Monitoring report form (Version 03.1)

Monitoring report

Title of the project activity	Switching of fuel from Low Sulphur Waxy Residue fuel oil to natural gas at Gangnam branch Korea District Heating Corporation Project
Reference number of the project activity	0835
Version number of the monitoring report	1.0
Completion date of the monitoring report	12/04/2013
Registration date of the project activity	02/04/2007
Monitoring period number and duration of this monitoring period	Monitoring period number : 3rd Monitoring period : 01/11/2011-31/12/2012
Project participant(s)	Korea District Heating Corporation
Host Party(ies)	Republic of Korea
Sectoral scope(s) and applied methodology(ies)	Sectoral scopes : 1. Energy industries 4. Manufacturing industries Methodology : ACM0009 Version 03
Estimated amount of GHG emission reductions or net anthropogenic GHG removals by sinks for this monitoring period in the registered PDD	74,653tCO_2e
Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved in this monitoring period	59,278tCO_2e

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 of for generating heat from Low Sulphur Waxy Residue fuel oil(LSWR) to natural gas(NG) at Korea District Heating Corporation(KDHC) Gangnam Branch, which operate 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 replaces 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^{2}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) : 29/11/2006 #2 NG HOB(#4 Boiler) : 30/11/2006 #3 NG HOB(#5 Boiler) : 23/04/2007
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 3rd monitoring period is from 01/11/2011 to 31/12/2012 and the total amount of GHG emission reductions achieved in the 3rd monitoring period is 59,278tCO_2e

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˚)

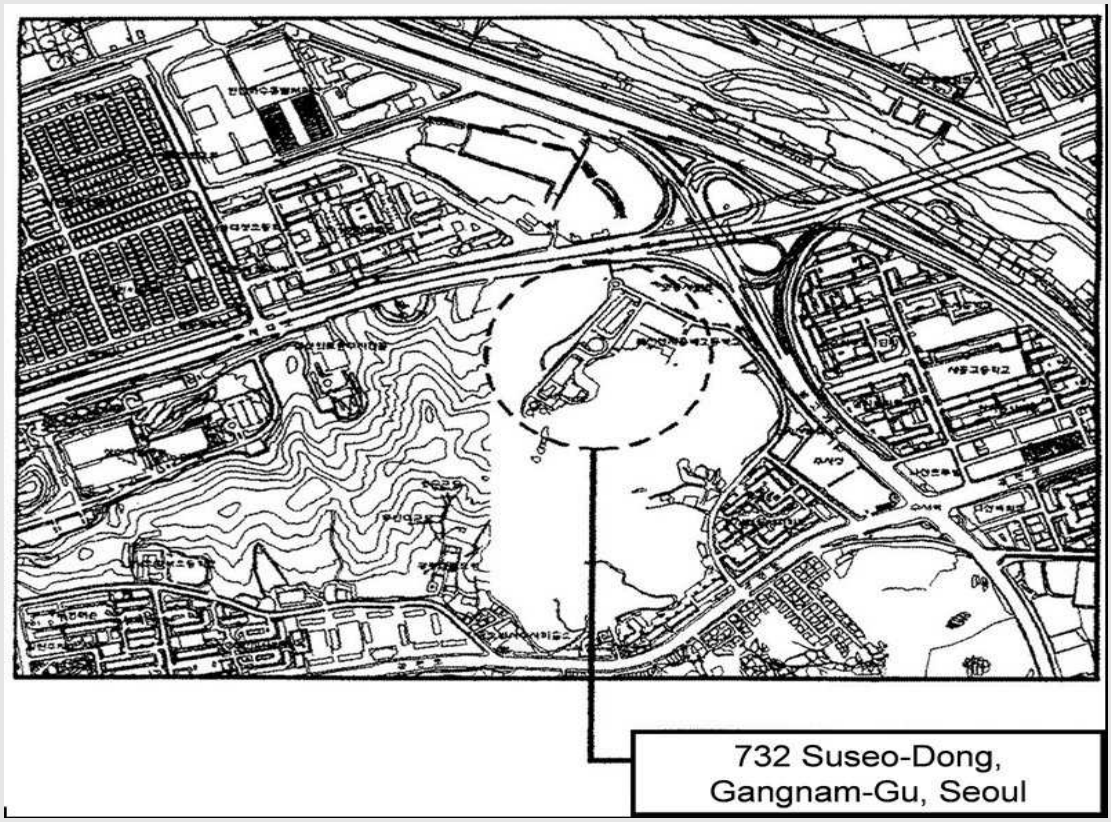

Figure 1. Location of the project facility

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^{2}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 form 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

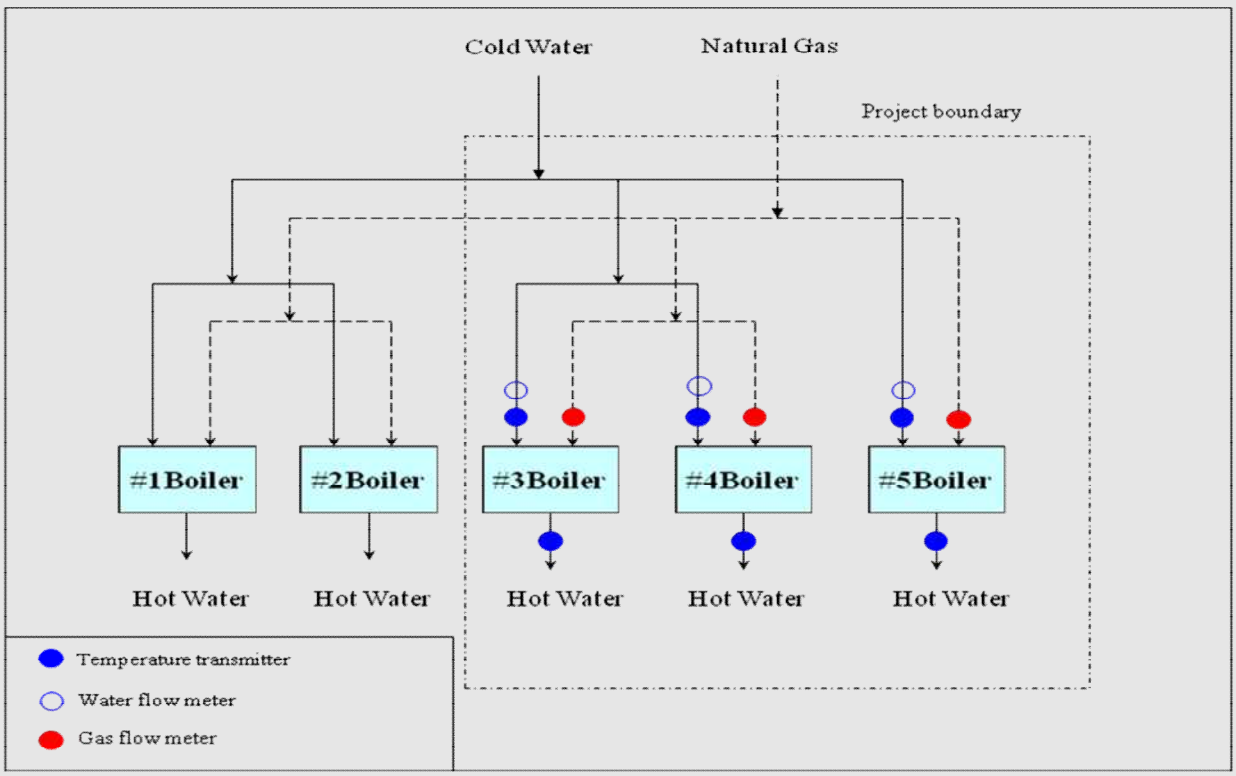

Figure 2. Diagram of the project activity

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

During this monitoring period, all equipment worked well and no error or accident ever occurred, and no activity that may affect the methodology took place.

Only the project NG boilers were not operated for a certain period of time in the summer that KDHC implemented periodic maintenance (overhaul) and there was no demand for heating because of hot weather

Overall there have been no events or situations besides periodic inactivity and overhaul during the monitoring period, which may have some impact on the applicability of methodology or the CERs calculations.

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

Table 4. Information of the actual operation

Item	#3 Boiler	#4 Boiler	#5 Boiler
Inactivity	29/03/2012-12/06/2012 02/08/2012-29/10/2012	15/04/2012-12/06/2012 02/08/2012-07/11/2012	24/04/2012-12/06/2012 02/08/2012-28/09/2012
Overhauls	13/06/2012-01/08/2012	13/06/2012-01/08/2012	13/06/2012-01/08/2012
Downtimes of equipment	N/A	N/A	N/A
Exchanges of equipment	N/A	N/A	N/A

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 form 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 dose 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

1. Monitoring data ($FF_{project,i,y}$, $HG_{project,i,y}$) are measured by the monitoring equipments identified in the table D.1

▼

2. Measured parameters are collected by DCS in CCR considering the temperature and pressure measured by the monitoring equipments

▼

3. Adjusted data are saved automatically by DCS as a spreadsheet

▼

4. QA/QC Process : Data crosschecking implemented by Operation Management Team
   - For $FF_{project,i,y}$: DCS-based data are compared by natural gas purchase record
   - For $HG_{project,i,y}$: DCS-based data are compared by the amount manually recorded by the facility operators

▼

5. If no issue is raised by the QA/QC process, the spreadsheet data are reported to Climate & Environment Team of Head Office. The person in charge of Head Office calculates emission reductions and prepare the CDM monitoring report based on the data

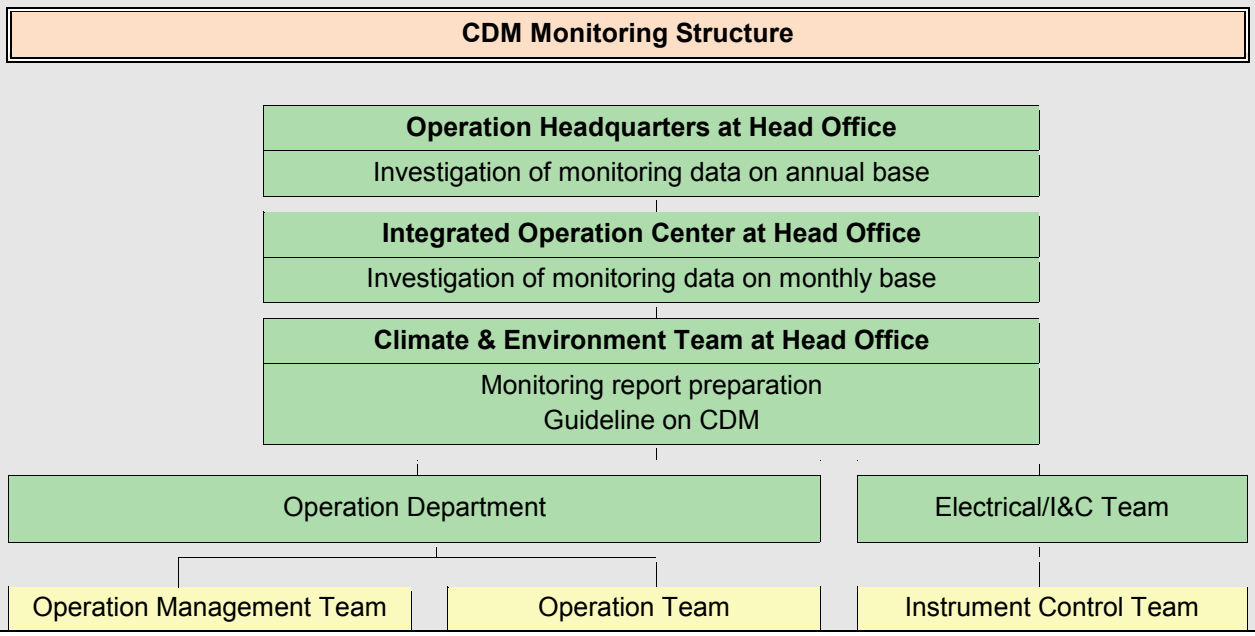
Figure 3. Data management procedure

1. The consumption of natural gas is continuously measured by the gas flow meters installed as each NG boilers. 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.



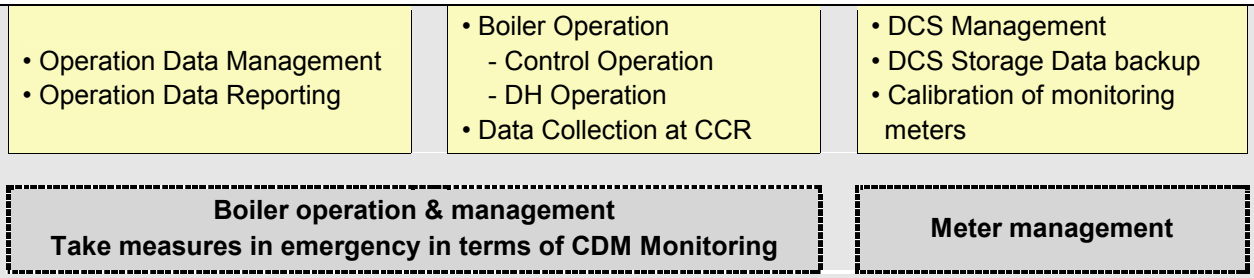


Figure 4. CDM Monitoring Structure

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

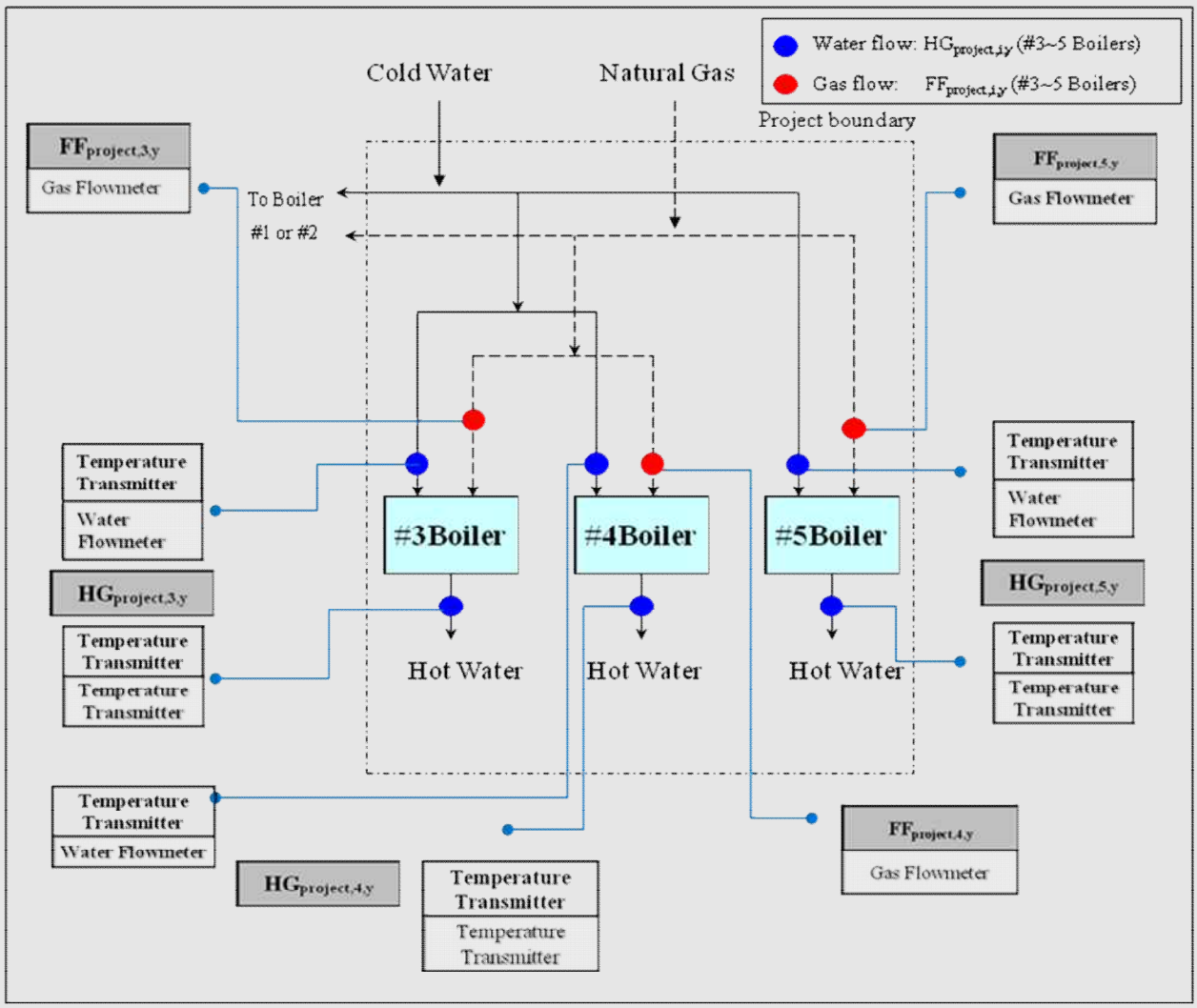


Figure 5. Monitoring point diagram

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^3
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:	

Data / Parameter:	$EF_{NG,CO2,y}$
Unit:	tCO_2/TJ
Description:	CO_2 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:	

Data / Parameter:	$NCV_{FF,y}$
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* 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:	

Data / Parameter:	$EF_{FF,CO2,y}$
Unit:	tCO_2/TJ
Description:	CO_2 emission factor of the LSWR that would be combusted in the absence of the project activity in the all element processes in tCO_2e/TJ
Source of data:	The Revised 1996 IPCC Guidelines
Value(s) applied):	77.3667
Purpose of data:	Baseline emission calculation
Additional comment:	

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

Data / Parameter:	$EF_{NG,upstream,CH4}$
Unit:	tCH_4/PJ
Description:	Emission factor for upstream fugitive methane emissions from production, transportation and distribution of natural gas in tCH_4 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:	

Data / Parameter:	$EF_{LSWR,upstream,CH4}$
Unit:	tCH_4/PJ
Description:	Emission factor for upstream fugitive methane emissions from production of the fuel LSWR in tCH_4 per PJ fuel produced
Source of data:	ACM0009 Version 03
Value(s) applied):	4.1
Purpose of data:	Leakage emission calculation
Additional comment:	

Data / Parameter:	GWP_{CH4}
Unit:	tCO_2e/tCH_4
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:	

Data / Parameter:	$EF_{CO2,upstream,LNG}$
Unit:	tCO_2/TJ
Description:	Emission factor for upstream CO_2 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

Data / Parameter:	$FF_{baseline,i,y}$
Unit:	ℓ
Description:	Quantity of LSWR that would be combusted in the absence of the project activity in element process *i* during the year *y*
Measured/ Calculated / Default:	Calculated

Source of data:	Calculated based on monitoring data by DCS
Value(s) of monitored parameter:	(*i* corresponds to #3~#5 boilers) #3 Boiler : 40,771,153 #4 Boiler : 39,398,323 #5 Boiler : 36,321,630
Monitoring equipment:	Refer to $FF_{proejct,i,y}$ and $HG_{project,i,y}$ of Table 6
Measuring/ Reading/ Recording frequency:	Monthly
Calculation method (if applicable):	Refer to **E.1.**
QA/QC procedures:	DCS-based data are compared by natural gas purchase record
Purpose of data:	Baseline and leakage emission calculations
Additional comment:	

Data / Parameter:	$FF_{project,i,y}$
Unit:	Nm^3
Description:	Quantity of natural gas consumed at the element process *i* in year y
Measured/ Calculated / Default:	Measured
Source of data:	Monitoring data by DCS
Value(s) of monitored parameter:	(*i* corresponds to #3~#5 boilers) #3 Boiler : 37,682,645 #4 Boiler : 35,369,106 #5 Boiler : 34,552,255
Monitoring equipment:	Refer to $FF_{proejct,i,y}$ of Table 6
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:	

Data / Parameter:	$HG_{project,i,y}$
Unit:	Gcal
Description:	Quantity of heat generated at the element process *i* in year y
Measured/ Calculated / Default:	Measured

Source of data:	Monitoring data by DCS
Value(s) of monitored parameter:	(*i* corresponds to #3~#5 boilers) #3 Boiler : 335,465 #4 Boiler : 324,169 #5 Boiler : 298,854
Monitoring equipment:	Refer to $HG_{project,i,y}$ of Table 6
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:	

Data / Parameter:	$\varepsilon_{project,i,y}$
Unit:	%
Description:	Fuel efficiency of natural gas used at the element process *i* in year y
Measured/ Calculated / Default:	Calculated
Source of data:	Calculated based on monitoring data by DCS
Value(s) of monitored parameter:	Fuel efficiency of natural gas is applied to the calculation of baseline emission per 12 months. Therefore there are two values each boiler because this monitoring period is 1 year and 2 months In average for the 1st period (01/11/2011-31/10/2012) (*i* corresponding to #3~#5 boilers) #3 Boiler : 94 #4 Boiler : 97 #5 Boiler : 91 In average for the 2nd period (01/11/2012-31/12/2012) (*i* corresponding to #3~#5 boilers) #3 Boiler : 92 #4 Boiler : 95 #5 Boiler : 90
Monitoring equipment:	Refer to $FF_{project,i,y}$ and $HG_{heat,i,y}$ of table 6
Measuring/ Reading/ Recording frequency:	Monthly
Calculation method (if applicable):	[Heat production(Gcal) / (NG consumption(Nm^3) x NCV_{NG}(kcal/Nm^3))]x 10^6kcal/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. All equipments have been managed validly according to calibration standard

Table 6. Information of monitoring equipment

Element process	Parameter	Type	Serial No.	Accuracy class	Data of last calibration	Validity
#3 Boiler	$FF_{project,i,y}$	Gas flow meter	10512539	±0.5	29/10/2011	28/10/2013
	$HG_{project,i,y}$	Temperature meter	B322662337	0.00225t + 0.3	07/08/2012	06/08/2014
		Temperature meter	B215675137	0.00225 + 0.3	07/08/2012	06/08/2014
		Temperature meter	B323684437	0.00225 + 0.3	07/08/2012	06/08/2014
		Water flow meter	A06 68017	±0.5	14/12/2012	13/12/2014
#4 Boiler	$FF_{project,i,y}$	Gas flow meter	10512540	±0.5	30/10/2011	29/10/2013
	$HG_{project,i,y}$	Temperature meter	B322662037	0.00225t + 0.3	07/08/2012	06/08/2014
		Temperature meter	B317603437	0.00225 + 0.3	07/08/2012	06/08/2014
		Temperature meter	B215679937	0.00225 + 0.3	07/08/2012	06/08/2014
		Water flow meter	A06 68015	±0.5	14/12/2012	13/12/2014
#5 Boiler	$FF_{project,i,y}$	Gas flow meter	10512747	±0.5	28/10/2011	27/10/2013
	$HG_{project,i,y}$	Temperature meter	B215674937	0.00225t + 0.3	07/08/2012	06/08/2014
		Temperature meter	B323679337	0.00225 + 0.3	07/08/2012	06/08/2014
		Temperature meter	B324699737	0.00225 + 0.3	07/08/2012	06/08/2014
		Water flow meter	A06 68016	±0.5	10/12/2012	09/12/2012

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 (BEy) include CO_2 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 ($FF_{baseline,i,y}$), net calorific value ($NCV_{FF,y}$) and CO_2 emission factor($EF_{FF,CO2,y}$) 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_y	Baseline emissions during the year y in tCO_2e
$FF_{baseline,i,y}$	Quantity of LSWR that would be combusted in the absence of the project activity in the element process *i* during the year y in ℓ
$FF_{project,i,y}$	Quantity of natural gas combusted in the element process *i* during the year *y* in m^3
$NCV_{NG,y}$	Average net calorific value of the natural gas combusted during the year *y* in kcal/Nm^3
$NCV_{FF,y}$	Average net calorific value of the LSWR that would be combusted in the absence of the project activity in the element process *i* during the year *y* in kcal/ℓ
$\varepsilon_{project,i,y}$	Energy efficiency of the element process *i* if fired with natural gas
$\varepsilon_{baseline,i,y}$	Energy efficiency of the element process *i* if fired with LSWR
$EF_{FF,CO2,y}$	CO_2 emission factor of the LSWR that would be combusted in the absence of the project activity in the element process *i* in tCO_2/TJ

Table 7. Measured data of $FF_{project,i,y}$

Month	$FF_{project,i,y}$			$HG_{project,i,y}$		
	#3 boiler	#4 boiler	#5 boiler	#3 boiler	#4 boiler	#5 boiler
Nov 11	2,358,400	1,825,460	1,953,360	20,930	16,777	16,935
Dec 11	6,874,640	6,753,220	4,835,380	61,578	62,352	42,969
Jan 12	4,692,980	6,705,970	7,397,200	41,934	61,785	63,434
Feb 12	6,249,550	3,546,280	7,244,340	55,968	32,571	62,415
Mar 12	5,351,600	4,087,460	1,862,020	47,846	37,860	15,562
Apr 12	0	1,445,260	1,050,860	0	13,421	9,527
May 12	0	0	0,	0	0	0

Jun 12	0	0	0	0	0	0
Jul 12	0	0	0	0	0	0
Aug 12	0	0	0	0	0	0
Sep 12	0	0	119,764	0	0	1,067
Oct 12	138,890	0	427,731	1,238	0	3,737
Nov 12	4,428,504	3,312,741	2,625,648	39,503	30,451	22,829
Dec 12	7,588,081	7,692,715	7,035,952	66,468	68,952	60,380
Total	37,682,645	35,369,106	34,552,255	335,465	324,169	298,854

Table 8. Energy efficiency

	1st Period(01/11/11-31/10/12)			2nd Period(01/11/12-31/12/12)		
	#3 boiler	#4 boiler	#5 boiler	#3 boiler	#4 boiler	#5 boiler
$\varepsilon_{project,i,y}$	93.6%	96.6%	90.7%	92.3%	94.6%	90.2%

During 1st period, $FF_{project,3,y}$ of #3 boiler and BE_y are calculated as follows

$$FF_{project,3,y} = 25,666,060 \times \frac{9,550 \times 93.6\%}{9,350 \times 88.0\%} = 27,891,831$$

$$BE_y = 27,891,831 \times 9,350 \times 77.3667 \times 4.1868(\text{kcal to kJ})/10^9(\text{Kilo to Tera}) = 84,474$$

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

>>

Project emissions (*PEy*) include 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 caloric value and CO_2 emission factors of natural gas ($EF_{NG, CO2}$) of natural gas

$$PE_y = \sum_{i=1}^{3} FF_{project,i,y} \times NCV_{NG,y} \times EF_{NG,CO_2,y}$$

Where

PE_y	Project emissions during the year in tCO_2e
$FF_{project,i,y}$	Quantity of natural gas combusted in all element process during the year y in m^3
$NCV_{NG,y}$	Average net calorific value of the natural gas combusted during the year y in kcal/m^3
$EF_{NG,CO2,y}$	CO2 emission factor of the natural gas combusted in all element processes in the year y in tCO_2/TJ

During 1st period, PE_y of #3 boiler are calculated as follow

$$PE_y = 25,666,060 \times 9,550 \times 56.1 \times 4.1868(\text{kcal to kJ})/10^9(\text{Kilo to Tera}) = 57,572$$

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 CH_4 emissions and CO_2emissions from associated fuel combustion and flaring. In this project, the following leakage emission sources shall be considered:

• Fugitive methane emissions

Fugitive 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_2 emissions from LNG

In the case LNG is used in the project plant: CO_2 emissions from fuel combustion or electricity consumption associated with the liquefaction, transportation, re-gasification and compression into a natural gas transmission or distribution system.

$$LE_y = LE_{CH4,y} + LE_{LNG,CO2,y}$$

Where,

LE_y	Leakage emission during the year y in tCO_2e
$LE_{CH4,y}$	Leakage emission due to fugitive upstream CH4 emissions in the year y in tCO_2e
$LE_{LNG,CO2,y}$	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_2e

During 1st period, *LEy* of #3 boiler are calculated as follow

LEy = $6{,}285 + 6{,}157 = 12{,}442$

Calculation of $LE_{CH4,y}$

$$LE_{CH4,y} = (FF_{project,y} \times NCV_{NG,y} \times EF_{NG,upstream,CH4} - FF_{baseline,LSWR,y} \times NCV_{LSWR} \times EF_{LSWR,upstream,CH4}) \times GWP_{CH4}$$

Where,

$FF_{project,i,y}$	Quantity of nautral gas combusted in all element processes during the year y in m^3
$NCV_{NG,y}$	Average net calorific value of the natural gas combusted during the year *y* in kcal/m^3
$EF_{NG,upstream,CH4}$	emission factor for upstream fugitive methane emissions from production, transportation and distribution of natural gas in tCH_4 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
$EF_{LSWR,upstream,CH4}$	Emission factor for upstream fugitive methane emissions from production of the fuel LSWR in tCH_4 per PJ fuel produced
GWP_{CH4}	Global warming potential of methane valid for the relevant commitment period

During 1st period, $LE_{CH4,y}$ of #3 boiler is calculated as follow

$$LE_{CH4,y} = (25{,}666{,}060 \times 9{,}550 \times 296 \times 4.1868(\text{kcal to kJ})/10^{12}(\text{Kilo to Peta}) - 27{,}891{,}831 \times 9{,}350 \times 4.1 \times 4.1868(\text{kcal to kJ})/10^{12}(\text{Kilo to Peta})) \times 21 = 6{,}285$$

Calculation of $LE_{LNG,CO2,y}$

$$LE_{LNG,CO2,y} = FF_{project,y} \times EF_{CO2,upstream,LNG}$$

Where,

$FF_{project,y}$	Quantity of nautral gas combusted in all element processes during the year y in m^3
$EF_{CO2,upstream,LNG}$	Emission factor for upstream CO_2 emission due to fossil fuel combustion/electricity consumption associated with the liquefaction, tranportation, re-gasfication and compression of LNG into a natural gas transmission or distribution system

During 1st period, $LE_{LNG,CO2,y}$ of #3 boiler is calculated as follow

$$LE_{LNG,CO2,y} = 25{,}666{,}060 \times 6 \times 9{,}550(\text{m}^3 \text{ to Kcal}) \times 4.1868(\text{kcal to kJ})/10^{9}(\text{Kilo to Tera}) = 6157$$

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 9. Calculation of BE_y, PE_y and LE_y for the monitoring period

Item	Baseline emissions or baseline net GHG removals by sinks (t CO_2e)	Project emissions or actual net GHG removals by sinks (t CO_2e)	Leakage (t CO_2e)	Emission reductions or net anthropogenic GHG removals by sinks (t CO_2e)
#3 boiler	123,481	84,526	18,268	20,687
#4 boiler	119,323	79,336	17,143	22,844
#5 boiler	110,005	77,504	16,754	15,747
Total	352,810	241,366	52,166	59,278

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

Item	Values estimated in ex-ante calculation of registered PDD	Actual values achieved during this monitoring period
Emission reductions (t CO_2e)	74,653	59,278

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

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In this monitoring period (01/11/11- 31/12/12), the actual emission reduction is 59,278tCO_2e. This amount is about 15,375tCO_2e 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_2e)	59,278	-

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Document information

Version	*Date*	*Description*
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