モンゴル･石炭火力発電所の複合的な効率改善に関する新メカニズム実現可能性調査

2012年1月23日

（株）数理計画

Purposes of Feasibility Study

- Comprehensive and multiple application of Energy Efficiency improvement measures will be introduced to the Coal-Fired Thermal Power Plants in Mongolia.
- Feasibility Study of the GHG emission reduction from these measures.
- Feasibility of new market mechanism is shared between Mongolia and Japan.
- The estimation of co-benefit effect.

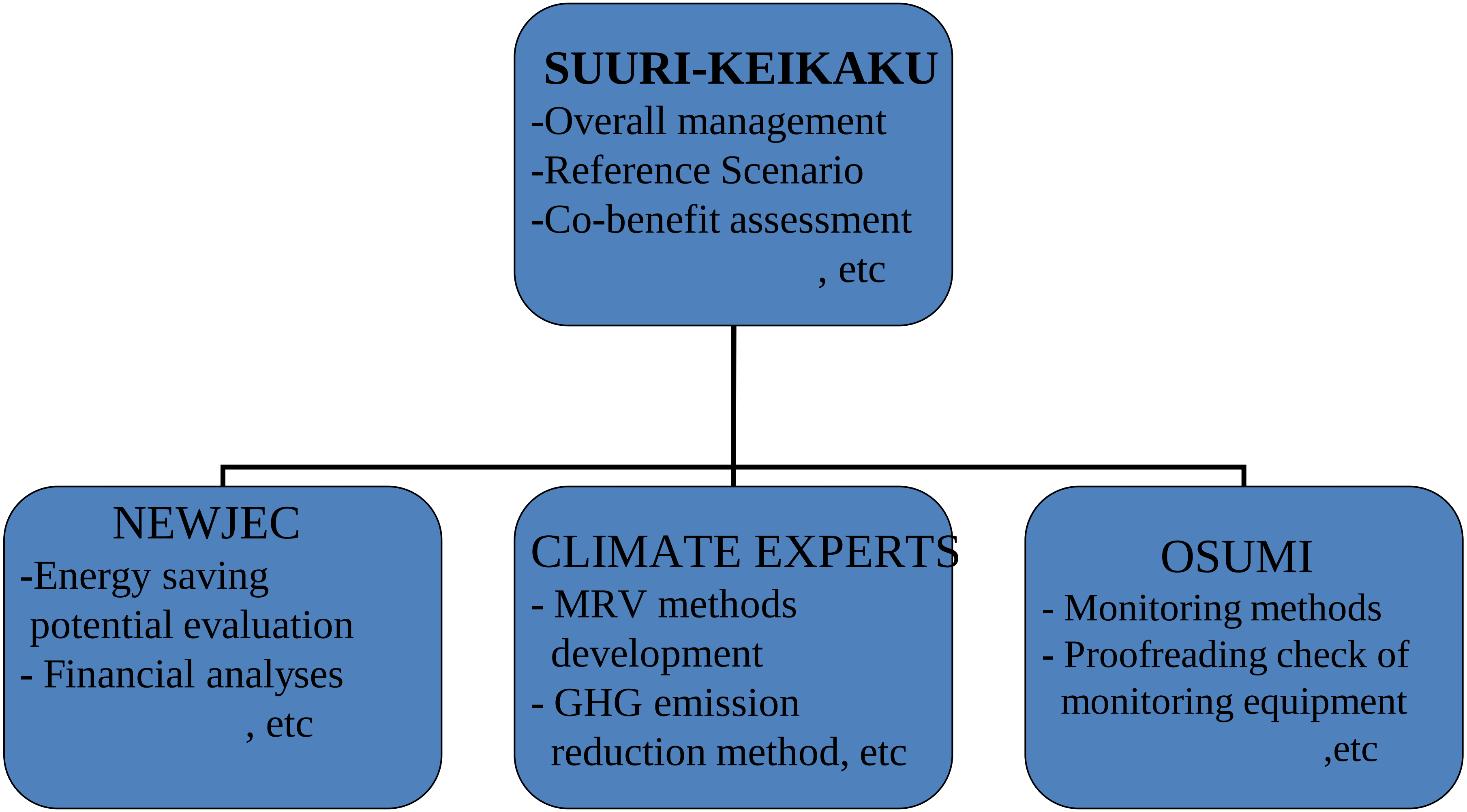
Outputs of the Expected Project Activities

- The Improvement of the Environmental Issues of Air Pollution in Mongolia, specially in Ulaanbaatar
- The Improvement of the Operation and Management Techniques of Coal Thermal Power Plants in Mongolia
- GHG Emission Reduction
- The Bilateral Offset Credits will be issued.
- Contribution to the Sustainable Development in Mongolia

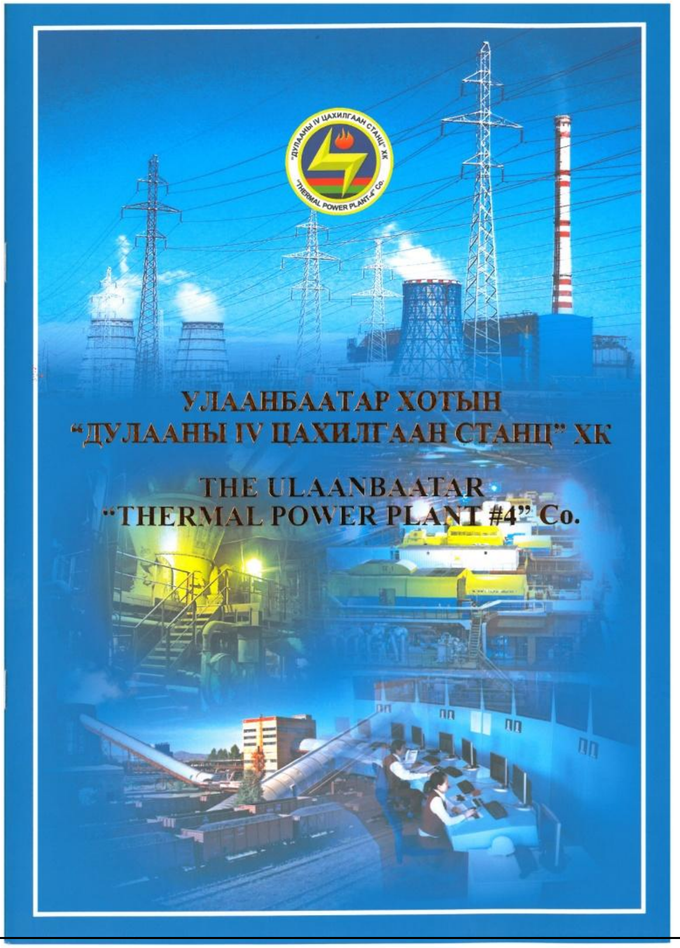
Outline of FS Survey

- The survey of the energy-saving potential is done at each coal-fired thermal power plant.
- The reference scenario will be set up.
- The GHG emission reductions will be quantified.
- MRV (measurable, reportable and verifiable) (Bilateral Offset Credit, Sustainable Development) methodology will be proposed.
- The co-benefits of air quality improvement and GHG emission reduction (support the policies of air pollution issues)

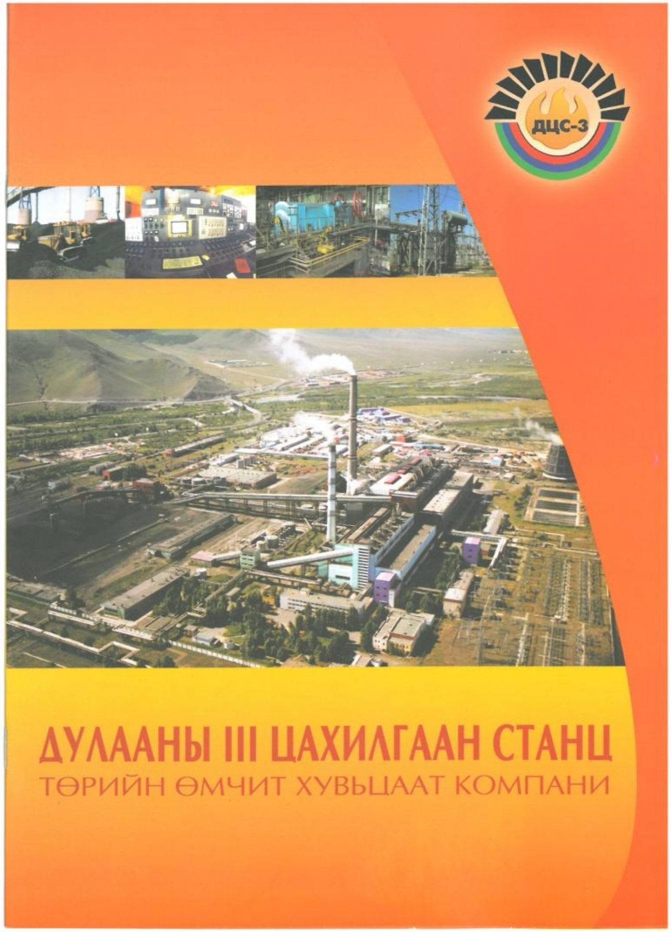
Implementation Structure of this Feasibility Study



Main Target Sites



Thermal Power Plant #4
（540MW, 1983～)



Thermal Power Plant #3
（148MW, 1968～)

Sub Target Sites

Darkhan CHP
（48MW, 1965～)

Erdenet CHP
（29MW, 1987～)

Thermal Power Plant #2
（24MW, 1961～)

"Energy Efficiency Improvement Measures" at CHP4 (part1)

Category	Measures	Effects
Boiler	Setup of "Soot Blower"	Improvement of power generation effect: 0.532 (%) Improvement of heat generation effect: 0.527 (%) CO_2 Emission Reduction : 8,320 (ton/year)
Turbine	Packaged Replacement to the "high-efficiency turbine" (including Electric Governor and Generator)	Improvement of turbine effect: 4.06 (%) CO_2 Emission Reduction: 106,144 (ton/year)
electric equipment	Update of "Top Runner of Electric Transformer"	Power reduction: 15,334 (MWh/year) CO_2 Emission Reduction : 9,937 (ton/year)
	Introduction of "LED Illumination"	Power reduction: 5,581 (MWh/year) CO_2 Emission Reduction : 3,615 (ton/year)

"Energy Efficiency Improvement Measures" at CHP4 (part2)

Category	Measures	Effects
auxiliary machine / pipework	Control of "Rotation Frequencies of Feed Water Pomp"	Power reduction: 36,807 (MWh/year) CO_2 Emission Reduction: 23,870 (ton/year)
	Coating or replacement of surface resin at the "Cooling Water Pump"	Power reduction: 2,237.5 (MWh/year) CO_2 Emission Reduction: 1,448 (ton/year)
	Coating or replacement of surface resin at the "Condensate Pump"	Power reduction: 223.2 (MWh/year) CO_2 Emission Reduction: 150 (ton/year)
	Enhancement of "Piping Insulation"	Power reduction: 6,216 (MWh/year) CO_2 Emission Reduction: 2,027 (ton/year)

"Energy Efficiency Improvement Measures" at CHP3

Category	Measures	Effects
Boiler	Improvement of combustion (low O_2 operation)	Improvement of power generation effect: 2.22 (%) Improvement of heat generation effect: 2.27 (%) CO_2 Emission Reduction : 26,360 (ton/year)
electric equipment	Update of "Top Runner of Electric Transformer"	Power reduction: 2,544.4 (MWh/year) CO_2 Emission Reduction : 1,837 (ton/year)
	Introduction of "LED Illumination"	Power reduction: 4,003 (MWh/year) CO_2 Emission Reduction : 2,893 (ton/year)
auxiliary machine / pipework	Control of "Rotation Frequencies of Feed Water Pomp"	Power reduction: 22,832 (MWh/year) CO_2 Emission Reduction: 16,500 (ton/year)
	Coating or replacement of surface resin at the "Condensate Pump"	Power reduction: 272.7 (MWh/year) CO_2 Emission Reduction: 197 (ton/year)
	Enhancement of "Piping Insulation"	Power reduction: 2,867 (MWh/year) CO_2 Emission Reduction: 935 (ton/year)

Expert Judgment
(Our Proposal Scheme)

- The bilateral mechanism should be developed under the country specific condition or under the industry specific situation as much as possible at the time of present. Therefore, we will propose to use the scheme of the expert judgment as following.
- (1) The expert judges the validity of the Reference Scenario.
- (2) The expert judges the validity of the calculation method of the amounts of GHG emission reductions.
- (3) The expert judges the validity of monitoring methodology (monitoring items, monitoring points and monitoring frequency).

Situation of Expert Judgment

- Expert: Mr. D.Battsend (he had been a chief engineer at the CHP#4 for a long time.)
- Our team staffs discussed the contents of expert judgment with him in December 2011.
- Now he is writing the report about expert judgment.
- The results of expert judgment will be reflected in our final report.

What is the “Reference Scenario”?

- Does this project bring the additional GHG emission reduction?
- The reference scenario is judged to be valid from the viewpoint of "What would happen otherwise?".
- Business-as-usual (the practice of continuing the status quo) is one scenario which should be examined.

Check items for identification of the reference scenario

- Lifetime of equipment, Equipment planning
- Criteria of decision-making of host company
- The various barriers which is the common sense of the sector of the host country (feasible finance, comparing the priority between production upgrade and reference scenario, access to the technology , human resources, common practice, etc)
- Profitability, etc

Reference Scenario of technology

- The reference scenario of "introduction of technology" is the following three possibilities;
- (A) The new technology will not be introduced in particular.
- (B) The different (low level) new technology will be introduced.
- (C) The new technology which is introduced in "Project" will be introduced.

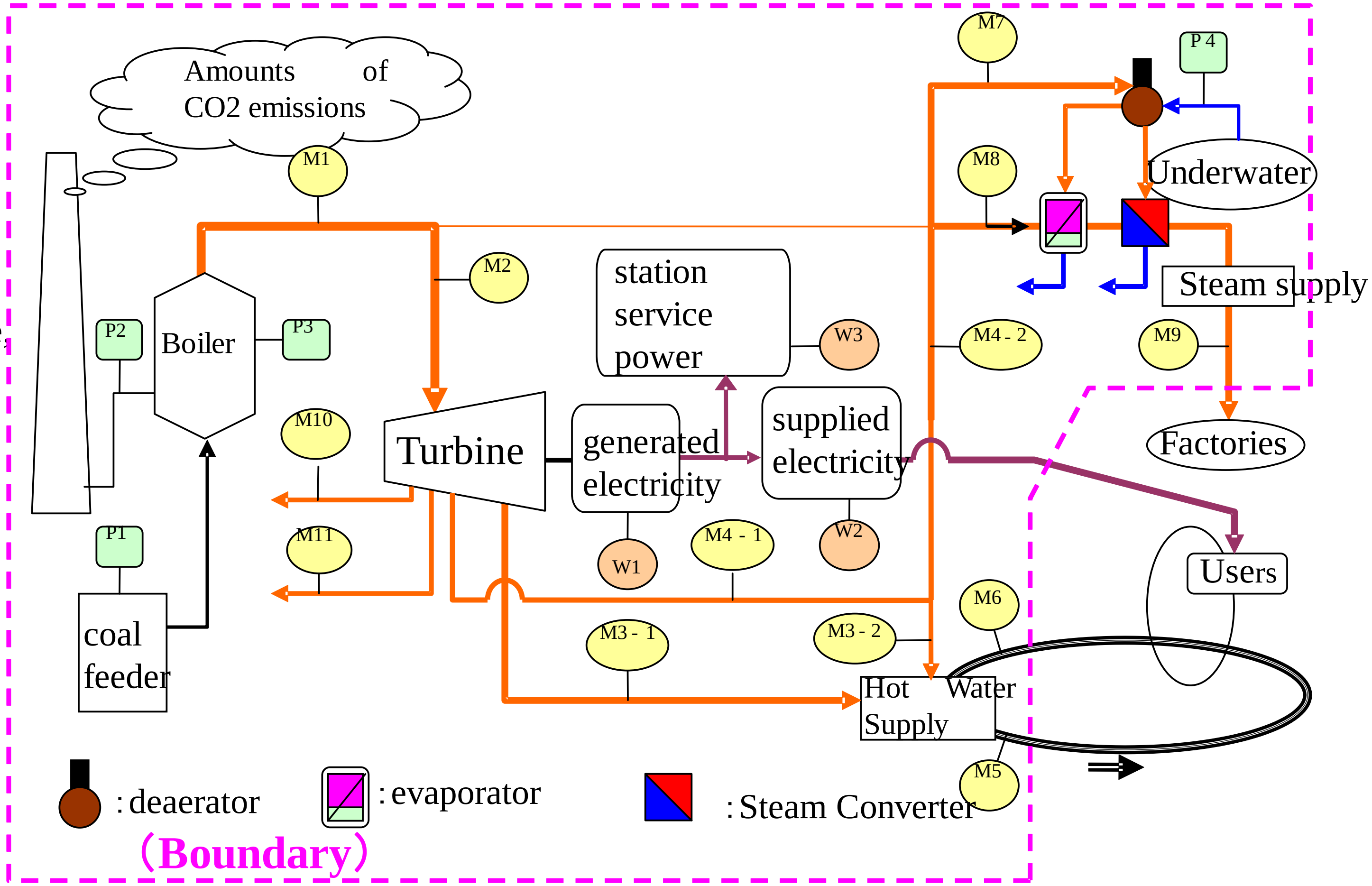
Reference Scenario of operation

- The reference scenario and project are in common with "the operation method of power plants" and there are two possibilities below.
- (1) Continuation of current practice (current operation) (before the operation start of CHP#5)
- (2) Introduction of new operation methods (after the operation start of CHP#5)
- This "(2)" new operation method can be comprehended by monitoring in the CHP#4 and CHP#3 after the operation start of CHP#5.

Project Boundary

M : Continuous Monitoring Point (Temperature, Gauge pressure, flow rate)

W : Continuous Monitoring Points (electric energy)



P :Regular Monitoring or Timely Lab Analysis Items, Some Continuous Monitoring Items (Temperature of Exhaust Gas, Temperature and Pressure of Steam Drum)

GHG Emission Reduction Calculation Methods

- $ER_y = RE_y - PE_y$

  $= ER(E)_y + ER(H)_y$

ER_y	Emissions reductions in a year y	tCO_2
$ER(E)_y$	Emissions reductions due to improvement of power generation efficiency in a year y	tCO_2
$ER(H)_y$	Emissions reductions due to improvement of heat efficiency in a year y	tCO_2

Specific Coal Consumption (in coal equivalent) (2008~2010)

Year	Specific coal consumption (coal weight for 7,000kcal/kg equivalent) per electricity supplied to the grid $SFC(E)_{BP,z,i}$		Specific coal consumption (coal weight for 7,000kcal/kg equivalent) per distributed net heat quantity $SFC(H)_{BP,z,i}$	
	$*10^{-3}$ ton-coal/MWh		$*10^{-3}$ ton-coal/Gcal	
	Variation for Monthly value	Annual value	Variation for Monthly value	Annual value
2008	263.3 – 461.7	357.9	181.2 – 190.9	183.3
2009	276.0 – 457.7	357.6	181.1 – 188.4	182.6
2010	283.5 – 475.5	382.5	181.2 – 189.2	183.5

Large Variation

Small Variation

Coal consumption by electricity supply to the grid in the absence of the project (in the reference scenario) [t-coal/month]

Coal consumption after the project) [t-coal/month]

CO_2 emission factor of coal for 7,000kcal/kg equivalent [tCO_2/t-coal]

$$ER(E)_y = \left(\sum_{i=1}^{12}[FC(E)_{RE,y,i}] - \sum_{i=1}^{12} FC(E)_{PJ,y,i}\right) * EF_{CO2,PJ,y}$$

$$= \sum_{i=1}^{12}[EGN_{PJ,y,i} * (SFC(E)_{RE,y,i} - SFC(E)_{PJ,y,i})] * EF_{CO2,PJ,y}$$

Total amount of electricity supplied to the grid after the project [MWh/month]

Specific coal consumption per electricity supplied to the grid in the absence of the project activity (reference scenario) [t-coal/MWh]

Specific coal consumption per electricity supplied to the grid after the project [t-coal/MWh]

$$SFC(E)_{RE,y,i} = FC(E)_{PJ,y,i} / EGN_{RE,y,i}$$

$$EGN_{RE,i}/QTE_{PJ,y,i} = a*(QTHD_{PJ,y,i}/QTE_{PJ,y,i})*M + b*(QTHF_{PJ,y,i}/QTE_{PJ,y,i})*M + c*TSCI_{PJ,y,i} + d$$

a, b, c, d ⇧ According to Data analysis during previous 3 years before the project implementation

$$EGN_{BP,z,i}/QTE_{BP,z,i} = a*(QTHD_{BP,z,i}/QTE_{BP,z,i,i}) + b*(QTHF_{BP,z,i,i}/QTE_{PJ,y,i}) + c*TSCI_{BP,z,i} + d$$

Coal consumption by electricity supply to the grid in the absence of the project (in the reference scenario) [t-coal/yr]

Coal consumption after the project [t-coal/yr]

CO_2 emission factor of coal for 7,000kcal/kg equivalent

$$ER(H)_y = ([FC(H)_{RE,y}] - FC(H)_{PJ,y}) * EF_{CO2,PJ,y}$$

$$= [QH_{PJ,y} * (SFC(H)_{RE,y} - SFC(H)_{PJ,y})] * EF_{CO2,PJ,y}$$

The total amount of distributed net heat quantity after the project [Gcal/yr]

Specific coal consumption per distributed net heat quantity in the absence of the project activity (reference scenario) [t-coal/Gcal]

Specific coal consumption per distributed net heat quantity after the project [ton-coal/Gcal]

$= SFC(H)_{BP}$
Average value of Specific coal consumption per distributed net heat quantity during previous 3 years before the project implementation

Monitoring Methods Monitoring Plan (part 1)

Monitoring Items	Notes
Total amount of electricity supplied to the grid by the power plant (Net)	Measuring period : Continuously Recording frequency : Daily
Total amount of electricity generated in the power plant (Gross)	Measuring period : Continuously Recording frequency : Daily
The total amount of net heat quantity supplied to district heat distribution system and factories around the plant	Measuring period : Continuously Recording frequency : Daily
Total fuel consumption due to electricity supply and heat distribution	Measuring period : Continuously Recording frequency : Daily
The total amount of net heat quantity used for power generation in turbines	Measuring period : Continuously Recording frequency : Daily

Monitoring Methods Monitoring Plan (part 2)

Monitoring Items	Notes
The total amount of net heat quantity taken out for district heat distribution system	Measuring period : Continuously Recording frequency : Daily
The total amount of net heat quantity taken out for factories around the plant	Measuring period : Continuously Recording frequency : Daily
Inlet temperature of steam condensates	Measuring period : Continuously Recording frequency : Daily
Other steam flow in other points	Measuring period : Continuously Recording frequency : Daily
Temperature in other points (Steam temperature, Water temperature and Gas temperature)	Measuring period : Continuously Recording frequency : Daily

Monitoring Methods Monitoring Plan (part 3)

Monitoring Items	Notes
Gauge pressure other points (Steam temperature, Water temperature and Gas temperature)	Measuring period : Continuously Recording frequency : Daily
Fuel consumption due to electricity supply to the grid	To be aggregated monthly
Fuel consumption due to heat distribution	To be aggregated monthly
Specific coal consumption per distributed net heat quantity	To be aggregated monthly
Specific coal consumption per electricity supplied to the grid in year y	To be aggregated monthly
Specific coal consumption per electricity supplied to the grid in the absence of the project activity (reference scenario)	To be aggregated monthly

MRV Methods (Application Condition)

- Project activities are efficiency improvements in the existing thermal power plant of co-generation type where the extraction turbine is introduced.
- The measurement data of main parameters and processing data of country's government approved processing data can be obtained for three years before project implementation and during a project implementation period.
- In the reference scenario, it is thought that the annual average power generation efficiency and thermal efficiency are maintenance of the status quo.

Key Points of Monitoring and Reporting

	Example of monitoring contents
Direct Monitoring Contents	Total amount of electricity supplied to the grid by the power plant (Net), Total amount of electricity generated in the power plant (Gross), The total amount of net heat quantity supplied to district heat distribution system and factories, etc.
Indirect Monitoring Contents	The total amount of net heat quantity used for power generation in turbines, The total amount of net heat quantity taken out for district heat distribution system, The total amount of net heat quantity taken out for factories around the plant
134 equations	Fuel consumption due to electricity supply to the grid, Fuel consumption due to heat distribution

Note: 134 equations is the calculation process by using "Manual for calculation of technical and economical parameters of CHP in Mongolia".

Key Points of Verification (part1)

- **<u>Items to be implemented by the related persons with the project and the monitoring</u>**
- - Clearly and in details described the related persons
- - Organization diagram of the project team and their roles will be made
- - Monitoring equipment calibration list
- - All documents and evidence of calibration will be kept.
- - Daily outline check of the monitoring situations for all items for the project, etc.

Key Points of Verification (part2)

- **<u>Operational Conditions of Plant (Boilers, Turbines, and Condensers etc.)</u>**
- - Daily report will be kept.
- - Parameters which may reflect the performance of efficiency improvement will be carefully monitored
- **<u>Implementation of Internal Audit</u>**
- - Internal audit team for the project will be established except the members of the monitoring of the project.
- - The internal audit team will make audit on operational condition of the plants, implementation situations of the monitoring of the project and the monitoring results and the compiled results.

Assessment of Co-benefit (part1)

- 1) The amounts of air pollutant emission reduction by measures are estimated.
- 2) The air quality concentrations by using the air pollutant emissions with and without measure are calculated by the diffusion simulation model.
- 3) The weighted average of exposure population is calculated by using the population distribution and concentration distribution (result of 2).
- 4) The improvement of health effect is evaluated by reductions of "exposure population weighted average concentration (result of 3)" and application of the Dose-Response equation.
- 5) The improvement of health effect is converted into the monetary value by using the WTP (Willingness To Pay) methods.

Assessment of Co-benefit (part2)

- The Calculation Conditions (Main Data Source; "Capacity Development Project for Air Pollution Control in Ulaanbaatar City Mongolia" (JICA)) are as follows;
- The meteorological conditions are the data (one hour values) of 2010.
- Reference scenario is assumed to be the emission inventories of thermal power plants of 2010.
- Project: The coal consumption reductions are assumed to be 1%.
- Other parameters (exposure – response coefficient, incidence rate WTP, COI (Cost of illness)) are the data from "Air Quality Analysis of Ulaanbaatar: Improving Air Quality to Reduce Health Impacts", "World Bank, 2009, Air Pollution in Ulaanbaatar Initial Assessment of Current Situation and Effects of Abatement Measures", etc.

Assessment of Co-benefit (part3)

- The parameters (Exposure- response coefficient, incidence rate, WTP (Willingness to Pay, COI (Cost of Illness)) are the data from World Bank Report.

Health end –point	Exposure- response coefficient (PM10 metric)	Baseline incidence rate	WTP COI (USD per case)
Premature death (World Bank method)	0.073	0.0067	221,000 (WTP)
Chronic bronchitis	0.48	0.0148	70,720 (WTP)
Respiratory Hospital admissions	0.12	0.0685	1,055 (COI)
Cardiovascular diseases Hospital admissions	0.07	0.0196	1,703 (COI)

Source: World Bank, 2011, Air Quality Analysis of Ulaanbaatar: Improving Air Quality to Reduce Health Impacts, etc

Assessment of Co-benefit (part4)

The calculation results of health benefits, etc by measures (unit: million USD)

	Premature death	Chronic bronchitis	Respiratory Hospital admissions	CVD Hospital admissions	Total
Reference scenario – project	0.121	0.506	0.008	0.002	**0.638**

Assessment of Co-benefit (CHP3 & CHP4)

Initial Investment	Operational Cost	CO_2 Reduction	PM10 Reduction
		205,374 (ton-CO_2)	5.27 %
		10 (USD/ton-CO_2)	0.679 (Mil $/%)
225 Million USD	4.5 Million USD	2.05 Million USD	3.58 MillionUSD

Outline of Financial Plan

- Summation of CHP#3 and CHP#4
- 1dollar = 80 Yen,
- Bilateral Offset Credits = 10dollar/tCO_2

Items	Amount of money
Initial Investment	17,966 million yen
Operation Cost	360 million yen /year
Annual Operation Cost Reduction	295.2 million yen /year
Income of Bilateral Offset Credits	152.0 million yen /year
Benefit of social economy	286.4 million yen /year

ありがとうございます
Баярлалаа.
Танд талархал илэрхийлье.