



## Monitoring report form (Version 03.2)

### Monitoring report

<b>Title of the project activity</b>	Switching of fuel from Low Sulphur Waxy Residue fuel oil to natural gas at Gangnam branch Korea District Heating Corporation Project
<b>Reference number of the project activity</b>	0835
<b>Version number of the monitoring report</b>	1.0
<b>Completion date of the monitoring report</b>	15/04/2014
<b>Registration date of the project activity</b>	02/04/2007
<b>Monitoring period number and duration of this monitoring period</b>	Monitoring period number : 4 <sup>th</sup> Monitoring period : 01/01/2013-31/12/2013
<b>Project participant(s)</b>	Korea District Heating Corporation
<b>Host Party(ies)</b>	Republic of Korea
<b>Sectoral scope(s) and applied methodology(ies)</b>	Sectoral scopes : 1. Energy industries 4. Manufacturing industries Methodology : ACM0009 Version 03
<b>Estimated amount of GHG emission reductions or net anthropogenic GHG removals by sinks for this monitoring period in the registered PDD</b>	63,988tCO <sub>2</sub> e
<b>Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved in this monitoring period</b>	37,123tCO <sub>2</sub> e
<b>Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved during the period up to 31 December 2012(if applicable)</b>	0 tCO <sub>2</sub> e
<b>Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved during the period from 1 January 2013 onwards (if applicable).</b>	37,123tCO <sub>2</sub> e

**SECTION A. Description of project activity****A.1. Purpose and general description of project activity**

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***Purpose of the project activity and the measures taken for GHG emission reductions***

This project activity is switching the fuel of the boilers for generating heat from Low Sulphur Waxy Residue fuel oil(LSWR) to natural gas(NG) at Korea District Heating Corporation(KDHC) Gangnam Branch, which operates and manages district heating system. The produced heat is supplied to the local district heating system. This project is developed, financed and implemented solely by KDHC

The project activity primarily aims to reduce greenhouse gas emissions by using NG which generates GHGs less than using LSWR in producing a unit of heat energy. In the project activity, the existing four LSWR-based heat only boilers(HOBs) were replaced by three NG-based heat only boilers

***Brief description of the installed technology and equipment;***

The facilities of the project activity consist of three NG HOBs(Heat Only Boilers) to generate hot water for district heating and other supplementary installations. The specifications of the new NG HOBs are shown in the table below

**Table 1. Specifications of the project NG HOB**

Type	Novita type hot water heat only boiler
Capacity	103.2 Gcal/hour
Pressure	16 kg/cm <sup>2</sup> g
Fuel	Natural gas
Efficiency	More than 95.0%
Draft type	Forced draft
Life expectancy	30 to 35 years

***Relevant dates for the project activity*****Table 2. History of the project activity promotion**

Description	Date
Date of completion of NG boiler test run	#1 NG HOB(#3 Boiler) : 30/11/2006 #2 NG HOB(#4 Boiler) : 01/12/2006 #3 NG HOB(#5 Boiler) : 24/04/2007
Start date of commercial operation	#1 NG HOB(#3 Boiler) : 16/12/2006 #2 NG HOB(#4 Boiler) : 16/12/2006 #3 NG HOB(#5 Boiler) : 01/11/2007
Date of crediting period start	01/04/2008

***Total GHG emission reductions achieved in this monitoring period***

The 4<sup>th</sup> monitoring period is from 01/01/2013 to 31/12/2013 and the total amount of GHG emission reductions achieved in the 4<sup>th</sup> monitoring period is 37,123tCO<sub>2</sub>e

**A.2. Location of project activity**

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The project site is located in the KDHC Gangnam branch, which is located in the residential area at 732 Suseo-dong, Gangnam-gu, Seoul, Republic of Korea (GPS : Latitude-37.490006° ,Longitude-127.094667°)

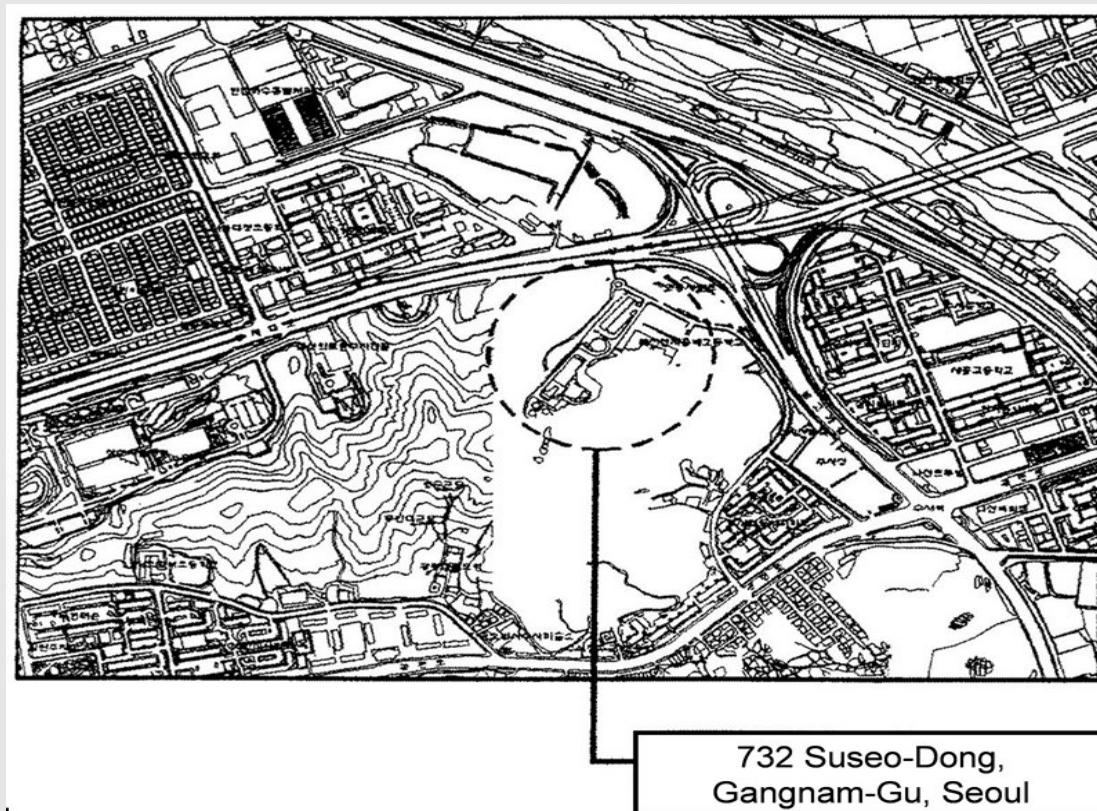


Figure 1. Location of the project facility

**A.3. Parties and project participant(s)**

Party involved ((host) indicates a host Party)	Private and/or public entity(ies) project participants(as applicable)	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
Republic of Korea(host)	Private entity : Korea District Heating Corporation	NO

**A.4. Reference of applied methodology**

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The approved methodology ACM0009 "Consolidated baseline and monitoring methodology for fuel switching from coal or petroleum fuel to natural gas" (Version 03) is applied for the project. For more information regarding the methodology, please refer to <http://cdm.unfccc.int/methodologies/PAmethodologies/approved>

**A.5. Crediting period of project activity**

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The fixed crediting period of 10 years is chosen. The start date of the crediting period is 01/04/2008

## SECTION B. Implementation of project activity

### B.1. Description of implemented registered project activity

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#### *The description of the installed technology, technical process and equipment*

The facilities of the project activity consist of three NG HOBs to generate hot water for district heating purpose and other supplementary installations. The whole construction of the proposed project activity has been completed on 31/10/2007, when the commercial operation of #3 NG HOBs(#5 Boiler) started. The specific information of the LSWR-based boilers of the baseline scenario is included in the registered PDD.

Korea does not possess enough technology for designing large scale natural gas hot water boiler. Therefore it was designed jointly with Finland's Novitor Oy. During this process, design technology was transferred to Korea. The specifications of the new NG HOBs are shown in the table below.

**Table 3. Specifications of the project NG HOB**

Type	Novita type hot water heat only boiler
Capacity	103.2 Gcal/hour
Pressure	16 kg/cm <sup>2</sup> g
Fuel	Natural gas
Efficiency	More than 95.0%
Draft type	Forced draft
Life expectancy	30 o 35 years

The natural gas to NG HOBs is supplied from Daehan City Gas Co., Ltd. In Korea, Korea Gas Corporation(KOGAS) has imported liquefied natural gas(LNG) from Indonesia, Malaysia, Qatar etc. KOGAS imported LNG is vaporized and supplied to retailers such as Daehan City Gas Co.,Ltd.

The following flowchart shows where the monitoring meters installed within the project boundary

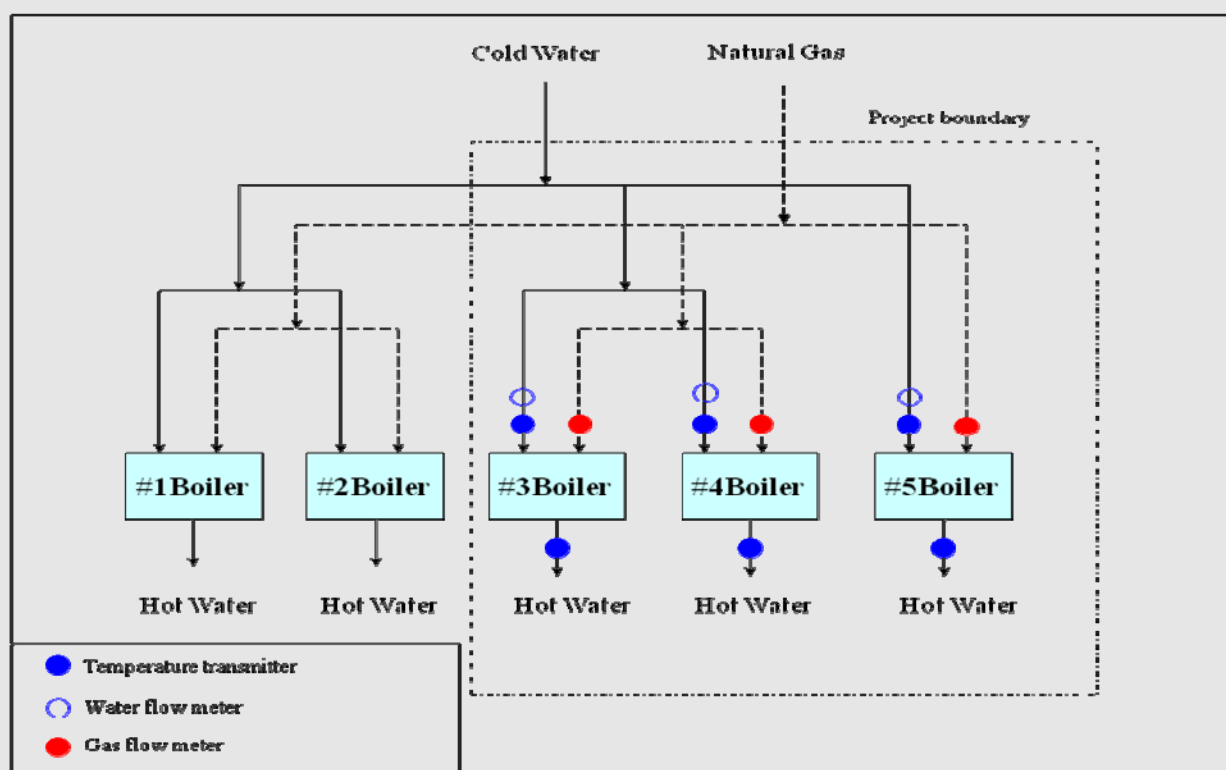


Figure 2. Diagram of the project activity

**Information on the implementation status of the project activity during this monitoring period**

During this monitoring period, there has been no event or situation that may affect the methodology took place. However, the monitoring equipment that impact its operation data and monitoring data has been shut down several times. For this reason, the monitoring system had to be reset.

Only the project NG boilers were not operated for a certain period of time in the summer because of hot weather

The information of the actual operation of the project activity is as follows

In the CER calculation, these items have been excluded

Table 4. Information of the actual operation

Item	#3 Boiler	#4 Boiler	#5 Boiler
Inactivity	12/04/2013 01:00 - 03/11/2013 18:00	15/04/2013 20:00 - 10/11/2013 17:00	26/04/2013 10:00 - 12/11/2013 23:00
reset of Monitoring system	23/01/2013 13:00–23:00 24/01/2013 23:00-24:00 25/01/2013 15:00-16:00 24/07/2013 19:00-18:00	23/01/2013 13:00–23:00 24/01/2013 23:00-24:00 25/01/2013 15:00-16:00 24/07/2013 19:00-18:00	21/08/2013 17:00-18:00
Downtimes of equipment	05/09/2013 pm 2 ~ 12 The monitoring system was shutdown caused by blackout during self-inspection in Suseo site.		

**B.2. Post registration changes**

**B.2.1. Temporary deviations from registered monitoring plan or applied methodology**

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N/A

**B.2.2. Corrections**

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(1) According to the Annex 66 and 67, EB48, the notification of PDD change has been sought EB's decision for the correct application of calorific value from Gross to Net and it was accepted on 20/05/2011. The changes were caused by the wrong baseline energy efficiency coming from wrong calculation using the gross calorific value (GCV) instead of the net calorific value (NCV) of Low Sulphur Waxy Residue fuel oil (LSWR). In addition the changes were also caused by the wrong application of project fuel efficiency, which was presented with GCV basis by the natural gas boiler manufacturer

Thus, the PDD was revised to apply the NCV for the energy efficiency on 18/02/2010 (ver.1.03), please refer to <http://cdm.unfccc.int/Projects/DB/DNV-CUK1167217026.24/history>

(2) According to the Annex 4 and Annex 5, EB65, the correction of PDD title has been implemented and then it was approved on 29/11/2012 (PRC ref : PRC-0835-001). The correction of PDD title also does not affect project design.

**Table 5. Timeline and changing history of the PDD title**

Completion date of PDD	PDD title	Remarks
08/11/2006 (ver.1.02)	Switching of fuel from Low Sulphur Waxy Residue fuel oil to natural gas at Gangnam branch Korea District Heating Corporation Project	Original PDD title at that time of CDM registration
18/02/2010 (ver.1.03)	Switching of fuel from Low Sulphur Waxy Residue fuel oil (LSWR) to natural gas at heat-only boiler in district heating system	Wrong PDD title at that time of notification of PDD changes approved on 20/05/2011
15/06/2012 (ver.1.04)	Switching of fuel from Low Sulphur Waxy Residue fuel oil to natural gas at Gangnam branch Korea District Heating Corporation Project	Corrected PDD title in accordance with the original PDD approved on 29/11/2012

**B.2.3. Permanent changes from registered monitoring plan or applied methodology**

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N/A

**B.2.4. Changes to project design of registered project activity**

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N/A

**B.2.5. Changes to start date of crediting period**

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There has been change of the start date of the crediting period in September of 2008. For checking the change record, please refer to <http://cdm.unfccc.int/Projects/DB/DNV-CUK1167217026.24/view>

- Previous crediting period at the CDM registration stage: 01/01/2008-31/12/2017
- Revised crediting period: 01/04/2008-31/03/2018 (approved on 10/11/2008)

**B.2.6. Types of changes specific to afforestation or reforestation project activity**

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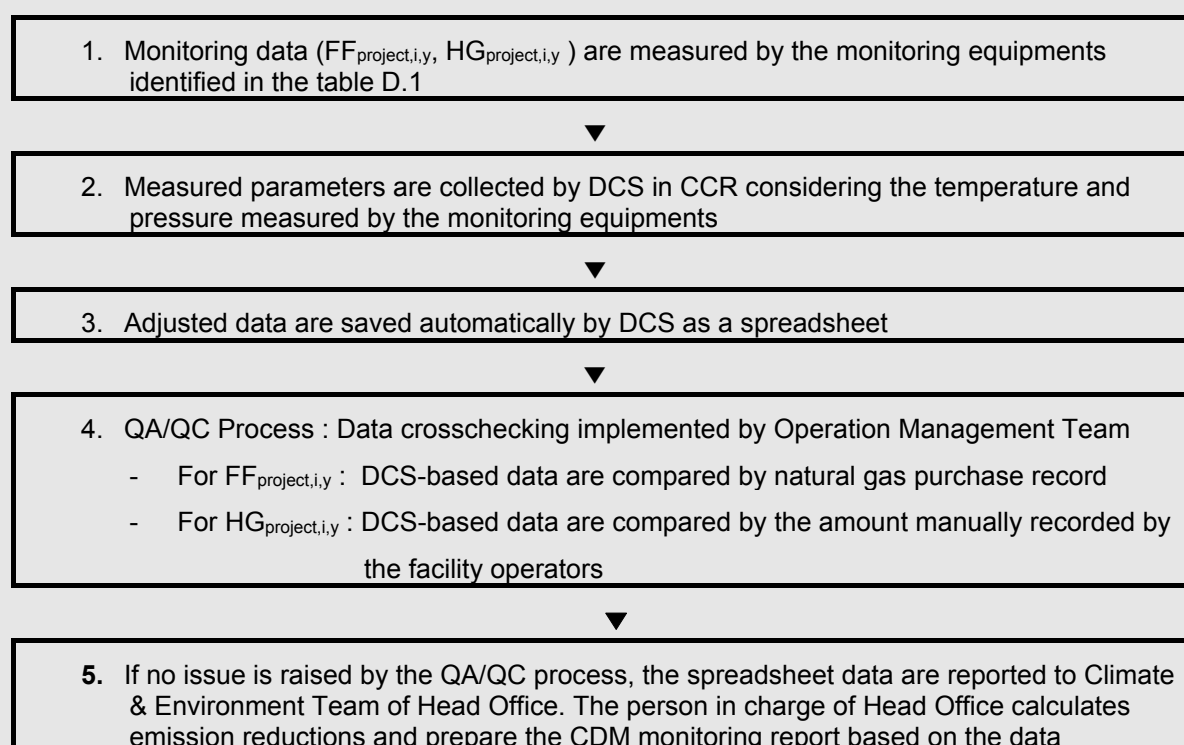
N/A

**SECTION C. Description of monitoring system**

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***Data collection procedure***

All measurable parameters related to the project activity in KDHC Gangnam branch are collected in real time by the DCS (Distributed Control System) located in central control room (CCR). Apart from this, the facility operator records the same parameters at central control room for the QA/QC purpose

**Figure 3. Data management procedure**

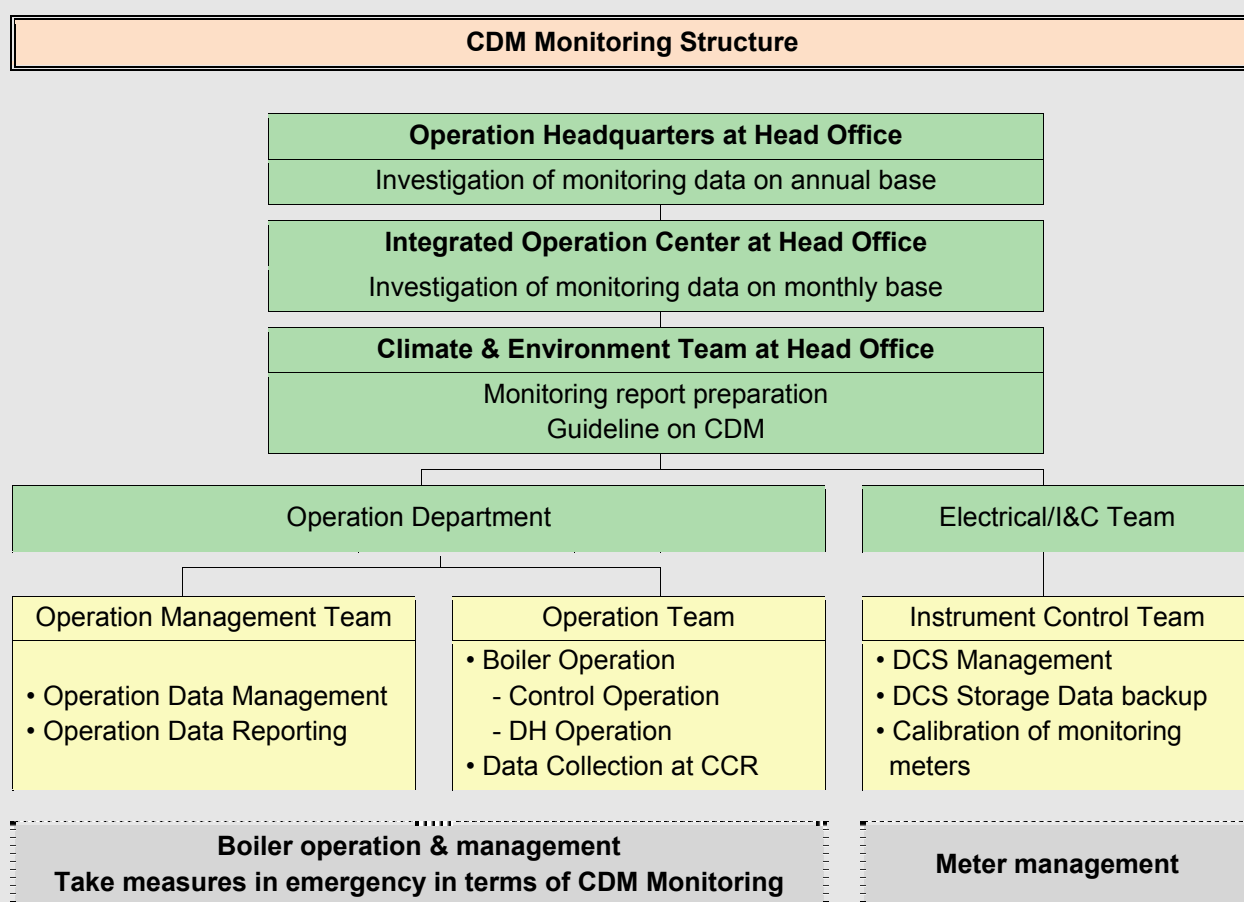
1. The consumption of natural gas is continuously measured by the gas flow meters installed as each NG boiler. The monitored data is managed at CCR of KDHC Gangnam branch
2. The heat production are calculated automatically by the DCS on the basis of DH (District Heating) water's flow rate continuously measured in front of boilers and temperature difference between DH water supplied to the users and DH water returned to KDHC that are also continuously measured at

the back of and in front of NG boilers

### CDM monitoring structure

As showed in the figure below, direct monitoring and its management (Boiler operation & management, monitoring data collection & management) are practiced by Operation Department and the Electrical/I&C Team of Gangnam branch. Climate & Environment Team of Headquarters takes charge of the calculation of emission reductions and monitoring report.

The monitoring data and calculations out of it are reported in accordance with the hierarchical structure below. If there is any change to this structure for the monitoring activity in the future, the changes will be described in the corresponding monitoring report.



**Figure 4. CDM Monitoring Structure**

CDM monitoring team is trained for boiler operation and management by Operation Headquarters of Head Office

### Emergency procedure

1. Difference between recorded data and monitored data
  - If manually recorded data are different from actually monitored data, the head of Operation Management Team will call a meeting to solve and adjust the difference with the manager of instrument control team,

the manager of operation team and the supplier of the monitoring equipment. The minutes of the meeting will be stored.

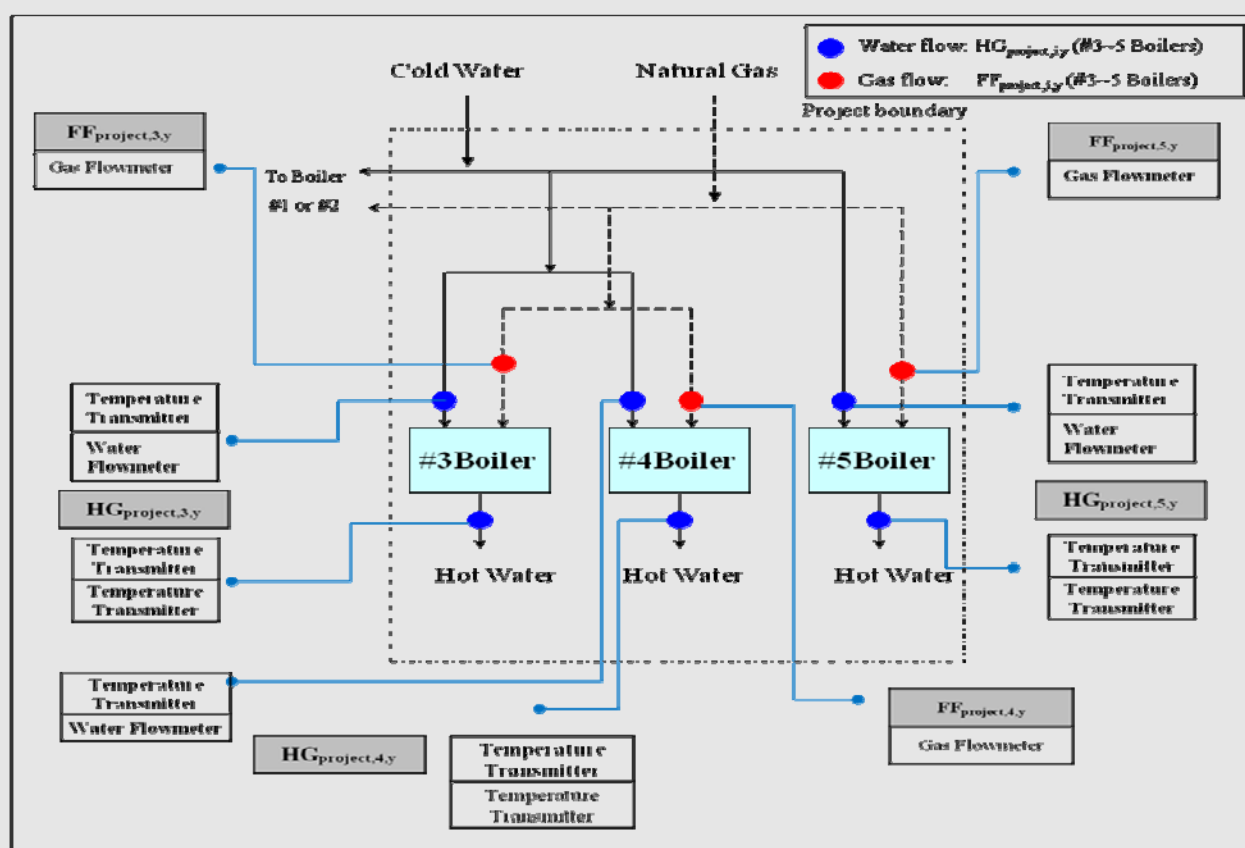
## 2. Measuring the amount of natural gas consumption ( $FF_{project,i,y}$ )

- If any meter installed on the boiler is not available or operational, the monitoring data from the records of DCG's flow meters (that are originally installed to measure DCG's dealing amount) will be used instead. However, such situation did not happen in the monitoring period.

## 3. Calculating thermal production amount ( $HG_{project,i,y}$ )

- Excluding anthropogenic shut down like periodic maintenance, when the monitoring data of temperature and/or flow meter for calculating thermal production amount is not available, the operating data manually recorded by facility operators will be used instead after the review of verifying DOE.

**Diagram of monitoring system**



**Figure 5. Monitoring point diagram**

## SECTION D. Data and parameters

### D.1. Data and parameters fixed ex ante or at renewal of crediting period

Data / Parameter:	$NCV_{NG,y}$
Unit:	kcal/N m <sup>3</sup>
Description:	Average net calorific value of the natural gas combusted during the year y

Source of data:	The Korean Ministry of Knowledge Economy
Value(s) applied:	9,550
Purpose of data:	Baseline, project and leakage emission calculations
Additional comment:	

<b>Data / Parameter:</b>	<b><math>EF_{NG,CO_2,y}</math></b>
Unit:	tCO <sub>2</sub> /TJ
Description:	CO <sub>2</sub> emission factor of the natural gas combusted in all element processes in the year y
Source of data:	The Revised 1996 IPCC Guidelines
Value(s) applied:	56.1
Purpose of data:	Project emission calculation
Additional comment:	

<b>Data / Parameter:</b>	<b><math>NCV_{FF,y}</math></b>
Unit:	kcal/l
Description:	Average net caloric value of LSWR that would be combusted in the absence of the project activity in the element process <i>i</i> during the year y
Source of data:	The Korean Ministry of Knowledge Economy
Value(s) applied:	9,350
Purpose of data:	Baseline emission calculation
Additional comment:	

<b>Data / Parameter:</b>	<b><math>EF_{FF,CO_2,y}</math></b>
Unit:	tCO <sub>2</sub> /TJ
Description:	CO <sub>2</sub> emission factor of the LSWR that would be combusted in the absence of the project activity in the all element processes in tCO <sub>2</sub> e/TJ
Source of data:	The Revised 1996 IPCC Guidelines
Value(s) applied:	77.3667
Purpose of data:	Baseline emission calculation
Additional comment:	

<b>Data / Parameter:</b>	<b><math>\epsilon_{baseline,i,y}</math></b>
Unit:	%
Description:	Energy efficiency of the element process <i>i</i> if fired with LSWR
Source of data:	KDHC
Value(s) applied:	(process <i>i</i> corresponds to #3~#5 boilers) #3 Boilers : 88% #4 Boilers : 88% #5 Boilers : 88%
Purpose of data:	Baseline emission calculation
Additional comment:	

<b>Data / Parameter:</b>	<b><math>EF_{NG,upstream,CH_4}</math></b>
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Unit:	tCH <sub>4</sub> /PJ
Description:	Emission factor for upstream fugitive methane emissions from production, transportation and distribution of natural gas in tCH <sub>4</sub> per PJ fuel supplied to final consumers
Source of data:	ACM0009 Version 03
Value(s) applied:	296
Purpose of data:	Leakage emission calculation
Additional comment:	

<b>Data / Parameter:</b>	<b><math>EF_{LSWR,upstream,CH_4}</math></b>
Unit:	tCH <sub>4</sub> /PJ
Description:	Emission factor for upstream fugitive methane emissions from production of the fuel LSWR in tCH <sub>4</sub> per PJ fuel produced
Source of data:	ACM0009 Version 03
Value(s) applied:	4.1
Purpose of data:	Leakage emission calculation
Additional comment:	

<b>Data / Parameter:</b>	<b><math>GWP_{CH_4}</math></b>
Unit:	tCO <sub>2</sub> e/tCH <sub>4</sub>
Description:	Global warming potential of methane valid for the relevant commitment period
Source of data:	The Revised 1996 IPCC Guidelines
Value(s) applied:	21
Purpose of data:	Leakage emission calculation
Additional comment:	

<b>Data / Parameter:</b>	<b><math>EF_{CO_2,upstream,LNG}</math></b>
Unit:	tCO <sub>2</sub> /TJ
Description:	Emission factor for upstream CO <sub>2</sub> emission due to fossil fuel combustion/electricity consumption associated with the liquefaction, transportation, re-gasification and compression of LNG into a natural gas transmission or distribution system
Source of data:	ACM0009 Version 03
Value(s) applied:	6
Purpose of data:	Leakage emission calculation
Additional comment:	

## D.2. Data and parameters monitored

<b>Data / Parameter:</b>	<b><math>FF_{baseline,i,y}</math></b>
Unit:	ℓ
Description:	Quantity of LSWR that would be combusted in the absence of the project activity in element process <i>i</i> during the year <i>y</i>

Measured/ Calculated / Default:	Calculated
Source of data:	Calculated based on monitoring data by DCS
Value(s) of monitored parameter:	( <i>i</i> corresponds to #3~#5 boilers) #3 Boiler : 29,770,786 #4 Boiler : 31,603,549 #5 Boiler : 24,293,267
Monitoring equipment:	Refer to $FF_{project,i,y}$ and $HG_{project,i,y}$ of Table 8
Measuring/ Reading/ Recording frequency:	Monthly
Calculation method (if applicable):	Refer to <b>E.1.</b>
QA/QC procedures:	DCS-based data are compared by natural gas purchase record
Purpose of data:	Baseline and leakage emission calculations
Additional comment:	

<b>Data / Parameter:</b>	<b><math>FF_{project,i,y}</math></b>
Unit:	Nm <sup>3</sup>
Description:	Quantity of natural gas consumed at the element process <i>i</i> in year <i>y</i>
Measured/ Calculated / Default:	Measured
Source of data:	Monitoring data by DCS
Value(s) of monitored parameter:	( <i>i</i> corresponds to #3~#5 boilers) #3 Boiler : 28,377,196 #4 Boiler : 29,501,224 #5 Boiler : 23,615,466
Monitoring equipment:	Refer to $FF_{project,i,y}$ of Table 8
Measuring/ Reading/ Recording frequency:	Continuously
Calculation method (if applicable):	N/A
QA/QC procedures:	DCS-based data are compared by natural gas purchase record
Purpose of data:	Baseline, project and leakage emission calculations
Additional comment:	

<b>Data / Parameter:</b>	<b><math>HG_{project,i,y}</math></b>
Unit:	Gcal
Description:	Quantity of heat generated at the element process <i>i</i> in year <i>y</i>
Measured/ Calculated / Default:	Measured
Source of data:	Monitoring data by DCS
Value(s) of monitored parameter:	( <i>i</i> corresponds to #3~#5 boilers) #3 Boiler : 244,954 #4 Boiler : 260,034 #5 Boiler : 199,885
Monitoring equipment:	Refer to $HG_{project,i,y}$ of Table 8

Measuring/ Reading/ Recording frequency:	Continuously
Calculation method (if applicable):	N/A
QA/QC procedures:	DCS-based data are compared by the amount manually recorded by the facility operators
Purpose of data:	Baseline and leakage emission calculations
Additional comment:	

<b>Data / Parameter:</b>	$\epsilon_{project,i,y}$
Unit:	%
Description:	Fuel efficiency of natural gas used at the element process <i>i</i> in year <i>y</i>
Measured/ Calculated / Default:	Calculated
Source of data:	Calculated based on monitoring data by DCS
Value(s) of monitored parameter:	( <i>i</i> corresponding to #3~#5 boilers) #3 Boiler : 90.4 #4 Boiler : 92.3 #5 Boiler : 88.6
Monitoring equipment:	Refer to $FF_{project,i,y}$ and $HG_{heat,i,y}$ of table 8
Measuring/ Reading/ Recording frequency:	Monthly
Calculation method (if applicable):	$[Heat\ production(Gcal) / (NG\ consumption(Nm^3) \times NCV_{NG}(kcal/Nm^3))] \times 10^6 kcal/Gcal$
QA/QC procedures:	DCS-based data are compared by the amount manually recorded by the facility operators
Purpose of data:	Baseline and leakage emission calculations
Additional comment:	

### Specification on calibration of monitoring equipment

The calibration frequency of all monitoring equipments is 2 years. Most of equipments have been managed validly according to calibration standard.

**Table 8. Information of monitoring equipment**

Element process	Parameter	Type	Serial No.	Accuracy class	Calibration		Validity
					Previous	Last	
#3 Boiler	$FF_{project,i,y}$	Gas flow meter	10512539	±0.5%	29/10/2011	03/10/2013	02/10/2015
	$HG_{project,i,y}$	Temperature meter	B322662337	0.00225t + 0.3	25/07/2010	07/08/2012	06/08/2014
		Temperature meter	B215675137	0.00225 + 0.3	25/07/2010	07/08/2012	06/08/2014
		Temperature meter	B323684437	0.00225 + 0.3	25/07/2010	07/08/2012	06/08/2014
		Water flow Meter	A06 68017	±0.5%	02/12/2011	10/12/2012	09/12/2014
#4 Boiler	$FF_{project,i,y}$	Gas flow meter	10512540	±0.5%	30/10/2011	05/10/2013	04/10/2015
	$HG_{project,i,y}$	Temperature meter	B322662037	0.00225t + 0.3	25/07/2010	07/08/2012	06/08/2014

#5 Boiler		Temperature meter	B317603437	0.00225 + 0.3	25/07/2010	07/08/2012	06/08/2014
		Temperature meter	B215679937	0.00225 + 0.3	25/07/2010	07/08/2012	06/08/2014
		Water flow Meter	A06 68015	±0.5%	02/12/2011	14/12/2012	13/12/2014
	FF <sub>project,i,y</sub>	Gas flow Meter	10512747	±0.5%	28/10/2011	04/10/2013	03/10/2015
	HG <sub>project,i,y</sub>	Temperature meter	B215674937	0.00225t + 0.3	25/07/2010	07/08/2012	06/08/2014
		Temperature meter	B323679337	0.00225 + 0.3	27/07/2010	07/08/2012	06/08/2014
		Temperature meter	B324699737	0.00225 + 0.3	27/07/2010	07/08/2012	06/08/2014
		Water flow meter	A06 68016	±0.5%	05/12/2011	14/12/2012	13/12/2014

### D.3. Implementation of sampling plan

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N/A

## SECTION E. Calculation of emission reductions or GHG removals by sinks

### E.1. Calculation of baseline emissions or baseline net GHG removals by sinks

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Baseline emissions (BE<sub>y</sub>) include CO<sub>2</sub> emissions from the combustion of the quantity of the baseline fuel (LSWR) that would be used in all element processes *i* (#3~#5 boilers) in the absence of the project activity. Baseline emissions are calculated based on the quantity of the calculated fuel consumption (FF<sub>baseline,i,y</sub>), net calorific value (NCV<sub>FF,y</sub>) and CO<sub>2</sub> emission factor (EF<sub>FF,CO2,y</sub>) of LSWR.

$$BE_y = \sum_{i=1}^3 FF_{baseline,i,y} \times NCV_{FF,y} \times EF_{FF,CO2,y}$$

with

$$FF_{baseline,i,y} = FF_{project,i,y} \times \frac{NCV_{NG,y} \times \varepsilon_{project,i,y}}{NCV_{FF,y} \times \varepsilon_{baseline,i,y}}$$

Where

BE <sub>y</sub>	Baseline emissions during the year <i>y</i> in tCO <sub>2</sub> e
FF <sub>baseline,i,y</sub>	Quantity of LSWR that would be combusted in the absence of the project activity in the element process <i>i</i> during the year <i>y</i> in ℓ
FF <sub>project,i,y</sub>	Quantity of natural gas combusted in the element process <i>i</i> during the year <i>y</i> in m <sup>3</sup>
NCV <sub>NG,y</sub>	Average net calorific value of the natural gas combusted during the year <i>y</i> in kcal/Nm <sup>3</sup>
NCV <sub>FF,y</sub>	Average net calorific value of the LSWR that would be combusted in the absence of the project activity in the element process <i>i</i> during the year <i>y</i> in kcal/ℓ
ε <sub>project,i,y</sub>	Energy efficiency of the element process <i>i</i> if fired with natural gas
ε <sub>baseline,i,y</sub>	Energy efficiency of the element process <i>i</i> if fired with LSWR
EF <sub>FF,CO2,y</sub>	CO <sub>2</sub> emission factor of the LSWR that would be combusted in the absence of the project activity in the element process <i>i</i> in tCO <sub>2</sub> /TJ

Table 9. Measured data of FF<sub>project,i,y</sub>

Month	FF <sub>project,i,y</sub>			HG <sub>project,i,y</sub>		
	#3 boiler	#4 boiler	#5 boiler	#3 boiler	#4 boiler	#5 boiler
Jan 13	7,281,039	7,429,285	7,466,128	62,726	65,249	62,836
Feb 13	5,409,991	5,628,743	6,174,994	46,499	49,545	51,619
Mar 13	3,713,303	4,396,443	1,515,821	31,771	38,412	12,763
Apr 13	772,262	769,738	1,050,459	6,636	6,746	9,004
May 13	0	0	0	0	0	0
Jun 13	0	0	0	0	0	0
Jul 13	0	0	0	0	0	0
Aug 13	0	0	0	0	0	0
Sep 13	0	0	0	0	0	0
Oct 13	0	0	0	0	0	0
Nov 13	4,595,389	4,352,147	1,888,682	39,996	38,626	16,357
Dec 13	6,605,212	6,924,868	5,519,382	57,326	61,456	47,306
Total	28,377,196	29,501,224	23,615,466	244,954	260,034	199,885

FF<sub>project,i,y</sub> and HG<sub>project,i,y</sub> of table 9 are the sum of amount estimated when the quantity of natural gas consumed in each boiler is greater than 365Nm<sup>3</sup>/h that is lower limit of the measuring range of the gas flow meter. To sum up, KDHC selected reliable values measured in measuring range of the gas meter with accuracy. The measuring range of the gas flow meter was calculated according to the formula below and relative documents was submitted to DOE

$$Q_{\max} = V \times \frac{P_a + P_g}{P_a} \times \frac{T_a}{T_g + T_a}$$

Where

Q<sub>max</sub> Max.flow rate in Nm<sup>3</sup>/h

V Maximum flow rate under operating conditions, 6500m<sup>3</sup>/h

P<sub>a</sub> Atmosphere pressure, 1.01325bar

P<sub>g</sub> Gage pressure under operating conditions, 2.451664 bar

T<sub>a</sub> Absolute temperature at normal state, 273 K

T<sub>g</sub> Absolute temperature under operating conditions, 293 K

$$Q_{\min} = \frac{Q_{\max}}{T.D.R} \times \frac{1}{\sqrt{P \times d}}$$

Where

Q<sub>min</sub> Min.flow rate in Nm<sup>3</sup>/h

T.D.R Turn down ratio, 20:1

P Absolute pressure under operating conditions, 3.464914 bar

d Specific gravity of NG, 0.624

**Table 10. Energy efficiency**

Item	#3 boiler	#4 boiler	#5 boiler
$\epsilon_{\text{project},i,y}$	90.4%	92.3%	88.6%

According to PDD, energy efficiency of the element process has to be calculated on the base of normal operating mode which has the longest period of operational mode but it is calculated on the base of whole operational mode. Because there is not a distinct criteria to distinguish the normal mode in whole operational mode, KDHC calculated energy efficiency conservatively including start-up and shut-down modes with lower energy efficiency compared with normal mode

For example,  $FF_{\text{baseline},3,y}$  of #3 boiler and  $BE_y$  are calculated as follows

$$FF_{\text{baseline},3,y} = 28,377,196 \times \frac{9,550 \times 90.4\%}{9,350 \times 88.0\%} = 29,770,786$$

$$BE_y = 29,770,786 \times 9,350 \times 77.3667 \times 4.1868(\text{kcal to kJ})/10^9(\text{Kilo to Tera}) = 90,168$$

## E.2. Calculation of project emissions or actual net GHG removals by sinks

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Project emissions ( $PE_y$ ) include  $\text{CO}_2$  emissions from the combustion of natural gas in all element process  $i$  (#3~#5 Boilers). Project emissions are calculated based on the quantity of natural gas combusted in all element process  $i$ , net calorific value and  $\text{CO}_2$  emission factors of natural gas ( $EF_{\text{NG}, \text{CO}_2, y}$ ) of natural gas

$$PE_y = \sum_{i=1}^3 FF_{\text{project},i,y} \times NCV_{\text{NG},y} \times EF_{\text{NG}, \text{CO}_2, y}$$

Where

$PE_y$  Project emissions during the year in  $\text{tCO}_2\text{e}$

$FF_{\text{project},i,y}$  Quantity of natural gas combusted in all element process during the year  $y$  in  $\text{m}^3$

$NCV_{\text{NG},y}$  Average net calorific value of the natural gas combusted during the year  $y$  in  $\text{kcal}/\text{m}^3$

$EF_{\text{NG}, \text{CO}_2, y}$   $\text{CO}_2$  emission factor of the natural gas combusted in all element processes in the year  $y$  in  $\text{tCO}_2/\text{TJ}$

For example,  $PE_y$  of #3 boiler are calculated as follow

$$PE_y = 28,377,196 \times 9,550 \times 56.1 \times 4.1868(\text{kcal to kJ})/10^9(\text{Kilo to Tera}) = 63,657$$

## E.3. Calculation of leakage

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Leakage may result from fuel extraction, processing, liquefaction, transportation, re-gasification and distribution of fossil fuels outside of the project boundary. This includes mainly fugitive  $\text{CH}_4$  emissions and  $\text{CO}_2$  emissions from associated fuel combustion and flaring. In this project, the following leakage emission sources shall be considered:

- Fugitive methane emissions

Fugitive  $\text{CH}_4$  emissions associated with fuel extraction, processing, liquefaction, transportation, re-

gasification and distribution of natural gas used in the project plant and fossil fuels used in the grid in the absence of the project activity.

- CO<sub>2</sub> emissions from LNG

In the case LNG is used in the project plant: CO<sub>2</sub> emissions from fuel combustion or electricity consumption associated with the liquefaction, transportation, re-gasification and compression into a natural gas transmission or distribution system.

$$LE_y = LE_{CH_4,y} + LE_{LNG,CO_2,y}$$

Where,

$LE_y$	Leakage emission during the year y in tCO <sub>2</sub> e
$LE_{CH_4,y}$	Leakage emission due to fugitive upstream CH <sub>4</sub> emissions in the year y in tCO <sub>2</sub> e
$LE_{LNG,CO_2,y}$	Leakage emission due to fossil combustion/electricity consumption associated with the liquefaction, transportation, re-gasification and compression of LNG into a natural gas transmission or distribution system during the year y in tCO <sub>2</sub> e

For example,  $LE_y$  of #3 boiler are calculated as follow

$$LE_y = 6,955 + 6,810 = 13,765$$

#### Calculation of $LE_{CH_4,y}$

$$LE_{CH_4,y} = (FF_{project,y} \times NCV_{NG,y} \times EF_{NG,upstream,CH_4} - FF_{baseline,LSWR,y} \times NCV_{LSWR} \times EF_{LSWR,upstream,CH_4}) \times GWP_{CH_4}$$

Where,

$FF_{project,i,y}$	Quantity of natural gas combusted in all element processes during the year y in m <sup>3</sup>
$NCV_{NG,y}$	Average net calorific value of the natural gas combusted during the year y in kcal/m <sup>3</sup>
$EF_{NG,upstream,CH_4}$	emission factor for upstream fugitive methane emissions from production, transportation and distribution of natural gas in tCH <sub>4</sub> per PJ fuel supplied to final consumers
$FF_{baseline,LSWR,y}$	Quantity of LSWR that would be combusted in the absence of the project activity in the element process during the year y in ℓ
$NCV_{LSWR}$	Average net calorific value of the LSWR that would be combusted in the absence of the project activity in the element process during the year y in kcal/ℓ
$EF_{LSWR,upstream,CH_4}$	Emission factor for upstream fugitive methane emissions from production of the fuel LSWR in tCH <sub>4</sub> per PJ fuel produced
$GWP_{CH_4}$	Global warming potential of methane valid for the relevant commitment period

For example,  $LE_{CH_4,y}$  of #3 boiler is calculated as follow

$$LE_{CH_4,y} = (28,377,196 \times 9,550 \times 296 \times 4.1868(\text{kca l to kJ})/10^{12}(\text{Kilo to Peta}) - 29,770,786 \times 9,350 \times 4.1 \times 4.1868(\text{kca l to kJ})/10^{12}(\text{Kilo to Peta})) \times 21 = 6,955$$

#### Calculation of $LE_{LNG,CO_2,y}$

$$LE_{LNG,CO_2,y} = FF_{project,y} \times EF_{CO_2,upstream,LNG}$$

Where,

$FF_{project,y}$  Quantity of natural gas combusted in all element processes during the year y in m<sup>3</sup>  
 $EF_{CO_2,upstream,LNG}$  Emission factor for upstream CO<sub>2</sub> emission due to fossil fuel combustion/electricity consumption associated with the liquefaction, transportation, re-gasification and compression of LNG into a natural gas transmission or distribution system

For example during 1<sup>st</sup> period,  $LE_{LNG,CO_2,y}$  of #3 boiler is calculated as follow

$$LE_{LNG,CO_2,y} = 28,377,196 \times 6 \times 9,550(\text{m}^3 \text{ to Kcal}) \times 4.1868(\text{kcal to kJ})/10^9(\text{Kilo to Tera}) = 6810$$

#### E.4. Summary of calculation of emission reductions or net anthropogenic GHG removals by sinks

The GHG emission reduction during the monitoring period is calculated as follow

$$ER_y = BE_y - PE_y - LE_y$$

**Table 11. Calculation of BE<sub>y</sub>, PE<sub>y</sub> and LE<sub>y</sub> for the monitoring period**

Item	Baseline emissions or baseline net GHG removals by sinks (t CO <sub>2</sub> e)	Project emissions or actual net GHG removals by sinks (t CO <sub>2</sub> e)	Leakage (t CO <sub>2</sub> e)	Emission reductions or net anthropogenic GHG removals by sinks (t CO <sub>2</sub> e)
#3 boiler	90,168	63,657	13,765	12,746
#4 boiler	95,720	66,177	14,309	15,234
#5 boiler	73,579	52,976	11,460	9,143
Total	259,467	182,810	39,534	37,123

#### E.5. Comparison of actual emission reductions or net anthropogenic GHG removals by sinks with estimates in registered PDD

Item	Values estimated in ex-ante calculation of registered PDD	Actual values achieved during this monitoring period
Emission reductions (t CO <sub>2</sub> e)	63,988	37,123

#### E.6. Remarks on difference from estimated value in registered PDD

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In this monitoring period (01/01/13- 31/12/13), the actual emission reduction is 59,303tCO<sub>2</sub>e. This amount is about 26,865tCO<sub>2</sub>e lower than the expected emission reduction as calculated in the PDD. This is mainly due to the fact that the amount of heat generated from the project site during this monitoring period was lower than the average heat generation amount in the past.

In short, the overall GHG emission from the heat generation went down as less fuel was consumed than expected. The main reason why less heat is generated compared to the past years is that the heat demand was relatively small during this monitoring period. Fuel consumption and heat generation vary year after year based on the demand of consumer.

**E.7. Actual emission reductions or net anthropogenic GHG removals by sinks during the first commitment period and the period from 1 January 2013 onwards**

Item	Actual values achieved up to 31 December 2012	Actual values achieved from 1 January 2013 onwards
Emission reductions or GHG removals by sinks (t CO <sub>2</sub> e)	-	37,123

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**Document information**

Version	Date	Description
03.2	5 November 2013	Editorial revision to correct table in page 1.
03.1	2 January 2013	Editorial revision to correct table in section E.5.
03.0	3 December 2012	Revision required to introduce a provision on reporting actual emission reductions or net anthropogenic GHG removals by sinks for the period up to 31 December 2012 and the period from 1 January 2013 onwards (EB70, Annex 11).
02.0	13 March 2012	Revision required to ensure consistency with the "Guidelines for completing the monitoring report form" (EB 66, Annex 20).
01	28 May 2010	EB 54, Annex 34. Initial adoption.
Decision Class: Regulatory		
Document Type: Form		
Business Function: issuance		
Keywords: monitoring report, performance monitoring		