Slack wax | 0.006 |
| Light oil | 0.044 |

4. Process scheme

The process scheme proposed is shown in Figure 1-2, Process Scheme. As a result of studies on advantages and disadvantages of washing coal for removing ash and sulfur, washing was included in the process. The rest of the process consists of drying coal and bagasse, crushing them into a fine powder, adding slaked lime to neutralize sulfur, briquetting them under a heavy pressure, and coating them with wax and oil to make them water-resistant.

5. Quality of product

The quality level was first set by the market survey so that the introduction of the coal briquettes would not affect the cooking practices of the common people. The target quality includes easy ignition, strong flame, smokelessness, odorlessness, safety, easy control, water-resistance and physical strength. In consideration of the economic disadvantages associated with complete removal of smoke, it was decided to tolerate a small amount of smoke during the initial period of combustion. The fact that the cooking places of the traditional houses are semi-open structures which permit smoke to dissipate to outside was taken into account. Also by the experimental production of coal briquettes and their burning test it has been established that by adding an appropriate amount of slaked lime it is possible to suppress the formation of irritating sulfur dioxide gas at the consuming ends.

6. Market area and price structure

The variable price system in which the consumers price reflects the cost of transportation is proposed; in other words, the farther away the market is from the plant and higher the transportation cost, the higher is the market price of the coal briquettes. The southern part of the country which initially had been considered as the main market proved not to be promising. It was found instead that, the area as far as Punjab or even beyond, where population density is high and people are relatively wealthy, could be counted on as a market. In this case the cost of transportation is high and the market price should include this cost in the first place. The consumers price of the coal briquettes is set at 70 percent of the forecast consumers price of kerosene for the initial four years and is unchanged for the rest of the project on real term basis.

7. Demand

The nationwide demand of coal briquettes is estimated as shown in Table 1-1.

**Table 1-1 Nationwide Demand of Coal Briquettes**

| Year | Coal Briquette Demand(thousand tons/year) |
|---|---|
| 1990 | 124 |
| 1991 | 135 |
| 1992 | 148 |
| 1993 | 161 |
| 1994 | 176 |
| 1995 | 192 |
| 1996 | 227 |
| 1997 | 269 |
| 1998 | 318 |
| 1999 | 378 |
| 2000 | 446 |
| 2001 | 493 |
| 2002 | 545 |
| 2003 | 602 |
| 2004 | 665 |
| 2005 | 735 |
| 2006 | 812 |

8. Plant capacity

Assuming the project will supply 40 percent of the nationwide demand, the following schedule for expansion is planned.

**Table 1-2 Plant Capacity**

| Year | Capacity installed (thousand tons/year) | | | Production | | | Operation rate Percent | | |
|---|---|---|---|---|---|---|---|---|---|
| Case | 1 con | 2 opt | 3 sub | 1 con | 2 opt | 3 sub | 1 con | 2 opt | 3 sub |
| 1989 | - | - | - | - | - | - | - | - | - |
| 1990 | - | - | - | - | - | - | - | - | - |
| 1991 | - | - | - | - | - | - | - | - | - |
| 1992 | 50 | 100 | 50 | 50 | 52 | 50 | 100 | 52 | 100 |
| 1993 | 50 | 100 | 50 | 50 | 57 | 50 | 100 | 57 | 100 |
| 1994 | 50 | 100 | 50 | 50 | 62 | 50 | 100 | 62 | 100 |
| 1995 | 75 | 100 | 50 | 75 | 68 | 50 | 100 | 68 | 100 |
| 1996 | 75 | 100 | 50 | 75 | 81 | 50 | 100 | 81 | 100 |
| 1997 | 100 | 150 | 50 | 100 | 96 | 50 | 100 | 64 | 100 |
| 1998 | 100 | 150 | 50 | 100 | 113 | 50 | 100 | 75 | 100 |
| 1999 | 100 | 150 | 100 | 100 | 134 | 100 | 100 | 89 | 100 |
| 2000 | 150 | 200 | 100 | 175 | 158 | 100 | 100 | 80 | 100 |
| 2001 | 150 | 200 | 100 | 175 | 180 | 100 | 100 | 90 | 100 |
| 2002 | 200 | 300 | 100 | 175 | 203 | 100 | 100 | 68 | 100 |
| 2003 | 200 | 300 | 200 | 175 | 230 | 200 | 100 | 77 | 100 |
| 2004 | 250 | 300 | 200 | 300 | 260 | 200 | 100 | 87 | 100 |
| 2005 | 250 | 300 | 200 | 300 | 293 | 200 | 100 | 98 | 100 |
| 2006 | 300 | 300 | 300 | 300 | 300 | 300 | 100 | 100 | 100 |

Note
con: Conservative
opt: Optimistic
sub: Kerosene subsidy remaining

9. Capital requirement

The capital requirement of the first 50,000-ton plant is estimated is follows:

**Table 1-3 Summary of Total Capital Requirement**

Unit: 1,000 yen and 1,000 Rs.

| | Case 1A, 3A | | Case 1B, 3B | |
|---|---|---|---|---|
| | Yen | Rs. | Yen | Rs. |
| Plant construction cost | 264,024 | 99,838 | 10,737 | 108,868 |
| Pre-operating expenses | 72,000 | 5,976 | 48,000 | 5,976 |
| Initial working capital | 18,396 | 10,462 | 0 | 12,228 |
| Interest during construction | 63,461 | 1,196 | 8,765 | 2,888 |
| Total | 417,881 | 117,472 | 67,502 | 129,960 |

10. Project feasibility

Table 1-4 shows ROI and ROE obtained as a result of the financial evaluation.

**Table 1-4 Summary of ROI and ROE**

| | Case 1 | | Case 2 | | Case 3 | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| ROI before tax | 18.5 | 20.4 | 16.0 | 17.4 | 19.5 | 21.8 |
| ROI after tax | 12.3 | 13.7 | 10.5 | 11.5 | 14.4 | 16.3 |
| ROE before tax | 17.4 | 22.8 | 7.7 | 16.7 | 14.4 | 22.4 |
| ROI after tax | 11.2 | 16.7 | N.R. | 11.4 | 8.3 | 17.7 |

11. Operation

Coal briquette plant

| | |
|---|---|
| Days per year | 300 |
| Hours per day | 24 |

Washing plant

| | |
|---|---|
| Days per year | 300 |
| Hours per day | 6.9 |

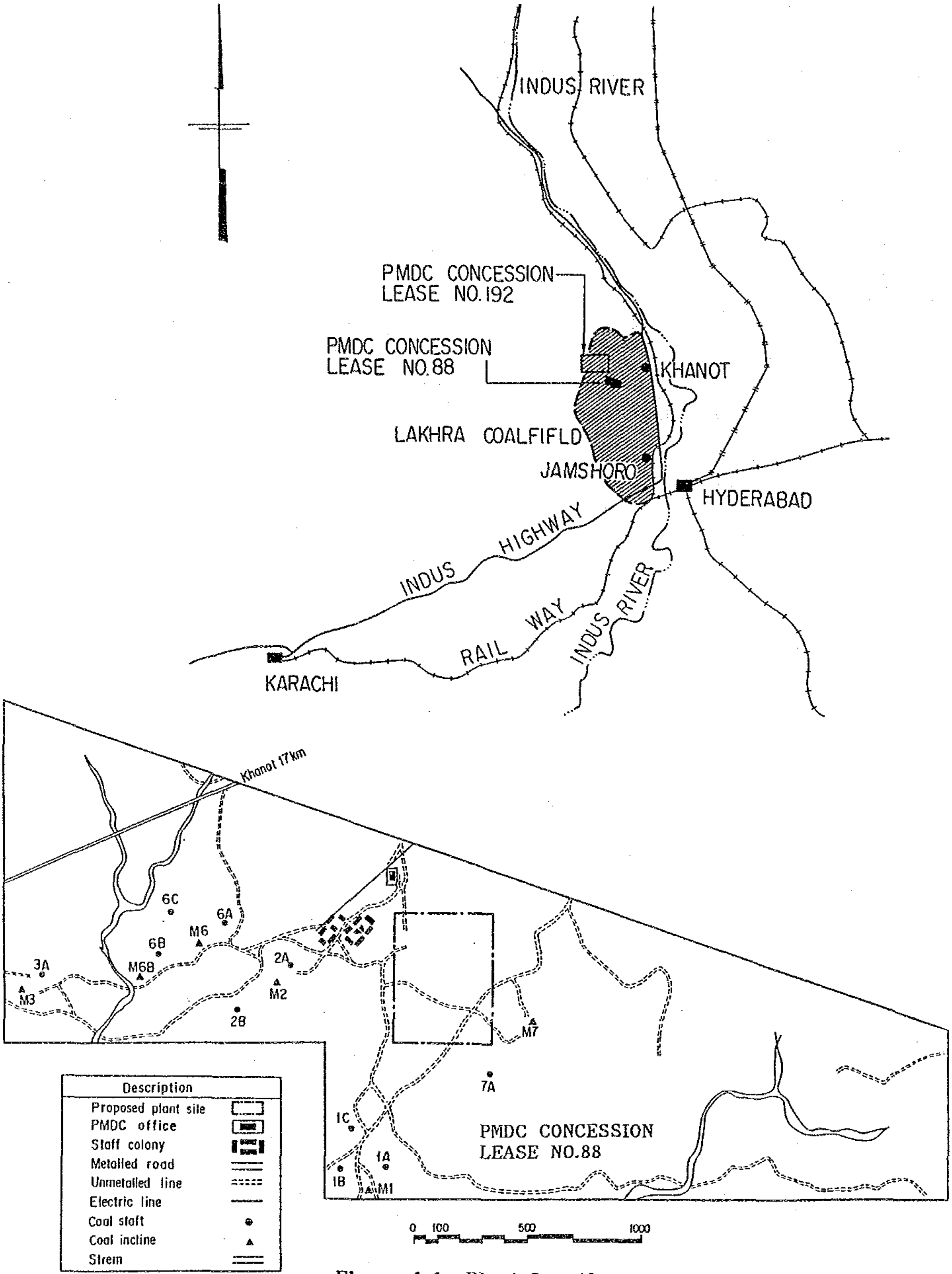



Figure 1-1 Plant Location

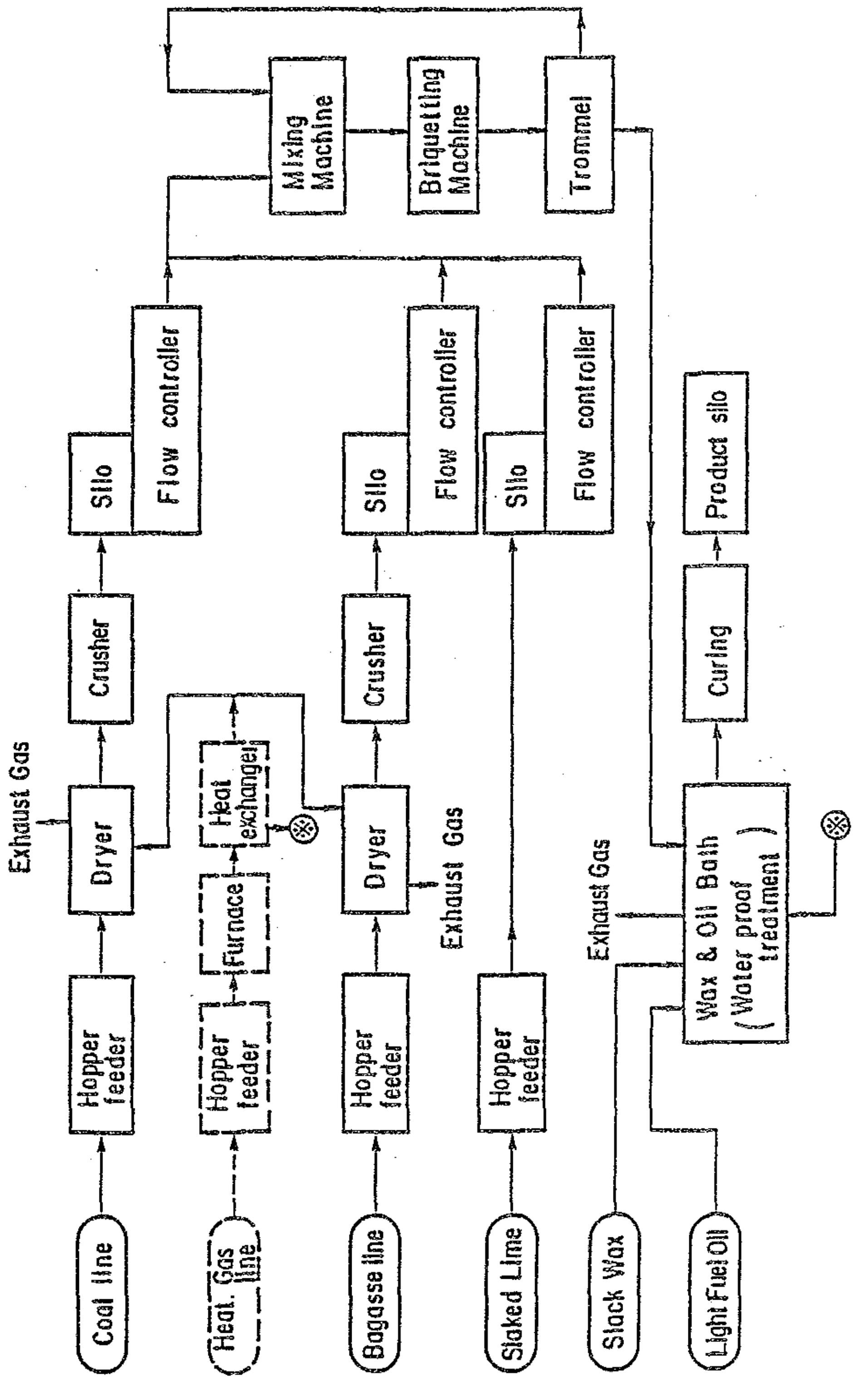



Figure 1-2 Process Scheme

Figure 1-2 Process Scheme

## CHAPTER 2 BACKGROUND

### 2-1 Energy Situation

#### 2-1-1 Pattern of Consumption

Pakistan is not richly endowed with underground energy resources. Table 2-1 gives the proven reserves of petroleum and natural gas and estimated reserves of coal.

**Table 2-1 Fossil Energy Endowment**

| | | | Oil Equivalent million tons |
|---|---|---|---|
| Petroleum | 139.4 | million barrels | 18.8 |
| Natural gas | 16,070 | billion cubic feet | 405 |
| Coal | 510 to 1,180 | million tons | 708 |
| Total | | | 1,132 |

Note: For coal the larger extreme is taken to calculate the total.

Source: Energy Year Book 1986

Against such endowment of the reserves, the past consumption of fossil commercial energy is as shown in Table 2-2.

**Table 2-2 Consumption of Fossil Commercial Energy**

(thousand ton oil equivalent)

| Year | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 |
|---|---|---|---|---|---|---|
| Petroleum products | 4,367 | 4,847 | 5,514 | 6,100 | 6,615 | 7,057 |
| Natural gas | 5,955 | 6,591 | 6,632 | 6,641 | 7,026 | 7,226 |
| Coal | 1,577 | 1,750 | 1,609 | 1,869 | 2,238 | 2,202 |
| Total | 11,898 | 13,188 | 13,755 | 14,610 | 15,878 | 16,485 |

Source: Energy Year Book 1986

Note: Metric ton is used for petroleum products.
Imported metallurgical coal is excluded.

The economy of Pakistan depends largely on petroleum and natural gas. Further, it is obvious from the comparison between Tables 2-1 and 2-2 that the consumption of fossil commercial energy does not follow the patterns of resource endowment.

### 2-1-2 Household Energy

The consumption of non-commercial energy is still predominantly large on one hand but the consumption of kerosene has been very rapidly increasing recently on the other as shown in Table 2-3.

**Table 2-3 Household Energy Consumption**

(thousand ton oil equivalent)

| Year | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 |
|---|---|---|---|---|---|---|
| Kerosene | 599 | 650 | 754 | 828 | 882 | 969 |
| Natural gas | 562 | 664 | 755 | 875 | 995 | 1,071 |
| Electricity | 767 | 893 | 1,079 | 1,208 | 1,391 | 1,620 |
| Coal | 10 | 10 | 10 | 7 | 6 | 3 |
| Non-com. Energy | | | | | 8,962 | |

Source: Energy Year Book 1987 and 1985

Note: Electricity is indicated in primary input which is to be multiplied by 0.3422 to obtain end consumption.

Any further increase of the supply of non-commercial energy is not expected in view of the severely depleted forest resources. The government has also decided to promote effective utilization of coal hitherto used almost entirely for baking bricks; a plan to install a 50 megawatt coal-fired power station has been almost decided. Further, the Sixth Five Year Plan explicitly mentions a plan to install at strategic locations plants to produce coal briquettes from domestic coal for household consumption.

## 2-2 History of the Feasibility Study

To cope with the situations above, PMDC, in line with the grand policy of the government, had been conducting research experiments for the production of smokeless coal briquettes using its coal briquette plant in Quetta.

Against such a background, the government of Pakistan filed a request with the government of Japan for cooperation in the form of a feasibility study on manufacturing coal briquettes for household consumption based on Lakhra lignite. Japan produces of its own technology various types of coal briquettes ; therefore, Japan was able to properly respond to the request of Pakistan. The government of Japan sent a preliminary survey team of Japan International Cooperation Agency (JICA) to Pakistan from November 30 to December 9, 1987 to conduct necessary surveys and to have talks with the government officials of Pakistan. The preliminary survey team of JICA concluded the mission by agreeing with PMDC, the counterpart agency, and the Ministry of Petroleum and Natural Resources on SCOPE OF WORK (S/W).

As agreed on S/W this study has been conducted in two stages; the first-stage study specializing in studying feasibility of marketing and the second-stage study in techno-economic investigation. The first-stage study started in March and ended with the presentation of Interim Report in June of 1988.

## 2-3 Method of Study

### 2-3-1 First-stage Study

The first-stage study aimed at establishing market feasibility of coal briquettes was concluded by the presentation of the Interim Report which bridged the first- and second-stage studies. This project aims to produce coal briquettes mainly to replace household kerosene and firewood. Therefore, the demands and prices of kerosene and firewood for household consumption had to be forecast at first; the forecast of the demand was done by means of simplified econometric methods using as parameters GDP, population, household number, and elasticity of the increase of household energy consumption with respect the growth of GDP per household. Since there is little room for further increase of the supplies of firewood and other biomass fuels, it was assumed that most of the increase in demand will have to be met by kerosene. In parallel with this demand study, supply possibility of kerosene was studied. By combining the demand-side study and supply-side study, the future demands of kerosene was developed as a function of assumed growth rate of GDP. The price of kerosene was derived from the forecast crude oil price and the phasing out of the incentive price now given to kerosene.

In addition to this, the price of coal briquettes at the market as a function of transportation cost from the plant was calculated using assumed raw coal cost, transportation cost obtained during the field survey and assumed manufacturing cost plus some margin of profit for the operation. Pakistan was divided into five zones in the order of increasing cost of transportation; different prices of coal briquettes were developed for these zones.

The next question was the forecast demands of competitive fuels, kerosene or firewood, for each zone and to what extent the competitive fuels may be expected to be replaceable by the coal briquettes. The approach to this question required estimation of the demands of the competitive fuels for each zone. This was done by first estimating the population that burns kerosene and firewood in each zone and then by distributing the forecast nationwide demand of kerosene and firewood to each zone in proportion to the population. In the estimation of the demand for each zone those who would be served by city gas were not counted and the effect of winter temperature on space heating demand was considered.

The extent the competitive fuels may be replaceable by coal briquettes were determined in terms of percentage of coal briquette price on the prices of competitive fuels.

Regarding the distribution and marketing, the existing organizations of demonstrated capability were examined; PMDC' rock salt dealers, PMDC' coal dealers, PSO's kerosene dealers, and free merchants including firewood/charcoal dealers were examined; some of them were actually interviewed for evaluation of their capability and confirmation of interest in the business. Existing marketing practices of PMDC for marketing rock salt and coal were studied for this project's marketing strategy: PMDC sells these products ex-mine; in other words, the dealers command distribution and marketing, promote sales, finance their operations and come to PMDC with the transportation they arrange. The fact that PMDC does not maintain and operate a large organization required for marketing was also considered.

### 2-3-2 Second-stage Study

The field survey started on June 16 with the arrival in Pakistan of the members of the second-stage study team.

The information and data concerning raw material availability and cost, plant site condition, infrastructure, public utility, local cost data, local equipment and materials, conditions of inputs to financial evaluation and economic evaluation, etc. were collected. Visit to the project site for observation and collection of the raw material samples and air-freighting them to the test site in Japan was an important assignment for the field survey. Unfortunately, the study team was unable to visit the project site because of the civil unrest that occurred in that area during the field survey period. The first-hand observation of the project site the study team intended to get by the visit to the site had to be supplemented by information and data collected in Karachi and Islamabad. In addition to Islamabad and Karachi the study team visited Quetta to see the PMDC' existing coal briquette plant.

The information and data obtained were analyzed and evaluated with the counterparts while they were being collected. An important key step for the second-stage study is establishment of the project scheme which was done in two steps, first, at the closing stage of the field survey for drawing the tentative project scheme, and second, in the stage of the home-office work for drawing the definitive project scheme. A series of discussions were held between the counterpart and the study team to establish a common understanding about the tentative project scheme. The project scheme actually defines the project in terms of all the constraints surrounding the project, policy of the government and the promoter, economic and technical consideration, etc. The process to arrive at the project scheme is elaborated in Chapter 8, PROJECT SCHEME of the full report.

The samples of Lakhra coal, bagasse, wheat straw, cotton seed oil extraction residue, limestone, slaked lime and cement were collected by PMDC in necessary amounts and sent to the Japanese test site. At the Japanese test site all the samples were tested for chemical and physical properties. The coal samples were first tested for amenability to coal washing operation the purpose of which is reduction of ash and sulfur. The raw coal and washed coals were subjected to briquetting experiments with the subordinate raw materials to establish ranges of compositions in which coal can be briquetted into hard solids. Within such a range, the recommended composition was determined mainly from a techno-economic standpoint and availability constraints of the raw materials. After the recommended composition had been finalized, conceptual design of the plant and associated facilities was carried out.

By that time the local cost data, prices of locally procured equipment and materials, and also inputs to the financial evaluation had been analyzed and the program for financial evaluation developed. The costs of investment and operation based on the conceptual design were estimated. The total capital requirement was calculated using the estimated capital investment and financial inputs. Financial and economic evaluations were done on the profits and benefits against the investment and costs. The overall evaluation was passed on the project from various angles: technical constraints, raw material availability, results of financial and economic evaluation, contribution to the nation and society, compliance with the policy of the government, etc. Based on all those, appropriate recommendations were presented to help realize the maximum benefit from the project and to facilitate smooth implementation.

# CHAPTER 3 ENERGY SITUATION

The previous chapter already mentioned the fossil energy endowment, their consumption and the pattern of the household energy consumption. This chapter explains the present state of coal utilization and forecast of kerosene demand for household consumption only.

## 3-1 Coal Utilization

The reserves of coal varies greatly depending upon sources of information. ENERGY YEAR BOOK, 1986, gives the following three estimates:

**Table 3-1 Coal Reserves in Pakistan**

(million metric tons)

| Source | Measured | Proven | Indicated | Inferred | Total |
|---|---|---|---|---|---|
| M/S Chemical Consultant | 84.70 | | 149.80 | 528.60 | 763.10 |
| M/S IEDC Consultant | | 102 | 1,076 | | 1,178 |
| Geological Survey | | 102 | 217 | 289 | 508 |

Source: ENERGY YEAR BOOK, 1986

The production in 1985/86 registered 2.2 million tons and the production has been increasing at an annual rate of 6.9 percent for the past five years. The consumption of coal as shown in Table 3-2 shows a very peculiar pattern unique to this country. Nearly all the domestic production of coal has been used for brick burning; in other words, coal has not been properly used as industrial fuel, fuel for power generation or household purposes. It is noted from this table that the increase in coal utilization is accounted for almost exclusively by the increase in brick-burning coal.

**Table 3-2 Sectorial Consumption of Coal**

(thousand metric ton)

| SECTOR | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 |
|---|---|---|---|---|---|---|
| Power | 31 | 2 | 33 | 24 | 32 | 26 |
| Brick Kiln | 1,517 | 1,715 | 1,546 | 1,811 | 2,174 | 2,148 |
| Domestic | 8 | 23 | 22 | 22 | 16 | 14 |
| Other Gov't | 21 | 10 | 8 | 13 | 15 | 13 |
| Total | 1,577 | 1,750 | 1,609 | 1,869 | 2,238 | 2,202 |

Source: ENERGY YEAR BOOK, 1986

Against such a background and given the large reserves of coal in Lakhra area and the foreign currency problem associated with the importation of increasing amount of petroleum, it is natural that the government should encourage promotion of coal utilization. The government of Pakistan is planning to install a series of thermal power plants that burn coal.

## 3-2 Demand Forecast of Kerosene and Firewood

The growth of the consumption of kerosene as household fuel in the past few years is tremendous as shown in Table 3-3.

**Table 3-3 Consumption of Kerosene**

| Year | Consumption | | |
|---|---|---|---|
| | Household | | Total |
| | (ton) | (%) | |
| 1980/81 | 516,958 | 97.79 | 528,652 |
| 1981/82 | 543,720 | 98.23 | 553,496 |
| 1982/83 | 593,887 | 98.31 | 604,114 |
| 1983/84 | 678,987 | 98.40 | 690,036 |
| 1984/85 | 748,426 | 98.53 | 759,555 |
| 1985/86 | 800,449 | 98.68 | 811,194 |

Source ENERGY YEAR BOOK, 1986

The domestic consumption of kerosene is almost entirely for household use which has increased at an annual rate of 9.14 percent; firewood on the other hand, although the estimated consumption is ten times that of kerosene, is not given much consideration. The coal briquettes are to replace portions of kerosene and firewood; therefore their demands and prices are forecast first. The demand of kerosene for household consumption was forecast as a function of GDP growth rate by an econometric method mentioned in 2-3-1.

**Table 3-4 Growth of Kerosene Demand vs GDP Growth Rate**

| Growth rate of GDP | 6.5 | 5.0 | 4.0 | 3.0 |
|---|---|---|---|---|
| 1989 | 1,709 | 1,709 | 1,709 | 1,709 |
| 1990 | 1,935 | 1,876 | 1,853 | 1,809 |
| 1995 | 3,596 | 2,993 | 2,780 | 2,402 |
| 2000 | 6,683 | 4,775 | 4,171 | 3,191 |
| 2005 | 12,421 | 7,618 | 6,256 | 4,238 |
| 2006 | 14,060 | 8,364 | 6,785 | 4,485 |
| %/year | 11.32 | 9.79 | 8.45 | 5.84 |

Apart from the simplified econometric analysis, a simple projection is made based on the past record. Starting from the consumption in 1985 of 800.4 thousand tons of kerosene the projection is made to 2006 on 9.14 percent per year, which is the growth rate of kerosene consumption from 1980 to 1985. The result of this operation is shown in Table 3-5.

**Table 3-5 Demand of Kerosene by Projection**

| | thousand tons |
|---|---|
| 1989 | 1,136 |
| 1990 | 1,239 |
| 1995 | 1,919 |
| 2000 | 2,971 |
| 2005 | 4,601 |
| 2006 | 5,021 |

### 3-2-2 Supply Study

Here supply possibility is analyzed. Since kerosene and aviation fuels are almost identical in quality, both products compete with each other for supply. Tables 3-6 and 3-7 show respectively the supply and consumption of kerosene and aviation fuel for the past five years.

**Table 3-6 Supply of Kerosene Fraction**

(thousand tons)

| | PRODUCTION | | | | | | | | | IMPORT | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kerosene | | | | Aviation fuel | | | | Ttl | Kero | A | |
| | A | P | N | T | A | P | R | T | | | | |
| 1980 | 43 | 26 | 100 | 169 | 4 | 330 | 206 | 540 | 709 | 377 | 2 | 1,088 |
| 1981 | 41 | 38 | 132 | 211 | 7 | 304 | 201 | 512 | 723 | 352 | 4 | 1,078 |
| 1982 | 36 | 70 | 135 | 241 | 9 | 279 | 180 | 468 | 709 | 390 | 2 | 1,065 |
| 1983 | 26 | 83 | 149 | 258 | 15 | 290 | 169 | 474 | 732 | 411 | 0 | 1,143 |
| 1984 | 60 | 148 | 99 | 307 | 20 | 277 | 166 | 463 | 770 | 489 | 2 | 1,261 |
| 1985 | 105 | 87 | 107 | 299 | 19 | 304 | 170 | 493 | 792 | 492 | 4 | 1,288 |

Note: A; Attock Refinery, Ltd. P; Pakistan Refinery Ltd.
N; National Refinery Ltd. T; Subtotal

**Table 3-7 Consumption of Kerosene Fraction**

| | Kero | JP-1 | Av.fuel | Total |
|---|---|---|---|---|
| 1980 | 529 | 218 | 316 | 1,063 |
| 1981 | 553 | 187 | 320 | 1,060 |
| 1982 | 604 | 143 | 330 | 1,077 |
| 1983 | 690 | 125 | 341 | 1,156 |
| 1984 | 760 | 113 | 346 | 1,219 |
| 1985 | 811 | 126 | 373 | 1,310 |

Source: ENERGY YEAR BOOK 1986

The following could be said from the above tables:

(1) The supply and consumption figures are in agreement within the accuracy of statistics.

(2) The production of kerosene fraction, or total of kerosene and aviation fuel reached 16.5 percent of crude in 1985, which is considered the maximum yield from the crude oil Pakistan is processing. In other words, the domestic production has

already reached the maximum; any further increase of supply must come from refinery expansions and import.

The future supply is estimated as shown in Table 3-8. This could be considered maximum because the refinery expansion and import are incorporated to the maximum extent.

**Table 3-8 Supply Possibility of Kerosene Fraction**

| | Supply possibility | | | | Consumption | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| 1989 | 792 | 628 | | 1,420 | 150 | 388 | 538 | 882 |
| 1990 | 792 | 669 | 672 | 2,133 | 150 | 396 | 546 | 1,587 |
| 1995 | 792 | 916 | 1,007 | 2,715 | 150 | 444 | 594 | 2,121 |
| 2000 | 792 | 1,255 | 1,679 | 3,726 | 150 | 497 | 647 | 3,079 |
| 2005 | 792 | 1,720 | 2,015 | 4,527 | 150 | 557 | 707 | 3,820 |
| 2006 | 792 | 1,832 | 2,015 | 4,527 | 150 | 570 | 720 | 3,807 |

(1) Production from the existing capacity
(2) Maximum allowable import assumed to increase at the rate of GDP growth, 6.3% for 1989/85 and 6.5% for 1989/2006
(3) Production from increased capacity, assumed as follows:
 1990: a new 100,000 BPSD refinery onstream, kerosene fraction yield at 16.0 percent
 1995: a new hydrocracker added to the new refinery increasing the kerosene yield to 24.0 percent
 2000: a new 100,000 BPSD refinery onstream
 2005: a new hydrocracker added
(4) (1)+(2)+(3)
(5) JP-1 production assumed from the past record
(6) Aviation fuel assumed to increase at the past trend
(7) (5)+(6)
(8) (4)-(7) Maximum allowed for kerosene consumption

In view of these supply constraints, the increase of supply as indicated by the result of the econometric method would not be very feasible. It would be possible to increase the amount of importation of kerosene faster than GDP grows; however, in the light of the result of supply possibility analysis one should be more conservative about the supply of kerosene than the econometric analysis indicates. For this reason in the forecast of the demand of coal briquettes, the result of the simple projection shown in Table 3-5, which gives a far smaller forecast than the econometric method, is used.

### 3-2-3 Consumers Price of Various Fuels

The present prices of common fuels were investigated during the field survey by means of interviews; the results are summarized in Table 3-9.

**Table 3-9 Current Consumer Price of Fuel**

| | | Rs/MMBTU | US$/MMBTU |
|---|---|---|---|
| Kerosene | 3.5 Rs/liter | 101.25 | 5.59 |
| | 4.5 Rs/liter | 130.18 | 7.19 |
| Firewood | | | |
| Hala | 16.0 Rs/40kg | 30.24 | 1.67 |
| Islamabad, Hyderabad | 26.0 Rs/40kg | 49.14 | 2.71 |
| Quetta | 35.0 Rs/40kg | 66.15 | 3.65 |
| Lahore | 40.0 Rs/40kg | 75.60 | 4.17 |
| City gas | 18.0 Rs/MCFT | 18.36 | 1.01 |
| | 27.0 Rs/MCFT | 27.55 | 1.52 |
| Electricity | 0.5 Rs/kwh | 146.46 | 8.09 |
| Charcoal | 50.0 Rs/40kg | 43.62 | 2.41 |
| | 80.0 Rs/40kg | 69.79 | 3.85 |
| Burner fuel | 1980.0 Rs/ton | 48.55 | 2.68 |

Source: Interviews, Energy Year Book 1986

Note: Heat of combustion used in the above calculation:
Kerosene 19,600 Btu/lb; Specific gravity 0.800
Firewood 6,000 Btu/lb
City gas 980 Btu/SCF
Charcoal 13,000 Btu/lb
Burner fuel 18,500 Btu/lb
Conversion rate 1US$=Rs18.11
1 lb=0.4536 kg
1 kwh=3414 Btu

For some fuels different prices were obtained from one place to another depending upon the use; for such cases various prices are shown.

These prices are converted into equivalent prices of coal briquettes of this project; the representative experimentally produced sample has a heat of combustion of 5,381 Kcal/kg.

**Table 3-10 Consumer Price of Fuels in Coal Briquette Equivalent**

| | | Rs/MMBtu | Rs/ton |
|---|---|---|---|
| Kerosene | 3.5 Rs/liter | 101.25 | 2,183 |
| | 4.5 Rs/liter | 130.18 | 2,807 |
| Firewood | | | |
| Hala | 16.0 Rs/40kg | 30.24 | 652 |
| Islamabad, Hyderabad | 26.0 Rs/40kg | 49.14 | 1,059 |
| Quetta | 35.0 Rs/40kg | 66.15 | 1,426 |
| Lahore | 40.0 Rs/40kg | 75.60 | 1,630 |
| City gas | 18.0 Rs/MCFT | 18.36 | 396 |
| | 27.0 Rs/MCFT | 27.55 | 594 |
| Electricity | 0.5 Rs/kwh | 146.46 | 3,158 |
| Charcoal | 50.0 Rs/40kg | 43.62 | 940 |
| | 80.0 Rs/40kg | 69.79 | 1,505 |
| Burner fuel | 1980.0 Rs/ton | 48.55 | 1,047 |

Table 3-10 gives an indication of the prices of coal briquettes at which coal briquettes become equivalent with other fuels in the price of heat at the consumers end.

### 3-2-4 Forecast Kerosene and Firewood Price

The future price of kerosene is forecast from correlations between the price of imported crude oil and the prices of petroleum products, and further from the correlation between the price of kerosene and other petroleum products. It is also assumed that the subsidy price now given to kerosene will be phased out in accordance with information from interviews conducted during the field survey. The result of the forecast is shown in Table 3-11.

**Table 3-11 Forecast Kerosene and Firewood Prices**

(1988 price)

| Year | Imported_Crude $/BBL | Rs/ton | Oil_Products Rs/ton | Kerosene Rs/ton | Firewood Rs/40kg |
|---|---|---|---|---|---|
| 1980/85 1) | 30.1 | 2,765 | 4,051 | 3,457 | |
| 1989 | 19.0 | 2,519 | 3,691 | 2)4,375 | 7)32.0 |
| 1990 | 19.5 | 2,585 | 3,787 | 3)4,489 | 7)32.8 |
| 1995 | 22.0 | 2,916 | 4,272 | 4)5,915 | 7)37.0 |
| 2000 | 26.0 | 3,447 | 5,050 | 5)7,691 | 7)43.8 |
| 2005 | 28.5 | 3,779 | 5,537 | 6)8,433 | 7)48.0 |

Note: Crude oil specific gravity 0.8591

Conversion rate: 1 US$=Rs18.11

1) See next page

2) 3.5 Rs/liter at consumers end converted into 4,375 Rs/ton using specific gravity of kerosene as 0.800

3) 4,375x3,787/3,691=4,489

4) Subsidy on kerosene is assumed to be lifted.
4,272/3,787x4,489x1.168=5,915

| | | |
|---|---|---|
| ex-refinery price of kerosene | 2.14340 Rs/liter |
| ex-refinery price of HDO | 2.62923 Rs/liter |
| specific gravity of kerosene | 0.800 |
| specific gravity of HDO | 0.840 |

(2.62923/2.14340)x(0.800/0.840)=1.168

5) Normally, kerosene should be 10 percent higher than LDO.
5,050/4,272x5,915x1.1=7,691

6) 5,537/5050x7,691=8,433

7) Assumed to increase in proportion to petroleum product price starting from Rs.30.0/40kg in 1989.

Table 3-12 shows past relationship among the prices of imported crude oil, average prices of petroleum products and kerosene prices.

**Table 3-12 Prices of Crude Oil, Products and Kerosene**

| | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 |
|---|---|---|---|---|---|---|
| (1)Crude price million US$ | 994.74 | 1,139.30 | 989.23 | 916.41 | 842.72 | 602.00 |
| (2)Crude volume 1,000 M.T. | 4,041 | 4,396 | 4,186 | 4,294 | 4,028 | 3,797 |
| (3)Average price US$/M.T.(1)/(2) | 246.2 | 259.2 | 236.3 | 213.4 | 209.7 | 158.6 |
| (4)Average price Rs/M.T. | 2,437.4 | 2,566.1 | 2,953.8 | 2,902.2 | 3,145.5 | 2,585.2 |
| (5)Av.prod.price Rs/M.T. | 3,543 | 3,480 | 3,982 | 4,292 | 4,472 | 4,536 |
| (6)Kerosene price Rs/M.T. | 3,087 | 3,086 | 3,395 | 3,395 | 3,704 | 4,074 |

AVERAGE CRUDE, PRODUCTS, AND KEROSENE PRICES

| | | | |
|---|---|---|---|
| Crude price | 30.1 $/BBL | 220.3$/ton | 2,765 Rs/ton |
| Average product price | | | 4,051 Rs/ton |
| Average kerosene price | | | 3,457 Rs/ton |

### 3-2-5 Assumption of Kerosene Subsidy to Remain

Along with the forecast prices of kerosene shown in Table 3-11, the prices of kerosene are forecast assuming the subsidy on kerosene price to continue. The operation of forecasting the prices is shown in Table 3-13.

**Table 3-13 Forecast Kerosene and Firewood Prices**

(1988 price)

| Year | Imported Crude | | Oil Products | Kerosene | Firewood |
|---|---|---|---|---|---|
| | $/BBL | Rs/ton | Rs/ton | Rs/ton | Rs/40kg |
| 1980/85 1) | 30.1 | 2,765 | 4,051 | 3,457 | |
| 1989 | 19.0 | 2,519 | 3,691 | 2)4,375 | 7)32.0 |
| 1990 | 19.5 | 2,585 | 3,787 | 3)4,489 | 7)32.8 |
| 1995 | 22.0 | 2,916 | 4,272 | 4)5,064 | 7)37.0 |
| 2000 | 26.0 | 3,447 | 5,050 | 5)6,585 | 7)43.8 |
| 2005 | 28.5 | 3,779 | 5,537 | 6)7,220 | 7)48.0 |

Note: Crude oil specific gravity 0.8591

Conversion rate: 1 US$=Rs18.11

1) See next page

2) 3.5 Rs/liter at consumers end converted into 4,375 Rs/ton using specific gravity of kerosene being 0.800

3) 4,375x3,787/3,691=4,489

4) Subsidy on kerosene is assumed to remain.(See Table 3-8-4) 4,272/3,787x4,489=5,064

5) Price is increased by 10% in addition to escalation. See Table 3-8-4. 5,050/4,272x5,064x1.1=6,585

6) 5,537/5050x6,585=7,220

7) Assumed to increase in proportion to petroleum product price starting from Rs.30.0/40kg in 1989.

Since the price equivalent to the subsidy portion is not declared, the amount of subsidy is assumed to be equal to the margin margin by which kerosene is cheaper than HDO in thermal basis.

# CHAPTER 4 COAL BRIQUETTE MARKET

## 4-1 Approach to Demand Forecast

Since the coal briquettes of the planned quality are an entirely new commodity for Pakistan, there is no past consumption from which projection is made to the future. The coal briquettes are intended as a replacement for kerosene, and if possible for some fire wood. It would be logical to forecast first the demands of kerosene and firewood and estimate the degrees of replacement of kerosene and firewood by the coal briquettes next. The driving force for the replacement is economic, that is, difference in price between the conventional fuels and coal briquettes. The price of kerosene is uniform throughout the nation down to the depots; the price of coal briquettes on the other hand increases with the distance of transportation. Accordingly, the price difference, or driving force for replacement, cannot be treated uniformly throughout the nation. Under such conditions the following approach was devised and employed in this study.

1. The entire nation is divided into five zones according to the cost of transportation from the plant: Zones 1, 2, 3, 4 and 5 for less than 200, 200/300, 300/400, 400/500, and greater than 500 Rupees per ton, respectively.

2. The future demand of kerosene has to be developed for each zone. For this purpose the entire population is divided into these zone using the demographic information. Those who are served by city gas would not be users of coal briquettes; conversely, those living in the cold area would use more fuels. Adjustment is made for them. The forecast demand of kerosene developed for the entire nation is prorated to each zone in proportion to the adjusted population distribution.

3. The future prices of kerosene and firewood are separately forecast. The price of coal briquettes are set at 70 percent of the price of kerosene for the initial three

years on thermal basis in Zone 3; the prices of coal briquettes in other zones are obtained by adding to or subtracting from the price in Zone 3 the difference of transportation cost. From the fourth year on, the price of coal briquettes is not escalated on real terms.

4. The degree of replacement of the conventional fuels by coal briquettes is assumed as a function of the ratio of the difference in price between the conventional fuels and coal briquettes.

5. The above ratio is calculated for 1990, 1995, 2000, 2005 for each zone and demand of coal briquettes are calculated for each zone for each year. The demands between the above five year intervals are calculated by assuming the same growth rate. The nationwide demand of coal briquettes is calculated by summing the demands by zone. This project is assumed to fill 40 percent of the entire demand of coal briquettes in line with the government policy to install coal briquette plants at major coal field.

## 4-2 Results of Study

Figures 4-1, 4-2 and 4-3 show the transportation cost and zoning, demographic distribution, and gas route,respectively. Tables 4-1, 4-2 and 4-3 shows the population distribution among zones, the population distribution adjusted for gas users, and that adjusted for gas users and space heating.

**Table 4-1 Forecast Population and Distribution**

(unit: million)

| Year | 1985 | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|---|
| Population | 96.18 | 111.59 | 127.58 | 145.86 | 166.77 |
| Zone | | | | | |
| 1. -200 | 18.85 | 21.87 | 25.01 | 28.59 | 32.69 |
| 2. 200/300 | 10.10 | 11.72 | 13.40 | 15.32 | 17.51 |
| 3. 300/400 | 25.58 | 29.68 | 33.94 | 38.80 | 44.36 |
| 4. 400/500 | 32.12 | 37.27 | 42.61 | 48.72 | 55.70 |
| 5. +500 | 9.53 | 11.05 | 12.62 | 14.43 | 16.51 |

**Table 4-2 Forecast Non-gas Users Population and Distribution**

(unit: million)

| Year | 1985 | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|---|
| Population | 76.92 | 89.24 | 102.04 | 116.64 | 133.39 |
| Zone | | | | | |
| 1. -200 | 10.31 | 11.96 | 13.68 | 15.64 | 17.88 |
| 2. 200/300 | 10.08 | 11.69 | 13.37 | 15.29 | 17.48 |
| 3. 300/400 | 24.77 | 28,74 | 32.86 | 37.57 | 42.96 |
| 4. 400/500 | 22.23 | 25.80 | 29.50 | 33.72 | 38.56 |
| 5. +500 | 9.53 | 11.05 | 12.62 | 14.43 | 16.51 |

**Table 4-3 Forecast Population Distribution without Gas and with heating**

(unit: million)

| Year | 1985 | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|---|
| Population | 76.66 | 91.27 | 104.36 | 119.28 | 136.42 |
| Zone | | | | | |
| 1. -200 | 10.31 | 11.96 | 13.68 | 15.64 | 17.88 |
| 2. 200/300 | 10.16 | 11.78 | 13.48 | 15.41 | 17.62 |
| 3. 300/400 | 25.14 | 29.17 | 33.35 | 38.13 | 43.60 |
| 4. 400/500 | 22.57 | 26.20 | 29.96 | 34.24 | 39.16 |
| 5. +500 | 10.48 | 12.16 | 13.89 | 15.86 | 18.16 |

Table 4-4 shows the forecast demand of kerosene and firewood prorated to each zone using population distribution of Table 4-3.

**Table 4-4 Forecast Demand of Kerosene and Firewood by Zone**

| | 1985 | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|---|
| Kerosene, thousand metric ton | | | | | |
| Zone 1 | 105 | 162 | 252 | 390 | 603 |
| 2 | 103 | 160 | 248 | 384 | 594 |
| 3 | 255 | 396 | 613 | 950 | 1,470 |
| 4 | 230 | 356 | 551 | 853 | 1,321 |
| 5 | 107 | 165 | 255 | 394 | 613 |
| Total | 800 | 1,239 | 1,919 | 2,971 | 4,601 |
| Firewood, thousand metric ton oil equivalent | | | | | |
| Zone 1 | 646.2 | 709.2 | 767.6 | 830.3 | 898.1 |
| 2 | 636.7 | 698.6 | 756.4 | 818.1 | 885.1 |
| 3 | 1,575,5 | 1,729.8 | 1,871.3 | 2,024.3 | 2,190.0 |
| 4 | 1,414.5 | 1,553.7 | 1,681.1 | 1,817.8 | 1,967.0 |
| 5 | 656.8 | 721.1 | 779.4 | 842.0 | 912.2 |
| Total | 4,929.7 | 5,412.4 | 5,855.8 | 6,332.5 | 6,852.4 |

Table 4-5 shows the forecast prices of kerosene and coal briquettes on their respective marketing units and on the equal heat base.

**Table 4-5 Comparison between Forecast Kerosene and Coal Briquette Price**

(1988 price)

| | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|
| Kerosene | | | | |
| (Rs/liter) | 3.59 | 4.73 | 6.15 | 6.75 |
| (US$/MMBTU) | 5.73 | 7.55 | 9.80 | 10.78 |
| Coal Briquette | | | | |
| (Rs/ton) | 1,566 | 2,063 | 2,063 | 2,063 |
| (US$/MMBTU) | 4.01 | 5.28 | 5.28 | 5.28 |

Table 4-6 gives the difference in price between kerosene and coal briquettes in terms of percentage of kerosene price.

**Table 4-6 Percentage of Price Differentials on Forecast Kerosene Price**

| | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|
| Kerosene Zone | | | | |
| 1 | 38.9 | 36.8 | 51.3 | 55.8 |
| 2 | 34.4 | 33.5 | 48.8 | 53.4 |
| 3 | 30.0 | 30.1 | 46.1 | 51.0 |
| 4 | 25.7 | 26.6 | 43.5 | 48.6 |
| 5 | 21.1 | 23.3 | 40.9 | 46.3 |

Similarly, Tables 4-7 and 4-8 compares the forecast prices of firewood and coal briquettes and show the difference in terms of percentage.

**Table 4-7 Comparison between Forecast Firewood and Coal Briquette Price**

| | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|
| Firewood | | | | |
| (Rs/40kg) | 32.8 | 37.0 | 43.8 | 48.0 |
| (US$/MMBTU) | 3.42 | 3.86 | 4.57 | 5.00 |
| Coal Briquette | | | | |
| (Rs/ton) | 1,566 | 2,063 | 2,063 | 2,063 |
| (US$/MMBTU) | 4.01 | 5.28 | 5.28 | 5.28 |

**Table 4-8 Percentage of Price Differentials on Forecast Firewood Price**

| | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|
| Firewood Zone | | | | |
| 1 | -2.3 | -15.8 | -4.48 | 4.6 |
| 2 | -9.6 | -30.1 | -9.8 | -0.4 |
| 3 | -17.3 | -36.8 | -15.5 | -5.6 |
| 4 | -24.9 | -43.5 | -21.2 | -10.8 |
| 5 | -32.2 | -50.0 | -26.7 | -15.8 |

Table 4-9 shows the percentage rate of replacement applied to estimate the demand of coal briquettes generated as a result of price difference incentive.

**Table 4-9 Rate of Replacement versus Price Differential**

| | Replacement of Conventional Fuel,% | |
|---|---|---|
| Price Differential,% | Kerosene | Firewood |
| -60 | 0 | 0 |
| -50 | 0 | 0 |
| -40 | 0 | 0 |
| -30 | 0 | 0 |
| -20 | 0 | 0 |
| -10 | 0 | 0 |
| 0 | 5 | 5 |
| 10 | 5 | 5 |
| 20 | 10 | 10 |
| 30 | 10 | 10 |
| 40 | 15 | 15 |
| 50 | 15 | 15 |
| 60 | 20 | 20 |

Note: Negative differentials indicate that coal briquettes are more expensive than conventional fuels. To be exact, the figures are not percentage of kerosene replaced, but the demand of coal briquettes generated expressed in terms of weight percent of kerosene.

Table 4-10 shows the operation to obtain estimated demands of coal briquettes.

## Table 4-10 Forecast Coal Briquette Demand

| Zone | 1990 | | | | 1995 | | | | 2000 | | | | 2005 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | KD | PR | RR | BD | KD | PR | RR | BD | KD | PR | RR | BD | KD | PR | RR | BD |
| 1 | 162 | 38.9 | 10 | 16.2 | 252 | 36.8 | 10 | 25.2 | 390 | 51.3 | 15 | 58.5 | 603 | 55.8 | 15 | 90.5 |
| 2 | 160 | 34.4 | 10 | 16.0 | 248 | 33.5 | 10 | 24.8 | 384 | 48.8 | 15 | 57.6 | 594 | 53.4 | 15 | 89.1 |
| 3 | 396 | 30.0 | 10 | 39.6 | 613 | 30.1 | 10 | 61.3 | 950 | 46.1 | 15 | 142.5 | 1470 | 51.0 | 15 | 220.5 |
| 4 | 356 | 25.7 | 10 | 35.6 | 551 | 26.6 | 10 | 55.1 | 853 | 43.5 | 15 | 128.0 | 1321 | 48.6 | 15 | 198.2 |
| 5 | 165 | 21.1 | 10 | 16.5 | 255 | 23.3 | 10 | 25.5 | 394 | 40.9 | 15 | 59.1 | 613 | 43.6 | 15 | 92.0 |
| Total | | | | 123.9 | | | | 191.9 | | | | 445.7 | | | | 690.3 |
| **Zone** | **1990** | | | | **1995** | | | | **2000** | | | | **2005** | | | |
| | **FD** | **PR** | **RR** | **BD** | **FD** | **PR** | **RR** | **BD** | **FD** | **PR** | **RR** | **BD** | **FD** | **PR** | **RR** | **BD** |
| 1 | | | | | | | | | | | | | 898.1 | 4.4 | 5 | 44.9 |
| 2 | | | | | | | | | | | | | 885.1 | -0.4 | 0 | |
| 3 | | | | | | | | | | | | | 2190.0 | -3.6 | 0 | |
| 4 | | | | | | | | | | | | | 1967.0 | -10.3 | 0 | |
| 5 | | | | | | | | | | | | | 912.2 | -17.1 | 0 | |
| Total | | | | | | | | | | | | | | | | 44.9 |
| Grand total | | | | 123.9 | | | | 191.9 | | | | 445.7 | | | | 735.2 |

Note:
KD: kerosene demand
FD: Firewood demand
PR: price ratio
RR: rate of replacement
BD: briquette demand

Table 4-10 shows the derivation of the estimated demands of coal briquettes for Cases 1 and 2. For Case 3, a similar derivation is presented in the full report.

Table 4-11 shows the nationwide demand obtained by interpolating the demand for every five years obtained in Table 4-10 to every year. The same rate of growth is assumed within each five year interval.

**Table 4-11 Forecast Coal Briquette Demand**

| Year | Coal Briquette Demand(thousand tons/year) | |
|---|---|---|
| | Cases 1,2 | Case 3 |
| 1990 | 124 | 124 |
| 1991 | 135 | 124 |
| 1992 | 148 | 124 |
| 1993 | 161 | 124 |
| 1994 | 176 | 124 |
| 1995 | 192 | 124 |
| 1996 | 227 | 151 |
| 1997 | 269 | 185 |
| 1998 | 318 | 226 |
| 1999 | 378 | 275 |
| 2000 | 446 | 336 |
| 2001 | 493 | 385 |
| 2002 | 545 | 440 |
| 2003 | 602 | 504 |
| 2004 | 665 | 577 |
| 2005 | 735 | 660 |
| 2006 | 812 | 755 |

Table 4-12 shows the plant capacities of PMDC for Cases 1,2 and Case 3.

**Table 4-12 Plant Capacity From Market Viewpoint**

| Year | Capacity installed (thousand tons/year) | | | Production | | | Operation rate Percent | | |
|---|---|---|---|---|---|---|---|---|---|
| Case | 1 con | 2 opt | 3 sub | 1 con | 2 opt | 3 sub | 1 con | 2 opt | 3 sub |
| 1989 | - | - | - | - | - | - | - | - | - |
| 1990 | - | - | - | - | - | - | - | - | - |
| 1991 | - | - | - | - | - | - | - | - | - |
| 1992 | 50 | 100 | 50 | 50 | 52 | 50 | 100 | 52 | 100 |
| 1993 | 50 | 100 | 50 | 50 | 57 | 50 | 100 | 57 | 100 |
| 1994 | 50 | 100 | 50 | 50 | 62 | 50 | 100 | 62 | 100 |
| 1995 | 75 | 100 | 50 | 75 | 68 | 50 | 100 | 68 | 100 |
| 1996 | 75 | 100 | 50 | 75 | 81 | 50 | 100 | 81 | 100 |
| 1997 | 100 | 150 | 50 | 100 | 96 | 50 | 100 | 64 | 100 |
| 1998 | 100 | 150 | 50 | 100 | 113 | 50 | 100 | 75 | 100 |
| 1999 | 100 | 150 | 100 | 100 | 134 | 100 | 100 | 89 | 100 |
| 2000 | 150 | 200 | 100 | 175 | 158 | 100 | 100 | 80 | 100 |
| 2001 | 150 | 200 | 100 | 175 | 180 | 100 | 100 | 90 | 100 |
| 2002 | 200 | 300 | 100 | 175 | 203 | 100 | 100 | 68 | 100 |
| 2003 | 200 | 300 | 200 | 175 | 230 | 200 | 100 | 77 | 100 |
| 2004 | 250 | 300 | 200 | 300 | 260 | 200 | 100 | 87 | 100 |
| 2005 | 250 | 300 | 200 | 300 | 293 | 200 | 100 | 98 | 100 |
| 2006 | 300 | 300 | 300 | 300 | 300 | 300 | 100 | 100 | 100 |

Table 4-13 calculates netback prices of coal briquettes for 1990 and 1995 during the period between these years the price is escalated maintaining 70 percent of the kerosene price; thereafter the price will not be raised in real terms. Sellers' margin of 200 Rs/ton is incorporated in the marketing price to give the marketers sufficient incentive.

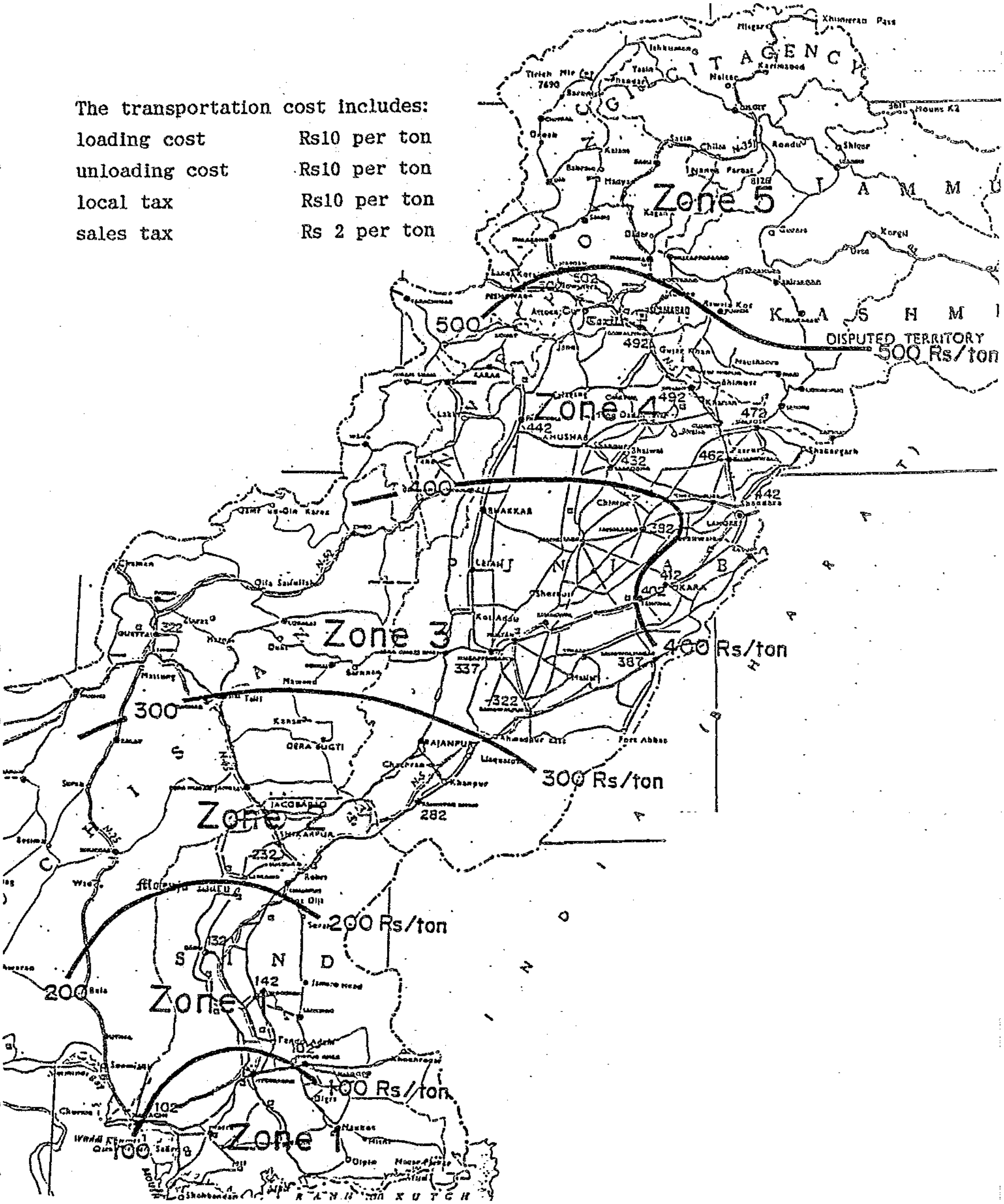
**Table 4-13 Netback Price of Coal Briquettes**

(1988 price)

| Zone | Consumer | Transportation | Margin | Ex-Plant |
|---|---|---|---|---|
| | | | Year 1990 | |
| 1 | 1,366 | 150 | 200 | 1,016 |
| 2 | 1,466 | 250 | 200 | 1,016 |
| 3 | 1,566 | 350 | 200 | 1,016 |
| 4 | 1,666 | 450 | 200 | 1,016 |
| 5 | 1,766 | 550 | 200 | 1,016 |
| | | | 1995 and onward | |
| Zone | Consumer | Transportation | Margin | Ex-Plant |
| 1 | 1,863 | 150 | 200 | 1,513 |
| 2 | 1,963 | 250 | 200 | 1,513 |
| 3 | 2,063 | 350 | 200 | 1,513 |
| 4 | 2,163 | 450 | 200 | 1,513 |
| 5 | 2,263 | 550 | 200 | 1,513 |

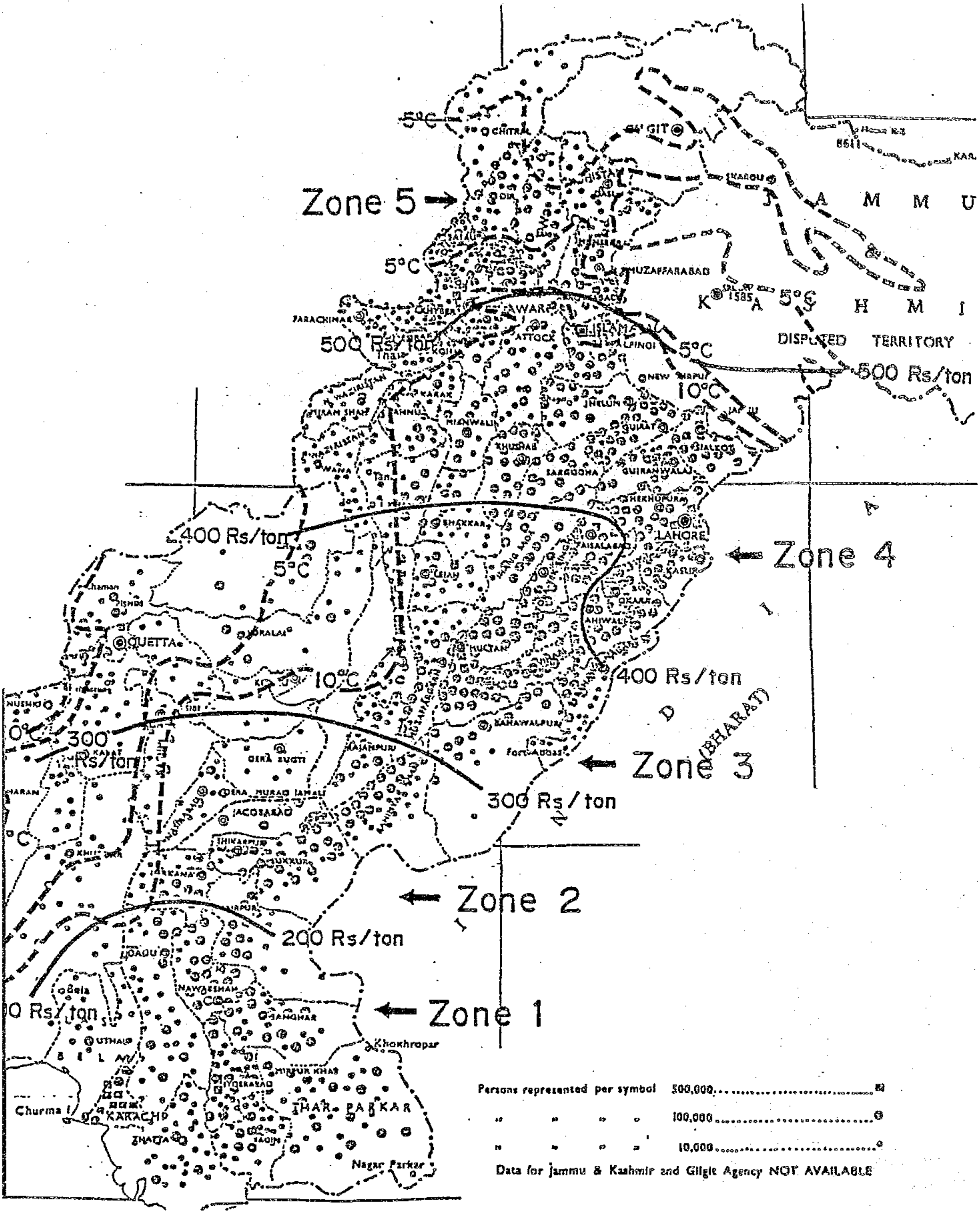
The transportation cost includes:

| | |
|---|---|
| loading cost | Rs10 per ton |
| unloading cost | Rs10 per ton |
| local tax | Rs10 per ton |
| sales tax | Rs 2 per ton |




Source: Standard truck fare from the struck station at Hyderabad

**Figure 4-1 Transportation Cost by Truck and Zoning**




Source: Atlas of Pakistan

**Figure 4-2 Demographic Distribution**

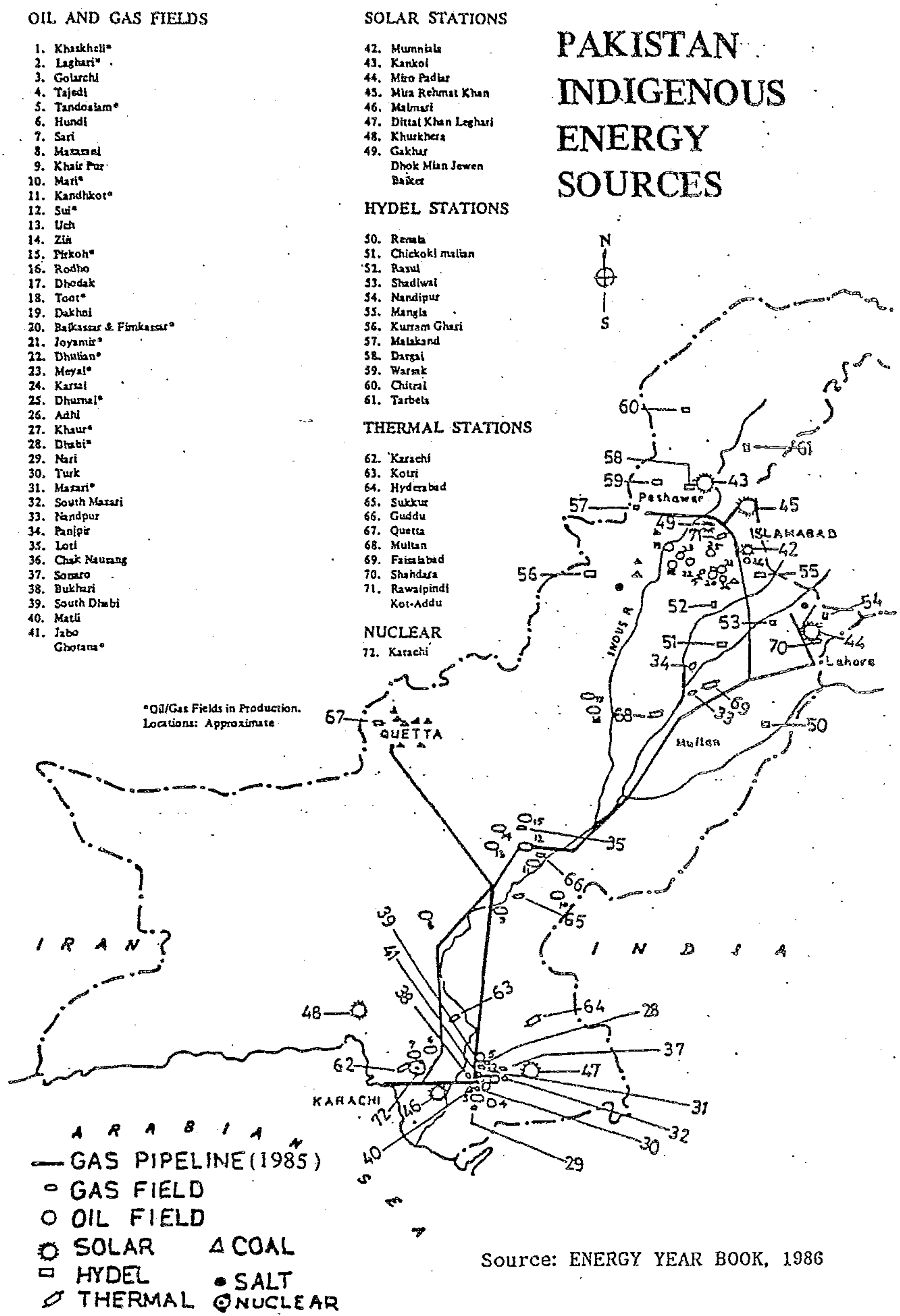



**Figure 4-3 Gas Pipeline Map**

# CHAPTER 5 RAW MATERIAL FOR COAL BRIQUETTE

## 5-1 Candidate Raw Material

Lakhra coal is the given main raw material; other candidate raw materials were bagasse, wheat straw, cotton seed oil residue, limestone, slaked lime, cement, slack wax and light fuel oil. Samples of these candidate raw materials were collected and sent to the Japanese test site. As a result of the experimental production and burning tests and also for techno-economic reasons, wheat straw, cotton seed oil residue, limestone and cement were dropped.

## 5-2 Availability and Price

Table 5-1 shows estimated availability of the selected main and subordinate raw materials within economic distance of transportation in comparison with the requirements.

**Table 5-1 Availability of Raw Material**

| | Requirement | Availability |
|---|---|---|
| Lakhra coal | 486,900 | Sufficient |
| Bagasse | 97,500 | 300,000 to 570,000 |
| Wheat straw | | 440,000 |
| Oil residue | | 36,000 to 40,000 |
| Limestone | | Sufficient |
| Slaked lime | 18,750 | Sufficient |
| Slack wax | 1,800 | 10,000 |
| Light fuel oil | 13,200 | |

Table 5-2 gives the price at the plant inlet, or the price plus transportation cost.

**Table 5-2 Price of Raw Material at Plant Inlet**

| | Price, Rs/ton at plant inlet |
|---|---|
| Lakhra coal | 326.8 |
| Bagasse | 214.8 |
| Wheat straw | 2,300 |
| Oil residue | 2,550 |
| Limestone | 115 |
| Slaked lime | 668 |
| Slack wax | 2,870 |
| Light fuel oil | 2,870 |

## 5-3 Quality of Raw Material

The analysis of the raw materials finally selected is given in Table 5-3.

**Table 5-3 Analysis of Raw Material**

| | ROM coal | Bagasse | Slaked lime |
|---|---|---|---|
| Moisture | Dry base | 18.1 | 10.97 |
| Ash | 34.7 | 2.5 | |
| Volatile matter | 35.2 | 69.5 | |
| Fixed carbon | 30.1 | 9.9 | |
| Heat of combustion | 4,414 | 3,880 | |
| Sulfur | 6.1 | 0.1 | |
| Carbon | 43.1 | 49.7 | |
| Hydrogen | 3.6 | 5.3 | |
| Nitrogen | 0.8 | 0.2 | |
| Oxygen | 12.7 | 41.6 | |
| Ignition loss | | | 19.56 |
| $SiO_2$+insoluble | | | 4.44 |
| $SiO_2+Fe_2O_3$ | | | 1.47 |
| CaO | | | 63.14 |
| MgO | | | 0.66 |

Note:
Moisture, ash, volatile matter, fixed carbon, total sulfur, total water, carbon, hydrogen, nitrogen and oxygen are in weight percent.
Heat of combustion is gross heat of combustion in Kcal/kg.

The slack wax is a by-product of lubricating oil production and available at National Refinery Ltd. at Karachi and light fuel oil is an ordinary diesel fuel available at PSO's depot.

None of the selected raw materials presents any serious difficulty to the feasibility of the project, from the viewpoints of availability, price and quality except that the sulfur content and its variation in ROM coal are very high which can be reduced of by washing and blending an appropriate amount of slaked lime.

The raw materials will be transported by trucks to the plant site; coal and bagasse will be stored in the open; slaked lime will be stored in a silo, slack wax and light oil in tanks.

# CHAPTER 6 PLANT SITE AND INFRASTRUCTURE

The plant site is selected on a flat piece of land in Lease 88 of the PMDC' Central Block near the mine office.

## 6-1 General Condition of the Site

The site is approximately 80 kilometers from Hyderabad. There are operating shafts and inclines around the plant site. The climatic condition is very dry and hot but not so severe as to prevent the normal operation of the plant. Figure 6-1 indicate the site with various facilities of Lease 88.

## 6-2 Infrastructure and Public Utility

A power line with the maximum capacity of 2,000kw has been installed to the mine office; this line is not energized yet but will be energized soon. This line can accommodate the power requirement of a 50,000 ton plant but not a 100,000 ton plant. A new power line will be laid over a distance of 50 kilometers from the nearest sub-station when the plant is expanded. There is no water main near the site; the water required for sanitation and coal washing will be transported to the site by truck.

A two-lane road of sufficient capacity runs along the mine area; this project needs only to lay a short lateral road of 1.5 kilometers. Telephone facilities are not available near the site; a wireless communication system will be established between the plant and the PMDC' office in Hyderabad. Since there are no living facilities around the site, a dormitory for the operating staff and a barrack for contract labor will be built.

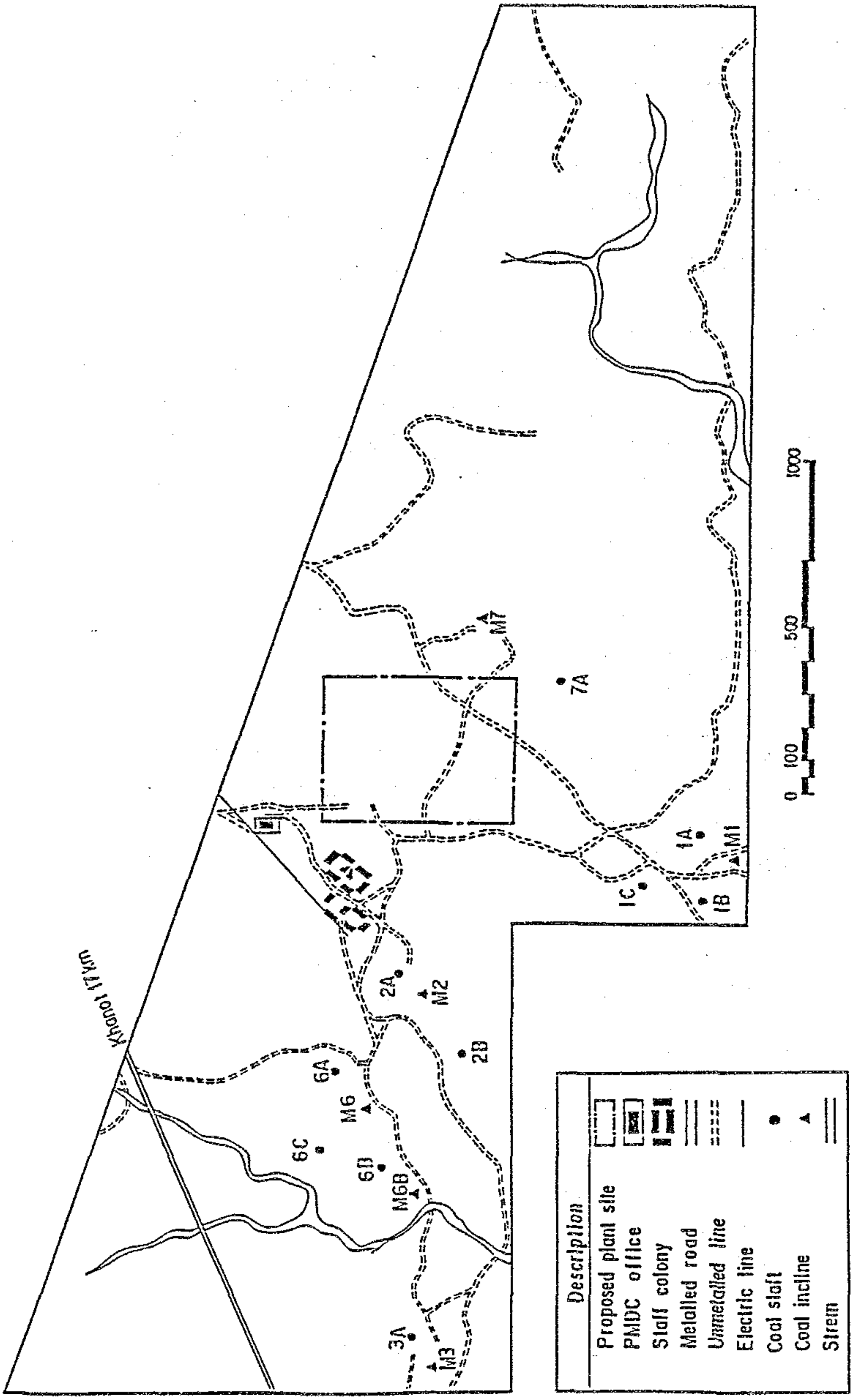



Figure 6-1 Plant Site

Figure 6-1 Plant Site

# CHAPTER 7 PROJECT SCHEME

The project scheme defines the project. At the closing stage of the field survey, PMDC and the study team agreed on the tentative project scheme on condition that the project scheme would be finalized incorporating the results of the home-office work. The tentative project scheme is recorded in the Interim Report with the rationale. Some changes have been made to the tentative project scheme in the establishment of the definitive project scheme. The major items of the definitive project scheme have already been presented in Chapter 1; therefore, here the reason why washing is included in the process will be explained; this constitutes the only major modification to the tentative project scheme.

In addition, the project schedule and the product price at the plant outlet which were left unspecified in the TENTATIVE PROJECT SCHEME are proposed here:

## 7-1 Coal Washing

At the stage of TENTATIVE PROJECT SCHEME, PMDC and the study team basically agreed on the outline of the process scheme as recorded on the Interim Report except on the necessity for pre-treatment (washing) of the raw coal which was left undecided for lack of information and data of its effect. Whether or not the pre-treatment should be incorporated in the process scheme was left to the home-office work to decide on the basis of data of washing tests. There was concern about two possible undesirable effects of washing: one is possible loss of briquetting potential that may result from wetting and perhaps from removal of certain components of coal and the other is cost of water, potentially prohibitive in the project site since the only means of procurement of water is to bring it by a tank truck.

Because of the concern over the detrimental effect of wetting, a dry method of pre-treatment of coal which is extensively employed in Japan to eliminate foreign substances was tested but was found ineffective. The experiments of wet process, or actual washing, proved quite effective contrary to the above concern: there is no discernible difference in briquetting potential between before and after washing; marked reduction of ash and sulfur content is attained by washing.

The problem with sulfur in unwashed coal is its great variation in content which cannot be detected beforehand: the sulfur content can vary greatly, say from as low as 4 to as high as 9 percent, among samples of even the same lot taken at the same time from the same seam of the same shaft. There is also no way of detecting such variation while feeding the coal to the plant. This gives rise to a very annoying process operation problem: the combustion effluent of sulfur, sulfur dioxide, which is very irritating to the eyes and throat, must be suppressed by all means at the consumers end. This is possible only by adding at the manufacturing stage the amount of slaked lime required to completely neutralize the expected maximum content of sulfur in the raw material. The added slaked lime ends up in ash reducing heating value of the product and increasing the cost of distribution per heating value. The ash content of the raw coal is already very high; there is scarcely any room to further increase ash beyond that already contained without adversely affecting the real value of coal briquettes as a household fuel.

There are two types of sulfur contained in the raw coal, namely, combustible and incombustible sulfur; the former could be further classified into organic sulfur and inorganic sulfur; the incombustible sulfur remains inert during combustion and regarded as harmless economically and otherwise provided the content is low, which is the case with the Lakhra coal. The organic sulfur exists as an integral member constituting with other elements like carbon, oxygen and nitrogen the chemical structures of coal itself. The inorganic combustible sulfur exists mostly in the form of pyrites, or a combustible compound of sulfur and iron, known to play an instrumental role in triggering spontaneous ignition of coal. Unlike the combustible organic sulfur, pyrites are contained in coal not as an integral part of the molecular structures of coal but as a heterogeneous existence. Pyrites can be spotted on the Lakhra coal samples by the naked eye as small bright golden specks irregularly scattered over surfaces of any fragment of coal. It is conceivably due to this very heterogeneous existence of pyrites in the Lakhra coal that the sulfur content varies greatly almost unpredictably from one lump to another even within the same lot.

Pyrites has a specific gravity of approximately 5 as compared to approximately 1.3, of pure coal; therefore, it should be possible to separate pyrites from coal by using the great difference in specific gravity. The results of washing test on the Lakhra coal attest to this: there is a great reduction in sulfur content from an average of six to less than three percent and also in variation for which pyrites may be considered the main factor.

Ash content is greatly reduced, of course, from about 30 to less than 10 percent by washing; the reduction of ash to increase calorific value is normally the main objective of washing process rather than reduction of sulfur. Because pyrites constitutes a significant portion of sulfur in coal, it is fortunately possible with the case of Lakhra coal to substantially reduce sulfur content along with ash, and more importantly the irregular variation of sulfur content of the feed coal, by washing. Such experimental results were obtained by using a fluid with a specific gravity adjusted to 1.6; however, similar results may be expected of washing processes using plain water as long as the processes employ sufficient differences in specific gravity.

The price of coal briquettes on the market is related to their heat content. The retail price of coal briquettes using unwashed coal has a heat content 74 percent of the coal briquettes made of the washed coal; hence the former will be sold at 74 percent of the price of latter. The transportation cost of the former from the plant to the market will be much higher on the basis of heat. A financial analysis was done on both cases and found the former nearly infeasible.

This study propose that a washing plant of 30 tons per hour be installed and operated daytime only while the plant will be operated 24 hours a day.

## 7-2 Project Schedule

As a result of the home-office work the following project schedule is proposed:

**Table 7-1 Project Schedule**

| Operation | Duration, month |
| --- | --- |
| Study of this report by PMDC | 1 |
| Study of this report by government | 1 |
| Decision on implementation | 1 |
| Study on funding | 1 |
| Basic design by consultant | 4 |
| Preparation of tender documents | 3 |
| Decision on contractor | 1 |
| Detailed design | 6 |
| Plant fabrication | 7 |
| Site installation and erection | 8 |
| Completion, test operation | 3 |
| Total | 36 |

## 7-2 Product price

The product price has been worked out at Rs.1,016/ton and Rs.1,513/ton for 1990 and 1995, respectively as explained in Chapter 4, COAL BRIQUETTE MARKET. The price is on 1988 price base and is expected to be raised at the same rate as general inflation; or remain constant at real-term basis. Between these two years the price is raised at a fixed rate as shown below:

**Table 7-2 Product Price at Plant Inlet**

| Year | Price, Rs/ton |
| --- | --- |
| 1990 | 1,016 |
| 1991 | 1,100 |
| 1992 | 1,191 |
| 1993 | 1,290 |
| 1994 | 1,397 |
| 1995 | 1,513 |

# CHAPTER 8 EXPERIMENTAL PRODUCTION OF COAL BRIQUETTES AND BURNING TEST

## 8-1 Experimental Production

A series of experimental production of coal briquettes has been carried out to establish the optimum blending ratio, determined partly by the physical properties and the results of burning test of the experimental products and partly by techno-economic constraints.

The major findings achieved in the course of the experiments and as follows:

1. There is a great and almost unpredictable variation in the content of sulfur in coal from one lump to another of the same lot. However, washing of coal can greatly reduce the sulfur content together with ash; also washing reduces the variation of sulfur content.

2. Bagasse and wheat straw give almost identical effects on the quality of the product if the same amount is used; cotton seed oil extraction residue gives far weaker collapse strength; given these experimental results bagasse is chosen for its economic advantages.

3. Without bagasse or wheat straw the coal does not form into rigid briquettes even under extremely high pressure or even with some cement added.

4. Limestone reacts too slowly with sulfur dioxide and hence is not very effective in arresting sulfur dioxide; slaked lime is found very effective. Coal briquettes blended with an appropriate amount of slaked lime do not emit irritating levels of sulfur dioxide upon combustion.

5. The particle sizes of coal and biomass smaller than 2 mm are found to produce the best briquettes.

6. The moisture contents of coal and biomass of 12 and 8.5 percent respectively are found to produce the best briquettes.

7. The ratio of coal and biomass of the above particle sizes and moisture contents are best at 80 to 20.

8. One hundred twenty percent the stoichiometric requirement of slaked lime is found sufficient to suppress the generation of sulfur dioxide.

9. Approximately 5 percent of a wax-containing light oil is enough to give water repellency.

10. The briquetting experiment done on the actual industrial machine on the above conditions gave coal briquettes of satisfactory quality: easy to start, with a strong flame, generating smoke only initial period of combustion, not irritating to the eyes and throat, water repellent, and sufficiently physically strong. Cement is found not necessary.

11. The burning tests with common Pakistani stoves, hoof-shaped and the most common kind made of metal, established that the experimental coal briquettes burn satisfactorily well. Six one-unit stoves and two separable stoves were experimentally produced correcting the defects of the previous designs in each succeeding design. The experimental designs achieved thermal efficiencies higher than 70 percent of the most common Pakistani household kerosene stoves. The speed of cooking with the coal briquettes are not inferior to the Pakistani kerosene stoves.

12. Thus, the experimental production and burning test provided the basis for conceptual design of the plant and operation.

# CHAPTER 9 CONCEPTUAL DESIGN

The conceptual design of the plant was made based on the experimental production of coal briquettes and material balance and energy requirement calculated for the material balance. The best sequence of unit operations and arrangement of processing facilities to achieve this operation scheme was worked out referring mainly to the experience of the experts in coal briquettes manufacturing. The specifications of major pieces of equipment were also developed. As a result of the above operations the process flow diagram shown in Figure 9-1 is proposed.

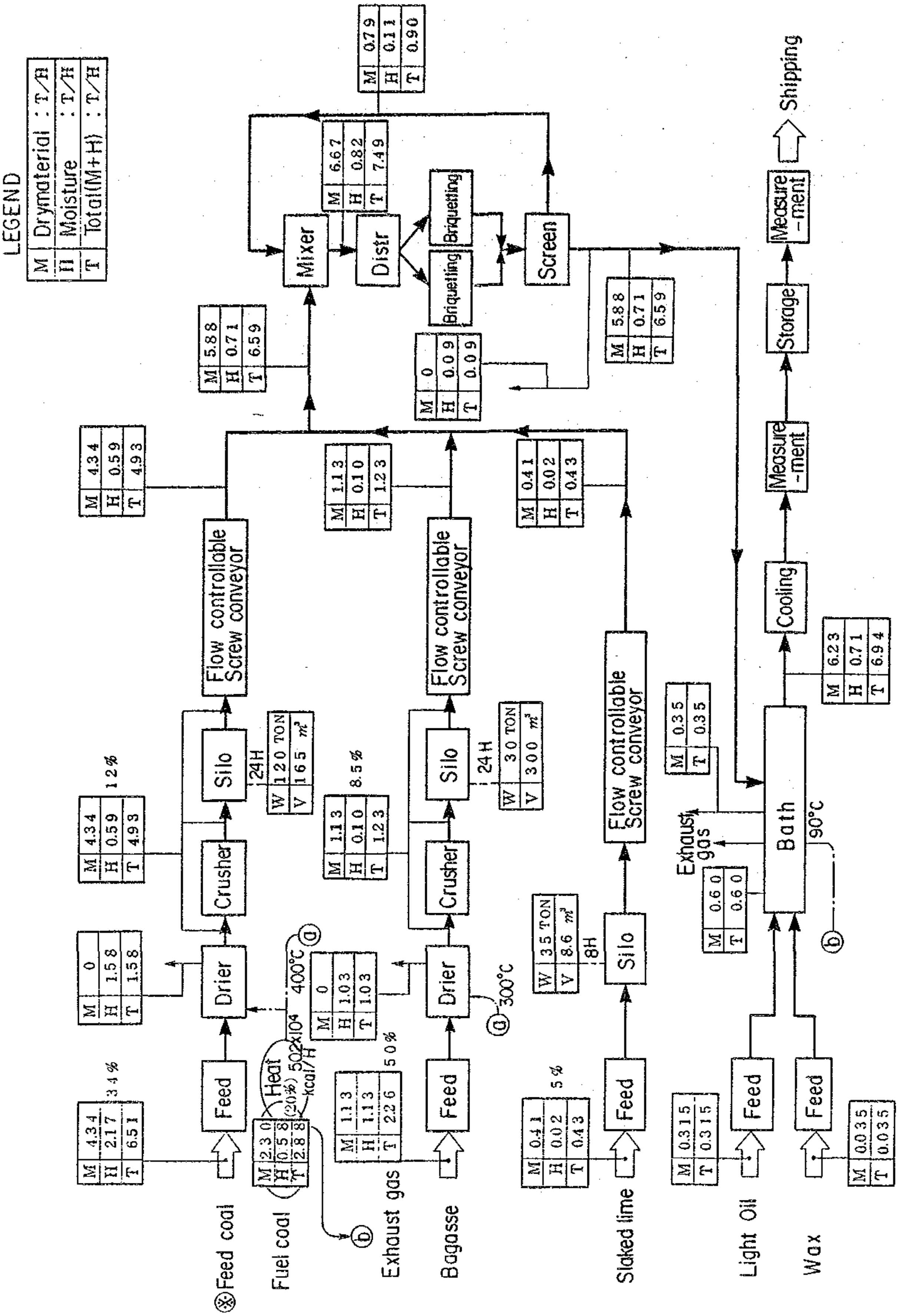



Figure 9-1 Process Flow Diagram

Figure 9-1 Process Flow Diagram

# CHAPTER 10 PLANT CONSTRUCTION

Pakistan has a good industrial base; Heavy Mechanical Complex Ltd., HMC, and Karachi Shipyard and Engineering Works, KSEW, are reputable machine manufacturers of established performance. They supply sugar mills and cement mills on turn-key contract. There are industries manufacturing the following inputs necessary to this project: steel beams, steel rods, sheet glass, cement, asbesto slate, and bricks. There are also good and experienced consulting companies and construction companies. There is a sufficient supply of local engineers, consultants, skilled workers, and unskilled workers. The construction can depend upon local skills provided and technical knowledge are provided from abroad. Constructing the plant with local supplies and skills would economize on the construction cost which is an essential factor to make this project financially feasible.

There is no physical obstacles which may prevent smooth construction of the plant; road conditions and site conditions are adequate.

The proposed schedule is given in Table 10-1.

**Table 10-1 Construction Schedule**

| Work | Month |
|---|---|
| Detail design | 1st to 6th |
| Site investigation and preparation | 1st to 2nd |
| Equipment fabrication and erection | 7th to 21st |
| Civil and building work | 14th to 21st |
| Commissioning | 22nd to 24th |

# CHAPTER 11 TOTAL CAPITAL REQUIREMENT AND OPERATING EXPENSE

Tables 11-1 and 11-2 give summaries of operating expense and total capital requirement.

**Table 11-1 Operating Expenses Summary**

(Unit : 1,000 Rupees)

| Items | CAse 1,3 | | Case 2 | |
|---|---|---|---|---|
| | A | B | A | B |
| Variable Operating Costs: | | | | |
| Raw material | 37,934 | 37,934 | 75,871 | 75,871 |
| Utility | 3,909 | 3,909 | 7,709 | 7,709 |
| Handling | 609 | 609 | 1,218 | 1,218 |
| Fixed Operating Costs: | | | | |
| Labor | 1,056 | 1,056 | 1,498 | 1,498 |
| Maintenance | 5,176 | 4,930 | 9,518 | 9,142 |
| Insurance | 860 | 698 | 1,518 | 1,285 |
| Plant overhead | 1,056 | 1,056 | 1,498 | 1,495 |
| Total Operating Expenses | 50,600 | 50,192 | 98,830 | 98,221 |

## Table 11-2 Total Capital Requirement

(Unit : 1,000)

| Items | Cases 1 and 3 : 50,000 ton/year | | | | Case 2 : 100,000 ton/year | | | |
|---|---|---|---|---|---|---|---|---|
| | Cases 1A,3A (Base case) | | Cases 1B,3B (Alternative case) | | Case 2A (Base case) | | Case 2B (Alternative case) | |
| | Foreign (Yen) | Local (Rupee) | Foreign (Yen) | Local (Rupee) | Foreign (Yen) | Local (Rupee) | Foreign (Yen) | Local (Rupee) |
| Plant Construction Costs: | | | | | | | | |
| (1)Machinery and equipment | 183,958 | 70,316 | 0 | 78,070 | 302,457 | 132,675 | 0 | 145,948 |
| (2)Vehicles | 0 | 8,103 | 0 | 8,103 | 0 | 13,874 | 0 | 13,874 |
| (3)Erection | 0 | 5,035 | 0 | 5,035 | 0 | 9,084 | 0 | 9,084 |
| (4)Structures and civil work | 0 | 8,430 | 0 | 8430 | 0 | 17,623 | 0 | 17,623 |
| (5)Engineering | 47,665 | 2,962 | 0 | 3,786 | 52,602 | 5,839 | 0 | 7,218 |
| (6)Supervision | 17,400 | 0 | 8,400 | 0 | 17,400 | 0 | 8,400 | 0 |
| (7)Commissioning | 1,800 | 0 | 1,800 | 0 | 1,800 | 0 | 1,800 | 0 |
| (8)Physical contingency | 13,201 | 4,992 | 537 | 5,443 | 19,698 | 9,426 | 537 | 10,197 |
| - Total Plant Cost - | 264,024 | 99,838 | 10,737 | 108,868 | 393,957 | 188,522 | 10,737 | 203,944 |
| Pre-operating Expenses | 72,000 | 5,976 | 48,000 | 5,976 | 72,000 | 11,652 | 48,000 | 11,652 |
| Initial Working Capital | 18,396 | 10,462 | 0 | 12,228 | 30,246 | 19,856 | 0 | 22,866 |
| Interest During Construction | 63,461 | 1,196 | 8,765 | 2,888 | 87,878 | 3,111 | 8,765 | 5,684 |
| Total | 417,881 | 117,472 | 67,502 | 129,960 | 584,081 | 223,141 | 67,502 | 244,146 |

Note) Base case : Coal washing plant and mixing/briquetting machine are imported.
Alternative case : All machinery and equipment are domestically made.

## CHAPTER 12 FINANCIAL AND ECONOMIC ANALYSIS

This summary version gives the major conclusions only; the process of development of these conclusions are elaborated in the full report.

### 12-1 Comparison between Case 1 and Case 2

Case 1 gives better economic results as shown in Table 12-1.

**Table 12-1 Comparison between Case 1 and Case 2**

| | Case 1 | | Case 2 | | Case 3 | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| ROI before tax | 18.5 | 20.4 | 16.0 | 17.4 | 19.5 | 21.8 |
| ROI after tax | 12.3 | 13.7 | 10.5 | 11.5 | 14.4 | 16.3 |
| ROE before tax | 17.4 | 22.8 | 7.7 | 16.7 | 14.4 | 22.4 |
| ROE after tax | 11.2 | 16.7 | N.R. | 11.4 | 8.3 | 17.7 |

Economic results of process with coal washing and process with out coal washing were calculated based on a 50,000 ton plant without incorporating the effects of expansions for both instances. The latter is found financially infeasible.

**Table 12-2 Financial Evaluation of 50,000 ton plant with and without Washing**

| | With washing | Without washing |
|---|---|---|
| ROI before tax | 13.2 | 1.7 |
| ROI after tax | 8.7 | no return |
| ROE before tax | no return | no return |
| ROE after tax | no return | no return |

Table 12-3 gives average debt service coverage ratios for Cases 1 and 2.

**Table 12-3 Financial Indicators for Case 1 and Case 2**

| | Case 1A | Case 1B | Case 2B |
|---|---|---|---|
| Debt service coverage ratio | 1.19 | 1.80 | 1.21 |

The profit and loss statement, balance sheet, sensitivity analysis, and net present value are developed for Case 1 and 2 and presented in the full report.

Regarding the economic analysis, or benefit-cost analysis for the nation and society, Cases 1 and 2 give the results shown in Table 12-4.

**Table 12-4 Results of Economic Analysis**

| | Case 1A | Case 1B |
|---|---|---|
| Balance of payment, MMRs. | 3,590 | 3,733 |
| Direct employment opportunity | 127 | 127 |

# CHAPTER 13 OVERALL EVALUATION AND RECOMMENDATION

## 13-1 Overall Evaluation of Project

As mentioned at various parts of this report, this feasibility study investigates six cases; Cases 1A, 1B, 2A, 2B, 3A and 3B. All cases are expanded in their capacities as the demand for coal briquettes grows. The expansion program of Cases 1A and 1B is modest; in other words, the capacities are increased so that no extra capacity will be created. Cases 2A and 2B are more optimistic, always with some extra capacities to meet additional demands. Cases 3A and 3B are sensitivity cases which assume continuation of the current subsidy price of kerosene. Cases with A and the corresponding cases with B are the same in capacity throughout the project life. Cases with A use imported washing and mixing/briquetting machines for the first plant while cases with B use all domestically produced machines.

Cases with B naturally show better financial returns than their corresponding cases with A, because of the lower costs of the domestic machines and lower associated costs; however, the differences are not very great in terms of ROI before and after tax. From the point of view of ensuring reliable operation, cases with A should have priority over their corresponding cases with B, especially when the differences in ROI between the corresponding cases with A and B are small.

Regarding the choice among Cases 1, 2 and 3, Case 1 is evaluated as more desirable than Case 2, as will be discussed in 13-1-1, Marketability. The choice between Cases 1A and 1B is a tradeoff between profitability and reliability of operation. The profitability itself depends upon the reliability of operation; therefore, as will be discussed later, this feasibility study recommends Case 1A over Case 1B.

All cases except for Case 2A may be regarded as financially justifiable with their modest returns on investment in view of this project being a national project. Secondly, this project would make a positive contribution to the improvement of the nation's balance of payments and support the established policy of the government to promote the use of domestic coal.

This project would also give a wide range of secondary and tertiary effects among which worth particular mention are:

(1) Transfer of technology of manufacturing coal briquettes to PMDC,

(2) Transfer of technology of manufacturing a whole range of equipment constituting the coal briquette plant,

(3) Creation of employment opportunities,

(4) Creation of business opportunities associated with the construction and operation of the plants,

(5) Utilization of the domestic resources in a manner to replace an imported commodity, namely kerosene,

(6) Establishment of an industry in a less developed region of the nation,

(7) Introduction of standard designs of stoves suited for burning coal briquettes to Pakistan for the cottage industry to utilize and market the stoves it makes,

(8) Contribution to the diversification of the domestic fuel supplies to the general consumers and thus making the household economy of the general populace less vulnerable to price fluctuation of energy in the international market, and

(9) Establishing the coal briquetting industry as an example that entrepreneurs in the private sector can emulate.

Of the three alternative capacities, Case 1 starting with 50,000 tons per year is financially better than Case 2 starting with 100,000 tons per year capacity. Although Case 1 has a definite economic advantage over Case 2, Case 2 will provide greater flexibility to meet sudden and unexpected surges of demand that may be created as a result of sharp increases of petroleum prices in the international market, which could happen any moment. However, it would be expecting too much of a nascent industry like this one to meet unexpected demand surges, particularly at the initial stage. Such an advantage of Case 2 would not offset its greater marketing risk associated with its greater production capacity. In short, Case 1 is evaluated as more recommendable than Case 2. Case 3, a sensitivity case, will make sense only if the government of Pakistan should opt to continue subsidy on kerosene price.

Overall, this project, except for Case 2A, may be evaluated as being financially feasible, economically viable, expected to provide favorable secondary and tertiary benefits to the society and nation; in short, this project may be evaluated as worthy of implementation but under carefully prepared conditions.

### 13-1-1 Marketability

With the price and quality of the coal briquettes proposed in PROJECT SCHEME, this project would be able to market the product coal briquettes as discussed in Chapter 4, COAL BRIQUETTE MARKET.

The capacity of Case 1 is designed not to have idle capacity throughout the project life; in other words, Case 1 gives priority to economic condition of the plant rather than to meeting the demand. On the other hand, Case 2 puts meeting supply responsibility, with some extra capacity, ahead of economics of the project. Naturally, Case 2 is at a disadvantage in economic terms in comparison with Case 1: Cases 1A and 2A give IRR's on investment of 12.3 and 10.5, respectively.

For a country like Pakistan where import of energy is under control of the government, the government and semi-governmental organizations like PMDC or PSO have responsibility for providing a stable supply of energy; in this respect the choice between

Cases 1 and 2 has special implications. Perhaps there are some who may argue that a public project like this should give priority to supply responsibility even at some economic sacrifice. Such an argument cannot be dismissed entirely. However, the study team believe that at the initial stage of operation this project should not be loaded with any such social responsibility until this project firmly establishes itself in the socio-economic fabric of Pakistan; in other words, the project should demonstrate its economic feasibility while attaining full-capacity operation to supply quality coal briquettes at competitive prices at consumers end. In short, Case 1 should be considered to satisfy the objective of this project more than Case 2.

This study recommends that the product be sold ex-plant; this is exactly what PMDC does for the sale of coal and rock salt. PMDC would not have to bear the burden of uncontrollable magnitude of marketing by adopting this system. Besides, this project could expect participation of the very effective distribution and marketing channels that already exist. They are rock salt dealers of PMDC, kerosene dealers of PSO, coal dealers of PMDC, and free merchants including firewood and charcoal dealers.

With such arrangements and marketing potentials discussed in Chapter 4, COAL BRIQUETTE MARKET, the marketing feasibility may be evaluated as positive.

Regarding the quality of the coal briquettes there are inherent disadvantages to coal briquettes as compared with kerosene which the coal briquettes are intended to replace. The calorific value of the coal briquettes is approximately only half that of kerosene. Coal briquettes also produce ashes while kerosene does not.

Notwithstanding, the design of the quality of coal briquettes takes into consideration every attribute household fuel should have in the Pakistani household environment. It must be admitted that kerosene is superior to coal briquettes as household fuel in relative terms. Nevertheless, the coal briquettes of this project would be a good household fuel meeting nearly all requirements as fuel for average Pakistani households.

Even with all these comparative disadvantages of the coal briquettes to kerosene, at the price incentive given to the coal briquettes against kerosene, the coal briquettes will be accepted by the general consumers. The price incentive this study gives to the coal briquettes is based upon the difference, plus some discount, in thermal efficiency between these two fuels confirmed by the burning test conducted by the study team under simulated household conditions.

**13-1-2 Technical Evaluation**

First and foremost, the experimental production of coal briquettes from the local raw materials and their burning test have established the feasibility of producing coal briquettes of the desired quality level from Lakhra coal, bagasse, slaked lime, slack wax, and light oil. All these materials are easily procurable at and around the site. It should be noted that the briquetting experiments were conducted at a commercial plant; therefore, the classic problem of unexpected troubles occurring one after another in the process of commercializing an experimentally proven process would be avoided. The plant is designed to consist of a series of processes, each proven with firmly established methods of design calculation. The process and equipment are not particularly specialized; therefore, no unusual difficulty is expected in the startup and breaking-in of the plant.

The plant site and infrastructure at and surrounding the plant site would not pose any problem beyond control of or unmanageable by the project; the only improvements that should be provided by the project are supply of electricity, supply of water, construction of a lateral road, all of which can be done easily. The road running through the Lakhra mine area will suffice for the transportation of the construction materials to the site and also transportation of the product from the plant to the markets stretching across the nation. Therefore,the project does not need to construct a road of its own accord for such purposes.

The project area is not a hazard-prone area although this area is hit, but only very rarely, by cyclones and heavy rains. They would not affect the plant or operations very seriously, because the plant site is on a hilly location and the soil is firm. Overall, the candidate site have conditions that are favorable to constructing and operating the plant.

The necessary technology, skills and facilities exist in Pakistan to provide construction materials, labor and machines needed to construct the plant. The local supplies are in general of acceptable quality and are priced lower than imports. The maximum utilization of local supplies intended for this project would make the plant cost economical enough to make this project financially feasible. Some of the best manufacturers of machines may be regarded as basically capable of manufacturing machines constituting the coal briquette plant. Actually, they supply sugar mills and cement plant on turn-key basis. However, none of them has had practical experience in manufacturing these machines. Therefore, this feasibility study compares cases with imported washing and mixing/briquetting machines and cases with all domestic machines. The commercially tried imported machines should be regarded as more reliable than the first domestic machines. Naturally, the domestic machines are cheaper than the imported ones; however, their effects on financial feasibility are small as explained in 13-1-4, Financial and Economic Evaluations. Besides, the economic advantage of the domestic machines would be easily wiped out if use of domestic machines adversely affects operation rates. Fortunately, Case 1A is found to give an acceptable returns in view of the nature of this project as a national project.

Thus, the technical aspects of this project are generally favorable; none of them presents a problem serious enough to jeopardize the feasibility of the project. However, it is very important to maintain a high operation rate in order to be viable.

### 13-1-3 Raw Materials

The availability, price, quality, ease or difficulty of procurement, and level of inventory required were investigated for all the candidate raw materials preliminarily selected for scrutiny: Lakhra coal, bagasse, wheat straw, cotton oil cake, limestone, slaked lime, cement, slack wax, and light fuel oil. Among them wheat straw, cotton oil cake, limestone and cement were dropped for the reason explained in Chapter 8, PROJECT SCHEME of the full report. All the selected raw materials are available in sufficient quantities within Sind to support the project through the project life, though there is seasonal fluctuations in availability of bagasse. Their prices are reasonable and their qualities are sufficiently good. A scarcity of raw materials would not occur to any degree that would threaten the feasibility of the project during the project life.

The only concern is that there may arise in Sind such industries that consume bagasse, even at higher prices, as raw materials. The conceivable candidate industries are paper making and board manufacturing. At present, there is no such industries in Sind. Pakistan makes good use of bagasse. With rapidly increasing population, the demands for such products will naturally increase; there is no denying the possibility of such industry starting in Sind. Even in such a case, the scales of these industry or their consumption of bagasse would not be so great as to threaten the stable and economical supply of bagasse to this project at least in the short run. Even in the long run the effect of these industries on bagasse price would in all probability be within the range of price tested by the sensitivity analysis of financial evaluation.

### 13-1-4 Financial and Economic Evaluations

The major results of financial and economic evaluations are as follows:

| | Case 1 | | Case 2 | | Case 3 | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| ROI before tax | 18.5 | 20.4 | 16.0 | 17.4 | 19.5 | 21.8 |
| ROI after tax | 12.3 | 13.7 | 10.5 | 11.5 | 14.4 | 16.3 |
| ROE before tax | 17.4 | 22.8 | 7.7 | 16.7 | 14.4 | 22.4 |
| ROE after tax | 11.2 | 16.7 | N.R. | 11.4 | 8.3 | 17.7 |

Cases 2A and 2B give much lower profitabilities than Case 1A and 1B because of the former's anticipated lower rates of operation. Case 1A and 1B give healthy rates of return on investment and equity. Though not shown here Case 1A and 1B could stand fluctuations of raw material prices, construction cost, etc. as indicated by the sensitivity analysis presented in Chapter 16, FINANCIAL EVALUATION of the full report.

As far as the results of financial and economic analyses indicate, cases with B appear preferable to cases with A. This would hold, however, only if cases with B attain the same operation rate as cases with A; this prerequisite may not be met.

This project is expected to make a substantial contribution to the improvement of the balance of payments situation; Cases 1A and 1B are expected to improve the balance of payments by respectively Rs.3,590 million and Rs.3,733 million throughout the project life.

To conclude, Case 1 may be evaluated more preferable to Case 2. With regard to comparison between Case 1A and Case 1B, Case 1A is recommended, although Case 1B shows better returns on calculation.

### 13-1-5 Social Contribution

This project supports the government policy of promoting utilization of coal: a policy explicitly declared in the Sixth Five Year Plan, 1983-88, of promoting utilization of coal hitherto used almost entirely for baking bricks, and specifically a policy of setting up smokeless briquetting plants of economical size based on major coal fields as a substitute for kerosene.

This project would increase the freedom the government and people in general, particularly those in the middle and lower income strata, could exercise in selecting household fuels. The supply of non-commercial fuels like firewood and charcoal is inherently limited; increasing it beyond limit will inevitably result in devastation of the already impaired natural environment. The supply of natural gas and electricity is rather rigid, meaning that they could be supplied only to the areas where pipelines and power lines of ample capacity are connected. The only measure Pakistan now has at its disposal for adjusting to the changes of demand or supply of household fuel is through adjustment of the volumes of importation of kerosene without regard to the price. At the beginning of the project when the capacity of coal briquette manufacturing is still small, the degree of freedom the government would have by virtue of this project is only symbolic. However, when the government policy mentioned above is fully realized, the degree of freedom would no longer be symbolic and both the government and the consumers would be able to exercise options.

Besides these, as explained in Chapter 17, ECONOMIC ANALYSIS of the full report, this project would bring about various social benefits among which the following are important:

1. Creation of business opportunities,
2. Creation of employment opportunities, direct and indirect,
3. Transfer of technology.

Of these, only direct employment opportunities are quantifiable.

The direct employment opportunities to be created by this project at maturity are 127. Other unquantifiable merits are significant. The business opportunities to be created include detail design of equipment to be installed, construction of the plant, transportation of the raw materials and product, distribution and marketing of coal briquettes, those industries who serve the above, manufacture and sale of stoves for burning coal briquettes, etc. There would be additional employment opportunities in all these sectors of industry. The transfer of technology would be made in the fields of plant design and construction, coal briquette manufacturing and stove design.

## 13-2 Recommendation for Implementation

To conclude this feasibility study the following recommendations are presented:

1. Implementation of Case 1A of this project is recommended.

2. For the best interests of this project, the project scheme proposed in Chapter 8 of the full report should be followed.

3. PMDC should concentrate in the production of coal briquettes entrusting the distribution and marketing of coal briquettes to such marketers of demonstrated capability as PMDC' rock salt dealers, PMDC' coal dealers, PSO's kerosene dealers and firewood and charcoal dealers.

4. If such arrangement is possible, coal briquettes of the quality comparable to the one planned by this study should be imported before the start of the operation to market them through the planned channels. This operation would accustom the consumers to coal briquettes.

5. PMDC should assign the managers, engineers, and operators with the highest qualifications to the operation of this project. PMDC should organize the operation of this plant to be simple and effective so that the economy of the project is not burdened by unnecessary manpower.

6. PMDC should employ the best consultants, design engineers, equipment manufacturers, construction companies, contractors for the construction of the plant.

7. If such arrangement is possible, the managers and engineers should be given opportunities to receive training at a coal briquette plant manufacturing the coal briquettes of the quality comparable to that planned by this project.

8. Although there is one coal briquette plant operating in Quetta, it caters only to the localized demand of the army in that area. The quality of the briquettes being made by the existing plant is entirely different from the quality of briquettes of this project intended chiefly to be household fuel. Therefore, this project may be considered to be the first enterprise of its kind in Pakistan. To make the first enterprise a success is by no means easy. Matters of crucial importance are:

(1) Construction of a dependable plant,
(2) Sufficient implementation of management and operation knowledge, and
(3) Establishment of marketing channels.

9. PMDC should maintain the operation rate not lower than 90 percent, the threshold value to keep the project viable, particularly by promoting sales and maintaining the reliability of the plant.

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