5.1.2 Direct utilization facilities (burning)

(1) Industry sector

As shown in Table 2.6, 14 % of the total coal consumption was consumed in industry sector in 1993. Efficiency of coal utilization is around 60 % and low comparability because the designs and operations of the majority of facilities are based on the former Soviet Union, without any energy conservation concepts. For example, in the cement industry, the production of cement was 82,300 ton/year and consumption of coal for cement was 56,800 ton/year in 1993. Specific energy consumptions is estimated 2,070 kcal/kg-clinker(based on heating value of coal: 3,000 kcal/kg),which can be compared with that of the same type of cement plant, 1,400 kcal/kg in China and 1,300 kcal/kg in Japan. The facilities designed by Czechoslovakia also does not have any energy conservation concepts. Therefore, by modification and improvement of process, energy consumption will be improved by 20 to 30 %.

(2) Public and household sector

As shown in Table 2.6, 4 % of coal is consumed in public and household sector. Actual efficiency of coal use in the sector is not available, but is estimated to be very low as the efficiency of small boilers and ovens is low, 20 to 30 %. Additionally, it is said that about one ton out of 4 to 6 tons of coal is not used in, which is purchased mainly by one family around urban area because it has been pulverized or powdered.

(3) Other sectors

Coal consumption of the other sectors is 2 % of total and used in almost same fields of public and household sector, heating and cooking. Present efficiency of coal use in the other sector is estimated to be the same level with public and household sector, because coal is used for heating and cooking.

5.1.3 Indirect coal utilization facilities (electricity and heat)

(1) Industry sector

As shown in Figure 2.3, 67 % of produced electricity is consumed in the industry sector. Share of the industry sector will be in the same range, 60 to 70 %, though actual data of share in thermal energy consumption is not available. Efficiency of electricity use and thermal energy use in the industry sector is not available, but estimated to be comparatively low because most of industrial facilities were designed by the former Soviet without any energy conservation concepts. According to ADB report, the following example data are reported. In a textile factory, specific energy consumption (fuel + electricity) for fabric is 19.0 kWh/kg fabric. The corresponding value for European textile mills is 16.5 kWh/kg fabric. This shows that the Mongolian textile mill has 10 to 15 % higher specific energy consumption level than European textile mills. Another example in Vodka, brewery and soft drinks shared companies are as follows: specific heat consumption of 48.1 kWh/hl beer corresponding to 10 kWh/hl of European breweries and specific power consumption of 270 kWh/hl beer corresponding to 11-15 kWh in European breweries. These figures show that the Mongolian brewery has a 4-10 time higher specific energy consumption level than European breweries.

(2) Other sectors

Electricity in the other sectors, 33 % of total consumption, is used for several usages, including heating of buildings and homes that are out of the hot water supply area. Present efficiency of electricity and thermal energy use in the other sectors is not available, but estimated to be very low due to no energy conservation effort and no energy control device. The electrical energy consumption in Mongolian households is approximately 2,000-2,500 kWh/year. The main areas of consumption are as follows:

- Lighting
- Cooking
- Refrigeration(food storage)
- TV and radio sets
- Miscellaneous

Refrigerators are estimated to consume 20 to 25 % of the total power consumption in the households. The annual specific energy consumption of refrigerator is 1.64- 3.80 kWh/year $dm^3$, and the specific consumption of comparable refrigerators sold in Sweden is 0.9-1.0 kWh/year $dm^3$.

Most multi-family buildings in Ulaanbaatar are very similar to the buildings in many places of the former Soviet Union. There are mainly two types:

1) Houses consisting of prefabricated structural concrete elements.
2) Brick buildings, where most parts are constructed on site.

The present annual specific energy consumption is approximately 480 kWh/m$^2$ today. This should be compared to an average consumption of approximately 220 kWh/m$^2$ in the average Swedish buildings under the similar climatic conditions.

## 5.2 Technical potential of energy (coal) conservation

In this section, technical analysis on possibility of energy-saving in existing facilities is not included, because such analysis is out of scope of the study.

### 5.2.1 Coal conservation in conversion facilities

(1) Electric power plant

It is planned to repair and modify the plants in CES before 2000, and therefore, it is sure that energy conservation measures would be applied in the course of renovation by 2000, utilizing the most modern technology. At the present, the internal use of electricity is higher than the design value due to bad condition of coal causing longer running time of mills. By improvement of condition of coal supply, energy consumption will be also improved in power plants. As mentioned in 4.1.2, a mine-mouth coal fired power plant will be constructed at coal mining site in around 2005. Such a new power plant would be designed to secure high energy efficiency, 35 % of gross generation efficiency, applying new technology. Application of more efficient power generation system such as combined cycle co-generation system will not be industrialized until the hike of the oil price.

(2) Heat supply system

Coal conservation for large boilers will be implemented by 2000 in the same schedule with the power plant. Heat loss of the hot water distribution system must be minimized by renovation of the system, which includes installation of the flow meter in each consumer. According to the ADB report, present heat loss amount to about 50 % of the delivered heat and it could be decreased to 30 % at least by renovation of facilities and energy-saving efforts by users. Taking renovation above into consideration, the effect of energy-saving in power sector is included in coal demand forecast of 2.4.

Note: 35 % of gross conversion efficiency as the average of recent coal fired power plants in Japan is used for estimation.

5.2.2 Coal saving in direct coal utilization (coal burning)

Present and desirable thermal efficiency of medium size boilers and the typical home ovens are as follows:

| | present | desirable efficiency |
|---|---|---|
| Industrial boiler/heater | 60 % | 88-92 % |
| Household oven | 50 % | 60-65 % |

As mentioned in 5.1.2 (1) above, kilns in cement plants are not so efficient in Mongolia compared with those in China and Japan. Rather high amount of energy-saving effort in the out of power sector will be achieved by the energy-saving effort which is promoted by price control of the Government, however, saving measures by modification of facilities will require rather long period due to lack of the capital fund. Taking uncertainty of expected energy conservation of said boilers into consideration, the effect of energy conservation in coal direct use, excepting power plants, is not included in coal demand forecast of 2.4

5.2.3 Energy conservation in indirect coal utilization (electricity and heat)

Best and faster method for electricity-saving is the price control by the Government, while the profit of price control policy must be applied to subsidy of capital fund for energy-saving. Electricity saving and thermal energy conservation in the industry sector can be achieved mostly by modification of the equipment and sometimes the whole plant, and therefore it will require a long period. According to the ADB report, in the textile factory, by implementation of low cost maintenance, specific energy consumption can be decreased by at least approximately 10 %. Another report prepared for the Ministry of Trade and Industry by the Boston Consulting Group describes that , in textile finishing operations, saving in the order of 20 - 30 % in consumption levels are typically realizable through minor changes, such as recuperation of waste heat, better insulation of steam and condensate pipes and process equipment, and improvements in the control of the production process and boiler operation. Taking uncertainty of expected energy conservation by electricity and heat users into consideration, the effect of energy conservation in indirect coal use is not included in the coal demand forecast of 2.4.

### 5.2.4 Other energy (coal) conservation potential

(1) Converting oil to coal

In Mongolia, petroleum products are used mainly in three fields, a) gasoline and diesel oil for vehicle and machines, b) diesel oil for power generation in rural areas, and c) fuel oil for controlling the coal fired boilers. Amount of petroleum consumption for a) and b) is 2 million tons (tce/y in 1990) and it will be difficult to convert it into coal in technical and economic point of view. Amount of fuel oil consumption for c) is about 4 % of coal consumption of power plants, 130,000 tons/year of coal(3,500 kcal/kg) or 50,000 tons/year of oil, and it will be minimized by repair and modification of existing boilers before 2000.

(2) Upgrading of coal quality

Upgrading of coal quality by washing is not recommendable because it is uneconomical procedure for lignite. Upgrading of coking coal in Tavantolgoi will be implemented for export. Briquetting of lignite is a recommendable upgrading method which could decrease air pollutants and increase thermal efficiency of small boilers and stoves.

(3) Utilization of flammable wastes

It is sure that an effective utilization of flammable wastes is already implemented as fuel for household use in Mongolia, and thus, it is not necessary to introduce a large scale waste disposal combustion boiler.

## 5.3 Policy and procedure for promotion of energy conservation

Basic political measures for promoting energy conservation are as follows:

| | |
|---|---|
| (i) Guidance and inducement | : Campaigns for energy conservation |
| | Establishment of standard energy efficiency |
| | Education and training program at the Energy Conservation Center |
| (ii)Incentives | :Price control for each fuel |
| | Tax control for energy saving devices |
| | Financial assistance for energy saving devices |
| (iii) Compulsory | : Restriction of car driving |
| | Restriction of petrol station |

Tax control and financial assistance are effective measures for energy-saving in the industry sectors.

Above all, the most effective political measures for the whole sectors are to increase prices including tax for each fuel controlled by the Government, the profit made by price increase, however, must be used to support of low income people as well as to fund tax control and low-interest loans.

## 5.4 Energy conservation plan

The energy conservation measure will be classified into the following three categories:

### (1) First category

The first category means the energy conservation by the methods of modification for operation and maintenance of plant and equipment, which will not be accompanied by new investments, and will include following measures,

1) Cultivation of energy conservation mind;
   - Education and training of workers to improve their ideas for energy conservation
   - Promotion and incentive to energy saving activities by the managements

2) Technical consideration;
   - Adjustment of fuel air ratio to improve efficiency of furnaces and
   - Repair of damaged thermal insulation
   - Prevention of steam leakage and recovery of condensate water
   - Stopping idle machinery
   - Cleaning of heat exchanger to keep good heat recovery conditions

The improvement in above mentioned first category, e.g. the appropriate management of operation and maintenance of plant and equipment, which does not require a large amount of new investments, can accomplish a certain (not a small) energy saving. The energy conservation in Mongolia shall be proceeded in this category first. Repair and modification of existing power plants should be proceeded immediately to avoid power failure and scheduled power cut.

(2) Second category

The second category means the energy conservation by partial improvement of existing machinery and equipment, which will be accompanied by some investments, and will include following measures:

- Recovery of waste heat and preheating of combustion air for furnaces and boilers
- Reinforcement of thermal and cold insulation
- Installment of meters for heat, electricity and fuel supply to households
- Installment of controlling instruments for small boilers

(3) Third category

The third category means the energy conservation by complete replacements of the obsolete equipment and facilities to energy conservation types, which will require large amount of investments. The objectives of these measures in the third category are usually not only for energy-saving but also for quality improvement and cost reduction of product as the fundamental reformation of the system. The examples of measures will be such as a continuous casting system in steel making industry and a new suspension preheater kiln in cement industry. As mentioned in 4.1 to 4.5, most of the equipment and facilities were designed by the former Soviet Union without any energy saving concepts, and the energy conservation has never been considered. Therefore it is necessary to proceed with the energy-saving in accordance with long-range energy saving modification plan.

In view of constraint on funds for modernization of industrial process and facility, including energy-saving measures, the Government must support the supply of the required funds by reviewing the tax system to industry sector and supplying low-interest loans. It will proceed energy-saving. In addition to study work for tax control and supplying low-interest loans, it is necessary to bring the energy price up to the international level, as soon as possible, particularly by considering its impact on the people's lives.

Before entering this action,the Government is required to resolve the issues regarding the unpreferable credit and debt system which the enterprises in Mongolia suffer from.

# 6 Air Quality Protection in Relation to Coal-Combustion

## 6.1 Present state of air quality

### 6.1.1 State of pollution sources

(1) General situation

More than half of the population of Mongolia live in urban areas, and half of the urban population live in Ulaanbaatar. Approximately 40% of the whole nation are supplied with electricity. However, the percentage for those living in gers is 15% at most.

Air quality in Mongolia has been reportedly worsening in urban areas such as Ulaanbaatar, Darkhan, Sharyngol, Erdenet and Choybalsan. The pollution is considered to be caused by exhaust gases from power plants, motorvehicles, and domestic heating devices. Among these pollution sources, coal-fired facilities and devices are considered to be the major cause of air pollution because coal is the dominant fuel in this country. Furthermore, the fact that the serious air pollution occurs in the cold season suggests that household heating is closely related to the pollution. In addition to individual stoves for gers and apartment houses, domestic heating also depends on coal-fired boilers for central heating systems and those in power plants and heating centers for district heating systems that provide steam through pipelines.

(2) Coal-fired power plant

Power plants in Mongolia burn domestically produced coal. The major power plants being operated are the Fourth Ulaanbaatar generating 70% of the national total production, the Third Ulaanbaatar generating 20% of the national total, Erdenet, Darkhan and the Second Ulaanbaatar. Thus in Ulaanbaatar City, three coal-fired power plants, the Second, the Third and the Fourth, are now in operation supplying electricity and steam as a heat medium to apartment houses and office buildings. These three power plants consumed 2.9 million ton of coal in 1993 ; the amount corresponds to approximately 80% of the total consumption in the City at 3.6 million tons. The Third Ulaanbaatar power plant has scrubbers and the Fourth Ulaanbaatar power plant has electrostatic precipitators. However, no plant has desulfurization or denitration facility.

(3) Boilers

Total 222 units of large to small boilers exist for industrial use and for heating of offices that are not connected to the district heating system. Among them, 137 units are now in operation consuming 0.4 million tons of coal per year. These boilers are not equipped with flue gas treatment devices such as filters.

(4) Stoves used in gers

Out of about 590,000 people in Ulaanbaatar, almost a half live in multi-story apartment houses constructed by the government. The rest lived in about 53,000 gers (or simple wooden houses) located at the foot of hills or in the suburbs. The numbers of gers by districts of the City are shown in Table 6.1.

Table 6.1 Number of Gers in Ulaanbaatar (1994)

| Sukhbaatar | Bayangol | Bayanzur-ukh | Chingeltei | Khauul | Songinoh-airhan | Total |
|---|---|---|---|---|---|---|
| 7,356 | 4,970 | 10,622 | 12,858 | 6,296 | 13,241 | 53,343 |

Average fuel consumption in gers for stoves is estimated at 4 to 5 tons of coal and approximately 4 $m^3$ of firewood per ger per year. Combustion efficiency of these stoves are very low and the height of stacks is low at 3 to 4 meters preventing dispersion of pollutants in the atmosphere. Therefore, the stoves are regarded as one of the major causes of high pollutant concentration at the ground level.

(5) Coal consumption in Ulaanbaatar

Coal, as a major fuel, was consumed at about 3.6 million tons in Ulaanbaatar in 1993. The shares of the consumption by end users are summarized in Table 6.2.

Table 6.2 Coal Consumption in Ulaanbaatar (1993)

| | Consumers | Consumption (1,000 ton) |
|---|---|---|
| Power Plants | No. 2 | 129 |
| | No. 3 | 861 |
| | No. 4 | 1,906 |
| | Sub-total | 2,896 |
| | Boilers for Factories | 400 |
| Others | Stoves in Households | 260 |
| | Sub-total | 660 |
| Total | | 3,556 |

### 6.1.2 Emission of coal-related pollutants

(1) Quality of coal

Quality of coal used in Ulaanbaatar is shown in Table 6.3 by coal producing mines. The table also gives the share of each mine at coal consumers. The average quality of the mixed coal is shown in Table 6.4 by respective consumers.

Table 6.3 Quality of Coal Used in Ulaanbaatar by Coal Mine

| Coal Mine | Sulfur Content | Calorific Value | | | | Share of Coal Mine by User (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | High Heating Value (dry, ash free basis) | | Low Heating Value (wet with ash) | | Power Plant | | | Others |
| | | | | | | No. 2 | No. 3 | No. 4 | |
| | weight % | kcal / kg | MJ / kg | kcal / kg | MJ / kg | | | | |
| Baganuur | 0.77 | 6,731 | 28.18 | 3,586 | 15.01 | 58.3 | 38.9 | 85.4 | 78.9 |
| Sharyngol | 0.60 | 7,200 | 30.14 | 4,050 | 16.96 | 40.7 | 59.6 | 0.0 | 0.6 |
| Shivee Ovoo | 0.75 | 6,700 | 28.05 | 3,527 | 14.77 | 1.0 | 1.5 | 14.6 | 20.5 |

Table 6.4 Average Quality of Coal by Consumers in Ulaanbaatar

| Consumer | Sulfur Content | Calorific Value | | | |
|---|---|---|---|---|---|
| | | High Heating Value (dry, ash free basis) | | Low Heating Value (wet, with ash basis) | |
| | weight % | kcal / kg | MJ / kg | kcal / kg | MJ / kg |
| Power Plant No. 2 | 0.70 | 6,921 | 28.98 | 3,774 | 15.80 |
| Power Plant No. 3 | 0.67 | 7,010 | 29.35 | 3,862 | 16.17 |
| Power Plant No. 4 | 0.77 | 6,726 | 28.16 | 3,577 | 14.98 |
| Boilers for Factories | 0.76 | 6,727 | 28.17 | 3,577 | 14.97 |
| Households | 0.76 | 6,727 | 28.17 | 3,577 | 14.97 |

(2) Emission factors for coal-related pollutants

In Mongolia, no officially determined emission factors are available. Therefore, foreign technical documents are referred to. One document is "Analysis of Structure of Energy Utilization and Global Environment, Science and Technology Agency of Japan, 1992" (hereinafter referred to as "Asia"), and the other is "Study of Comprehensive Energy Plan in East-Siberia and Far East of Russian Federation, the Institute of Energy Economics of Japan, 1994" (hereinafter referred to as "Russia"). Combining the information from both documents, the adaptable emission factors of coal-related pollutants, i.e. $SO_2$, NOx, dust and benzpylene, are proposed as shown in Table 6.5.

Table 6.5 Proposed Emission Factors of Coal-related Air Pollutants

| Pollutants | Unit | Power plants | Boilers | Stoves | Reference |
|---|---|---|---|---|---|
| $SO_2$ | kg/t | 19.5 x S% | 15.5 x S% | 12.0 x S% | 1 |
| NO2 | kg/TJ | 430 | 240 | 110 | 2 |
| Dust | kg/TJ | 1,045 | 2,000 | 1,420 | 2 |
| Benzpyrene | g/TJ | 0.17 | 1.5 | 22 | 2 |

Note : Reference 1 : Asia
Reference 2 : Russia

In selection of the emission factors from those given in above two documents, the Russia is more beneficial because it has the wider coverage of pollutants than that of the Asia. But since the emission factor for $SO_2$ is given with a very wide range, 180 to 680 kg/TJ, it is difficult to select proper values without the information of sulfur contents of Russian brown coal for which the emission factors were determined. Therefore, the $SO_2$ emission factor alone was referred to the document Asia as shown in the table.

(3) Estimated present emissions of pollutants

Present emissions of coal-related pollutants were estimated based on the afore-mentioned emission factors, coal amount and quality. They are shown in Table 6.6.

Table 6.6 Estimated Present Emissions of Coal-related Pollutants (1993)

| Emission Sources | $SO_2$ (1,000 ton/y) | $NO_2$ (1,000 ton/y) | Dust (1,000 ton/y) | Benzpyrene (kg/y) |
|---|---|---|---|---|
| Power Plant No.2 | 1.8 | 1.6 | 3.9 | 0.6 |
| Power Plant No.3 | 11.2 | 10.9 | 26.4 | 4.3 |
| Power Plant No.4 | 28.6 | 23.1 | 56.1 | 9.1 |
| Boilers for Factory | 4.7 | 2.7 | 22.5 | 16.9 |
| Stoves | 2.4 | 0.8 | 10.4 | 160.9 |
| Total | 48.7 | 39.1 | 119.3 | 191.9 |

6.1.3 Concentration of air pollutants

(1) Environmental standards of pollutant concentration

The environmental standards for concentrations of $SO_2$, $NO_2$ and dust in Mongolia are shown in Table 6.7 in comparison with those in Japan.

Table 6.7 Environmental Standards of $SO_2$, $NO_2$ and Dust

| | Averaging time | Mongolia | Japan |
|---|---|---|---|
| $SO_2$ | 1 day | 0.05 mg/m$^3$ (19 ppb) | (0.106 mg/m$^3$) 40 ppb |
| | 1 hour | 0.5 mg/m$^3$ (188 ppb) | (0.266 mg/m$^3$) 100 ppb |
| $NO_2$ | 1 day | 0.04 mg/m$^3$ (21 ppb) | (0.077 - 0.115 mg/m$^3$) 40 - 60 ppb |
| | 1 hour | 0.085 mg/m$^3$ (45 ppb) | - |
| | | TSP | SPM |
| Dust | 1 day | 0.15 mg/m$^3$ | 0.1 mg/m$^3$ |
| | 1 hour | 0.5 mg/m$^3$ | 0.2 mg/m$^3$ |

Note : 1) The conversion of unit between mg/m$^3$ and ppb for $SO_2$ and $NO_2$ was made for the condition of 20℃ and 1 atmospheric pressure.

2) TSP : Total suspended particulates

SPM : Suspended particulate matter of the diameter less than 10 $\mu$m.

The daily average standards for $SO_2$ and $NO_2$ in Mongolia are about two times more stringent than those in Japan.

(2) Results of monitoring by the government

The Ministry of Environment has following three fixed stations for air quality monitoring in Ulaanbaatar City.

ST-1 : Central Laboratory of Environmental Monitoring

ST-2 : Baruum Durvon Zam

ST-3 : Bayan Khoshuu

Their locations are shown in Figure 6.1. The stations are operated by the Central Laboratory of Environmental Monitoring, a subordinate to the Ministry of Environment. The laboratory also operates a mobile monitoring unit to cover the whole city. $SO_2$ and $NO_2$ are observed at both the fixed and mobile stations.

1) Fixed monitoring stations

Results of monitoring of $SO_2$ and $NO_2$ at the fixed stations since 1990 are shown in Table 6.8 and Table 6.9.

(a) $SO_2$

Annual average concentrations ranged from 0.004 mg/m$^3$ (ST-1 in 1994) to 0.013 mg/m$^3$ (ST-3 in 1992). Annual maximum daily average values ranged from 0.03 mg/m$^3$ (ST-2 in 1994) to 0.25 mg/m$^3$ (ST-2 in 1992). Although the environmental standard of 0.05 mg/m$^3$ as daily average was exceeded by the annual maximum daily average value in 1990 through 1993 at all stations, it was satisfied in 1994 at all stations. Referring to the seasonal variation, the summer average for the 4 - 5 year period was low at 0.003 mg/m$^3$ (ST-1, ST-2) to 0.005 mg/m$^3$ (ST-3), but the winter average was much higher at 0.011 mg/m$^3$ (ST-1) to 0.017 mg/m$^3$ (ST-3).

(b) $NO_2$

The $NO_2$ pollution in Ulaanbaatar can be said, in general, to be worse than that of $SO_2$ Annual average concentrations ranged from 0.025 mg/m$^3$ (ST-1 in 1994) to 0.115 mg/m$^3$ (ST-2 in 1993). All of annual maximum daily average values exceeded the environmental standard of 0.04 mg/m$^3$ for daily average. The concentration was highest at ST-2 where even annual average values exceeded the daily average standard. This station is located besides a major road and considered to be strongly affected by automobile exhaust gases. At station ST-3, annual average values exceeded the daily average standard in 1991 and 1993. The general seasonal trend is that the concentration is highest in the winter and lowest in the summer.

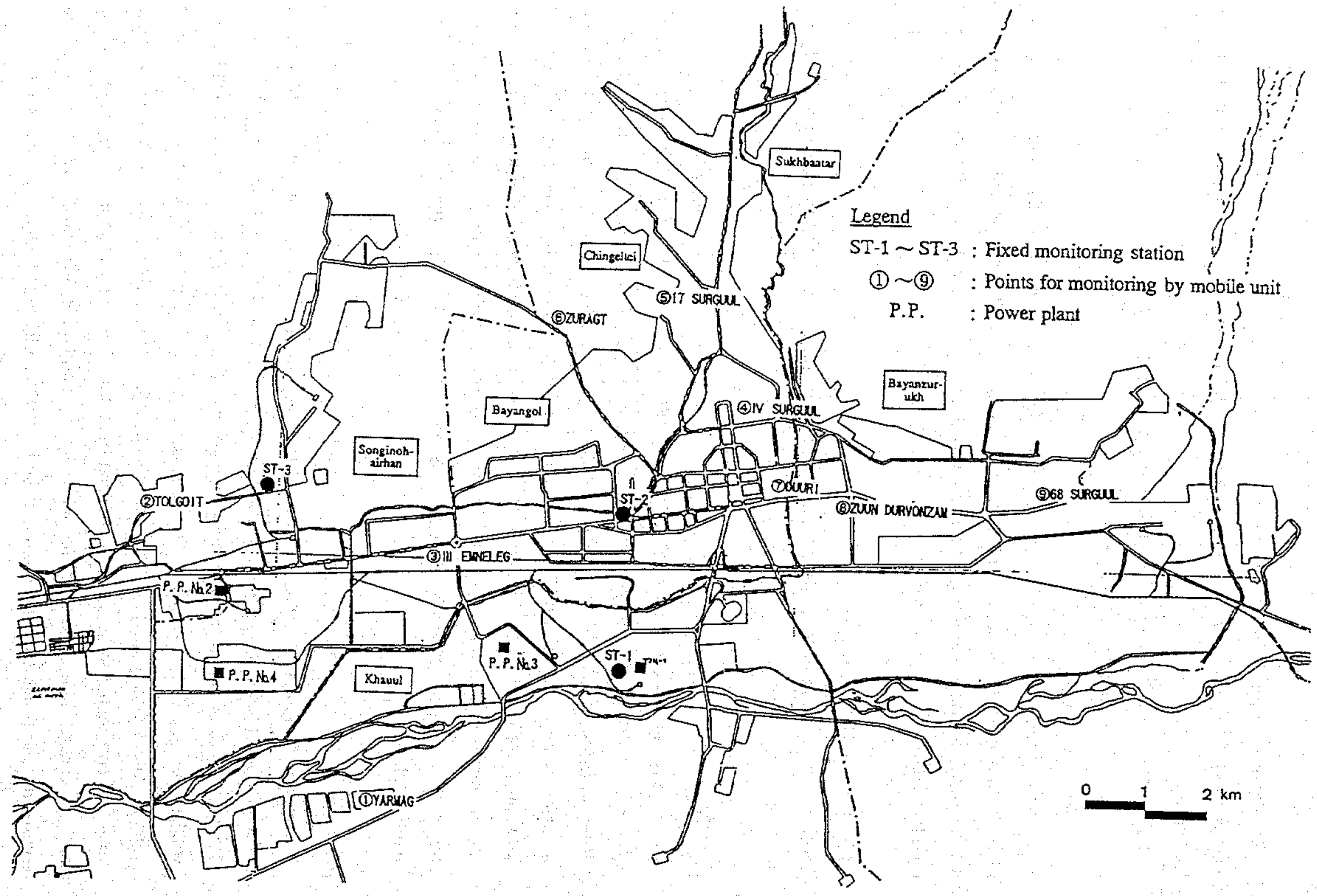



Figure 6.1 Location of Monitoring Stations and Power Plants in Ulaanbaatar

2) Points monitored by mobile unit

Monitoring by the mobile unit in Ulaanbaatar City in 1994 was conducted at nine points shown in Figure 6.1. Sampling at each point was made three times a day, morning, daytime and evening, with a sampling period of two to three hours. The monitoring was repeated through the year so that the measurements at each station could cover four seasons. Results acquired at monitoring points are shown in Table 6.10.

(a) $SO_2$

The maximum seasonal average of hourly concentration was 0.034 mg/m$^3$ at point 3 in the autumn. The maximum hourly concentration in the year was 0.1 mg/m$^3$ at point 5 and was far below the hourly environmental standard of 0.5 mg/m$^3$.

(b) $NO_2$

The maximum seasonal average of hourly concentration was 0.090 mg/m$^3$ at point 3 in the autumn. The maximum hourly concentrations in the year ranged from 0.084 mg/m$^3$ at point 2 to 0.2 mg/m$^3$ at point 6, and exceeded the hourly standard of 0.085 mg/m$^3$ except at point 2.

Table 6.8 Yearly Change of $SO_2$ and $NO_2$ Concentrations at Fixed Monitoring Stations in Ulaanbaatar

(unit : $mg/m^3$)

| Year | | ST - 1 | | ST - 2 | | ST - 3 | |
|---|---|---|---|---|---|---|---|
| | | $SO_2$ | $NO_2$ | $SO_2$ | $NO_2$ | $SO_2$ | $NO_2$ |
| 1990 | Max. | 0.07 | 0.22 | 0.13 | 0.30 | 0.08 | 0.16 |
| | Ave. | 0.007 | 0.037 | 0.006 | 0.083 | 0.006 | 0.036 |
| 1991 | Max. | 0.10 | 0.21 | 0.11 | 0.39 | 0.12 | 0.17 |
| | Ave. | 0.009 | 0.034 | 0.009 | 0.086 | 0.006 | 0.042 |
| 1992 | Max. | 0.19 | 0.13 | 0.25 | 0.40 | 0.17 | 0.19 |
| | Ave. | 0.009 | 0.029 | 0.012 | 0.103 | 0.013 | 0.039 |
| 1993 | Max. | 0.07 | 0.11 | 0.10 | 0.38 | 0.06 | 0.17 |
| | Ave. | 0.009 | 0.032 | 0.007 | 0.115 | 0.008 | 0.046 |
| 1994 | Max. | 0.04 | 0.19 | 0.03 | 0.38 | - | - |
| | Ave. | 0.004 | 0.025 | 0.004 | 0.048 | - | - |
| Average through 1990 to1994 | Max. | 0.19 | 0.22 | 0.25 | 0.40 | 0.17 | 0.19 |
| | Ave. | 0.007 | 0.031 | 0.008 | 0.087 | 0.008 | 0.041 |
| Environmental Standard | daily | 0.05 | 0.04 | 0.05 | 0.04 | 0.05 | 0.04 |
| | hourly | 0.5 | 0.085 | 0.5 | 0.085 | 0.5 | 0.085 |

Note : Max. values refer to the maximum of daily average values.

Table 6.9 Seasonal Variation of $SO_2$ and $NO_2$ Concentrations at Fixed Monitoring Stations in Ulaanbaatar (1990 ~ 1994)

(unit : mg/m3)

| Monitoring Station | | $SO_2$ | | | | | $NO_2$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | winter | spring | summer | autumun | whole period | winter | spring | summer | autumun | whole period |
| ST - 1 | Max. | 0.094 | 0.15 | 0.072 | 0.19 | 0.19 | 0.22 | 0.019 | 0.10 | 0.19 | 0.22 |
| | Ave. | 0.011 | 0.007 | 0.003 | 0.007 | 0.007 | 0.041 | 0.026 | 0.02 | 0.036 | 0.031 |
| ST - 2 | Max. | 0.16 | 0.25 | 0.058 | 0.13 | 0.25 | 0.40 | 0.26 | 0.30 | 0.39 | 0.40 |
| | Ave. | 0.012 | 0.008 | 0.003 | 0.008 | 0.008 | 0.12 | 0.074 | 0.062 | 0.094 | 0.087 |
| ST - 3 | Max. | 0.17 | 0.13 | 0.036 | 0.12 | 0.17 | 0.19 | 0.15 | 0.081 | 0.16 | 0.19 |
| | Ave. | 0.017 | 0.006 | 0.005 | 0.005 | 0.008 | 0.052 | 0.035 | 0.028 | 0.041 | 0.041 |

Note : 1) Winter : December to February, Spring : March to May, Summer : June to August, Autumn : September to November
2) Max. values refer to the maximum of daily average values
3) Data at ST-3 are for the period of 1990 - 1993.

Table 6.10 Result of Seasonal Monitoring of $SO_2$ and $NO_2$ in Ulaanbaatar by Mobile Unit (1994)

(unit : mg/m3)

| Monitoring Point | | $SO_2$ | | | | | $NO_2$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | winter | spring | summer | autumn | whole year | winter | spring | summer | autumn | whole year |
| 1 YARMAG | Max. | 0.024 | 0.013 | 0.009 | 0.028 | 0.028 | 0.084 | 0.100 | 0.028 | 0.090 | 0.100 |
| | Ave. | 0.006 | 0.008 | 0.007 | 0.021 | 0.009 | 0.039 | 0.050 | 0.018 | 0.054 | 0.041 |
| 2 TOLGOIT | Max. | 0.044 | 0.015 | 0.016 | 0.037 | 0.044 | 0.078 | 0.068 | 0.025 | 0.084 | 0.084 |
| | Ave. | 0.016 | 0.009 | 0.009 | 0.029 | 0.015 | 0.041 | 0.032 | 0.021 | 0.068 | 0.039 |
| 3 III EMNELEG | Max. | 0.018 | 0.012 | 0.009 | 0.040 | 0.040 | 0.147 | 0.051 | 0.031 | 0.127 | 0.147 |
| | Ave. | 0.008 | 0.008 | 0.006 | 0.034 | 0.011 | 0.057 | 0.031 | 0.021 | 0.090 | 0.049 |
| 4 IV SURGUUL | Max. | 0.026 | 0.011 | 0.008 | 0.022 | 0.026 | 0.096 | 0.149 | 0.060 | 0.109 | 0.149 |
| | Ave. | 0.011 | 0.006 | 0.006 | 0.015 | 0.009 | 0.047 | 0.038 | 0.031 | 0.050 | 0.042 |
| 5 17 SURGUUL | Max. | 0.040 | 0.100 | 0.003 | 0.024 | 0.100 | 0.112 | 0.045 | 0.045 | 0.087 | 0.112 |
| | Ave. | 0.013 | 0.020 | 0.002 | 0.016 | 0.014 | 0.059 | 0.030 | 0.026 | 0.044 | 0.044 |
| 6 ZURAGT | Max. | 0.027 | 0.010 | 0.008 | 0.016 | 0.027 | 0.200 | 0.089 | 0.016 | 0.069 | 0.200 |
| | Ave. | 0.012 | 0.006 | 0.006 | 0.010 | 0.009 | 0.078 | 0.041 | 0.011 | 0.049 | 0.054 |
| 7 DUURI | Max. | 0.040 | 0.010 | 0.002 | 0.009 | 0.040 | 0.154 | 0.064 | 0.045 | 0.101 | 0.154 |
| | Ave. | 0.015 | 0.006 | 0.002 | 0.007 | 0.009 | 0.066 | 0.042 | 0.027 | 0.070 | 0.054 |
| 8 ZUUN | Max. | 0.062 | 0.008 | 0.005 | 0.018 | 0.062 | 0.126 | 0.124 | 0.038 | 0.076 | 0.126 |
| DURVONZAM | Ave. | 0.014 | 0.004 | 0.004 | 0.012 | 0.009 | 0.066 | 0.044 | 0.025 | 0.069 | 0.054 |
| 9 68 SURGUUL | Max. | 0.042 | 0.011 | 0.008 | 0.042 | 0.042 | 0.082 | 0.088 | 0.013 | 0.079 | 0.088 |
| | Ave. | 0.012 | 0.005 | 0.004 | 0.027 | 0.011 | 0.053 | 0.039 | 0.011 | 0.052 | 0.043 |

Note : Winter corresponds to December, January and February, spring to March and April, summer to June, and autumn to November.

(2) Dust (TSP) concentration observed by the JICA team

Dust (total suspended particulates : TSP) concentrations were observed at existing three fixed monitoring stations in Ulaanbaatar City by using a high-volume air sampler and an analytical balance. Sampling was made by turns from one point to another because only one sampler was available. Results obtained are summarized in Tables 6.11 and 6.12. Detailed results are shown in Table 6.13.

ST-1 is located 1.5 km east of the Third power plant, and the TSP concentration was lower than in other stations. The daily average TSP concentrations at ST-1 ranged from 0.06 to 1.21 $mg/m^3$, and the environmental standard of 0.15 $mg/m^3$ was exceed for 15 days out of 35 days of the measurement. The maximum concentration appeared on April 27. The overall average was 0.18 $mg/m^3$, which was the lowest among the three points.

ST-2 is located at a busy intersection of Enkhtayvan Avenue and Zanabazar Street. The TSP concentration was possibly affected by the exhaust of motor vehicles and road dust. The daily average TSP concentrations at ST-2 ranged from 0.12 to 0.77 $mg/m^3$, and the environmental standard of 0.15 $mg/m^3$ was exceeded for 33 days out of 36 days of the measurement. The maximum concentration appeared on April 16. The overall average was 0.30 $mg/m^3$, which was the medium among the three points.

ST-3 is located northwest of Ulaanbaatar City where many gers exist. Therefore, the station is likely to be influenced by the exhaust of stoves for domestic heating in the morning and the evening. The daily average TSP concentrations at ST-3 ranged from 0.16 to 1.17 $mg/m^3$, and the environmental standard of 0.15 $mg/m^3$ was exceeded in all of 33 days of measurement. The maximum concentration appeared on March 10, and it was as high as about eight times the standard. The overall average was 0.47 $mg/m^3$,which was the highest among the three points.

Table 6.11 Summary of Measurement of Daily Average TSP Concentration in Ulaanbaatar (January - May, 1995)

| Data | | ST - 1 | ST - 2 | ST - 3 |
|---|---|---|---|---|
| Average | ($mg/m^3$) | 0.18 | 0.30 | 0.47 |
| Minimum | ($mg/m^3$) | 0.06 | 0.12 | 0.16 |
| Maximum | ($mg/m^3$) | 1.21 | 0.77 | 1.17 |
| Number of data | | 35 | 36 | 33 |

Table 6.12 Frequency of Appearance of Daily Average TSP Concentration Levels

| Concentration Level | Frequency of Appearance (day) | | |
|---|---|---|---|
| ($mg/m^3$) | ST - 1 | ST - 2 | ST - 3 |
| ~0.15 | 20 | 3 | 0 |
| ~0.20 | 9 | 11 | 4 |
| ~0.30 | 1 | 10 | 10 |
| ~0.40 | 3 | 4 | 7 |
| ~0.50 | 1 | 3 | 4 |
| ~1.00 | 0 | 5 | 4 |
| 1.00 < | 1 | 0 | 4 |
| Number of data | 35 | 36 | 33 |

Table 6.13 Daily Average Concentration of TSP in Ulaanbaatar Observed by the JICA Team (January - May, 1995)

| ST - 1 | | ST - 2 | | ST - 3 | |
|---|---|---|---|---|---|
| Date | TSP Concentration (mg/m³) | Date | TSP Concentration (mg/m³) | Date | TSP Concentration (mg/m³) |
| Jan. 13 | 0.09 | Jan. 17 | 0.13 | Jan. 20 | 0.32 |
| 14 | 0.31 | 18 | 0.12 | 21 | 0.19 |
| 15 | 0.13 | 19 | 0.18 | 22 | 0.23 |
| 16 | 0.09 | 26 | 0.16 | 30 | 0.32 |
| 23 | 0.15 | 27 | 0.21 | 31 | 0.28 |
| 24 | 0.14 | 28 | 0.18 | Feb. 01 | 0.30 |
| 25 | 0.17 | 29 | 0.18 | 14 | 0.36 |
| Feb. 02 | 0.16 | Feb. 08 | 0.16 | 15 | 0.28 |
| 03 | 0.07 | 09 | 0.18 | 16 | 0.29 |
| 04 | 0.08 | 10 | 0.16 | 17 | 0.29 |
| 05 | 0.07 | 11 | 0.20 | 18 | 0.29 |
| 06 | 0.09 | 12 | 0.22 | 19 | 0.25 |
| 07 | 0.08 | 13 | 0.23 | 20 | 0.39 |
| 21 | 0.11 | 28 | 0.33 | Mar. 07 | 0.89 |
| 22 | 0.10 | Mar. 01 | 0.21 | 08 | 0.41 |
| 23 | 0.20 | 02 | 0.19 | 09 | 0.20 |
| 24 | 0.12 | 03 | 0.24 | 10 | 1.17 |
| 25 | 0.11 | 04 | 0.30 | 11 | 0.16 |
| 26 | 0.16 | 05 | 0.32 | 12 | 0.44 |
| 27 | 0.11 | 06 | 0.42 | 13 | 0.50 |
| Mar. 14 | 0.09 | 21 | 0.59 | Apr. 05 | 1.71 |
| 15 | 0.16 | 22 | 0.30 | 06 | 1.28 |
| 16 | 0.46 | 23 | 0.60 | 07 | 0.39 |
| 17 | 0.34 | 24 | 0.26 | 08 | 0.32 |
| 18 | 0.24 | Apr. 11 | 0.32 | 09 | 0.20 |
| 19 | 0.10 | 12 | 0.24 | 10 | 1.04 |
| 20 | 0.14 | 13 | 0.20 | May 02 | 0.55 |
| Apr. 24 | 0.17 | 14 | 0.40 | 03 | 0.48 |
| 25 | 0.19 | 15 | 0.74 | 04 | 0.31 |
| 26 | 0.17 | 16 | 0.77 | 05 | 0.57 |
| 27 | 1.21 | May 09 | 0.47 | 06 | 0.60 |
| 28 | 0.18 | 10 | 0.23 | 07 | 0.29 |
| 29 | 0.31 | 11 | 0.70 | 08 | 0.28 |
| 30 | 0.06 | 12 | 0.16 | | |
| May 01 | 0.06 | 13 | 0.18 | | |
| | | 14 | 0.15 | | |

## 6.2 Air quality in the future

### 6.2.1 Estimated emissions of pollutants from coal-related facilities

From the result of the coal demand forecast described in Section 2.4, expected coal consumption in Ulaanbaatar by sector in 2000, 2005 and 2010 is summarized in Table 6.14. For each future year, two cases are considered: high demand case and low demand case.

Amounts of pollutant emissions in the future years resulting from the forecasted coal consumption were estimated in the same manner as that in Section 6.1.1. The result of the estimation is shown in Table 6.15.

### 6.2.2 Ground-level concentration of $SO_2$ and $NO_2$ emitted from power plants

(1) Basic consideration

Wind characteristics in Ulaanbaatar are complex because the city lies on the basined topography surrounded by mountains and the Tuul River. Instantaneous wind directions vary from placed to place as it was often observable through the trajectories of the smoke from the Third and the Fourth power plants. Atmospheric thermal inversion is said to occur frequently in the winter in Ulaanbaatar. The inversion layer acts as a lid because it prevents pollutants from dispersing into the upper atmosphere. Although the height of the lid changes from time to time, pollutants from the stacks of the Third and the Fourth power plants are often discharged above the lid. In this case, the contributions of these power plants to the ground-level pollutant concentration are relatively small.

In the following analysis, ground-level concentrations of $SO_2$ and $NO_2$ emitted from the power plants are estimated under the no-lid condition where the emissions from the power plants have relatively large influence on the ground.

(2) Estimatimation of ground-level concentrations of $SO_2$ and $NO_2$

The following Sutton equation is used to estimate a maximum ground-level concentration of a pollutant.

$$Cmax = 0.234(Q/uHe^2)(Cz/Cy)$$

Table 6.14 Forecasted Coal Consumption in Ulaanbaatar (unit: 1,000 ton)

| | | 1993 | 2000 | | 2005 | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| | | Actual | H | L | H | L | H | L |
| Power Plants | No. 2 | 129 | 0 | 0 | 0 | 0 | 0 | 0 |
| | No. 3 | 861 | 738 | 668 | 880 | 766 | 1,073 | 890 |
| | No. 4 | 1,906 | 2,102 | 1,961 | 2,377 | 2,027 | 2,875 | 2,364 |
| | Sub-total | 2,896 | 2,840 | 2,630 | 3,257 | 2,794 | 3,948 | 3,255 |
| Industries | Industry | 400 | 286 | 273 | 369 | 335 | 498 | 420 |
| | Add. Indus. | 0 | 100 | 100 | 200 | 200 | 300 | 300 |
| | Sub-total | 400 | 386 | 373 | 569 | 535 | 798 | 720 |
| Others | Transport | | 30 | 30 | 33 | 33 | 36 | 36 |
| | Agriculture | | 204 | 204 | 226 | 226 | 249 | 249 |
| | Residential | | 291 | 291 | 322 | 322 | 355 | 355 |
| | Others | | 267 | 267 | 295 | 295 | 326 | 326 |
| | Sub-total | 260 | 793 | 793 | 875 | 875 | 966 | 966 |
| Total | | 3,556 | 4,019 | 3,795 | 4,701 | 4,203 | 5,712 | 4,941 |

Note : H : high demand case, L : low demand case

Table 6.15 Estimate Pollutants Emissions Corresponding to Forecasted Coal Consumption in Ulaanbaatar

| | Year 2000 (High demand case) | | | | Year 2000 (Low demand case) | | | |
|---|---|---|---|---|---|---|---|---|
| | $SO_2$ (1,000 ton) | $NO_2$ (1,000 ton) | Dust (1,000 ton) | Benzpyrene (kg) | $SO_2$ (1,000 ton)) | $NO_2$ (1,000 ton) | Dust (1,000 ton) | Benzpyrene (kg) |
| P.P. No. 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P.P. No. 3 | 9.6 | 9.3 | 22.6 | 3.7 | 8.7 | 8.4 | 20.2 | 3.3 |
| P.P. No. 4 | 31.6 | 25.5 | 61.9 | 10.1 | 29.4 | 23.8 | 59.4 | 9.4 |
| Industries | 4.6 | 2.6 | 21.8 | 16.3 | 4.4 | 2.5 | 21.0 | 15.8 |
| Stoves | 7.2 | 2.5 | 31.7 | 491.2 | 7.2 | 2.5 | 31.7 | 491.2 |
| Total | 53.0 | 39.8 | 138.0 | 521.3 | 49.8 | 37.2 | 132.4 | 519.7 |
| | **Year 2005 (High demand case)** | | | | **Year 2005 (Low demand case)** | | | |
| | $SO_2$ (1,000 ton) | $NO_2$ (1,000 ton) | Dust (1,000 ton) | Benzpyrene (kg) | $SO_2$ (1,000 ton)) | $NO_2$ (1,000 ton) | Dust (1,000 ton) | Benzpyrene (kg) |
| P.P. No. 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P.P. No. 3 | 12.0 | 11.1 | 27.0 | 4.4 | 10.5 | 9.7 | 23.5 | 3.8 |
| P.P. No. 4 | 32.4 | 28.8 | 70.0 | 11.4 | 27.7 | 24.5 | 59.7 | 9.7 |
| Industries | 6.7 | 3.8 | 32.0 | 24.0 | 6.3 | 3.6 | 30.1 | 22.6 |
| Stoves | 8.0 | 2.7 | 35.0 | 542.3 | 8.0 | 2.7 | 35.0 | 542.3 |
| Total | 59.1 | 46.4 | 164.0 | 582.1 | 52.4 | 40.5 | 148.3 | 578.4 |
| | **Year 2010 (High demand case)** | | | | **Year 2010 (Low demand case)** | | | |
| | $SO_2$ (1,000 ton) | $NO_2$ (1,000 ton) | Dust (1,000 ton) | Benzpyrene (kg) | $SO_2$ (1,000 ton)) | $NO_2$ (1,000 ton) | Dust (1,000 ton) | Benzpyrene (kg) |
| P.P. No. 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P.P. No. 3 | 14.6 | 13.5 | 32.9 | 5.4 | 12.2 | 11.2 | 27.3 | 4.4 |
| P.P. No. 4 | 39.2 | 34.8 | 84.6 | 13.8 | 32.3 | 28.6 | 69.6 | 11.3 |
| Industries | 9.4 | 5.4 | 44.9 | 33.7 | 8.5 | 4.9 | 40.6 | 30.4 |
| Stoves | 8.8 | 3.0 | 38.6 | 598.7 | 8.8 | 3.0 | 38.6 | 598.7 |
| Total | 72.1 | 56.7 | 201.1 | 651.6 | 61.7 | 47.7 | 176.1 | 644.9 |

where, Cmax : Maximum ground-level pollutant concentration ($mg/m^3$)

Q : Pollutant emission intensity (mg/s)

u : Wind speed (m/s)

He : Effective stack height (m)

Cz, Cy : Sutton's dispersion parameters

The effective stack height He is calculated as follows.

$$He = H + dH$$

where, H : Actual stack height (m)

dH : Rise of the plume (m) to be calculated by the following CONCAWE equation

$$dH = 0.175(Qh)^{1/2}(u)^{-3/4}$$

where, Qh : Heat emission intensity (cal/s) = (d)(Cp)(Qg)(dT)

d : Density of exhaust gas at 0 °C ($1.293 \times 10^3$ $g/m^3$)

Cp : Specific heat at constant pressure (0.24 cal/°K/g)

Qg : Gas discharge rate ($m^3N/s$)

dT : Difference between exhaust gas temperature and air temperature (°K)

The annual average wind speed in Ulaanbaatar during 1983 - 1992 was 2.1 m/s as shown in Table 6.16. Therefore, the wind speed of 2.0 m/s was used.

Table 6.16 Monthly Mean Temperature and Wind Speed in Ulaanbaatar (1983 - 1992)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature (℃) | -21.3 | -17.3 | -8.7 | 0.8 | 10.4 | 14.3 | 16.5 | 15.2 | 8.3 | 1.0 | -11.1 | -18.5 | -0.9 |
| Wind speed (m/s) | 1.5 | 2.0 | 2.6 | 3.7 | 3.8 | 3.3 | 2.8 | 2.7 | 2.8 | 2.5 | 2.0 | 1.7 | 2.1 |

The value of Cz/Cy was selected to be 0.15 which corresponds to the atomospheric stability class of "neutral."

The stack height of each power plant is as follows:

the Second plant : 100 m, the Third plant : 150 m, the Fourth plant : 250 m

Table 6.17 Estimated Maximum Ground-level Concentration of $SO_2$

| Source | Item | 1993 | 2000 | | 2005 | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| | | Present | H | L | H | L | H | L |
| P.P. No. 2 | Cmax (mg/m$^3$) | 0.022 | - | - | - | - | - | - |
| | Xmax (m) | 6,851 | - | - | - | - | - | - |
| P.P. No. 3 | Cmax (mg/m$^3$) | 0.037 | 0.034 | 0.032 | 0.039 | 0.036 | 0.043 | 0.039 |
| | Xmax (m) | 13,780 | 13,211 | 12,869 | 13,863 | 13,346 | 14,676 | 13,910 |
| P.P. No. 4 | Cmax (mg/m$^3$) | 0.037 | 0.040 | 0.038 | 0.039 | 0.035 | 0.043 | 0.038 |
| | Xmax (m) | 21,712 | 22,244 | 21,864 | 22,952 | 22,043 | 24,145 | 22,921 |

Note : 1) H : High coal demand case, L : Low coal demand case
2) Cmax : Maximum ground-level concentration
3) Xmax : Distance from the source to the point of Cmax

Table 6.18 Estimated Maximum Ground-level Concentration of $NO_2$

| Source | Item | 1993 | 2000 | | 2005 | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| | | Present | H | L | H | L | H | L |
| P.P. No. 2 | Cmax (mg/m$^3$) | 0.020 | - | - | - | - | - | - |
| | Xmax (m) | 6,851 | - | - | - | - | - | - |
| P.P. No. 3 | Cmax (mg/m$^3$) | 0.036 | 0.033 | 0.031 | 0.036 | 0.034 | 0.040 | 0.036 |
| | Xmax (m) | 13,780 | 13,211 | 12,869 | 13,863 | 13,346 | 14,676 | 13,910 |
| P.P. No. 4 | Cmax (mg/m$^3$) | 0.030 | 0.032 | 0.031 | 0.034 | 0.031 | 0.038 | 0.034 |
| | Xmax (m) | 21,712 | 22,244 | 21,864 | 22,952 | 22,043 | 24,145 | 22,921 |

Note : 1) H and L : Same as Table 6.17
2) Cmax and Xmax : Same as Table 6.17

Computed maximum ground- level concentrations of $SO_2$ and $NO_2$ emitted from each of three power plants are shown in Table 6.17 and Table 6.18, respectively. Computations for the future years were made for the two cases of coal demand: high demand and low demand.

Although the total coal consumption in the power plants is expected to increase from 1993 to 2010, the results of the simplified simulation in Tables 6.17 and 6.18 indicate that the increases of the ground-level concentrations of $SO_2$ and $NO_2$ emitted from each of the Third and the Fourth power plants are rather small at 10 - 15 %.

### 6.2.3 Dust and benzpyrene

#### (1) Dust

As shown in Table 6.14, the current total coal consumption in three power plants accounts for about 80 % of the total coal consumption in Ulaanbaatar. In the Fourth power plant which consumes coal by 66 % of the power plants total, electrostatic precipitators with dust collection efficiency over 98 % are installed, and the stack is as high as 250 m. Therefore, its influence on the ground-level concentration of dust is considered to be relatively small.

In the Third power plant which consumes coal by 30 % of the power plants total, scrubbers are installed and the stack height is 150 m. This plant also is considered to have relatively small influence on the ground-level concentration of dust.

The coal consumption in the Second power plant is small at 5 % of the power plants total. But since the stack height is lower at 100 m and no dust collectors are installed, it is likely to have certain influence on the ambient concentration of dust. However, there will be no dust emission from this plant in 2000 since it is planned to be abolished.

Attention should be paid to dust emissions from stoves in gers. Although amount of the emission from each stove is small, these stoves are considered to be a significant cause of dust pollution in the zones concentrated with gers, because the height of stacks for these stoves are very low.

#### (2) Benzpyrene

Among common fuels such as oil, coal, gas and wood, generation of benzpyrene through fuel combustion is generally highest with coal followed by wood, oil and gas. The generation rate with a fuel widely varies depending on the combustion efficiency; the lower the combustion efficiency, the higher the generation rate. Since combustion efficiency of household stoves is generally lower than that of large combustion facilities due to incomplete combustion, the benzpyrene generation per unit amount of coal is much higher in household stoves than in power generation boilers. In addition, stacks of household stoves are very low. Therefore, benzpyrene generated in coal-burning household stoves in Ulaanbaatar must have much larger environmental impact than that generated in power plants.

## 6.3 Technical potential of air pollution control

### 6.3.1 Sources and pollutants necessary to be controlled

As discussed above, among stationary air pollution sources burning coal in Ulaanbaatar, low-height emission sources such as household heating stoves and small-to-medium size boilers, rather than power generation boilers, are likely to have large influence on the ground-level air quality, particularly on the concentrations of dust and benzpyrene.

Therefore, it is considered that the priority in air pollution control should be placed on the control of low-height emission sources for improvement of air quality in Ulaanbaatar towards the future.

### 6.3.2 Introduction of bio-briquette

The switchover of presently used coal to other quality fuels such as gas is economically difficult in Mongolia. A more realistic measure would be the use of briquette made of Mongolian coal in stoves and small-to-medium size boilers. Among various kinds of briquette, that produced by mixing biomass into pulverized coal and shaping into pellets by high compression, called "bio-briquette", is considered to be most suitable in terms of cost and pollutant reducing effects. If necessary, a desulfurization agent such as lime can be also added.

An example in Japan for the effects of bio-briqutte in reducing pollutant emission is reported to be as follows:

Reduction of dust (smoke and soot) : about 70 %

Reduction of $SO_2$ (with an agent) : 75 - 85 % for coals of the sulfur content at 1 % or less
80 - 93 % for coals of the sulfur content at more than 1 %

When dust is reduced, benzpyrene would be also reduced roughly in proportion.
Reductions of pollutant emissions in Ulaanbaatar by the use of bio-briquette are roughly estimated under the following conditions and assumptions.

Target year : 2010

Case of coal demand : high demand
Sources using bio-briquette : hosehold stoves and boilers other than power generation boilers
Dust and benzpyrene reduction rate : 70 %
$SO_2$ reduction rate : 75 % (sulfur content of coal : 0.76 %)

The estimated reductions of pollutant emissions are shown in Table 6.19

Table 6.19 Reduction of Pullutant Emission by the Use of Bio-briquette in Stoves and Small-to-medium Size Boilers
(2010, Case of high coal demand)

| Pllutant Source | Pollutant Emission Without use of bio-briquette | | | Pollutant Emission With use of bio-briquette | | |
|---|---|---|---|---|---|---|
| | Dust (1,000 ton) | Benzpyrene (kg) | $SO_2$ (1,000 ton) | Dust (1,000 ton) | Benzpyrene (kg) | $SO_2$ (1,000 ton) |
| Power plants | 117.5 | 19.2 | 53.8 | 117.5 | 19.2 | 53.8 |
| Boilers | 44.9 | 33.7 | 9.4 | 13.5 | 10.1 | 2.4 |
| Stoves | 38.6 | 598.7 | 8.8 | 11.6 | 179.6 | 2.2 |
| Total | 201.1 | 651.6 | 72.1 | 142.6 | 208.9 | 58.4 |
| (%) | (100) | (100) | (100) | (71) | (32) | (81) |

Table 6.19 indicates significant reductions of pollutant emissions through the use of bio-briquette, particularly of dust and benzpyrene emissions. Moreover, the effects on the reduction of the ground-level concentrations will be much larger.

If $SO_2$ pollution due to stoves and boilers is confirmed to be insignificant, bio-briquette can be made without addition of a desulfurizing agent.

## 6.4 Environmental protection plan

As result of this chapter, coal-burning household stoves (particularly, stoves in gers) in

Ulaanbaatar have much larger environmental impact for pollutant emissions and Bio-briquette is key factor in order to improve the pollutant emissions. In this section, Bio-briquette plant for stoves in gers is investigated.

### 6.4.1 Coal consumption of gers' stoves

At present, there are about 50 thousand gers in Ulaanbaatar and it is said that about 4~5 tons per annum of coal are consumed in a ger. Moreover, it is also said that about 20% of coal is lost due to pulverized. If number of gers in Ulaanbaatar aren't change in the future (2010), total coal consumption in gers amounts to 200 thousand ton per annum. Amount of benzpyrene through these coal combustion will be 154kg per year. However, it is expected to reduce amount of benzpyrene by 70% through using Bio-briquette.

### 6.4.2 Required capacity and investment cost of Bio-briquette plants

Bio-briquette will be reduced coal consumption in gers because of decreasing of pulverized coal loss and improvement of combustion efficiency. As the result, it is considered that the capacity of Bio-briquette plants will need total 160 thousand tons per annum. However, it is difficult immediately to finance in order to construct Bio-briquette plants. It is supposed that the area of gathering gers are half of total gers. Therefore, first of all, Bio-briquette plants should be constructed for half of total gers and capacity of the plant is 80 thousand tons per annum. Considering financing, it is desirable to construct two plants of 40,000 t/y capacity every five years. Required investment cost and operating cost is described in section 7.2.2 and according to this section, capital investment cost of about 40,000 t/y capacity of Bio-briquette plant is about US$ 6.5 million and operating cost without raw materials is about US$ 2.7/ton-briquette. Construction of Bio-briquette plant should be examined in view of the environmental protection and improving the energy efficiency.

# 7 Preliminary Study on Selected Plans

## 7.1 Preliminary study on selected coal development plans

In order to evaluate economics of the selected coal mine development plans, the detailed plans of each coal mines are examined in this section. The plans include project term, mining method, mining equipments, manpower, cost estimation, surface facilities, social infrastructure, etc. Based upon these data, for the purpose of economic evaluation, coal prices at 10% EIRR is calculated on the basis of the following criteria:

- project life : 23 years
- time value of money : constant price in 1994 with 400Tg/US$
- project financing : 100% of own fund
- price and the life span of equipment : based on Part 1 of the study
- inflation : no inflation

Formula for cash flow used in the economic analysis of EIRR is as follows:

+Revenue
-Total operating cost
-Total capital cost
-Increase in working capital
= Cash flow for EIRR on total project

However, economic evaluation of Tavantolgoi mine can not be calculated so that the development of the coal mine depends on the electric power market and the coking coal market in the neighbor countries, which the demands and price of the products cannot be estimated at present time.

### 7.1.1 Tsaidamnuur mine

(1) Details of plan

1) Infrastructure and surrounding mines

This coal deposit is located in the south of Baganuur mine. A 110kV and a 200V power lines are located in the east and south of the Tsaidamnuur deposit. Two road routes pass through the deposit. Bagahangai coal mine and a fluorite mine are located around the Tsaidamnuur deposit.

The features of local conditions are as follows:

- Infrastructure facilities are accessible.
- Geological structure and coal quality are very similar to those of Baganuur mine.
- Therefore, it is easy to develop this deposit with a small investment for the infrastructure.

2) Design basis Coal mine development plan is made on the following conditions:

- The project term is 23 years.
- Oxidized coal from the surface till 10m depth is regarded as overburden, which must be removed.
- Stripping ratio and mining depth are up to 4.2 and less than 200m, respectively.
- Stripping ratio is defined as overall average stripping ratio and constant during project term.
- Bench cut method by using shovel and truck system is adopted as the mining method.
- Average transportation distance is three km and constant during project term.

(2) Machinery requirement, manpower, cost estimation, etc.

The proposed mining plan is shown on Table 7.1 including major mining machine and surface facilities.

1) Major mining machines

The fleet for overburden removal consists of 12 $m^3$ electric shovel and 80 ton dump trucks. The electric shovel is selected because it has stronger digging force and durability and can be driven by electricity instead of imported fuel oil. Because the electric mining machine is suitable for the large-scaled work with less frequency of working place change, it is necessary to operate it in advancing stripping activity. This fleet is recommended as a superior in Part 1 study. The fleet for coal mining consists of 5.7 $m^3$ backhoe type hydraulic shovel and 46 ton dump trucks. Backhoe type hydraulic shovel has advantages as follows:

- precise selective mining effective for coal quality control.
- adaptability for overburden removal with its greater digging force.
- capability of digging below the machine level.
- capability of performing incidental works such as making drainage ditch and treating surface of working face, etc.

2) Manpower requirement

Manpower requirement in the Tsaidamnuur coal mine is estimated based on the Shivee Ovoo and 480 persons will be required. Manpower requirement in detail should be established by categories in the next step.

3) Surface facilities

(a) General

Usually the following facilities are required; workshops and warehouses, power supply and distribution, water supply, dewatering and drainage, crushing/sizing/loading, office, stockpile, transportation, communication, etc.

(b) Workshop

Workshops must provide adequate facilities for the inspection, repair and maintenance of plants and mining equipment. Repair shops require the following spaces or bays for:

- Equipment repair
- Heavy vehicle repair
- Light vehicle repair
- Electric repair
- Undercarriage repair

Workshop areas are composed of repair shop, service facility, warehouses, material handling, vehicle washing, vehicle parking, etc. Mine fleet services are performed in general near the working areas and are included refueling, routine servicing, tire maintenance, etc. Service facilities provide,

- Light vehicle services
- Heavy vehicle services
- Washing services
- Refueling and greasing services

Mines are usually located in remote areas, therefore they should maintain stocks of spare parts, consumable items and replacement components required for plants and equipment in the warehouses.

(c) Power supply and distribution facilities

Power is to be obtained from the CES (Central Energy System) through existing power lines and/or extension. Sometimes power is also provided through a private generating station. Transformers provide power at the required working voltage. Power is generally transmitted via overhead line to transformers, then by cable to the equipment.

(d) Water supply facilities

Potable water and industrial water are required for mining operations and townships. Hot water is also needed for both mining operations and townships as well. Underground water from the dewatering wells and drainage water may not be suitable for drinking, but for industrial purposes. All sources should be considered in order to select the optimum; rivers, lakes, groundwater, etc. It is necessary to investigate to prove the sustainability of a water source. Water is taken from rivers, lakes or groundwater, then sent to the pump station through pipelines, sometimes directly, sometimes via water treatment facilities, at the mining complex, and then delivered to places required. A number of processes require steam and hot water for heating and industrial purposes. Therefore boilers are to be constructed to meet the demand. Hot water is delivered from the coal-fired boilers to places required through insulated pipelines.

(e) Dewatering and drainage facilities

If the groundwater level is high and affects on mining conditions and coal quality, it is necessary to dewater and lower the water level before mining. The groundwater is to be dewatered for a certain period before mining starts. It will be very difficult to mine the coal seams without dewatering, if the moisture content of the seams are very high. Therefore, it is essential to dewater the groundwater without any delay. Water drainage is of prime importance for open pit mining operations. Ditches and sumps should be dug in and around the pit, and pumping facilities should be installed for the drainage.

(f) Crushing/sizing/loading facilities

In regard to the coal quality, end users of coal suffer not only from poor quality of coal but also uncrushed run-of-mine coal, mixing with lumpy waste and foreign materials.A crushing, sizing and loading plant is needed for the coal mine, and all the run-of-mine coal should be processed at the plant before shipping.

(g) Office facilities

In order to maintain mining and plant operations, an operational center will be required for management, planning and control of daily activities.

(h) Stockpile facilities and transportation facilities

Crushed coal is delivered from the crushing/sizing plant to a loading section. Most of the coal is directly transhipped to train loading silos through a conveyor system. In the case that freight cars are not available for loading, crushed coal is diverted to stockpile areas for temporary stock. Spontaneous combustion characteristics of coal must be seriously studied and proper procedures and facilities should be provided in both the raw coal stockyard and product coal stockyard. A process of natural drying of coal may be required to reduce moisture content.

(i) Communication

It is important to consider any communication both external and internal services. Telephone, facsimile and mobile radio services may be required for the mine operations.

(j) Mine infrastructure

a) Townships

Due to the remote location of the project, a new town will be developed to provide accommodation for the labor force. It is expected that the population of the town will depend on the total labor force. The town development will commence at the same time as the mine pre-production development, so that accommodation will be available for operational personnel when mine development starts. Location, size of workforce, mine life, existing facilities, and company and government policies will influence the magnitude of the residential and community facilities required. Township size is based on the workforce requirements and allowance.The following facilities should be provided for the town:

- Housing: for employees
- Roads
- Services: potable water, power, sewerage and drainage
- Recreation facilities
- Shopping facilities

- Community facilities: town hall, fire station, police, bank and post office
- Commercial facilities
- Medical facilities
- Educational facilities

As mentioned earlier, construction costs will be covered by the three major portions:

- National and/or local governments,
- Coal mine,
- Private or commercial entities

The coal mining company will be responsible to construct houses for employees. The following costs are estimated for the construction of town-ships and housings.

| | |
|---|---|
| - Employees | 480 |
| - Population | 1,300 |
| - Cost estimates (US$ 1,000) | 9,000 |

It is estimated that total costs of twnships are US$ 26,000 thousand. However, US$17,000 thousand out of total costs should be prepared by governments. It is expected that the coal mining company will prepare US 9,000 thousand for developing townships.

| | |
|---|---|
| Governments | 17,000 |
| Company | 9,000 |
| Private | - |
| Total | 26,000 |

b) Transportation and power line

Consideration and evaluation of the available transportation are essential. The transportation systems available for consideration include:

- Road
- Railroad

(i) Road

Two kilometers of roads are to be constructed for the access road from the main roads.

Cost estimate: 247/km × 2km = 495 (US$ 1,000)

(ii) Railroad in the property

Two kilometers of side track road is to be constructed for the material and coal haulage.

- Cost estimate for side track: 675/km × 2km = 1,350 (US$ 1,000)
- Rolling stock =1,350 (US$1,000)

  Assumption: All the produced coal will be hauled to Ulaanbaatar
  Haul distance to Ulaanbaatar is 90km
  Unit rolling stock: $7,500/million ton. km

- Total costs of railroad (US$1,000)

| | |
|---|---|
| Side track | 1,350 |
| Rolling stock | 1,350 |
| Total | 2,700 |

(iii) Power line and communication method

Power line is to be extended from the CES for convenience.It is important to consider any communication both the external and internal services. Telephone, facsimile and mobile radio services may be required for the mine operations.

Power line: $71,250 × 2km ≒ 143 (US$1,000)

(iv) Other = 334 (US$1,000)

c) Total (a)+b)) 12,672 (US$1,000)

4) Infrastructure development costs

(a) General

New facilities of townships, railroads, roads, power lines, etc. should be developed for the new potential mines.

a) Road

Existing roads in the area provide access to the portion of the property. Some parts of roads will be newly developed.

b) Railroad

The coal will be transported by trains to consuming cities. A new rail line is to be constructed from the project site to connect with the existing line.

c) Power line and communication

It is necessary to extend power line for supplying power from CES system.

d) Townships (Undertating by governments)

(b) Cost estimates

| | | |
|---|---|---|
| Railroad: | Length (km) | 10 |
| | Costs (US$1,000) | 6,750 |
| Road: | Length (km) | 10 |
| | Costs (US$1,000) | 2,475 |
| Power line: | Length (km) | 25 |
| | Costs (US$1,000) | 1,780 |
| Other facilities: | | 1,100 |
| Town ships | | 17,000 |
| Total (US$1,000) | | 29,105 |

(3) Total capital cost

Capital cost for coal mine consists of the major mining equipment and the general purpose equipment and the surface facilities, which is not include any taxation.

| | | |
|---|---|---|
| Initial capital costs: | | 70,800 (US$ 1,000) |
| Replacement cost : | | 85,600 (US$ 1,000) |
| Total capital costs : | | 156,400 (US$ 1,000) |
| Infrastructure cost: | Railroad | 6,800 (US$ 1,000) |
| | Road | 2,500 (US$ 1,000) |
| | Power line | 1,800 (US$ 1,000) |
| | Townships | 17,000 (US$ 1,000) |
| | Other | 1,100 (US$ 1,000) |
| | Sub-total | 29,100 (US$ 1,000) |
| Grand total: | | 185,500 (US$ 1,000) |

(4) Operating costs

Operating costs consist of two components; material and labor and depreciation.The cost index of $1.43/BCM of the shovel and truck system is used for the comparison of new mining system in Baganuur coal mine renovation study in Part 1. This index is used to plan the new potential mines because the shovel and truck system is adopted, too.

(5) Economic evaluation

Coal price in 10% EIRR (Economic Internal Rate of Return) was calculated in order to evaluate economic of the project. Project year is 23 and capital cost of initial and replacement is invested as shown Table 7.1. These capital cost is shown in border price based on Part 1 of the study. Operating cost per ton-coal that is calculated by the cost index of US$1.43/BCM is US$5.43/t. The economic evaluation doesn't include social infrastructure (Social infrastructure means the cost of railroad, road, and power line from coal mine site to existing facilities, cost of township and other costs). Table 7.2 shows the net cash flow of EIRR every year and coal price in 10% EIRR is US$11.1/t (4,444Tg/t).

# Table 7.1 Proposed Mining Plan of Tsaidamnuur Mine (1/2)

1) Details of plan

| Coal seam condition | | | Reserves (×10⁶t) | | | Development plan | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thickness | Dip | Strike length | Depth | Stripping ratio | Reserves | Annual Production | Cumurative coal Production | Strike length | Depth | Total Stripping ratio | Average overbuden removal | Volume of coal production | Fleet number | |
| | | | | | | | | | | | | | Coal mining | Stripping |
| (m) | (°) | (km) | (m) | | (×10⁶t) | (×10³t) | (×10³) | (km) | (m) | | (×10³ m³) | (×10³ m³) | 5.7m³+46t | 12m³+80t |
|  15 / 40 / 30 / 20 / 15 | 5 | 4, 5, 6 } 5 | 200 | 2.3 | 864 | 2,000 | 40,000 | 2 | 34 | 3.0 | 6,000 | 1,600 | 1 | 3 (2.41) |

2) Cost estimation

Capital costs (Initial)

(×10³ US$)

| Mining equipment | | | | General purpose equipment | Surface facilities | | Grand Total |
|---|---|---|---|---|---|---|---|
| Equipment | Specification | Quantity | Amount of price | | | | |
| Power shovel | 12m³ (waste) | 3 | 12,027 | (Bulldozer, | Workshop | 1,355 | |
| Hydraulic shovel | 5.7m³ (coal) | 1 | 2,016 | Grader, | Warehouse | 543 | |
| Front end loader | 5 m³ | 2 | 867 | Front end loader, | Coal stockyard | 799 | |
| Dump truck | 80t (waste) | 20 | 15,800 | Service truck, | Sizing & loading | 4,704 | |
| Dump truck | 40t (coal) | 8 | 3,520 | Water truck, | Power distribution | 1,038 | |
| Bulldozer | 400 Hp | 4 | 2,096 | Fuel truck, | Communication | 85 | |
| Grader | 254 Hp | 4 | 1,464 | Anfo truck, | Drainage & water supply | 4,000 | 70,816 |
| Drill | 160 mm | 4 | 1,836 | etc.) | Mine office | 500 | |
| Sub-Total | | | 39,626 | 4,454 | Explosiv magazine | 200 | |
| | | | | | Boiler | 300 | |
| | | | | | Road maintenance | 300 | |
| | | | | | Coal quality system | 240 | |
| | | | | | Mine infrastructure | 12,672 | |
| | | | | | | | |
| Equipment total | 44,080 | | | | Subtotal | 26,736 | |

## Table 7.1 Proposed Mining Plan of Tsaidamnuur Mine (2/2)

Capital Costs for coal mine (Initial & replacement)

US$ 000's

| Year | Mining Equipment | General Purpose Equipment | Surface Facilities | Total |
|---|---|---|---|---|
| -3 | — | 153 | 12, 672 | 12, 825 |
| -2 | 24, 242 | 2, 553 | 9, 180 | 35, 975 |
| -1 | 15, 384 | 1, 748 | 4, 884 | 22, 016 |
| Initial total | 39, 626 | 4, 454 | 26, 736 | 70, 816 |
| 1 | — | — | — | — |
| 2 | — | — | — | — |
| 3 | — | — | — | — |
| 4 | — | — | 4, 000 | 4, 000 |
| 5 | — | — | 255 | 255 |
| 6 | — | — | — | — |
| 7 | 16, 224 | 153 | 2, 181 | 18, 558 |
| 8 | 11, 375 | 2, 553 | 799 | 14, 727 |
| 9 | — | 1, 748 | 6, 976 | 8, 724 |
| 10 | — | — | 85 | 85 |
| 11 | — | — | 255 | 255 |
| 12 | — | — | — | — |
| 13 | — | — | — | — |
| 14 | — | 153 | 4, 000 | 4, 153 |
| 15 | 16, 224 | 2, 553 | 2, 181 | 20, 958 |
| 16 | 11, 375 | 1, 748 | 799 | 13, 922 |
| 17 | — | — | — | — |
| 18 | — | — | — | — |
| 19 | — | — | — | — |
| 20 | — | — | — | — |
| Replacement total | 55, 198 | 8, 908 | 21, 531 | 85, 637 |
| Total capaital | 94, 824 | 13, 362 | 48, 267 | 156, 453 |

Capital costs for infrastructure

| | |
|---|---|
| Rilroad | |
| Length (km) | 10 |
| Costs ($000's) | 6, 750 |
| Road | |
| Length (km) | 10 |
| Costs ($000's) | 2, 475 |
| Powerline (km) | 25 |
| Costs ($000's) | 1, 780 |
| Township | |
| Population | 1, 300 (480 employees included) |
| Costs ($000's) | 17, 000 |
| Other | |
| Costs ($000's) | 1, 100 |
| Total | 29, 105 |

Operating Costs

| Year | Waste million BCM | Coal Million ton | Costs Million $ | $/T |
|---|---|---|---|---|
| -3 | — | — | — | — |
| -2 | 4. 72 | 1. 00 | 7. 89 | 7. 89 |
| -1 | 5. 42 | 1. 50 | 9. 47 | 6. 31 |
| 1 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 2 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 3 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 4 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 5 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 6 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 7 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 8 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 9 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 10 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 11 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 12 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 13 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 14 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 15 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 16 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 17 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 18 | 6. 00 | 2. 00 | 10. 87 | 5. 43 |
| 19 | 1. 68 | 1. 00 | 3. 55 | 3. 55 |
| 20 | 0. 18 | 0. 50 | 0. 83 | 1. 66 |
| Total | 120. 00 | 40. 00 | 217. 40 | 5. 44 |

Details of Operating cost

| Index | Unit | |
|---|---|---|
| Operating cost | $/BCM | 1. 43 |
| Strip ratio | 3. 0 : 1 | |
| Production ※ | | |
| Waste | | 6. 0 |
| Coal | | 1. 6 |
| Total | | 7. 6 |

※ million bcm

Table 7.2 Economic Evaluation of Tsaidamnuur Mine

Coal price of 10% EIRR 4,444Tg/t

| Year | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Price ($US/t) | 11.11 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| Production (mil.t) | | | 1.0 | 1.5 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Revenue(mil.$US) | | 0.0 | 11.1 | 16.7 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 |
| Investment (mil.$) | | 12.8 | 36.0 | 22.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.3 | 0.0 | 18.6 | 14.7 | 8.7 |
| A Initial | | 12.8 | 36.0 | 22.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mining Equipment | | 0.0 | 24.2 | 15.4 | | | | | | | | | |
| General Purpose Equipment | | 0.2 | 2.6 | 1.7 | | | | | | | | | |
| Surface Facilities | | 12.7 | 9.2 | 4.9 | | | | | | | | | |
| B Replacement | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.3 | 0.0 | 18.6 | 14.7 | 8.7 |
| Operating Cost (mil.$) | | 0.0 | 5.4 | 8.1 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 |
| NCF before Tax (mil.$) | | -12.8 | -30.3 | -13.5 | 11.4 | 11.4 | 11.4 | 7.4 | 11.1 | 11.4 | -7.2 | -3.4 | 2.6 |
| (=Revenue-Investment-Operating Cost) | | | | | | | | | | | | | |

| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Price ($US/t) | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | |
| Production (mil.t) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 0.5 | 40.0 |
| Revenue(mil.$US) | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 11.1 | 5.6 | 444.4 |
| Investment (mil.$) | 0.1 | 0.3 | 0.0 | 0.0 | 4.2 | 21.0 | 13.9 | 0.0 | 0.0 | 0.0 | 0.0 | 156.5 |
| A Initial | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 70.8 |
| Mining Equipment | | | | | | | | | | | | 39.6 |
| General Purpose Equipment | | | | | | | | | | | | 4.5 |
| Surface Facilities | | | | | | | | | | | | 26.7 |
| B Replacement | 0.1 | 0.3 | 0.0 | 0.0 | 4.2 | 21.0 | 13.9 | 0.0 | 0.0 | 0.0 | 0.0 | 85.7 |
| Operating Cost (mil.$) | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 10.9 | 5.4 | 2.7 | 217.1 |
| NCF before Tax (mil.$) | 11.3 | 11.1 | 11.4 | 11.4 | 7.2 | -9.6 | -2.6 | 11.4 | 11.4 | 5.7 | 2.8 | 70.9 |
| (=Revenue-Investment-Operating Cost) | | | | | | | | | | | | |

Discount Rate 10%
Total NPV before Tax 0 (mil.$)
EIRR (IRR on NCF B.Tax) 10%

### 7.1.2 Tugrugnuur mine

(1) Details of plan

1) Infrastructure

- This coal deposit is located 25km east of the existing railway.
- Power will be supplied through a 110kV transmission line which is laid from Baganuur mine to Shivee Ovoo mine via Baganjargalan. A 220V power line is also laid from Maint to Baganjargalan which is one of the regional township around the deposit.
- Geological, mining and infrastructure conditions are similar to those of Tsaidamnuur deposit.
- It will be easy to develop this deposit as well as Tsaidamnuur with a small investment for the infrastructure.

2) Design basis

Coal mine development plan is made on the following conditions:

- The project term is 23 years.
- Oxidized coal from the surface till 10m depth is regarded as overburden, which must be removed.
- Stripping ratio and mining depth are up to 4.2 and less than 200m, respectively.
- Stripping ratio is defined as overall average stripping ratio and constant during project term.
- Bench cut method by using shovel and truck system is adopted as the mining method.
- Average transportation distance is three km and constant during project term.

(2) Machinery requirement, manpower, cost estimation, etc.

The proposed mining plan is shown on Table 7.3 including major machines and surface facilities.

1) Major mining machines

The fleet for overburden removal consists of 12 $m^3$ electric shovel and 80 ton dump trucks. The electric shovel is selected because it has stronger digging force and durability and can be driven by electricity instead of imported fuel oil. Because the electric mining machine is suitable for the large-scaled work with less frequency of working place change, it is necessary to operate it in advancing stripping activity. This fleet is recommended as a superior in Part 1 study. The fleet for coal mining consists of 5.7 $m^3$ backhoe type hydraulic shovel and 46 ton dump trucks. Backhoe type hydraulic shovel has advantages as follows:

- precise selective mining effective for coal quality control.
- adaptability for overburden removal with its greater digging force.
- capability of digging below the machine level.
- capability of performing incidental works such as making drainage ditch and treating surface of working face, etc.

2) Manpower requirement

Manpower requirement in the Tugrugnuur coal mine is estimated based on the Shivee Ovoo, and 570 persons will be required. Manpower requirement in detail should be established by categories in the next step.

3) Surface facilities

(a) General

Usually the following facilities are required; workshops and warehouses, power supply and distribution, water supply, dewatering and drainage, crushing/sizing/loading, office, stockpile, transportation, communication, etc.

(b) Workshop

Workshops must provide adequate facilities for the inspection, repair and maintenance of plants and mining equipment. Repair shops require the following spaces or bays for:

- Equipment repair
- Heavy vehicle repair
- Light vehicle repair
- Electric repair
- Undercarriage repair

Workshop areas are composed of repair shop, service facility, warehouses, material handling, vehicle washing, vehicle parking, etc. Mine fleet services are performed in general near the working areas and are included refueling, routine servicing, tire maintenance, etc. Service facilities provide,

- Light vehicle services
- Heavy vehicle services
- Washing services
- Refueling and greasing services

Mines are usually located in remote areas, therefore they should maintain stocks of spare parts, consumable items and replacement components required for plants and equipment in the warehouses.

(c) Power supply and distribution facilities

Power is to be obtained from the CES (Central Energy System) through existing power lines and/or extension. Sometimes power is also provided through a private generating station. Transformers provide power at the required working voltage. Power is generally transmitted via overhead line to transformers, then by cable to the equipment.

(d) Water supply facilities

Potable water and industrial water are required for mining operations and townships. Hot water is also needed for both mining operations and townships as well. Underground water from the dewatering wells and drainage water may not be suitable for drinking, but for industrial purposes. All sources should be considered in order to select the optimum; rivers, lakes, groundwater, etc. It is necessary to investigate to prove the sustainability of a water source. Water is taken from rivers, lakes or groundwater, then sent to the pump station through pipelines, sometimes directly, sometimes via water treatment facilities, at the mining complex, and then delivered to places required. A number of processes require steam and hot water for heating and industrial purposes. Therefore boilers are to be constructed to meet the demand. Hot water is delivered from the coal-fired boilers to places required through insulated pipelines.

(e) Dewatering and drainage facilities

If the groundwater level is high and affects on mining conditions and coal quality, it is necessary to dewater and lower the water level before mining. The groundwater is to be dewatered for a certain period before mining starts. It will be very difficult to mine the coal seams without dewatering, if the moisture content of the seams are very high. Therefore, it is essential to dewater the groundwater without any delay. Water drainage is of prime importance for open pit mining operations. Ditches and sumps should be dug in and around the pit, and pumping facilities should be installed for the drainage.

(f) Crushing/sizing/loading facilities

In regard to the coal quality, end users of coal suffer not only from poor quality of coal but also uncrushed run-of-mine coal, mixing with lumpy waste and foreign materials.A crushing, sizing and loading plant is needed for the coal mine, and all the run-of-mine coal should be processed at the plant before shipping.

(g) Office facilities

In order to maintain mining and plant operations, an operational center will be required for management, planning and control of daily activities.

(h) Stockpile facilities and transportation facilities

Crushed coal is delivered from the crushing/sizing plant to a loading section. Most of the coal is directly transhipped to train loading silos through a conveyor system. In the case that freight cars are not available for loading, crushed coal is diverted to stockpile areas for temporary stock. Spontaneous combustion characteristics of coal must be seriously studied and proper procedures and facilities should be provided in both the raw coal stockyard and product coal stockyard. A process of natural drying of coal may be required to reduce moisture content.

(i) Communication

It is important to consider any communication both external and internal services. Telephone, facsimile and mobile radio services may be required for the mine operations.

(j) Mine infrastructure

a) Townships

Due to the remote location of the project, a new town will be developed to provide accommodation for the labor force. It is expected that the population of the town will depend on the total labor force. The town development will commence at the same time as the mine pre-production development, so that accommodation will be available for operational personnel when mine development starts. Location, size of workforce, mine life, existing facilities, and company and government policies will influence the magnitude of the residential and community facilities required. Township size is based on the workforce requirements and allowance. The following facilities should be provide for the town:

- Housing: for employees
- Roads
- Services: potable water, power, sewerage and drainage
- Recreation facilities
- Shopping facilities
- Community facilities: town hall, fire station, police, bank and post office
- Commercial facilities
- Medical facilities
- Educational facilities.

As mentioned earlier, construction costs will be covered by the three major portions:

- National and/or local governments,
- Coal mine,
- Private or commercial entities

The coal mining company will be responsible to construct houses for employees. The following costs are estimated for the construction of town-ships and housings.

| | |
|---|---|
| - Employees | 570 |
| - Population | 1,550 |
| - Cost estimates (US$ 1,000) | 9,000 |

It is estimated that total costs of twnships are US$ 27,000 thousand. However, US$18,000 thousand out of total costs should be prepared by governments. It is expected that the coal mining company will prepare US 9,000 thousand for developing townships.

| | |
|---|---|
| Governments | 18,000 |
| Company | 9,000 |

| | |
|---|---|
| Private | - |
| Total | 27,000 |

b) Transportation and power line

Consideration and evaluation of the available transportation are essential. The transportation systems available for consideration include:

- Road
- Railroad

(i) Road

Two kilometers of roads are to be constructed for the access road from the main roads.

Cost estimate: 247/km × 2km = 495 (US$ 1,000)

(ii) Railroad in the property

Two kilometers of side track road is to be constructed for the material and coal haulage.

- Cost estimate for side track: 675/km × 2km = 1,350 (US$ 1,000)
- Rolling stock

Assumption : All the produced coal will be hauled to Ulaanbaatar

Haul distance to Ulaanbaatar: 135km

Unit rolling stock: $7,500/million ton. km

Rolling stock: 2,025 (US$1,000)

- Total costs of railroad (US$1,000)

| | |
|---|---|
| Side track | 1,350 |
| Rolling stock | 2,025 |
| Total | 3,375 |

(iii) Power line and communication method

Power line is to be extended from the CES for convenience.

It is important to consider any communication both the external and internal services. Telephone, facsimile and mobile radio services may be required for the mine operations.

Power line: $71,250 × 2km ≒ 143 (US$1,000)

(iv) Other 400 (US$1,000)

c) Total (a)+b)) 13,413 (US$1,000)

4) Infrastructure development costs

(a) General

New facilities of townships, railroads, roads, power lines, etc. should be developed for the new potential mines.

a) Road

Existing roads in the area provide access to the portion of the property. Some parts of roads will be newly developed.

b) Railroad

The coal will be transported by trains to consuming cities. A new rail line is to be constructed from the project site to connect with the existing line.

c) Power line and communication

It is necessary to extend power line for supplying power from CES system.

d) Townships (Undertaking by governments)

(b) Cost estimates

| | | |
|---|---|---|
| Railroad: | Length (km) | 25 |
| | Costs (US$1,000) | 16,875 |
| Road: | Length (km) | 25 |
| | Costs (US$1,000) | 6,188 |
| Power line: | Length (km) | 15 |
| | Costs (US$1,000) | 1,065 |
| Other facilities: | (US$1,000) | 2,413 |
| Townships: | (US$1,000) | 18,000 |
| Total (US$1,000) | | 44,545 |

(3) Total capital cost

Capital cost for coal mine consists of the major mining equipment and the general purpose equipment and the surface facilities, which is not include any taxation.

| | | |
|---|---|---|
| Initial capital costs: | | 84,200 (US$ 1,000) |
| Replacement cost : | | 101,800 (US$ 1,000) |
| Total capital costs : | | 186,000 (US$ 1,000) |
| Infrastructure cost: | Railroad | 16,900 (US$ 1,000) |
| | Road | 6,200 (US$ 1,000) |
| | Power line | 1,100 (US$ 1,000) |
| | Townships | 18,000 (US$ 1,000) |
| | Other | 2,400 (US$ 1,000) |
| | Sub-total | 44,500 (US$ 1,000) |
| Grand total: | | 230,500 (US$ 1,000) |

(4) Operating costs

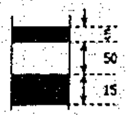
Operating costs consist of two components; material and labor and depreciation.The cost index of $1.43/BCM of the shovel and truck system is used for the comparison of new mining system in Baganuur coal mine renovation study in Part 1. This index is used to plan the new potential mines because the shovel and truck system is adopted, too.

(5) Economic evaluation

Coal price in 10% EIRR was calculated under the same assumption of Tsaidamunuur coal mine. Table 7.4 shows the net cash flow of EIRR every year and coal price in 10% EIRR is US$13.9/t (5,547Tg/t).

## Table 7.3 Proposed Mining Plan of Tugrugnuur Mine (1/2)

1) Details of plan

| Coal seam condition | | | Reserves (×10⁶t) | | | Development plan | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thickness | Dip | Strike length | Depth | Stripping ratio | Reserves | Annual Production | Cumurative coal Production | Strike length | Depth | Total Stripping ratio | Average overbuden removal | Volume of coal production | Fleet number | |
| | | | | | | | | | | | | | Coal mining | Stripping |
| (m) | (°) | (km) | (m) | | (×10⁶t) | (×10³t) | (×10³) | (km) | (m) | | (×10³ m³) | (×10³ m³) | 5.7m³+46t | 12m³+80t |
|  | 7 | 15 | 88 | 4.2 | 288 | 2,000 | 40,000 | 4 | 47 | 4.2 | 8,400 | 1,600 | 1 | 4 (3.37) |

2) Cost estimation

Capital costs (Initial)

(×10³ US$)

| Mining equipment | | | | General purpose equipment | Surface facilities | | Total |
|---|---|---|---|---|---|---|---|
| Equipment | Specification | Quantity | Amount of price | | | | |
| Power shovel | 12m³ (waste) | 4 | 16,037 | (Bulldozer, | Workshop | 1,599 | |
| Hydraulic shovel | 5.7m³ (coal) | 1 | 2,016 | Grader, | Warehouse | 633 | |
| Front end loader | 5 m³ | 2 | 867 | Front end loader, | Coal stockyard | 799 | |
| Dump truck | 80t (waste) | 27 | 21,330 | Service truck, | Sizing & loading | 4,704 | |
| Dump truck | 40t (coal) | 8 | 3,520 | Water truck, | Power distribution | 1,038 | |
| Bulldozer | 400 Hp | 5 | 2,620 | Fuel truck, | Communication | 85 | |
| Grader | 254 Hp | 5 | 1,830 | Anfo truck, | Drainage & water supply | 4,000 | 84,182 |
| Drill | 160 mm | 5 | 2,295 | etc.) | Mine office | 590 | |
| Sub-Total | | | 50,514 | 5,623 | Explosive magazine | 236 | |
| | | | | | Boiler | 354 | |
| | | | | | Road maintenance | 354 | |
| | | | | | Coal quality system | 240 | |
| | | | | | Mine infrastructure | 13,413 | |
| | | | | | | | |
| Equipment total | 56,137 | | | | Subtotal | 28,045 | |

## Table 7.3 Proposed Mining Plan of Tugrugnuur Mine (2/2)

Capital Costs for coal mine (Initial & replacement)

US$ 000's

| Year | Mining Equipment | General Purpose Equipment | Surface facilities | Total |
|---|---|---|---|---|
| -3 | — | 153 | 13,413 | 13,566 |
| -2 | 27,768 | 3,424 | 9,833 | 41,025 |
| -1 | 22,746 | 2,046 | 4,799 | 29,591 |
| Initial total | 50,514 | 5,623 | 28,045 | 84,182 |
| 1 | — | — | — | — |
| 2 | — | — | — | — |
| 3 | — | — | — | — |
| 4 | — | — | 4,000 | 4,000 |
| 5 | — | — | 301 | 301 |
| 6 | — | 153 | — | 153 |
| 7 | 19,750 | 3,424 | 2,181 | 25,355 |
| 8 | 14,728 | 2,046 | 799 | 17,573 |
| 9 | — | — | 6,976 | 6,976 |
| 10 | — | — | 85 | 85 |
| 11 | — | — | 301 | 301 |
| 12 | — | — | — | — |
| 13 | — | — | — | — |
| 14 | — | 153 | 4,000 | 4,153 |
| 15 | 19,750 | 3,424 | 2,181 | 25,355 |
| 16 | 14,728 | 2,046 | 799 | 17,573 |
| 17 | — | — | — | — |
| 18 | — | — | — | — |
| 19 | — | — | — | — |
| 20 | — | — | — | — |
| Replacement total | 68,956 | 11,246 | 21,623 | 101,825 |
| Total capaital | 119,470 | 16,869 | 49,668 | 186,007 |

Capital costs for infrastructure

| | | |
|---|---|---|
| Railroad | | |
| | Length (km) | 25 |
| | Costs ($000's) | 16,875 |
| Road | | |
| | Length (km) | 25 |
| | Costs ($000's) | 6,188 |
| Powerline (km) | | 15 |
| | Costs ($000's) | 1,069 |
| Township | | |
| | Population | 1,550 (570 employees included) |
| | Costs ($000's) | 18,000 |
| Other | | |
| | Costs ($000's) | 2,413 |
| Total | | 44,545 |

Operating Costs

| Year | Waste million BCM | Coal million ton | Costs million $ | $/T |
|---|---|---|---|---|
| -3 | — | — | — | — |
| -2 | 7.77 | 1.00 | 12.26 | 12.26 |
| -1 | 7.37 | 1.50 | 12.26 | 8.17 |
| 1 | 8.40 | 2.00 | 14.30 | 7.15 |
| 2 | 8.40 | 2.00 | 14.30 | 7.15 |
| 3 | 8.40 | 2.00 | 14.30 | 7.15 |
| 4 | 8.40 | 2.00 | 14.30 | 7.15 |
| 5 | 8.40 | 2.00 | 14.30 | 7.15 |
| 6 | 8.40 | 2.00 | 14.30 | 7.15 |
| 7 | 8.40 | 2.00 | 14.30 | 7.15 |
| 8 | 8.40 | 2.00 | 14.30 | 7.15 |
| 9 | 8.40 | 2.00 | 14.30 | 7.15 |
| 10 | 8.40 | 2.00 | 14.30 | 7.15 |
| 11 | 8.40 | 2.00 | 14.30 | 7.15 |
| 12 | 8.40 | 2.00 | 14.30 | 7.15 |
| 13 | 8.40 | 2.00 | 14.30 | 7.15 |
| 14 | 8.40 | 2.00 | 14.30 | 7.15 |
| 15 | 8.40 | 2.00 | 14.30 | 7.15 |
| 16 | 8.40 | 2.00 | 14.30 | 7.15 |
| 17 | 8.40 | 2.00 | 14.30 | 7.15 |
| 18 | 8.40 | 2.00 | 14.30 | 7.15 |
| 19 | 1.20 | 1.00 | 2.86 | 2.86 |
| 20 | 0.46 | 0.50 | 1.23 | 2.46 |
| Total | 168.00 | 40.00 | 286.01 | 7.15 |

Details of Operating cost

| Index | Unit |
|---|---|
| Operating cost | $/BCM 1.43 |
| Strip ratio | 4.2 : 1 |
| Production ※ | |
| Waste | 8.4 |
| Coal | 1.6 |
| Total | 10.0 |

※ million bcm

Table 7.4 Economic Evaluation of Tugrugnuur Mine

Coal price of 10% EIRR 5,547Tg/t

| Year | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Price ($US/t) | 13.867 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 |
| Production (mil.t) | | | 1.0 | 1.5 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Revenue(mil.$US) | | 0.0 | 13.9 | 20.8 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 |
| Investment cost(mil.$) | | 13.6 | 41.0 | 29.6 | 0.0 | 0.0 | 0.0 | 4.0 | 0.3 | 0.2 | 25.4 | 17.6 | 7.0 |
| A Initial | | 13.6 | 41.0 | 29.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mining Equipment | | 0.0 | 27.8 | 22.7 | 0.0 | | | | | | | | |
| General Purpose Equipment | | 0.2 | 3.4 | 2.0 | | | | | | | | | |
| Surface Facilities | | 13.4 | 9.8 | 4.8 | | | | | | | | | |
| B Replacement | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.3 | 0.2 | 25.4 | 17.6 | 7.0 |
| Operating Cost (mil.$) | | 0.0 | 7.1 | 10.7 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 |
| NCF before Tax (mil.$) | | -13.6 | -34.3 | -19.5 | 13.5 | 13.5 | 13.5 | 9.5 | 13.2 | 13.3 | -11.9 | -4.1 | 6.5 |
| (=Revenue-Investment-Operating cost) | | | | | | | | | | | | | |

| Year | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Price ($US/t) | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | |
| Production (mil.t) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 0.5 | 40.0 |
| Revenue(mil.$US) | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 13.9 | 6.9 | 554.7 |
| Investment cost(mil.$) | 0.1 | 0.3 | 0.0 | 0.0 | 4.2 | 25.4 | 17.6 | 0.0 | 0.0 | 0.0 | 0.0 | 186.0 |
| A Initial | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 84.2 |
| Mining Equipment | | | | | | | | | | | | 50.5 |
| General Purpose Equipment | | | | | | | | | | | | 5.6 |
| Surface Facilities | | | | | | | | | | | | 28.0 |
| B Replacement | 0.1 | 0.3 | 0.0 | 0.0 | 4.2 | 25.4 | 17.6 | 0.0 | 0.0 | 0.0 | 0.0 | 101.8 |
| Operating Cost (mil.$) | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 7.1 | 3.6 | 285.6 |
| NCF before Tax (mil.$) | 13.4 | 13.2 | 13.5 | 13.5 | 9.3 | -11.9 | -4.1 | 13.5 | 13.5 | 6.7 | 3.4 | 83.1 |
| (=Revenue-Investment-Operating cost) | | | | | | | | | | | | |

| | |
|---|---|
| Discount Rate | 10% |
| Total NPV before Tax | 0 (mil.$) |
| EIRR (IRR on NCF B.Tax) | 10% |

### 7.1.3 Khoot mine

#### (1) Details of plan

##### 1) General

Khoot coal mine will be developed as the substitution for Sharyngol mine. Present mining areas of Sharyngol mine are deeper than 200 meters and the strip ratios have been increasing year by year. As a minable reserve is limited to 30 million tons, it is supposed to maintain a production level at 1 million tons per annum from now on. And further, mining conditions become worse and operating costs have been increasing. However, very luckily, coal quality of Sharyngol mine is superior to that of Baganuur or Shivee Ovoo mine. The quality of Sharyngol coal is as below:

- Moisture (as received): 15.0%
- Ash (dry): 17.5%
- Sulfur (dry): 0.6%
- Volatile Matter (dry ash free): 41.0%
- Calorific value (as received) : 3,900 ~ 4,200 kcal/kg

On the other hand, the quality of Khoot mine is as below:

- Moisture (as received): 13.8%
- Ash (dry): 14.5%
- Sulfur (dry): 0.7%
- Volatile Matter (dry ash free): 43.0%
- Calorific value (as received) : 4,800 kcal/kg

The quality of Khoot mine is well superior to that of Sharyngol mine, and Khoot coal can be utilized as a substitute for Sharyngol coal.The industries which need the medium calory coal such as Sharyngol coal are located in Ulaanbaatar, Darkhan, Choir, etc. along the railway both now and in future. No coal field without Khoot can be found near the railway, which can produce and supply the medium calory coal like Sharyngol easily and stably. The Khoot deposit is the only potential area to be a substitute for the Sharyngol mine. Therefore, the Khoot deposit should be developed as one of the new development areas.

##### 2) Infrastructure and surrounding mines

A power line is already available between Choir and Govi-Ugtall and this line will be extended toward Mandalgovi and be completed in the summer of 1995. Khoot mine is located 40km south of Govi-Ugtaal. It is planned that a new power line is extended from Mandalgovi to Tavantolgoi in the future. It is also planned that a new spur track of around 90km is constructed from Choir to Khoot. And further, the railway will be constructed from Khoot to Tavantolgoi in the future. Uvdokhuduk deposit is located about 40km south-east of Khoot. This deposit was explored in detail and feasibility reports are now available for the development. However, coal seams contain high sulfur, ranging up to 5 to 7%, then it is difficult to utilize the coal for burning. It is very attractive to utilize this source for coal liquefaction in the long term plan. Surrounding areas of the Khoot deposit are rich in mineral resources; fluorite, lead, limestone, uranium and so on. Some are in exploration stages, and others are in development stages. It has been proved that the underground water source is available around Khoot area. A good potable water source is located 15km and an industrial water source 50km from the Khoot deposit. The water yield must provide adequate insurance in meeting demand.

The features of local conditions are as fllows:

- A small coal mine has already been developed since 1993 and produces some thousand tons per annum for local use.
- This area is rich in coal, oil shale, fluorite, limestone, uranium, lead and so on. Therefore, it is very interesting to develop comprehensively all the available mineral resources.
- The Khoot coal is an only source to be utilized as a substitute for Sharyngol coal.
- However, regional infrastructure should be developed in terms of railways, roads, power lines, communications, water supply, etc.
- Once this area was developed and infrastructure facilities were established, it would be easy to justify a development of the Tavantolgoi project for the next development stage.

3) Design basis

Coal mine development plan is made on the following conditions:

- The project term is 23 years.
- Oxidized coal from the surface till 10m depth is regarded as overburden, which must be removed.
- Stripping ratio and mining depth are up to 4.2 and less than 200m, respectively.

- Stripping ratio is defined as overall average stripping ratio and constant during project term.
- Bench cut method by using shovel and truck system is adopted as the mining method.
- Average transportation distance is three km and constant during project term.

(2) Machinery requirement, manpower, cost estimation, etc.

The proposed mining plan is shown on Table 7.5 including major mining machines and surface facilitites.

1) Major mining machines

The fleet for overburden removal consists of 12 $m^3$ electric shovel and 80 ton dump trucks. The electric shovel is selected because it has stronger digging force and durability and can be driven by electricity instead of imported fuel oil. Because the electric mining machine is suitable for the large-scaled work with less frequency of working place change, it is necessary to operate it in advancing stripping activity. This fleet is recommended as a superior in Part 1 study. The fleet for coal mining consists of 5.7 $m^3$ backhoe type hydraulic shovel and 46 ton dump trucks. Backhoe type hydraulic shovel has advantages as follows:

- precise selective mining effective for coal quality control.
- adaptability for overburden removal with its greater digging force.
- capability of digging below the machine level.
- capability of performing incidental works such as making drainage ditch and treating surface of working face, etc.

2) Manpower requirement

Manpower requirement in the Khoot coal mine is estimated based on the Shivee Ovoo, and 360 persons will be required. Manpower requirement in detail should be established by categories in the next step.

3) Surface facilities

(a) General

Usually the following facilities are required; workshops and warehouses, power supply and distribution, water supply, dewatering and drainage, crushing/sizing/loading, office, stockpile, transportation, communication, etc.

(b) Workshop

Workshops must provide adequate facilities for the inspection, repair and maintenance of plants and mining equipment. Repair shops require the following spaces or bays for:

- Equipment repair
- Heavy vehicle repair
- Light vehicle repair
- Electric repair
- Undercarriage repair

Workshop areas are composed of repair shop, service facility, warehouses, material handling, vehicle washing, vehicle parking, etc. Mine fleet services are performed in general near the working areas and includes refueling, routine servicing, tire maintenance, etc. Service facilities provide,

- Light vehicle services
- Heavy vehicle services
- Washing services
- Refueling and greasing services

Mines are usually located in remote areas therefore they should maintain stocks of spare parts, consumable items and replacement components required for plants and equipment in the warehouses.

(c) Power supply and distribution facilities

Power is to be obtained from the CES (Central Energy System) through existing power lines and/or extension. Sometimes power is also provided through a private generating station. Transformers provide power at the required working voltage. Power is generally transmitted via overhead line to transformers, then by cable to the equipment.

(d) Water supply facilities

Potable water and industrial water are required for mining operations and townships. Hot water is also needed for both mining operations and townships as well. Underground water from the dewatering wells and drainage water may not be suitable for drinking, but for industrial purposes. All sources should be considered in order to select the optimum; rivers, lakes, groundwater, etc. It is necessary to investigate to prove the sustainability of a water source. Water is taken from rivers, lakes or groundwater, then sent to the pump station through pipelines, sometimes directly, sometimes via water treatment facilities, at the mining complex, and then delivered to places required. A number of processes require steam and hot water for heating and industrial purposes. Therefore boilers are to be constructed to meet the demand. Hot water is delivered from the coal-fired boilers to places required through insulated pipelines.

(e) Dewatering and drainage facilities

If the groundwater level is high and affects on mining conditions and coal quality, it is necessary to dewater and lower the water level before mining. The groundwater is to be dewatered for a certain period before mining starts. It will be very difficult to mine the coal seams without dewatering, if the moisture content of the seams are very high. Therefore, it is essential to dewater the groundwater without any delay. Water drainage is of prime importance for open pit mining operations. Ditches and sumps should be dug in and around the pit, and pumping facilities should be installed for the drainage.

(f) Crushing/sizing/loading facilities

In regard to the coal quality, end users of coal suffer not only from poor quality of coal but also uncrushed run-of-mine coal, mixing with lumpy waste and foreign materials.A crushing, sizing and loading plant is needed for the coal mine, and all the run-of-mine coal should be processed at the plant before shipping.

(g) Office facilities

In order to maintain mining and plant operations, an operational center will be required for management, planning and control of daily activities.

(h) Stockpile facilities and transportation facilities

Crushed coal is delivered from the crushing/sizing plant to a loading section. Most of the coal is directly transhipped to train loading silos through a conveyor system. In the case that freight cars are not available for loading, crushed coal is diverted to stockpile areas for temporary stock. Spontaneous combustion characteristics of coal must be seriously studied and proper procedures and facilities should be provided in both the raw coal stockyard and product coal stockyard. A process of natural drying of coal may be required to reduce moisture content.

(i) Communication

It is important to consider any communication both external and internal services. Telephone, facsimile and mobile radio services may be required for the mine operations.

(j) Mine infrastructure

a) Townships

Due to the remote location of the project, a new town will be developed to provide accommodation for the labor force. It is expected that the population of the town will depend on the total labor force. The town development will commence at the same time as the mine pre-production development, so that accommodation will be available for operational personnel when mine development starts. Location, size of workforce, mine life, existing facilities, and company and government policies will influence the magnitude of the residential and community facilities required. Township size is based on the workforce requirements and allowance.The following facilities should be provided for the town:

- Housing: for employees
- Roads
- Services: potable water, power, sewerage and drainage
- Recreation facilities
- Shopping facilities
- Community facilities: town hall, fire station, police, bank and post office
- Commercial facilities
- Medical facilities
- Educational facilities.

As mentioned earlier, construction costs will be covered by the three major portions:

- National and/or local governments,
- Coal mine,
- Private or commercial entities

The coal mining company will be responsible to construct houses for employees. The following costs are estimated for the construction of town-ships and housings.

- Employees 360
- Population 980
- Cost estimates (US$ 1,000) 8,000

It is estimated that total costs of twnships are US$ 24,000 thousand. However, US$16,000 thousand out of total costs should be prepared by governments. It is expected that the coal mining company will prepare US 8,000 thousand for developing townships.

| | |
|---|---|
| Governments | 16,000 |
| Company | 8,000 |
| Private | - |
| Total | 24,000 |

b) Transportation and power line

Consideration and evaluation of the available transportation are essential. The transportation systems available for consideration include:

- Road
- Railroad

(i) Road

Two kilometers of roads are to be constructed for the access road from the main roads.

Cost estimate: 247/km × 2km = 495 (US$ 1,000)

(ii) Railroad in the property

Two kilometers of side track road is to be constructed for the material and coal haulage.

- Cost estimate for side track: 675/km × 2km = $1,350 (US$ 1,000)
- Rolling stock

Assumption: All the produced coal will be hauled to Ulaanbaatar
Haul distance to Ulaanbaatar: 270km
Unit rolling stock: $7,500/million ton. km
Rolling stock: 2,025 (US$1,000)

- Total costs of railroad (US$1,000)

| | |
|---|---|
| Side track | 1,350 |
| Rolling stock | 2,025 |
| Total | 3,375 |

(iii) Power line and communication method

Power line is to be extended from the CES for convenience. It is important to consider any communication both the external and internal services. Telephone, facsimile and mobile radio services may be required for the mine operations.

Power line: $71,250 ×2km ≒ 143 (US$1,000)

(iv) Other 401 (US$1,000)

c) Total (a)+b)) 12,414 (US$1,000)

4) Infrastructure development costs

(a) General

New facilities of townships, railroads, roads, power lines, etc. should be developed for the new potential mines.

a) Road

Existing roads in the area provide access to the portion of the property. Some parts of roads will be newly upgraded.

b) Railroad

The coal will be transported by trains to consuming cities. A new rail line is to be constructed from the project site to connect with the existing line.

c) Power line and communication

It is necessary to extend power line for supplying power from CES system.

d) Townships (Undertaking by governments)

(b) Cost estimates

| | | |
|---|---|---|
| Railroad: | Length (km) | 90 |
| | Costs (US$1,000) | 60,750 |
| Road: | Length (km) | 90 |
| | Costs (US$1,000) | 4,050 (up grade) |

| | | |
|---|---|---|
| Power line: | Length (km) | 40 |
| | Costs (US$1,000) | 2,850 |
| Other facilities: | | 6,765 |
| Town ships | | 16,000 |
| Total (US$1,000) | | 90,415 |

(3) Total capital cost

Capital cost for coal mine consists of the major mining equipment and the general purpose equipment and the surface facilities, which is not include any taxation.

| | | |
|---|---|---|
| Initial capital costs: | | 51,600 (US$ 1,000) |
| Replacement cost: | | 57,800 (US$ 1,000) |
| Total capital costs: | | 109,400 (US$ 1,000) |
| Infrastructure cost: | Railroad | 60,800 (US$ 1,000) |
| | Road | 4,100 (US$ 1,000) |
| | Power line | 2,900 (US$ 1,000) |
| | Townships | 16,000 (US$ 1,000) |
| | Other | 6,800 (US$ 1,000) |
| | Sub-total | 90,400 (US$ 1,000) |
| Grand total: | | 199,800 (US$ 1,000) |

(4) Operating costs

Operating costs consist of two components; material and labor. The cost index of $1.43/BCM of the shovel and truck system is used for the comparison of new mining system in Baganuur coal mine renovation study in Part 1. This index is used to plan the new potential mines because the shovel and truck system is adopted, too.

(5) Economic evaluation

Coal price in 10% EIRR was calculated under the same assumption of Tsaidamunuur coal mine. Table 7.6 shows the net cash flow of EIRR every year and coal price in 10% EIRR is US$14.7/t (5,892Tg/t).

# Table 7.5 Proposed Mining Plan of Khoot Mine (1/2)

1) Details of plan

| Coal seam condition | | | Reserves ($\times10^6$t) | | | Development plan | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thickness | Dip | Strike length | Depth | Stripping ratio | Reserves | Annual Production | Cumurative coal Production | Strike length | Depth | Total Stripping ratio | Average overbuden removal | Volume of coal production | Fleet number | |
| | | | | | | | | | | | | | Coal mining | Stripping |
| (m) | ( ° ) | (km) | (m) | | ($\times10^6$t) | ($\times10^3$t) | ($\times10^3$) | (km) | (m) | | ($\times10^3$ m³) | ($\times10^3$ m³) | 5.7m³+46t | 12m³+80t |
| 7 | 5 | 3 | 65 | 4.2 | 20 | 1,000 | 20,000 | 3 | 34 | 3.8 | 3,800 | 800 | 1 (0.50) | 2 (1.52) |
| 6 | 5 | 3 | 55 | 4.2 | 15 | | | | | | | | | |
| 7 | 2 | 3 | 58 | 4.2 | 50 | | | | | | | | | |
| | | | | | 85 | | | | | | | | | |

2) Cost estimation

Capital costs (Initial)

($\times10^3$ US$)

| Mining equipment | | | | General purpose equipment | Surface facilities | | Total |
|---|---|---|---|---|---|---|---|
| Equipment | Specification | Quantity | Amount of price | | | | |
| Power shovel | 12m³ (waste) | 2 | 8,018 | (Bulldozer, | Workshop | 1,003 | 51,629 |
| Hydraulic shovel | 5.7m³ (coal) | 1 | 2,016 | Grader, | Warehouse | 413 | |
| Front end loader | 5 m³ | 2 | 867 | Front end loader, | Coal stockyard | 777 | |
| Dump truck | 80t (waste) | 13 | 10,270 | Service truck, | Sizing & loading | 2,753 | |
| Dump truck | 40t (coal) | 4 | 1,760 | Water truck, | Power distribution | 845 | |
| Bulldozer | 400 Hp | 3 | 1,572 | Fuel truck, | Communication | 63 | |
| Grader | 254 Hp | 2 | 732 | Anfo truck, | Drainage & water supply | 2,960 | |
| Drill | 160 mm | 3 | 1,377 | etc.) | Mine office | 370 | |
| Sub-Total | | | 26,612 | 2,587 | Explosive magazine | 148 | |
| | | | | | Boiler | 222 | |
| | | | | | Road maintenance | 222 | |
| | | | | | Coal quality system | 240 | |
| | | | | | Mine infrastructure | 12,414 | |
| | | | | | | | |
| Equipment total | 29,199 | | | | Subtotal | 22,430 | |

# Table 7.5 Proposed Mining Plan of Khoot Mine (2/2)

Capital Costs for coal mine (Initial & replacement)

US$ 000's

| Year | Mining Equipment | General Purpose Equipment | Surface facilities | Total |
|---|---|---|---|---|
| -3 | — | 168 | 12,414 | 12,582 |
| -2 | 15,634 | 1,674 | 9,180 | 26,488 |
| -1 | 10,978 | 745 | 836 | 12,559 |
| Initial total | 26,612 | 2,587 | 22,430 | 51,629 |
| 1 | — | — | — | — |
| 2 | — | — | — | — |
| 3 | — | — | — | — |
| 4 | — | — | 2,960 | 2,960 |
| 5 | — | — | 189 | 189 |
| 6 | — | 168 | — | 168 |
| 7 | 11,625 | 1,674 | 1,467 | 14,766 |
| 8 | 6,969 | 745 | 777 | 8,491 |
| 9 | — | — | 4,616 | 4,616 |
| 10 | — | — | 80 | 80 |
| 11 | — | — | 189 | 189 |
| 12 | — | — | — | — |
| 13 | — | — | — | — |
| 14 | — | 168 | 2,960 | 3,128 |
| 15 | 11,625 | 1,674 | 1,467 | 14,766 |
| 16 | 6,969 | 745 | 777 | 8,491 |
| 17 | — | — | — | — |
| 18 | — | — | — | — |
| 19 | — | — | — | — |
| 20 | — | — | — | — |
| Replacement total | 37,188 | 5,174 | 15,482 | 57,844 |
| Total capaital | 63,800 | 7,761 | 37,912 | 109,473 |

Capital costs for infrastructure

| | |
|---|---|
| Railroad | |
| Length (km) | 90 |
| Costs ($000's) | 60,750 |
| Road | |
| Length (km) | 90 |
| Costs ($000's) | 4,050 |
| Powerline (km) | 40 |
| Costs ($000's) | 2,850 |
| Township | |
| Population | 980 (360 employees included) |
| Costs ($000's) | 16,000 |
| Other | |
| Costs ($000's) | 6,765 |
| Total | 90,415 |

Operating Costs

| Year | Waste million BCM | Coal million ton | Costs million $ | $/T |
|---|---|---|---|---|
| -3 | — | — | — | — |
| -2 | 3.57 | 0.50 | 5.68 | 11.35 |
| -1 | 3.37 | 0.75 | 5.68 | 7.57 |
| 1 | 3.80 | 1.00 | 6.58 | 6.58 |
| 2 | 3.80 | 1.00 | 6.58 | 6.58 |
| 3 | 3.80 | 1.00 | 6.58 | 6.58 |
| 4 | 3.80 | 1.00 | 6.58 | 6.58 |
| 5 | 3.80 | 1.00 | 6.58 | 6.58 |
| 6 | 3.80 | 1.00 | 6.58 | 6.58 |
| 7 | 3.80 | 1.00 | 6.58 | 6.58 |
| 8 | 3.80 | 1.00 | 6.58 | 6.58 |
| 9 | 3.80 | 1.00 | 6.58 | 6.58 |
| 10 | 3.80 | 1.00 | 6.58 | 6.58 |
| 11 | 3.80 | 1.00 | 6.58 | 6.58 |
| 12 | 3.80 | 1.00 | 6.58 | 6.58 |
| 13 | 3.80 | 1.00 | 6.58 | 6.58 |
| 14 | 3.80 | 1.00 | 6.58 | 6.58 |
| 15 | 3.80 | 1.00 | 6.58 | 6.58 |
| 16 | 3.80 | 1.00 | 6.58 | 6.58 |
| 17 | 3.80 | 1.00 | 6.58 | 6.58 |
| 18 | 3.80 | 1.00 | 6.58 | 6.58 |
| 19 | 0.66 | 0.50 | 1.52 | 3.03 |
| 20 | 0 | 0.25 | 0.29 | 1.14 |
| Total | 76.00 | 20.00 | 131.61 | 6.58 |

Details of Operating cost

| Index | Unit |
|---|---|
| Operating cost | $/BCM 1.43 |
| Strip ratio | 3.8 : 1 |
| Production ※ | |
| Waste | 3.8 |
| Coal | 0.8 |
| Total | 4.6 |

※ million bcm

Table 7.6 Economic Evaluation of Khoot Mine

Coal price of 10% EIRR 5,892Tg/t

| Year | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Price ($US/t) | 14.729 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 |
| Production (mil.t) | | | 0.5 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Revenue(mil.$US) | | 0.0 | 7.4 | 11.8 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 |
| Investment cost (mil.$) | | 12.6 | 26.5 | 12.6 | 0.0 | 0.0 | 0.0 | 3.0 | 0.2 | 0.2 | 14.8 | 8.5 | 4.6 |
| A Initial | | 12.6 | 26.5 | 12.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mining Equipment | | 0.0 | 15.6 | 11.0 | 0.0 | | | | | | | | |
| General Purpose Equipment | | 0.2 | 1.7 | 0.7 | | | | | | | | | |
| Surface Facilities | | 12.4 | 9.2 | 0.8 | | | | | | | | | |
| B Replacement | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.2 | 0.2 | 14.8 | 8.5 | 4.6 |
| Operating Cost (mil.$) | | 0.0 | 3.3 | 5.3 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 |
| NCF before Tax (mil.$) | | -12.6 | -22.4 | -6.0 | 8.2 | 8.2 | 8.2 | 5.2 | 8.0 | 8.0 | -6.6 | -0.3 | 3.5 |
| (=Revenue-Investment-Operating cost) | | | | | | | | | | | | | |

| Year | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Price ($US/t) | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | |
| Production (mil.t) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.3 | 20.1 |
| Revenue(mil.$US) | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 7.4 | 4.4 | 296.1 |
| Investment cost (mil.$) | 0.1 | 0.2 | 0.0 | 0.0 | 3.1 | 14.8 | 8.5 | 0.0 | 0.0 | 0.0 | 0.0 | 109.5 |
| A Initial | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 51.6 |
| Mining Equipment | | | | | | | | | | | | 26.6 |
| General Purpose Equipment | | | | | | | | | | | | 2.6 |
| Surface Facilities | | | | | | | | | | | | 22.4 |
| B Replacement | 0.1 | 0.2 | 0.0 | 0.0 | 3.1 | 14.8 | 8.5 | 0.0 | 0.0 | 0.0 | 0.0 | 57.9 |
| Operating Cost (mil.$) | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 3.3 | 2.0 | 132.0 |
| NCF before Tax (mil.$) | 8.0 | 8.0 | 8.2 | 8.2 | 5.0 | -6.6 | -0.3 | 8.2 | 8.2 | 4.1 | 2.4 | 54.5 |
| (=Revenue-Investment-Operating cost) | | | | | | | | | | | | |

| | |
|---|---|
| Discount Rate | 10% |
| Total NPV before Tax | 0 (mil.$) |
| EIRR (IRR on NCF B.Tax) | 10% |

7.1.4 Tavantolgoi mine

(1) Basis of plan

1) Feathures of the coal deposit

Tavantolgoi deposit is located 540km south of Ulaanbaatar and 96km east of Dalanzadgad. The climate of this area is semi-desert and the population is sparse. Reserves of this deposit is tremendous, geological and mining conditions are excellent. Coal quality is classified into bituminous coal and the several coal seams are classified into coking coal, which can be produced with washing process for industrial use. However, large amount of investment should be required for the construction of infrastructure. This area is currently short of infrastructure, such as railway, road, power line, water supply, etc. A new power line is planned to be extended from Mandalgovi to Tavantolgoi around 2000. The railway is planned to be constructed from Choir to Khoot, and in the next stage from Khoot to Tavantolgoi in future.

2) Design basis

Coal mine development plan is made on the following conditions:

- The plan should be conducted on the base of the future export market.
- The project term is 23 years
- The annual production is 11.0 million ton of run of mine coal.
- The breakdown of the annual production is as follows:

(a) Thermal coal for the mine mouth power plant to export electric power by HVDC transmission line; 9 million ton

(b) Coking coal for export; 1.21 million ton

(c) Thermal coal for local use; 0.79 million ton

(d) Total: 11.0 million ton

- The plant yield of coking coal is 55.0%
- Stripping ratio is 4.4 and constant during project term.
- Bench cut method of using shovel and truck system is adopted as the mining method.
- Average transportation distance is three km and constant during project term.

(2) Machinery requirement

1) Major mining machines

Table 7.7 shows the machinery requirement for above-mentioned design basis.

The fleet for overburden removal consists of 12 $m^3$ electric shovel and 80 ton dump trucks. The electric shovel is selected because it has stronger digging force and durability and can be driven by electricity instead of imported fuel oil. Because the electric mining machine is suitable for the large-scaled work with less frequency of working place change, it is necessary to operate it in advancing stripping activity. This fleet is recommended as a superior in Part 1 of the study. The fleet for coal mining consists of 5.7 $m^3$ backhoe type hydraulic shovel and 46 ton dump trucks. Backhoe type hydraulic shovel has advantages as follows:

- precise selective mining effective for coal quality control.
- adaptability for overburden removal with its greater digging force.
- capability of digging below the machine level.
- capability of performing incidental works such as making drainage ditch and treating surface of working face, etc.

2) Manpower requirement

Manpower requirement in the Tavantolgoi coal mine is estimated based on the Shivee Ovoo coal mine, and 3,200 persons will be required. Manpower requirement in detail should be established by categories in the next stage.

(3) Surface facilities

The typical coal mine producing coking coal needs the following surface facilities; Washing plant, workshops and warehouses, power supply and distribution, water supply, dewatering and drainage, crushing/sizing/loading, office, stockpile, transportation, communication, etc. Table 7.7 includes the list of surface facilities.

1) Washing plant

To produce coking coal washing process is needed. The heavy medium separator is adopted to washing plant. The possibility of industrial water supply from ground water or surface water resources must be surveyed.

2) Workshop and warehouses

Workshops must provide adequate facilities for the inspection, repair and maintenance of plants and mining equipment.

Workshop areas are composed of repair shop, service facility, warehouses, material handling, vehicle washing, vehicle parking, etc. Mine fleet services are performed in general near the working areas and includes refueling, routine servicing, tire maintenance, etc.

Repair shops require the following functions for:

- Equipment repair
- Heavy vehicle repair
- Light vehicle repair
- Electric repair
- Undercarriage repair

Mines are usually located in remote areas therefore they should maintain stocks of spare parts, consumable items and replacement components required for plants and equipment in the warehouses.

3) Power supply and distribution facilities

Power is to be obtained from the mine mouth power plant constructed near the Tarantolgoi coal mine, which power is also provided through a new transmission line from CES at the beginning of the project. Transformers provide power at the required working voltage. Power is generally transmitted via overhead line to transformers, then by cable to the equipment.

4) Water supply facilities

Potable water and industrial water are required for mining operations, especially in washing process, and townships. Underground water from the dewatering wells and drainage water may not be suitable for drinking, but for industrial purposes. All sources should be considered in order to select the optimum water supply system; rivers, lakes, groundwater, etc. It is necessary to investigate to prove the sustainability of a water source. Water is taken from rivers, lakes or groundwater, then sent to the pump station through pipelines, sometimes directly, sometimes via water treatment facilities, at the mining complex, and then delivered to places required.

5) Dewatering and drainage facilities

If the groundwater level is high in Tavantolgoi area and affects on mining works and coal quality, it is necessary to dewater and lower the water level before mining. Dewatering of the groundwater is to be started for a certain period before mining starts and is necessary to be continued during the project period without any trouble. Water drainage is of prime importance for open pit mining operations. Ditches and sumps should be dug in and around the pit, and pumping facilities should be installed for the drainage.

6) Crushing/sizing/loading Facilities

In regard to the coal quality, end users of thermal coal suffer not only from poor quality of coal but also uncrushed run-of-mine coal, mixing with lumpy waste and foreign materials.A crushing, sizing and loading plant is needed for the coal mine, and all the run-of-mine coal should be processed at the plant before shipping.

7) Office facilities

In order to maintain mining and plant operations, an operational center will be required for management, planning and control of daily activities.

8) Stockpile facilities and transportation facilities

Crushed thermal coal is delivered from the crushing/sizing plant to the mine mouth power plant silos through a conveyor system directly. Thermal coal for local use is conveyed to a loading section. Crushed coal for local use is diverted to stockpile areas for temporary stock. Spontaneous combustion characteristics of coal must be seriously studied and proper procedures and facilities should be provided in both the raw coal stockyard and product coal stockyard. A process of natural drying of coal may be required to reduce moisture content. Coking coal produced with washing process is transported by rail for export.

9) Communication

It is important to consider any communication both external and internal services. Telephone, facsimile and mobile radio services may be required for the mine operations.

10) Mine infrastructure

(a) Townships

Due to the remote location of the project, a new town will be developed to provide accommodation for the labor force. The town development will be commenced at the same time as the mine pre-production development, so that accommodation will be available for operational personnel when mine development starts. The following facilities should be provided for the town:

- Housing: for employees
- Utilities supply ficilities: potable water, power, sewerage and drainage
- Recreation facilities
- Shopping facilities
- Community facilities: town hall, fire station, police, bank and post office
- Medical facilities
- Educational facilities

As mentioned earlier, construction costs will be covered by the two major portions:

- National and/or local governments
- Coal mine company

The coal mining company will be responsible to construct houses for employees. The followings are estimated for the construction of town-ships and housings.

- Employees 3,200
- Population 8,700

(b) Transportation and power line

a) Road

Two kilometers of roads are to be constructed for the access road from the main roads.

b) Railroad in the property

Two kilometers of side track road is to be constructed for the material and coal haulage.

c) Power line and communication method

Power line is planned to be extended from the CES. It is important to consider any communication both the external and internal services. Telephone, facsimile and mobile radio services may be required for the mine operations.

(4) Capital cost for coal mine

1) Mining equipment and surface facilities

Capital cost consists of the mining equipment and the general purpose equipment and the surface facilities, which is not include any taxation..

| | | |
|---|---|---|
| Initial capital costs: | | 365,900 (US$ 1,000) |
| Replacement cost: | | 451,500 (US$ 1,000) |
| Total capital costs: | | 817,400 (US$ 1,000) |
| Infrastructure cost: | Railroad | 297,000 (US$ 1,000) |
| | Road | 13,500 (US$ 1,000) |
| | Power line | 21,400 (US$ 1,000) |
| | Townships | 46,000 (US$ 1,000) |
| | Other | 33,200 (US$ 1,000) |
| | Sub-total | 411,100 (US$ 1,000) |
| Grand total: | | 1,228,500 (US$ 1,000) |

2) Infrastructure development costs

(a) General

New facilities of townships, railroads, roads, power lines, etc. should be developed.

a) Road

Existing roads in the area provide access to the portion of the property. Some parts of roads will be newly upgraded.

b) Railroad

The coal will be transported by trains to consuming cities and for export. A new rail line is to be constructed from the project site to connect with the existing line.

c) Power line

It is planned to extend power line for supplying power from CES system.

d) Town ships (Above mentioned)

(b) Cost estimates

| | | |
|---|---|---|
| Railroad: | Length (km) | 440 |
| | Costs (US$1,000) | 297,000 |
| Road: | Length (km) | 300 |
| | Costs (US$1,000) | 13,500 (up grade) |
| Power line: | Length (km) | 300 |
| | Costs (US$1,000) | 21,375 |
| Other facilities: (US$1,000) | | 33,188 |
| Town ships: (US$1,000) | | 46,000 |
| Total (US$1,000) | | 411,063 |

## Table 7.7 Proposed Mining Plan of Tavantolgoi Mine (1/2)

1) Details of plan

| Reserves (Tsankha area) (million ton) | | Development plan | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Annual Production (million ton) | | | | | | | Total Stripping Ratio | Average Overburden Removal | Volume of Coal Production | Fleet number | |
| Total | Coking coal | 11.0 | | | | | | | | (million BCM) | (million BCM) | Coal mining 5.7m³+46t | Stripping 12m³+80t |
| | | Thermal Coal (million ton) | Raw coal for washing (million ton) | | Thermal Coal for mine mouth power plant (million ton) | Thermal coal for local use (million ton) | Coking coal for export (million ton) | | | | | | |
| | | | 2.2 | | | | | | | | | | |
| | | | Middlings (million ton) | Coking coal (million ton) | | | | | | | | | |
| 1,395 | 725 | 8.8 | 0.99 | 1.21 | 9.0 | 0.79 | 1.21 | | 4.4 | 48.4 | 7.86 | 5 (4.92) | 20 (19.41) |

2) Cost estimation

Capital costs (Initial)

| Mining equipment | | | | General purpose equipment | Service facilities | | Total |
|---|---|---|---|---|---|---|---|
| Equipment | Specification | Quantity | Amount of price | | | | |
| Power shovel | 12m³ (waste) | 20 | 80,018 | (Bulldozer, | Washing plant | 12,000 | |
| Hydraulic shovel | 5.7m³ (coal) | 5 | 10,080 | Grader, | Workshop | 4,508 | |
| Front end loader | 5 m³ | 10 | 4,335 | Front end loader, | Warehouse | 1,785 | |
| Dump truck | 80t (waste) | 156 | 123,240 | Service truck, | Coal stockyard | 2,253 | |
| Dump truck | 40t (coal) | 40 | 17,600 | Water truck, | Sizing & loading | 11,445 | |
| Bulldozer | 400 Hp | 25 | 13,100 | Fuel truck, | Power distribution | 2,926 | |
| Grader | 254 Hp | 10 | 3,660 | Anfo truck, | Communication | 240 | 365,924 |
| Drill | 160 mm | 25 | 11,475 | etc.) | Drainage & water supply | 11,277 | |
| Sub-Total. | | | 263,670 | 15,852 | Mine office | 1,663 | |
| | | | | | Explosive magazine | 665 | |
| | | | | | Boiler | 998 | |
| | | | | | Road maintenance | 998 | |
| | | | | | Coal quality system | 677 | |
| | | | | | Mine infrastructure | 34,970 | |
| | | | | | | | |
| Equipment total | 279,522 | | | | Subtotal | 86,402 | |

## Table 7.7 Proposed Mining Plan of Tavantolgoi Mine (2/2)

Capital Costs for coal mine
(Initiai & replacement)

US$ 000's

| Year | Mining Equipment | General Purpose Equipment | Surface facilities | Total |
|---|---|---|---|---|
| -3 | — | 433 | 34, 970 | 35, 403 |
| -2 | 145, 018 | 9, 653 | 25, 904 | 180, 575 |
| -1 | 118, 652 | 5, 766 | 25, 528 | 149, 946 |
| Initial total | 263, 670 | 15, 852 | 86, 402 | 365, 924 |
| 1 | — | — | — | — |
| 2 | — | — | — | — |
| 3 | — | — | — | — |
| 4 | — | — | 11, 276 | 11, 276 |
| 5 | — | — | 849 | 849 |
| 6 | — | 433 | — | 433 |
| 7 | 103, 460 | 9, 653 | 5, 416 | 118, 529 |
| 8 | 77, 154 | 5, 766 | 2, 253 | 85, 173 |
| 9 | — | — | 18, 763 | 18, 763 |
| 10 | — | — | 240 | 240 |
| 11 | — | — | 849 | 849 |
| 12 | — | — | — | — |
| 13 | — | — | — | — |
| 14 | — | 433 | 11, 276 | 11, 709 |
| 15 | 103, 460 | 9, 653 | 5, 416 | 118, 529 |
| 16 | 77, 154 | 5, 766 | 2, 253 | 85, 173 |
| 17 | — | — | — | — |
| 18 | — | — | — | — |
| 19 | — | — | — | — |
| 20 | — | — | — | — |
| Replacement total | 361, 228 | 31, 704 | 58, 591 | 451, 523 |
| Total capaital | 624, 898 | 47, 556 | 144, 993 | 817, 447 |

Capital costs for infrastructure

| | | |
|---|---|---|
| Railroad | | |
| | Length (km) | 440 |
| | Costs ($000's) | 297, 000 |
| Road | | |
| | Length (km) | 300 |
| | Costs ($000's) | 13, 500 |
| Powerline (km) | | 300 |
| | Costs ($000's) | 21, 375 |
| Township | | |
| | Population | 8, 700<br>(3, 200 employees included) |
| | Costs ($000's) | 46, 000 |
| Other | | |
| | Costs ($000's) | 33, 188 |
| Total | | 411, 063 |

7.1.5 Training center

The Training center consists of three major section; training section, maintenance section and parts supply section.

Note: At the initial stage of the training center, the foreign experts dispatched by the economic aid system may assist each section.

(1) Training

1) Training courses

| Course | Training period(month) | No. of trainees | No. of course/y |
|---|---|---|---|
| Operator | 6+2+4 | 5 | 1 |
| Mechanic | | | |
| Engine | 6+2+4 | 5 | 1 |
| Chassis | 6+2+4 | 5 | 1 |

2) Organization,staff

Director: 1

Instructor

Operator course

Instructor : 1

Sub-instructor: 1

Mechanic course

Instructor: 1

Sub-instructor: 1

Administration: 2 (supported by the administration of the existing coal mine)

Total: 7

3) Investment required (US$ 1,000)

| | |
|---|---|
| Buildings : | 1,000 |
| Facilities & equipment: | 4,000 |
| Total | 5,000 |

4) Annual budget : 155 (US$ 1,000)

Salary for staff , consumable and general administration are included, but education fees for instructors at the initial stage are not included.

(2) Maintenance section

1) Facilities

This function serves for overhaul, repair and preventive maintenance and has following facilities.

- chassis repair equipment
- engine repair and test equipment
- fuel system repair and test equipment
- power line component repair and test equipment
- electronic component repair equipment
- undercarriage and tire repair equipment
- welding and fabrication group equipment
- washing equipment
- painting equipment

In addition to the facilities mentioned above, such facilities are installed as offices, amenity facilities, warehouses, service facilities, material handling facilities, parking lots etc.

2) Figure 7.1(1/4-4/4)show examples of workshop.

3) Organization, staff

| | |
|---|---|
| General manager: | 1 |
| Chief engineer: | 5 |
| Engineer: | 5 |
| Mechanic /electrician: | 30 |
| Administration: | - (covered by training part) |
| Total: | 41 |

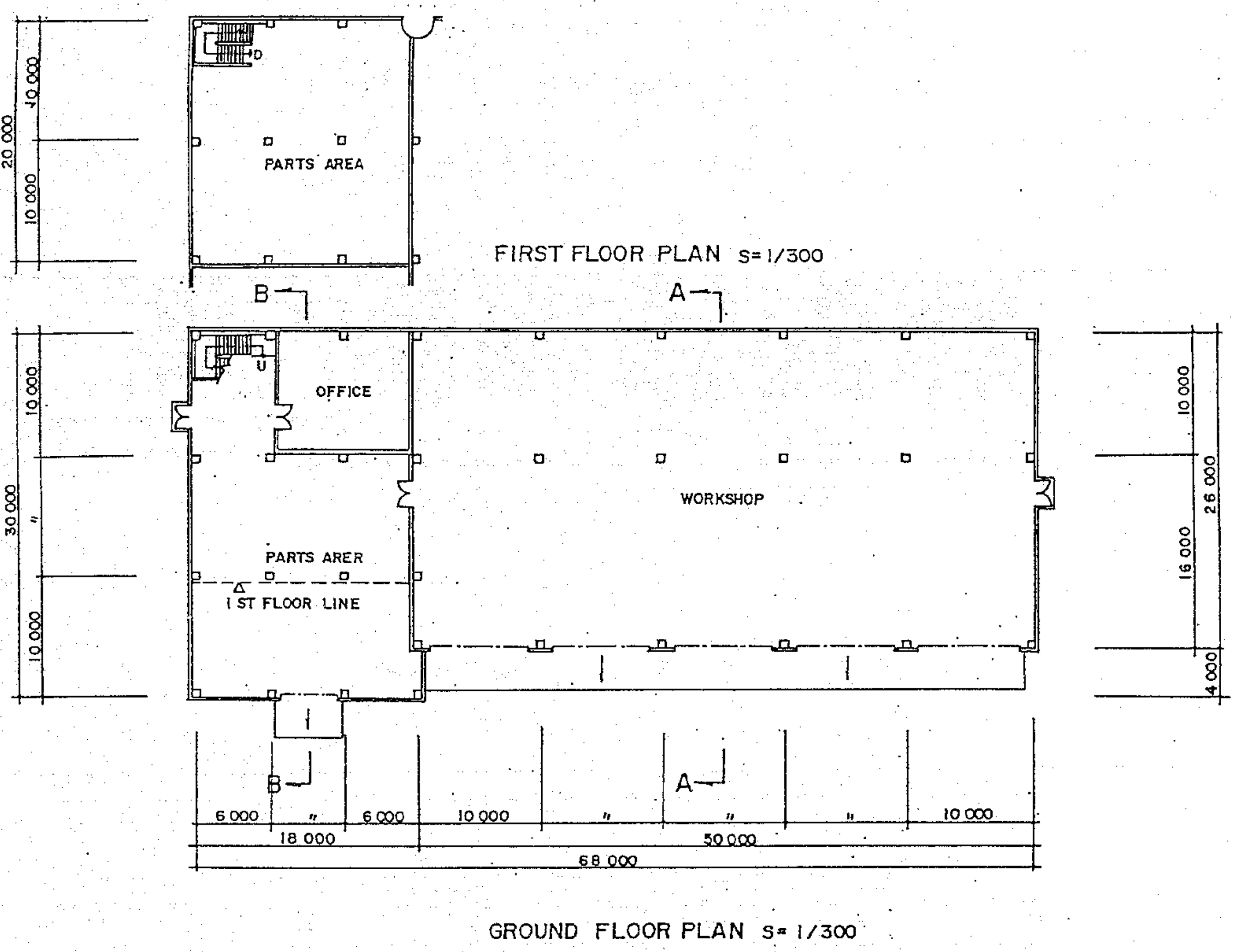
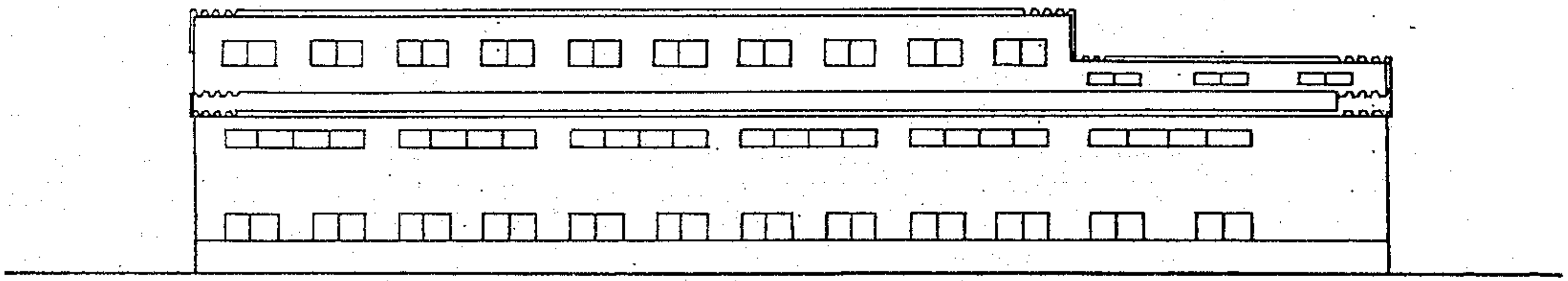
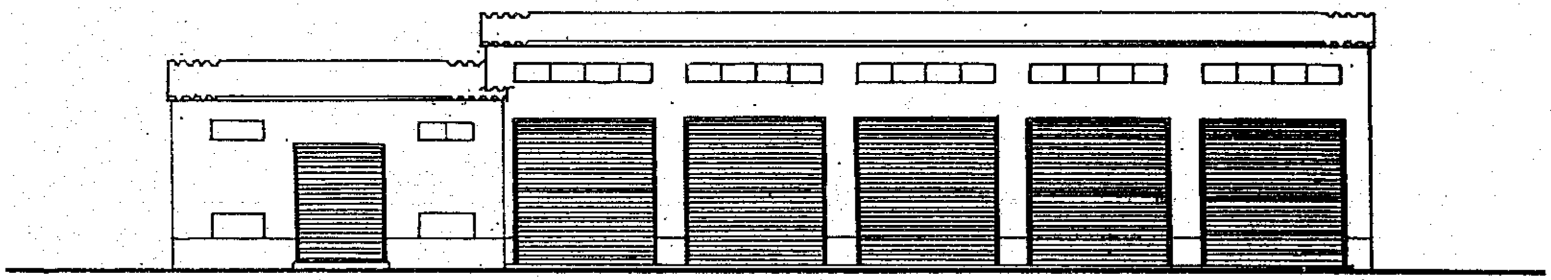



Figure 7.1 Example of Workshop (1/4)

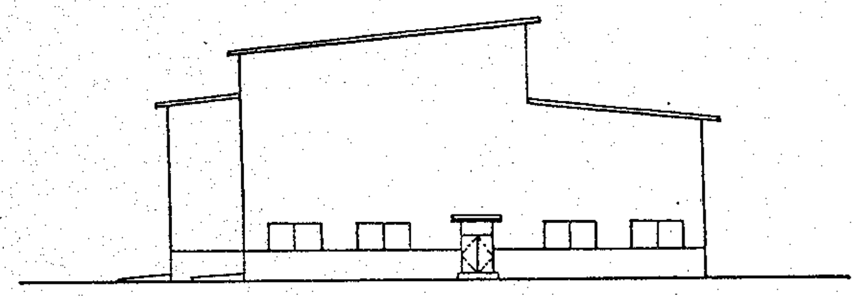


A-SIDE ELEVATION S= 1/300

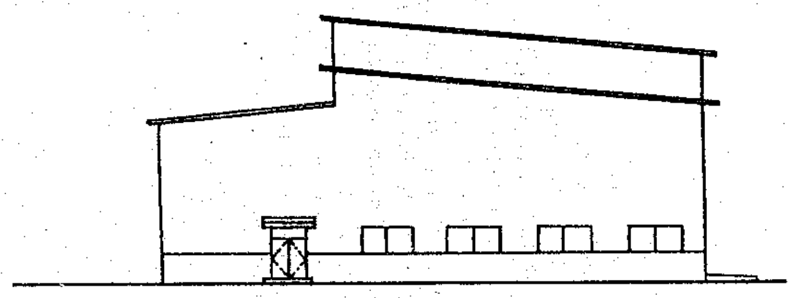


C-SIDE ELEVATION S= 1/300

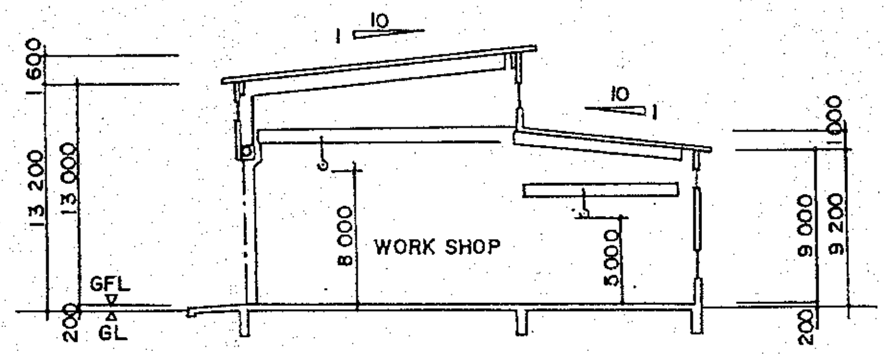
Figure 7.1 Example of Workshop (2/4)



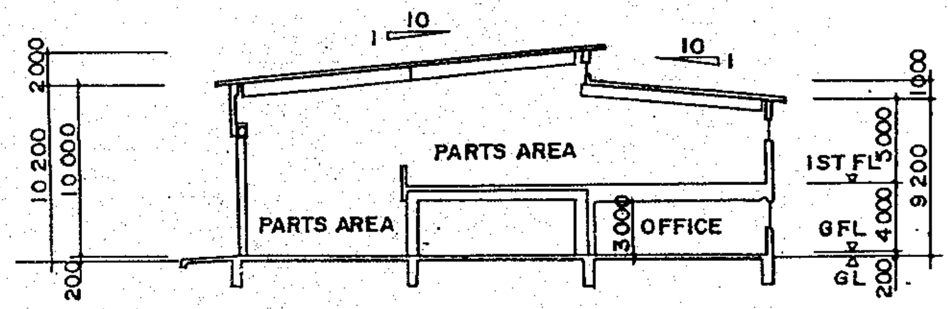
B-SIDE ELEVATION S=1/300



D-SIDE ELEVATION S=1/300




A - A SECTION S=1/300




B - B SECTION S=1/300

Figure 7.1 Example of Workshop (3/4)

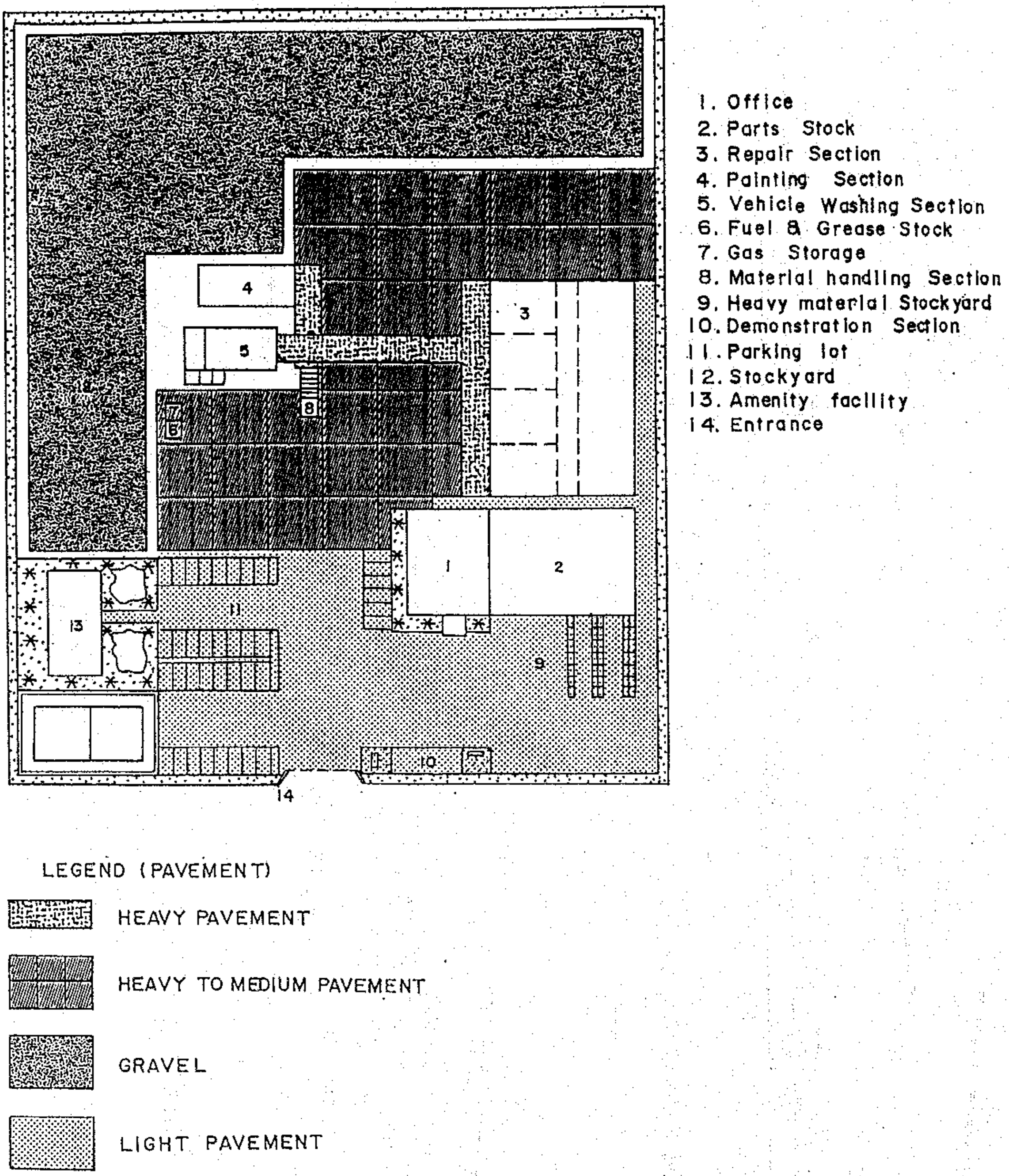



Figure 7.1 Example of Workshop (4/4)

4) Investment required (US$ 1,000)

| | |
|---|---|
| Buildings: | 2,000 |
| Facilities & equipment : | 2,200 |
| Total: | 4,200 |

5) Annual operating cost: 230 (US$ 1,000)

(3) Spare parts service section

- Procurement and store of common spare parts that existing coal mines in Mongolia use.
- Distribution of common spare parts
- Repair of recovery parts
- Management of stocks

Common spare parts is the follow:

- Engine set
- Chassis set
- Power line component
- Electronic component
- undercarriage and tire

(4) Summary of the training center

1) Investment required (US$ 1,000)

| | |
|---|---|
| Buildings: | 3,000 |
| Facilities & equipment: | 6,200 |
| Total: | 9,200 |

2) Annual operating cost: 385 (US$ 1,000)

3) Number of staff : 48

4) Funds for investment and annual operating cost

- Initial cost is prepared by government
- Operating cost is prepared by each coal mine at the rate of coal production