MOEJ/GEC JCM Feasibility Study (FS) 2014
Summary of the Final Report

"Efficiency Improvement of Combined Heat and Power by Thermal Insulation"

(Implementing Entity: Kanden Plant Corporation)

1. Overview of the Proposed JCM Project

	Country Name	Organization name involved in the study	Contents
Study partners	Japan	Suuri-Keikaku Co., Ltd.	・Support for formulating methodology and surveys of environmental impact assessment and environmental integrity required for PDD ・Evaluation of contribution for sustainable development of the host country
	Japan	Japan Quality Assurance Organization	・Support for setting of eligibility criteria based on validation ・Support for establishing effective monitoring plan ・Support for establishing MRV system based on verification process
	Japan	Nichias Corporation	・Support for extracting problems and decision of solutions to facility investment project (overwrapping insulation method) in year 2015 ・Data collection for formulating methodology by means of implementation of sample insulation installation ・Support for make of installation work planning and management planning ・Support for capacity building

<table>
<tr><td></td><td colspan="4"><table>
<tr><td>Mongolia</td><td>・Thermal power plant 3 (Hereinafter referred as CHP3) ＆Thermal power plant 4 (Hereinafter referred as CHP4)
・Ministry of Energy ＆Ministry of Environment Green Development Tourism</td><td>・Support of field survey</td></tr>
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<tr><td>Project site</td><td colspan="4">Mongolia/Ulaanbaatar</td></tr>
<tr><td>Category of project</td><td colspan="4">Energy Efficiency Improvement</td></tr>
<tr><td>Description of project</td><td colspan="4">「Overwrapping insulation method (ECO-AIM)」of insulation installation is patented by NICHIAS Corporation and contributes not only to emission reduction of greenhouse gas but also to the effect against atmospheric pollution and the waste reduction because of non-requirement for removal of existing insulation.
The project is to install the project insulation material by「Overwrapping insulation method (ECO-AIM)」onto existing asbestos insulation of main steam pipes from outlets of existing boilers to inlets of existing turbine in both of CHP3 & CHP4. It realizes emission reduction of radiation heat quantity from surfaces of heat and generating facilities and carbon dioxide and also prevents scattering asbestos from the existing insulation.</td></tr>
<tr><td rowspan="2">Expected project implementer</td><td>Japan</td><td colspan="3">Kanden Plant Corporation</td></tr>
<tr><td>Host country</td><td colspan="3">CHP3＆CHP4</td></tr>
<tr><td>Initial investment</td><td>(￥MILLION)<table><tr><td>CHP3</td><td>CHP4</td></tr><tr><td>141</td><td>187</td></tr></table></td><td>Date of groundbreaking</td><td colspan="2">Late July in 2015</td></tr>
<tr><td>Annual maintenance cost</td><td>(￥MILLION)<table><tr><td>CHP3</td><td>CHP4</td></tr><tr><td>1</td><td>1</td></tr></table></td><td>Construction period</td><td colspan="2">16 months</td></tr>
<tr><td>Willingness to investment</td><td colspan="2">Yes</td><td>Date of project commencement</td><td>November 1, 2016</td></tr>
<tr><td>Financial plan of project</td><td colspan="4">・ CHP3 held technical committee on 17 September 2014 and approved implementation of project based on the result of technical deliberations. And CHP3 intends to use the state budget (Ministry of Energy) for the project because of severe budgetary condition of CHP3.
The study team visited Ministry of Energy and requested urgent consideration to</td></tr>
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<tr><td></td><td>finance for implementation of CHP3 project after confirmation of no technical problem in conference in the science and technical committee held by Ministry of Energy
・CHP4 confirmed that no technical problem exists for the project in attended capacity building by Kanden-Plant in September 2014. CHP4 approved implementation of the project by the result of conference on technical issues as no problem in technical committee held on 23 September 2014. The study team confirmed that CHP4 intends to finance for implementation of the project using CHP4's own budget.</td></tr>
<tr><td>GHG emission reductions</td><td>(tCO2/y)
<table>
<tr><th>Project activity</th><th>Breakdown of savings</th><th>CHP3</th><th>CHP4</th><th>Total</th></tr>
<tr><td>Overwrapping Insulation Installation</td><td>Reduction of the amount of heat dissipation</td><td>761</td><td>962</td><td>1,723</td></tr>
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2. Study Contents

(1) Project development and implementation

1) Project planning

a. Specification of existing insulation materials

Specifications of existing insulation materials of main steam pipes in CHP3 & CHP4 surveied by hearings are as shown in the table below.

(unit mm)

Object	CHP3: Structure of insulation materials	Insulation thickness	CHP4: Structure of insulation materials	Insulation thickness
Main steam pipes	Fire-resiting cement + Calcium silicate + Asbestos cement	150	Fire-resiting cement + Calcium silicate + Asbestos cement	200

※1) Structures and thicknesses of insulation materials are not constant because just the available materials at the times of past maintenance works were used.

b. Applied areas of project insulation installations:

(unit: m2)

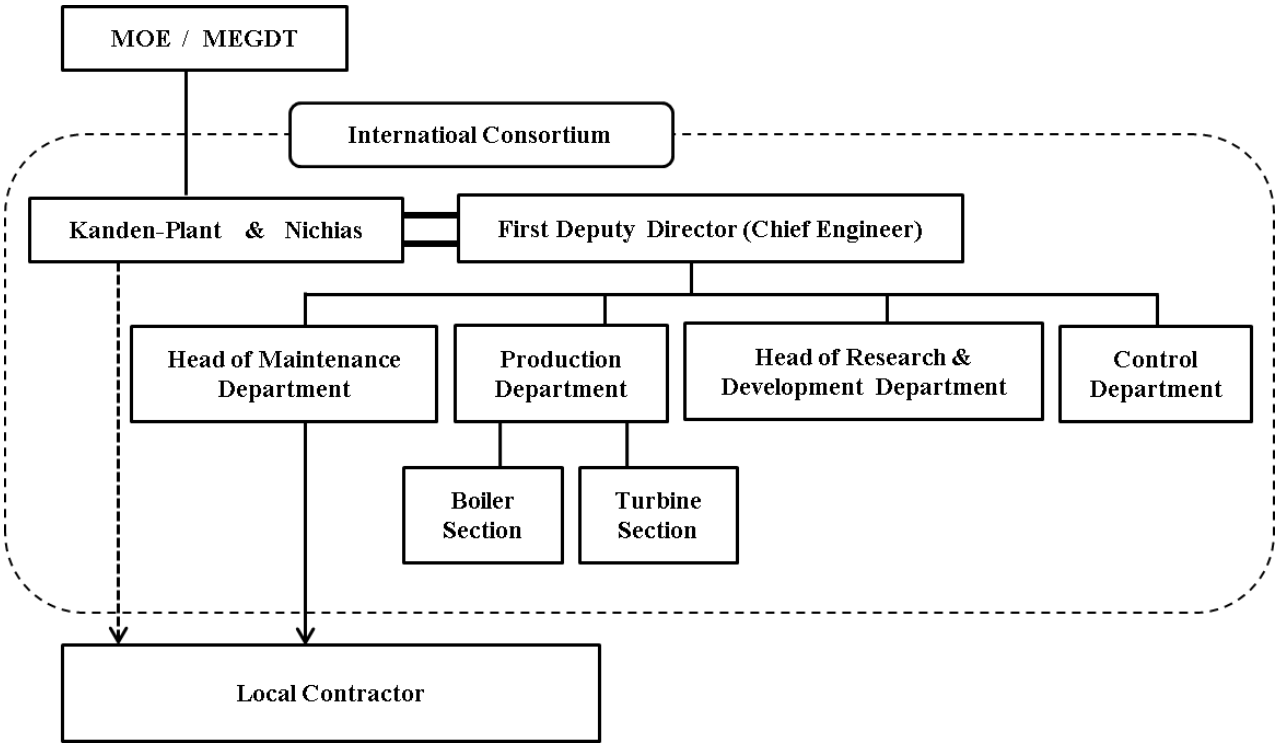
CHP3	CHP4
2,211	3,300

c. Thickness of project insulation materials:

It was agreed through the discussion on the thickness of project insulation material with CHP3 & CHP4 that 20mm of thickness of "overwrapping insulation method" is applied to all the steam pipes from the boiler outlets to the turbine inlets except the common header pipe to the new unit of turbine

installed in 2014 after comparison among the cases of plan A (10mm), plan B (20mm) and plan C (40mm) (additionally 30mm in CHP4) of thicknesses. This was revised the proposal at the time of FS in 2014 that the "overwrapping insulation method" is applied to the representative unit of boiler and main steam pipes pertaining to the boiler.

d. **Project implementation structure and roles of entities for the CHP4 project are shown in the table below.**



<Roles of entities>

Name of Divisions	Roles
First Deputy Director (Chief Engineer)	General manager of the main entity of the project who is totally responsible in the project.
Head of Research & Development Department	Manager of representative department of CHP4 who makes and submits required documents for the project in Mongolia.
Head of Production Department	Responsible person for collecting monitoring data in CHP4
Boiler Section	Records running time of boilers and result of daily check of installed insulation.
Turbine Section	Records running time of turbines and result of daily check of installed insulation.
Head of Maintenance Department	Responsible person who orders and controls site insulation installation works and temporary works.
Control Department	Executes safety control in site works.
Kanden Plant Corporation	A joint entity of the project who executes schedule and quality controls in site works and responsible to processes for

	JCM (submits required documents to the Japanese governors after completion of the project).
NICHIAS Corporation	A joint entity of the project who executes procurement and transportation of insulation materials, supervising of site installation work and support of monitoring trial.
Local Contractor	Executes site insulation installation and temporary works.

e. Project schedule

Major items of project schedules are shown in the table below.

Item	Content	Period	Duration
Material Procurement	From procurement of project material and sub-materials to delivery to the sites	From 1 April 2016 to 15 June 2016	2.5 months
Insulation material installation	From temporary works including scaffolding assembly, insulation material installation, to finish of temporary works including scaffolding dismantlement	From 1 June 2016 to 30 September 2016	4 months
Monitoring trial	Installation of monitoring material and training of implementers of monitoring	From 15 September 2016 to 31 October 2016	1.5 months

2) Permits and License for the project development and implementation

Required permits and licenses for the project in each power plant of CHP3 & CHP4 have been obtained.

It requires environmental impact assessment that is to implement detailed environmental impact assessment after implementation of general environmental impact assessment complied with article 7 of the law of environmental impact assessment in Mongolia.

It is agreed with each of CHP3 & CHP4 by conference that required procedure for the environmental impact assessment is executed by the CHP's section in charge of environmental issues after the JCM project is officially adopted.

It is confirmed that required variety of documents for the environmental impact assessment are mostly prepared.

3) Advantage of Japanese technology

There is no equivalent competing technology executed in the project,「Overwrapping insulation method (ECO-AIM)」. It has been a simple idea to improve thermal insulating performance by means of overwrapping a new insulation material onto an existing insulation material. However,「Overwrapping insulation method (ECO-AIM)」realizes extreme improvement in thermal insulating performance by using thin sheet type of insulation material having excellent thermal insulating performance and minimizing increase of insulation thickness regardless of easy installation of it. Therefore it is patented in Japan and applied (disclosed) an international patent as there is no competing method.

※It is released that there is no problem in thermal performances for twenty (20) years as the life of the project insulation material by the documentation of the supplier.

4) MRV structure

It is not necessary to add new section in CHP3 & CHP4 for implementation of MRV in emission reduction project. It is based on the present system. Therefore additional loads in CHPs are not required and constructing sustainable MRV systems are expected as available.

It is planned that each CHP implements monitoring activities within regular operation, collects monitoring data and makes monitoring report. Kanden-Plant confirms the monitoring report and submit it to JC after taking verification by TPE.

5) Environmental integrity and Sustainable development in host country

It is confirmed that the project activity is expected not to be a target object of detailed environmental impact assessment.

Life prolongation of existing facilities is realized by means of execution of「Overwrapping insulation method (ECO-AIM)」to coal thermal power plants in Mongolia. The coal thermal power plants continuously use the facilities maintaining necessary performances and it results to save wasting social expenses. The fact leads sustainable development in Mongolia.

CHP3 & CHP4 use the thermal insulation material of the combination of asbestos cement and calcium silicate and it gives serious problems in thermal performance and environmental view. One is of the performance, high surface temperature of facilities and large radiation heat quantity from the surface. Another is state of disposal and scattering of asbestos.

It is understood by the result of hearing in the local surveys that local parties highly expect such insulation method by means of new technology.「Overwrapping insulation method (ECO-AIM)」is the solution for the problems in performance and environment maintaining the existing insulation and substantial contribution for sustainable development is expected by the use of it.

6) Toward project realization (planned schedule and possible obstacles to be overcome)

General implementation schedule (planned) for the project as follows.

a. Adoption of facility investment project by Ministry of Environment in Japan: July 2015
b. Application and approval of methodology (proposed): August 2015
c. Environmental impact assessment: August 2015
d. Submittal of PDD (proposed) to JC/ NREC: January 2016
e. Start of validation: January 2016
f. Application of registration as JCM project: April 2016
g. Start of installation works (procurement of insulation materials) to end of installation works: April 2016 to September 2016
h. Opening of credit account: October 2016
i. Monitoring: November 2016 to 31 March 2021

Concerned subjects for developing JCM and solutions are shown in the table below.

No.	Concerned subject for developing JCM	Solution
1.	Simplification of monitoring activity	One of the follows of monitoring is to be selected: ① to limit the monitoring onto the acting quantity of sending power to the grid, or, ② to automate the monitoring by monitoring equipment. In case of ①, it is required to make methodology as project-wise specified methodology and fix the monitoring items except the activity as default values and reference value. To the purpose, default value sustaining validity during monitoring period and reference value is to be defined. Therefore, validated analysis using detailed past data is required. In the case of ②, installation of monitoring equipment available to automate is required that results to be costly. Every case of ① and ②, cost is expected to be expensive and feasibility of JCM project is to be reduced in case the monitoring cost (including MRV) is covered by PP.
2.	MRV activities (verification/ validation): Cost for verification and validation are unclear. Validation is costly in case implemented by Japanese TPE. Verification is implemented in every monitoring period and affecting to budget. It is to be concerned as much costly in case implemented by the TPE out of the host country.	It is required to develop TPE in the host country. It is impossible to develop TPE as educating the persons operating by themselves in the level of several times per year of seminar. It is possible to develop TPE utilizing experienced persons and organizations on validation and verification and referencing actual projects as models. Such supporting activities for developing TPE in the host country by Japanese government are necessary. Verification by Japanese TPE is considered as not sustainable in the view of its cost and future of credit is unclear.
3.	Scheme for facility investment project is not entirely conformed to the situation in the host country because it is based on the facility investment projects in Japan.	Project is to be delayed one year if financial measures by both of Japan and the host country are required. The periods of financial year are different as every April to March in Japan and every January to December in most of the host country. Therefore even the budget for a year is assured in Japan, it is not meet to the timing of financing in the host country and sent to the next financial year in some cases, that gives a year of delay.

		And facility investment project is based on the project in Japan. It results to increase table works because estimation is unfit to the JCM project and influences financial planning because it is uncertain what rate of estimated amount becomes the objective of the investment. Eventually, JCM project is recommendable only for the project that investment is not necessary at this time.
4.	Concept of PDD and methodology is unclear.	”JCM Guidelines for Developing PDD and Monitoring Report” of ”Example of a Monitoring Report Sheet” is the same description as ”JCM Guidelines for Developing Proposed Methodology” of ”Proposed methodology spreadsheet”. The versatility of applied methodology in CDM is assured as methodology is applicable to the project when applicability of methodology is satisfied. Therefore, required eligibility criteria are defined when PDD is formulated as methodology is applied to the specified project in CDM. It is that methodology defines eligibility criteria and description of methodology is not the same as PDD because PDD describes contents to the project according to eligibility criteria of methodology in CDM. When the description of methodology is the same as PDD as indicated in the JCM guideline, a methodology is to be applied to a specified project. If so, it is enough only to approve a PDD to the specified project and it is not necessary previously to formulate a methodology and approve the methodology by JC. However, it is difficult previously to define what type of project is the project with additionality to the host country in such the manner. The additionality is to be judged every time of judgment of PDD by JC at the result and trouble to JC is possibly increased. Therefore, it is necessary to define the concept of PDD and methodology as to require versatility or specified type to the individual project to the methodology.
5.	Establishment of panel of methodology	High level of specialties are necessary to validate/ verify methodology and PDD regardless to require versatility or specified type to the individual project. Especially to such the type of this project, it is required not only knowledge of

		operation in power plant but also specialists for heat, boiler, turbine and condenser. JC is organized by governmental persons from both the countries and it is necessary to secure persons who are able to provide enough materials for judgment. We propose to establish a panel of methodology that is assembled with various fields of specialists from Japan and the host country to the purpose
6.	Restrictions on implementation of validation/ verification, establishment of ISO14065 certification system and training of TPE candidates	Even the party that is certified by DOE or ISO1405 in foreign country such as Japan is not able to implement validation/ verification in Mongolia unless the party is authorized by Mongolian Agency for Standardization and Metrology (MASM, corresponding to METI of Japan & JAB). However, the certification system of ISO14065 is currently not established in Mongolia. Therefore, it was agreed due to negotiation between the members of JC (Joint Committee), Ministry of Environment and Green Development and Mongolian Agency for Standardization and Metrology that even foreign TPE is able to implement validation/ verification without authorization by Mongolian Agency for Standardization and Metrology during the early stage (transition period: 2 to 3 years) of JCM system till TPE in Mongolia is established. Accordingly, it is expected that establishment of approval system of ISO14065 and Mongolian parties assigned to TPE with certification of ISO 14065 during the 2 to 3 years of transition period. It is necessary for the purpose to establish ISO 1405 certification system by Mongolian Agency for Standardization and Metrology and certification of ISO14065 to local TPE candidates. From above, it is considered that capacity buildings to Mongolian Agency for Standardization and Metrology and the local TPE candidates are required in 2014. We propose that JC and Mongolian Agency for Standardization and Metrology are together to establish a panel of certification assembled with authorized specialists who are persons provide enough materials for JC's judgment for the purpose of ISO14065 certification based on JCM

		scheme and assignment of TPE by JC. And we consider that conditions for certification of ISO14065 by the member of IAF (International Accreditation Forum) are to be satisfied under this proposal.

(2) JCM methodology development

1) Eligibility criteria

As the following table, 5 items are listed. Intentions for setting are described in right columns.

Criterion 1	The project activity is to reduce heat quantity radiated from surfaces of existing main steam pipe system in coal-fired thermal power plant due to thermal insulation installation by application of high performing thermal insulation materials.	This criterion is a fundamental item what activity is applicable to the methodology.
Criterion 2	Installation works can be carried out without removing existing thermal insulation materials (e.g. asbestos).	This criterion is a fundamental item what facility is applicable to project activity described in Criterion 1.
Criterion 3	Non-asbestos Flexible Aerogel thermal insulation is to be employed in order to ensuring appropriate installation works which prevent scatter of asbestos. Furthermore, fluorocarbon foaming agent is not also to be contained in the material from a standpoint of environmental integrity.	This criterion is an item for ensuring environmental integrity.
Criterion 4	Thermal insulation materials employed for project has apparent thermal at the same level as or lower than (not exceeding plus 20% of) ones defined by ASTM C1728-12 and ones calculated by the following approximate expression extrapolated to high temperature range based on ones defined by ASTM C1728-12. Thermal conductivity of Flexible Aerogel thermal insulation defined by ASTM C1728-12	This criterion is an item for additionality which ensures emission reduction effect by employed technology ASTM C1728 is selected for Flexible Aerogel Insulation for criterion for judgment, in order to ensuring objective superiority. ASTM C1728 standardizes the specification.

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<tr><th>Mean Temperature [°C]</th><th>Apparent thermal conductivity [W/m･K]</th></tr>
<tr><td>23.9</td><td>0.021</td></tr>
<tr><td>37.8</td><td>0.022</td></tr>
<tr><td>93.3</td><td>0.023</td></tr>
<tr><td>149</td><td>0.025</td></tr>
<tr><td>204</td><td>0.029</td></tr>
<tr><td>260</td><td>0.032</td></tr>
<tr><td>316</td><td>0.036</td></tr>
<tr><td>371</td><td>0.043</td></tr>
</table>

Approximate expression extrapolated to high temperature range based thermal conductivity of Flexible Aerogel thermal insulation defined by ASTM C1728-12
$\lambda = 2.771E{-}10 \cdot \theta^3 - 3.098\ E{-}9 \cdot \theta^2 + 3.328\ E{-}5 \cdot \theta + 0.02034$
where;
λ : Thermal conductivity of Flexible Aerogel thermal insulation [W/m･K]
θ : Temperature [°C]
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<tr>
<td>Criterion 5</td>
<td>Thermal insulation materials employed for project covers operating high temperature range for the project as the manufacturer’s catalog value.</td>
<td>This criterion is an item for ensuring high performance of employed production. The manufacturer’s catalog value is selected for information for making an judgment because of various conditions at thermal power plants.</td>
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2) Calculation of GHG emissions (including reference and project emissions)

The reference emissions and the project emissions are calculated as follows;

Reference emissions [tCO_2/y]

=∑(Reference radiation heat quantity [W/m^2] × Reference radiation surface area [m^2] × Steam flow hours in main steam pipe line [h/y]) × $3600*10^{-9}$ / Boiler efficiency [–] × CO_2 emission factor of coal [tCO_2/GJ]

Reference radiation surface area [m^2]

= Surface area covered by existing thermal insulation material where will be installed by the project

thermal insulation material [m^2] × (1-Total area where project thermal insulation materials have stripped [m^2] / Surface area covered by the project thermal insulation material [m^2])

Project emissions [tCO_2/y]
=∑(Project radiation heat quantity [W/m^2] × Project radiation surface area [m^2] × Steam flow hours in main steam pipe line [h/y]) × $3600*10^{-9}$ / Boiler efficiency [–] × CO_2 emission factor of coal [tCO_2/GJ]

Project radiation surface area [m^2]
= Surface area covered by the project thermal insulation material [m^2] × (1-Total area where project thermal insulation materials have stripped [m^2] / Surface area covered by the project thermal insulation material [m^2])

Project radiation heat quantity [W/m^2]
= Reference radiation heat quantity [W/m^2] × {1 - (Initial thermal insulation efficiency by the project thermal insulation material [-] × (1 - Decreasing rate from initial thermal insulation efficiency of the project thermal insulation material [-])}

•Reference radiation heat quantity [W/m^2] •Initial thermal insulation efficiency by the project thermal insulation material [-]	Parameter to be fixed ex ante. These values are identified by this FS. (Please see "3) Data and parameters fixed ex ante".)
Boiler efficiency [-]	Default value. 1.0(Most conservative value) is applied to the parameter, although in conservative manner.
CO_2 emission factor of coal [GJ/tCO_2]	Default value. 0.101GJ/tCO_2 is applied to the parameter according to default value for lignite in "2006 IPCC Guidelines for National Greenhouse Gas Inventory".
Decreasing rate from initial thermal insulation efficiency of the project thermal insulation material [-]	Monitoring parameter. Based on actual measurement value for 2 thermal conductivities, this value is calculated in conservative manner as follows; (Please see regarding justification for the following equation) Decreasing rate from initial thermal insulation efficiency of the project thermal insulation material ={(Thermal conductivity of used project thermal insulation material)}/ (Thermal conductivity of new project thermal insulation material)

Total area where project thermal insulation materials have stripped [m^2]	Monitoring parameter. ·On the last day during each monitoring period, the person in charge does checking whether physical damaged points are founded or not at all installation areas of the project thermal insulation and takes some electronic pictures for evidences.) ·Physical damaged areas are counted in conservative manner.
•Surface area covered by the project thermal insulation material [m^2] •Surface area covered by existing thermal insulation material where will be installed by the project thermal insulation material [m^2]	Parameters to be fixed after 1st verification. The following parameters are not needed to monitor but cannot be parameters to be fixed ex ante, because these ones will be fixed after installation work of the project thermal insulation.
Steam flow hours in main steam pipe line [h/y]	Monitoring parameter. [In case of boiler-common steam header line] Hourly data for steam flow rate, steam temperature and steam pressure in the main steam pipe at the boiler outlet is manually recorded in the control room. In case that hourly values for these parameters are recorded, the operation of on-off bulb of steam during the hour is regarded as on-status. In case that hourly values for these parameters are not recorded, the operation of on-off bulb of steam during the hour is regarded as off-status. [In case of common steam header-turbine line] The following parameters are manually recorded in the control room. ·Hourly data for electricity generated the generator linked the turbine ·Hourly data for steam flow rate, steam temperature and steam pressure in the main steam pipe at the turbine inlet This parameter is counted by one of above-mentioned two items. In case that hourly value for this parameter is recorded, the turbine operation (steam is fed to the turbine) during the hour is regarded as on-status. In case that hourly value for this parameter is not recorded, the turbine operation (steam is fed to the turbine) during the hour is

	regarded as on-status. [In case of common steam header line] In conservative manner, this value is counted by average steam flow hours on all common header-turbine steam lines.

3) Data and parameters fixed *ex ante*

Identification method of reference radiation heat quantity and thermal insulation efficiency by the project thermal insulation material (which are parameters fixed ex ante)

In this FS, the following study was performed for the purpose of identification method of reference radiation heat quantity and thermal insulation efficiency by the project thermal insulation material (which are parameters fixed ex ante)

- Pyrogel XT (Project thermal insulation material for the proposal project) has actually installed for sample at 6 areas on main steam pipes at CHP3 (high pressure unit) and CHP4.
- At each area of 6 one, 4 positions (1 position for non-installation and 3 installation positions for thickness of 10mm, 20mm and 40mm) are set.
- At each area, radiation heat quantities with and without installation were identified by the following 2 methods;
  - Taking thermographic images by infrared thermography (including measuring surface temperature and ambient temperature by contact type thermo-meter) just before measurement of heat flow meter
  - Measuring radiation heat quantity by heat flow meter

Characteristics of infrared thermography and heat flow meter are as follows;

- Infrared thermography cannot directly measure radiation heat quantity from the surface of the measured object, but can provide a radiation heat distribution from a wide area (can indirectly convert to radiation heat quantity (heat flow) according to equations based on JIS 9501.).
- Heat flow meter can directly measure radiation heat quantity (heat flow) from the surface of the measured object for pinpoint (for only area attached by the sensor), but cannot measure widely.

The surface temperature distribution on the existing thermal insulation material at CHPs in Mongolia ranges in scope, because the content of asbestos in the existing thermal insulation material are considerably different with location and we can see many deterioration points on them.

Under these circumstances, infrared thermography is better for the measurement, however reference radiation heat quantity cannot be identified only by data identified based on infrared thermography, because infrared thermography cannot directly measure radiation heat quantity from the surface of the measured object.

So, values of radiation heat quantity identified by infrared thermography were compared with ones measured by heat flow meter. The correlation chart between both ones is as follows;

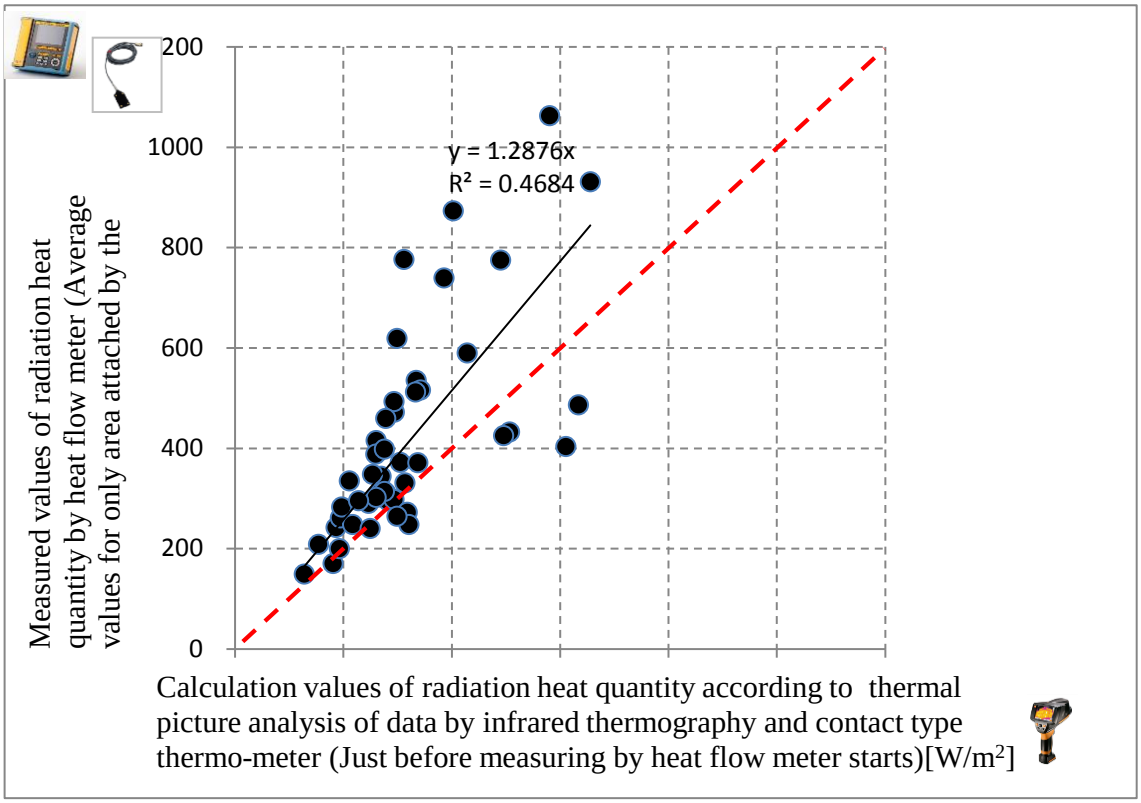

Figure Correlation chart between both values for radiation heat quantity identified by heat flow meter and infrared thermography

As the Figure illustrates, values measured by heat flow meter are wholly a little higher than ones calculated by infrared thermography. As for correlation between both ones, it follows that the contributing rate is 0.4684 (the correlation coefficient is 0.6844.). One could argue that this correlation is significant to a satisfactory extent although sample correlation coefficient is 0.368326 in case of in case sample size of 48 and significance level of 1%.

Furthermore, values measured by heat flow meter are wholly a little higher than ones calculated by infrared thermography. So, data of thermal diagnosis (in FS of FY2013) is applied to identify the representative value for reference radiation heat quantity (before thermal insulation installation) in conservative manner.

The thermal diagnosis test for CHP3 was performed on 15 and 16 October in 2013. And the one for CHP4 was performed on 21 and 23 in October 2013. The season is seemed to close to be the annually-averaged one. According to the result of these tests, there was no measuring point for ambient temperatures around main steam pipes over 45 °C.

So, for the purpose of identifying reference radiation heat quantity in conservative manner, 45°C is applied to the conservative value for ambient temperature around main steam pipe at CHP3 and CHP4.

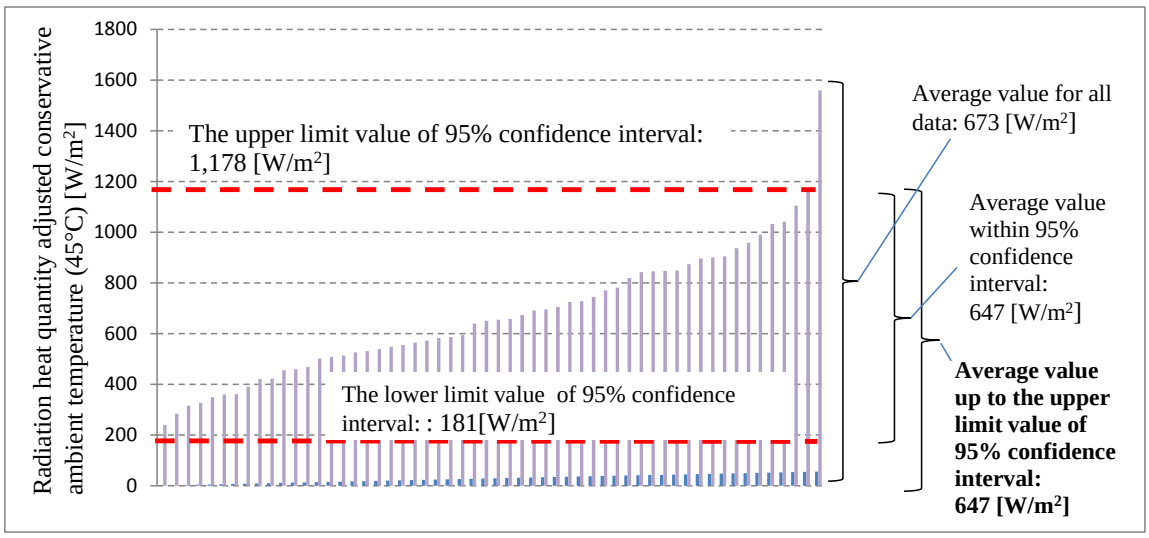

Figure Sorting figure for conservative radiation heat quantities (CHP3 high pressure unit)

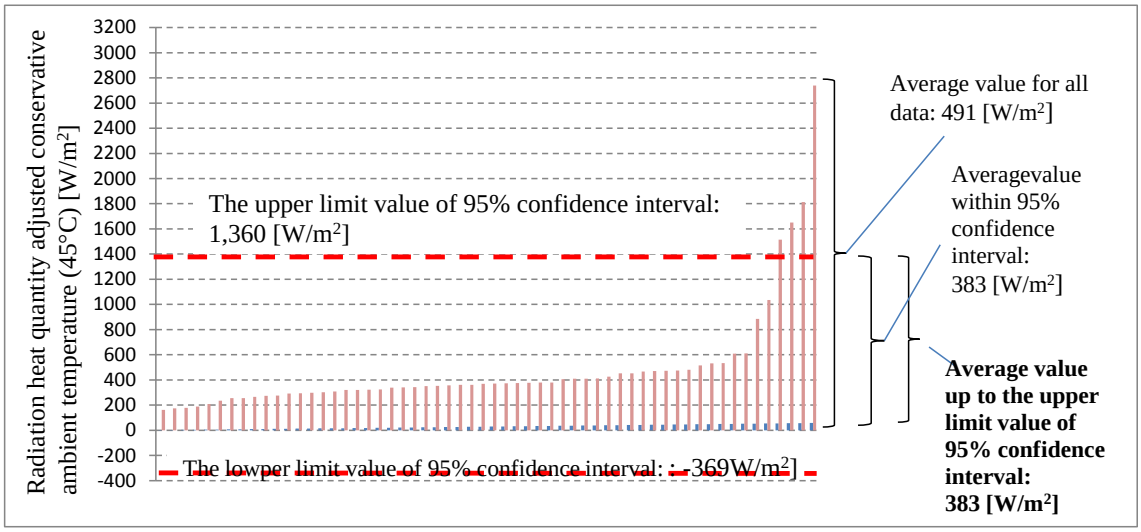

Figure Sorting figure for conservative radiation heat quantities (CHP4)

For each CHP3 and CHP4, the average value up to the upper limit value of 95% confidence interval is applied to the representative value for reference radiation heat quantity (which is a parameter fixed ex ante, in conservative manner) in conservative manner.

- Reference radiation heat quantity at CHP3 high pressure unit: 647 W/m^2
- Reference radiation heat quantity at CHP4: 383 W/m^2

Next, based on radiation heat quantities with and without installation identified by infrared thermography at 4 positions (1 position for non-installation and 3 installation positions for thickness of 10mm, 20mm and 40mm) are set., decreasing rates of radiation heat quantity (according to installation thickness of project thermal insulation material) was calculated as the following figure;.

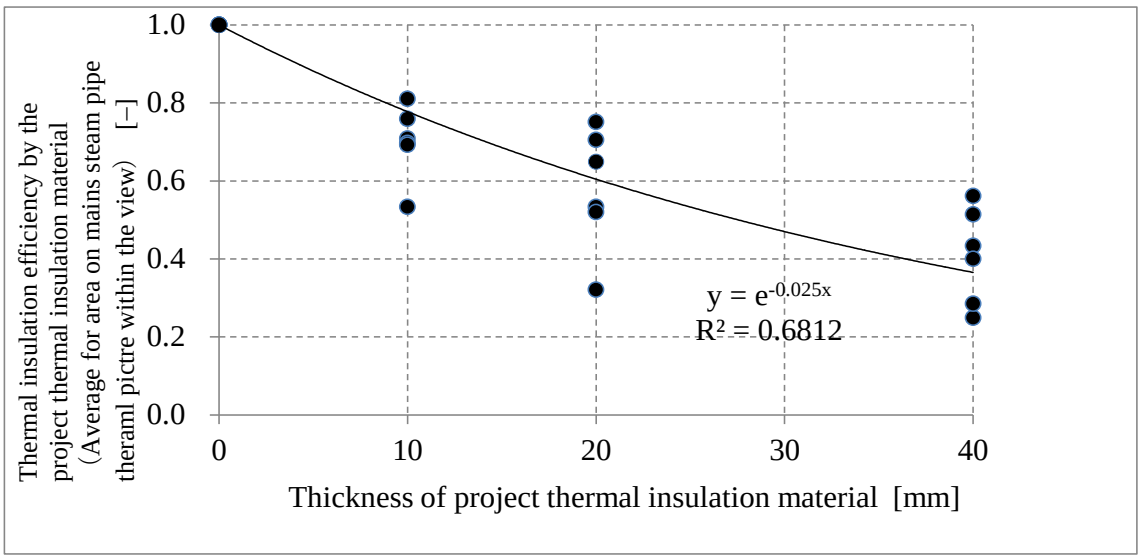

Figure Decreasing rate of radiation heat quantity according to installation thickness of project thermal insulation material

According to the exponential approximation formula, it follows that the contributing rate is 0.6812 (the correlation coefficient is 0.8524.). One could argue that this correlation is significant to a satisfactory extent although sample correlation coefficient is 0.575067 in case of in case sample size of 19 and significance level of 1%.

According to the exponential approximation formula, initial thermal insulation efficiency by the project thermal insulation material was identified as the follows;

- In case of installation thickness of 10mm: 0.22 [Non-dimension]
- In case of installation thickness of 20mm: 0.39 [Non-dimension]
- In case of installation thickness of 40mm: 0.63 [Non-dimension]