Monitoring report form for CDM project activity
(Version 06.0)

Complete this form in accordance with the instructions attached at the end of this form.

MONITORING REPORT		
Title of the project activity	LG Chem Naju plant fuel switching project	
UNFCCC reference number of the project activity	2475	
Version number of the PDD applicable to this monitoring report	10.4	
Version number of this monitoring report	3.0	
Completion date of this monitoring report	02/03/2018	
Monitoring period number	2nd Monitoring Period	
Duration of this monitoring period	24/02/2011 - 31/10/2016	
Monitoring report number for this monitoring report	1	
Project participants	LG Chem, Ltd.	
Host Party	Republic of Korea	
Sectoral scopes	Sectoral Scope 1 – Energy industries (renewable - / non-renewable sources)	
Applied methodologies and standardized baselines	AMS-III.B. ver. 12 - Switching fossil fuels	
Amount of GHG emission reductions or net anthropogenic GHG removals achieved by the project activity in this monitoring period	Amount achieved before 1 January 2013	Amount achieved from 1 January 2013
	24,573	56,288
Amount of GHG emission reductions or net anthropogenic GHG removals estimated ex ante for this monitoring period in the PDD	111,632 tCO_2e	

SECTION A. Description of project activity

A.1. General description of project activity

(a) LG Chem produces octanol, plasticizers and acrylic acid at its Naju plant. In the baseline scenario, steam, which is used in the production process of petrochemical products, is mainly produced in a boiler using bunker fuel oil C (Sulphur 0.5%). The Project activity involves retrofitting the boilers to allow fuel switching from bunker fuel oil C to natural gas. Natural gas is less carbon intensive than bunker fuel oil C. Therefore switching fuel from bunker fuel oil C to natural gas reduces GHG emissions.

(b) The existing boiler has been retrofitted by installing special purpose burners for natural gas combustion as well as other necessary minor modifications. For fuel switching from bunker fuel oil C to natural gas, four natural gas burners have been installed for the main boiler. The total capacity of the four natural gas burners installed is 5,353 Nm_3/hr, which is of sufficient capacity for the expected amount of natural gas consumption at Naju plant. The natural gas burners are provided by Hamworthy Combustion.

(c) The start date of the project activity (the purchase date of the natural gas burners) was 21/06/2006. The project boiler retrofit was started on 30/09/2006 and a test-run of the project activity undertaken in November 2006. Project operation began on 20/11/2006. The project was registered on 04/06/2009.

(d) The total emission reductions achieved in this monitoring period(24/02/2011 - 31/10/2016) are 80,861 tCO_2e

A.2. Location of project activity

(a) Country(Host): Republic of Korea

(b) Province: Jeollanam-do

(c) City: Naju, 1, Songwal-dong (520-130)
It is located in Naju city about 20 km southwest of Gwangju International Airport.

(d) The coordinates for the plant site are: 35.023013 N, 126.717460 E.

A.3. Parties and project participants

Parties involved	Project participants	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
Republic of Korea (host)	LG Chem, Ltd.	No

A.4. Reference to applied methodologies and standardized baselines

In accordance with Appendix B of the simplified modalities and procedures for small-scale clean development mechanism project activities (“SSC M&P”), the project falls under the following methodology and tools.

(a) Applied methodology: AMS-III.B. Switching fossil fuels (Version12)[1]

(b) Applied methodological tool: No methodological tools are used.

(C) Applied standardized baseline: No standardized baselines are used.

A.5. Crediting period type and duration

Type of the crediting period: Fixed
Start date of the crediting period: 04/06/2009
End date of the crediting period: 03/06/2019
Length of the crediting period: 10 years

SECTION B. Implementation of project activity

B.1. Description of implemented project activity

(a) Information on the implementation status of the project activity

The starting date of the project activity was 21/06/2006 and commercial operation started on 20/11/2006 following retrofit of the boilers.
The first monitoring period is from 04/06/2009 to 23/02/2011.
The second monitoring period is from 24/02/2011 to 31/10/2016.

The project has been implemented and is operated as per the registered PDD with all physical features (technology, project equipment, monitoring and metering equipment) in place. Monitoring is done according to the applied methodology (AMS-III.B. Ver12.0) and revised monitoring plan.

(b) Description of the installed technology, technical processes and equipment

General description

LG Chem currently produces octanol, plasticizers and acrylic acid at Naju plant. Originally, Naju plant was founded as a fertilizer plant, in 1962 and was modified in 1982 to allow production of octanol. Through subsequent modification and expansion of the plant, current production has reached 190,000 MT/year for octanol, 166,000 MT/year for plasticizers and 26,000 MT/year for acrylic acid.

Project specific description

The existing boiler has been retrofitted by installing special purpose burners for natural gas combustion as well as other necessary minor modifications. There are three boilers in Naju plant. Among the three boilers, one boiler, which is the main boiler in Naju plant and of which specification is described in the following table, is retrofitted. As a result of the Project activity, the capacity of the boiler and the remaining lifetime of the boiler are not changed.

The existing boilers have also combusted purge gas and by-product liquid fuel generated from the processes. However, the combustion of such by-products is not be affected by the Project activity, since only bunker fuel oil C is switched to natural gas.

[1] https://cdm.unfccc.int/methodologies/DB/1T8IU3YG99FQOYHN12FM3T0QZFFPBX

By-product liquid fuel is generated from EPA Vaporiser, Refine Column, n-Slop Column, Batch Still, VPH Vaporiser and Refine Column.

Purge gas is non-reaction gas from OXO reactor, OXO recycle loop and VPH loop. Since these processes are not be affected by the fuel type used for the steam generation, the amount of purge gas and by-product liquid fuel is independent from the fuel switching project activity. Moreover, there is no change in the process/equipment for the deliver/combustion of purge gas and by-product liquid fuel before and after the project implementation. Therefore, purge gas and by-product liquid fuel will continue to be combusted in the existing boiler without any change, i.e. the amount of purge gas and by-product liquid fuel to be combusted under the baseline scenario and project scenario would be same and only bunker fuel oil C is switched to natural gas.

For fuel switching from bunker fuel oil C to natural gas, four natural gas burners have been installed for the main boiler. Total capacity of four natural gas burners installed is 5,353 Nm^3/hr, which is of sufficient capacity for the expected amount of natural gas consumption at Naju plant. The natural gas burners are provided by HAMWORTHY COMBUSTION, which is one of the world's largest combustion equipment manufacturers, with the experiences of equipment installation in over 100 countries. The specifications of the current boiler, the Project boiler (after modification) and natural gas burner are as follows:

Table 1. Boiler specification

Description	Baseline scenario	Project scenario
Capacity	70 T/H	70 T/H
Operating pressure	35 kg/cm^2G	35 kg/cm^2G
Steam Temperature	400 ℃	400 ℃
Mail fuel used	Bunker fuel oil C	Natural gas
Efficiency	91 %	91 %

Source: LG Chem, Ltd & Manufacturer

Table 2. Burner specification

Description	Specification	
Maker	HAMWORTHY	
Model	DF 505	
Type	Manifold & Spud	
Burning Capacity	Max	1,405 (Nm^3/hr)
	MCR	1,338 (Nm^3/hr)
	Min	267 (Nm^3/hr)

Source: HAMWORTHY COMBUSTION

The natural gas is supplied by Hae Yang City Gas in Gwangju Metropolitan City. The composition of the natural gas sample is described in the following table.

Table 3. Composition of natural gas (sample)

Component	Value
Methane (CH_4)	89.78 %
Ethane (C_2H_6)	7.48 %
Propane (C_3H_3)	2.02 %
Propylene (C_3H_6)	-

Butane	$i\text{-}C_4H_{10}$	0.36 %
	$n\text{-}C_4H_{10}$	0.34 %
Nitrogen (N_2)		0.02 %
Oxygen (O_2)		-

Source: Hae Yang City Gas

(c) Actual operation of the project activity during the covered monitoring period

The plant was offline for 182 days during the second monitoring period. The outages were due to boiler cleaning or turn around (annual plant shutdown for maintenance). The offline outages are described as below:

Table 4. Description of the offline outages

No.	Date	Days	Affected Parameter	Reason
1	05-07/04/2011	3	All(Steam, LNG, PG, LF)	Boiler Cleaning
2	24/09/2011	1	LF	Turn around: Annual plant shut-down for maintenance
3	23-24/09/2011	2	PG	
4	25-30/09/2011	6	All(Steam, LNG, PG, LF)	
5	01-06/10/2011	6	LF	
6	01-05/10/2011	5	PG	
7	07-08/02/2012	2	All(Steam, LNG, PG, LF)	Boiler Cleaning
8	28/08/2012	1	All(Steam, LNG, PG, LF)	Power Failure
9	04-08/09/2012	5	PG	Turn around
10	05-08/09/2012	4	LF	
11	09-16/09/2012	7	All(Steam, LNG, PG, LF)	
12	17-18/09/2012	2	LF	
13	17-19/09/2012	3	PG	
14	08-13/01/2013	6	All(Steam, LNG, PG, LF)	Boiler Cleaning
15	18-20/06/2013	3	All(Steam, LNG, PG, LF)	Boiler Cleaning
16	20/10/2013	1	LF	Turn around & 70T/H Economizer Replacement
17	21/10-11/11/2013	22	All(Steam, LNG, PG, LF)	
18	12-14/11/2013	3	LF, PG	
19	04-05/02/2014	2	All(Steam, LNG, PG, LF)	Boiler Cleaning
20	27-28/05/2014	2	All(Steam, LNG, PG, LF)	Boiler Cleaning
21	08/08/2014	1	PG	OCT plant trouble
22	21/10-03/11/2014	14	All(Steam, LNG, PG, LF)	Turn around
23	04-05/11/2014	2	LF	
24	04-06/11/2014	3	PG	
25	13-15/01/2015	3	All(Steam, LNG, PG, LF)	Boiler Cleaning
26	17-23/04/2015	7	All(Steam, LNG, PG, LF)	Boiler Cleaning
27	11-15/07/2015	5	All(Steam, LNG, PG, LF)	Boiler Cleaning
28	18-21/07/2015	4	All(Steam, LNG, PG, LF)	Boiler Manhole & Castable Repair Work
29	14-18/11/2015	5	All(Steam, LNG, PG, LF)	Boiler Cleaning
30	26-28/01/2016	3	All(Steam, LNG, PG, LF)	Boiler Cleaning
31	12-23/04/2016	12	All(Steam, LNG, PG, LF)	Turn around
32	24-30/04/2016	7	LF	
33	24/04-01/05/2016	8	PG	
34	19-26/05/2016	8	All(Steam, LNG, PG, LF)	55T/H F.D Fan Replacement & Boiler Cleaning
35	30/08-04/09/2016	6	All(Steam, LNG, PG, LF)	Boiler Cleaning
36	12-16/11/2016	5	All(Steam, LNG, PG, LF)	Boiler Cleaning
Total		**182**		

There was no event during the monitoring period that had an impact on the applicability of the methodology.

(d) Situations with impact on the applicability of the methodology

No such situations occurred during the covered monitoring period.

B.2. Post-registration changes

B.2.0. Temporary deviations from the registered monitoring plan, applied methodologies or standardized baselines

No deviation has been applied to the monitoring period.

B.2.1. Corrections

No such corrections have been applied during this monitoring period, neither to any previous monitoring period.

B.2.2. Changes to the start date of the crediting period

No such changes have applied to this monitoring period neither to previous monitoring period in the crediting period.

B.2.3. Inclusion of monitoring plan

No such inclusion has applied to this monitoring period.

B.2.4. Permanent changes to the registered monitoring plan, or permanent deviation of monitoring from the applied methodologies, standardized baselines, or other applied standards or tools

No permanent changes from the registered monitoring plan, applied standardized baseline have been approved during this monitoring period or submitted with this monitoring report.

B.2.5. Changes to project design

No such changes have applied to this monitoring period neither to any previous monitoring period.

SECTION C. Description of monitoring system

LG Chem has organized an Operating and Monitoring Team, as per the PDD, which composes a manager and operators. The manager is responsible for monitoring and archiving all data associated with items depicted in the PDD monitoring plan. Operators working under the manager are assigned to the task of monitoring the different parameters on a timely basis as well as recording and archiving data in an orderly manner. All data collected as part of the monitoring plan will be archived electronically and be kept at least two (2) years after the end of the crediting period. Monitoring reports are reviewed by the manager on a monthly basis in order to ensure that the Project activity meets all requirements.

1. Allocation of Project management responsibilities

The management and operation of the Project is the responsibility of LG Chem, the Project operator. Ensuring the environmental credibility of the Project through accurate and systematic monitoring of the Project's implementation and operation for the purpose of achieving trustworthy CERs is the key responsibility and accountability of the operator.

2. Management and operational systems

The project developers have implemented a management and operational system that meets the requirements of the Project. This includes:

2.1 Data handling

– The establishment of a transparent system for the collection, computation and storage of data, including adequate record keeping and data monitoring systems.

2.2 Quality assurance

– LG Chem has designated a manager to be accountable for the generation of CERs including monitoring, record keeping, computation of CERs, audits and verification. The manager officially sign-offs on all GHG Emission worksheets.
– The manager follows well-defined protocols and routine procedures, with good, professional data entry, extraction and reporting are undertaken to maximize transparency of data archiving.
– Proper management processes and recording of all official data is undertaken.

2.3 Training

– Internal training is made available to operational staff to enable them to undertake the tasks required by the MP.

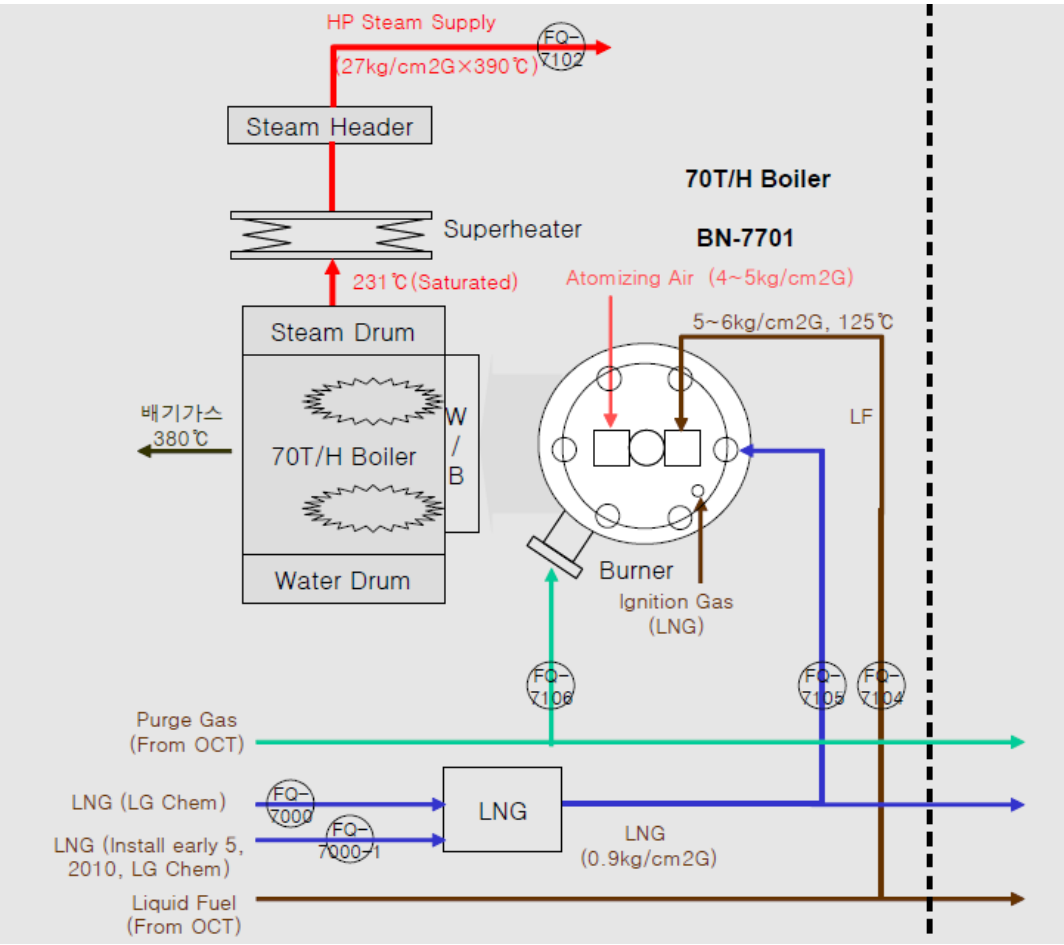

Figure 1. All relevant project monitoring points

SECTION D. Data and parameters

D.1. Data and parameters fixed ex ante

Data/parameter:	**$EF_{NG,CO2}$**
Unit	tCO_2/TJ
Description	CO_2 emission factor of the natural gas combusted
Source of data	2006 IPCC Guidelines for National Greenhouse Gas Inventories
Value(s) applied)	56.1
Choice of data or measurement methods and procedures	N/A
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex-ante

Data/parameter:	**$FF_{baseline}$**
Unit	Liter
Description	Quantity of bunker fuel oil C combusted in the baseline situation
Source of data	LG Chem.
Value(s) applied)	70,730,291

Choice of data or measurement methods and procedures	N/A
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex-ante. 3 years data prior to the project implementation (from 1st, November 2003 to 31st, October 2006) is used.

Data/parameter:	$EF_{baseline,CO2}$
Unit	tCO_2/TJ
Description	CO_2 emission factor of bunker fuel oil C
Source of data	2006 IPCC Guidelines for National Greenhouse Gas Inventories
Value(s) applied)	77.4
Choice of data or measurement methods and procedures	N/A
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex-ante

Data/parameter:	$Q_{total,baseline}$
Unit	TJ
Description	Total quantity of steam generated by bunker fuel oil C, purge gas and by-product liquid fuel in the baseline situation
Source of data	LG Chem,
Value(s) applied)	3,701.09
Choice of data or measurement methods and procedures	3 years data prior to the project implementation (from 1st, November 2003 to 31st, October 2006) is used. LG Chem produces superheated steam at 27 atm, 390°C. The enthalpy of the superheated steam is 767.7kcal/kg of steam according to the steam table (Spirax Sarco: http://www.spiraxsarco.com/Resources/Pages/Steam-Tables/superheated-steam.aspx). The temperature of the feed water is 104℃.
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex-ante.

Data/parameter:	$PG_{baseline}$
Unit	Nm^3
Description	Quantity of purge gas combusted in the boiler in the baseline situation
Source of data	LG Chem.
Value(s) applied)	13,203,959
Choice of data or measurement methods and procedures	3 years data prior to the project implementation (from 1st, November 2003 to 31st, October 2006) is used.
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex-ante.

Data/parameter:	$LF_{baseline}$
Unit	Liter

Description	Quantity of by-product liquid fuel combusted in the boiler in the baseline situation
Source of data	LG Chem.
Value(s) applied)	26,297,017
Choice of data or measurement methods and procedures	3 years data prior to the project implementation (from 1st, November 2003 to 31st, October 2006) is used.
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex-ante.

Data/parameter:	**$NCV_{PG,baseline}$**
Unit	TJ/Nm^3
Description	Net calorific value of purge gas
Source of data	LG Chem
Value(s) applied)	52.15×10^{-6}
Choice of data or measurement methods and procedures	3 years data prior to the project implementation (from 1st, November 2003 to 31st, October 2006) is used.
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex-ante.

Data/parameter:	**$NCV_{LF,baseline}$**
Unit	TJ/Nm^3
Description	Net calorific value of by-product liquid fuel
Source of data	LG Chem
Value(s) applied)	30.576×10^{-6}
Choice of data or measurement methods and procedures	Due to the absence of the reliable data for the period of 3 year prior to the project implementation (from 1st, November 2003 to 31st, October 2006) does not exist, the data recently measured by the independent laboratory is used.
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex-ante.

Data/parameter:	**$NCV_{baseline}$**
Unit	TJ/liter
Description	Net calorific value of bunker fuel oil C
Measured/calculated/default	Default
Source of data	Calorific Value table approved by the Government
Value(s) of monitored parameter	39.1×10^{-6}
Monitoring equipment	N/A
Measuring/reading/recording frequency:	Yearly
Calculation method (if applicable):	N/A
QA/QC procedures:	The accurate and reliable national data is used. The value is from the Calorific Value Table in “Energy Act” approved by Korean Government.
Purpose of data	Baseline emission calculations
Additional comments	The value is set ex- ante.

D.2. Data and parameters monitored

Data/parameter:	**$FF_{projcet,y}$**
Unit	Nm^3
Description	Quantity of natural gas combusted in the project boiler during the year, y
Measured/calculated/default	Measured
Source of data	On-site measurement
Value(s) of monitored parameter	Before 2013 : 30,902,352 From 2013 : 56,601,999 Sum : 87,504,351
Monitoring equipment	Type: Vortex(Orifice) Accuracy Class: ±1.0% Name: FQ_7105 Serial Number: 15-S0728HN Calibration frequency: Every 3 years Date and validity of the meter`s the most recent calibration during the monitoring period: 4-Nov-2013 (4-Nov-2013 to 3-Nov-2016) Date and validity of the meter`s the 2_{nd} re cent calibration during the monitoring peri od: 5-Nov-2010 (5-Nov-2010 to 4-Nov-2013)
Measuring/reading/recording frequency	Continuous
Calculation method (if applicable)	N/A
QA/QC procedures	The meter (Tag No. 7105) has been calibrated at least every 3 years and calibration certificates have been issued. According to the revised monitoring plan, the amount measured by this meter was cross-checked monthly with the purchased amount which was measured by trading meter and stated on receipts, and the amount consumed by another point which was measured by the meter FQ-5105. The result of cross-checking shows that the average difference between total natural gas consumption and the purchased total amount of natural gas is only 2%, within a reasonable and acceptable range. The meter FQ-5105 was also calibrated periodically as per the revised monitoring plan of the Project. The quantity of the combusted natural gas has been measured by the meter of orifice type, the pressure is normalized, and the thermometer(TE-7105) of the natural gas were periodically calibrated during monitoring period for normalization of the quantity of the natural gas.
Purpose of data/parameter	Project emission calculations
Additional comments	N/A

Data/parameter:	**$NCV_{NG,y}$**
Unit	TJ/Nm^3
Description	Net calorific value of natural gas in year, y
Measured/calculated/default	Default
Source of data	Calorific Value Table approved by the Government

<table>
<tr><td>Value(s) of monitored parameter</td><td>Before 2013, weighted average : 39.65 X 10^{-6}
<table>
<tr><th>Sort</th><th>Net Calorific value</th><th>Quantity of natural gas</th></tr>
<tr><td>Until 31/12/2011</td><td>40.0 X 10^{-6}</td><td>13,037,029</td></tr>
<tr><td>After 01/01/2012</td><td>39.4 X 10^{-6}</td><td>17,865,323</td></tr>
<tr><td>Weighted average</td><td>39.65 X 10^{-6}</td><td>(Sum) 30,902,352</td></tr>
</table>
After 2013, default value : 39.4 X 10^{-6}</td></tr>
<tr><td>Monitoring equipment</td><td>N/A</td></tr>
<tr><td>Measuring/reading/recording frequency</td><td>Yearly</td></tr>
<tr><td>Calculation method (if applicable)</td><td>N/A</td></tr>
<tr><td>QA/QC procedures</td><td>The accurate and reliable national data is used. The value is from the Calorific Value Table in “Energy Act” approved on 30 December 2011 by Korean Government.</td></tr>
<tr><td>Purpose of data/parameter</td><td>Project emission calculations</td></tr>
<tr><td>Additional comments</td><td>The weighted average value is used for the project emission calculations.</td></tr>
</table>

Data/parameter:	$\mathbf{Q_{total,y}}$
Unit	TJ
Description	Total quantity of steam generated by natural gas, purge gas and by-product liquid fuel in the project boiler during the year, y
Measured/calculated/default	Measured
Source of data	On-site measurement
Value(s) of monitored parameter	Before 2013 : 2,123.35 After 2013 : 4,128.57 Sum : 6,251.92

<table>
<tr><td>Monitoring equipment</td><td>
<table>
<tr><td>Type</td><td>Differential pressure</td></tr>
<tr><td>Accuracy Class</td><td>±2.0%</td></tr>
<tr><td>Name</td><td>FQ_7102</td></tr>
<tr><td>Serial Number</td><td>91M642405</td></tr>
<tr><td>Calibration frequency</td><td>Every year</td></tr>
<tr><td>Date and validity of the meter`s the most recent calibration during the monitoring period</td><td>16-Apr-2016
(16-Apr-2016 to 15-Apr-2017)</td></tr>
<tr><td>Date and validity of the meter`s the 2nd recent calibration during the monitoring period</td><td>15-Nov-2015
(15-Nov-2015 to 14-Nov-2016)</td></tr>
<tr><td>Date and validity of the meter`s the 3rd recent calibration during the monitoring period</td><td>29-Oct-2014
(29-Oct-2014 to 28-Oct-2015)</td></tr>
<tr><td>Date and validity of the meter`s the 4th recent calibration during the monitoring period</td><td>3-Nov-2013
(3-Nov-2013 to 2-Nov-2014)</td></tr>
<tr><td>Date and validity of the meter`s the 5th recent calibration during the monitoring period</td><td>10-Sep-2012
(10-Sep-2012 to 9-Sep-2013)</td></tr>
<tr><td>Date and validity of the meter`s the 6th recent calibration during the monitoring period</td><td>26-Sep-2011
(26-Sep-2011 to 25-Sep-2011)</td></tr>
<tr><td>Date and validity of the meter`s the 7th recent calibration during the monitoring period</td><td>11-Sep-2010
(11-Sep-2010 to 10-Sep-2011)</td></tr>
</table>
</td></tr>
<tr><td>Measuring/reading/recording frequency</td><td>Continuous</td></tr>
<tr><td>Calculation method
(if applicable)</td><td>The total quantity of steam generated from the combustion of natural gas, purge gas, and by-product liquid fuel (the difference in the energy of the feedwater going into the system and the steam leaving the system) was calculated via steam tables. The minimum values identified during the monitoring period were used in the calculation. For steam, 27 kgf/cm^2 and 386°C and for feedwater, 112°C are used from 24 February 2011 to 31 December 2012 and 26.6 kgf/cm^2 for steam, 373°C and for feedwater, 112°C are used from 01 January 2013 to 31 October 2016.

The enthalpy of the superheated steam is 765.1 kcal/kg for before 2013 and 758.2 kcal/kg for after 2013 of steam according to the steam table. The enthalpy of the feedwater is 112 kcal/kg. (http://www.spiraxsarco.com/Resources/Pages/Steam-Tables/superheated-steam.aspx).</td></tr>
</table>

QA/QC procedures	The revised monitoring plan on PDD does not specify a calibration frequency of the meter (Tag No. 7102), but the calibration has conducted yearly with previous monitoring report. The yearly calibration frequency for the steam flow meter is satisfied with “Law of measurement” approved by Korean Government. The meter (Tag No. 7102) has been calibrated periodically and a calibration certificate has been issued. The meter was calibrated on 11 September 2010, 26 September 2011, 10 September 2012, 3 November 2013, 29 October 2014, 15 November 2015, and 16 April 2016. To take into consideration of its calibration frequeancy, some delayed calibration occurred during this monitoring period. LG Chem applied corrected data from 11 September 2011 to 25 September 2011, from 10 September 2013 to 2 November 2013 and from 29 October 2015 to 14 November 2015 with previous calibration report as a conservative manner. - 01 Sep 2011 to 30 Sep 2011 : 2.0% (Applied maximum permissible error) - 01 Sep 2013 to 30 Nov 2013 : 2.0% (Applied maximum permissible error) - 01 Oct 2015 to 30 Nov 2015 : 2.0% (Applied maximum permissible error) The thermometer(Tag No. TE-7112) and pressure gauges(Tag No. PT-7101) were managed through comparative testing according to internal standards by LG Chem. Both have no erroneous measurement or malfunction detected during the monitoring period.
Purpose of data/parameter	Project emission calculations
Additional comments	The last calibration of the meter on 16 April 2016 was a replacement of its transmitter. Serial number was changed from 4100404001 to 91M642405.

Data/parameter:	**PG_y**
Unit	Nm^3
Description	Quantity of purge gas combusted in the project boiler during the year, y
Measured/calculated/default	Measured
Source of data	On-site measurement
Value(s) of monitored parameter	Before 2013 : 12,825,597 After 2013 : 34,566,201 Sum : 47,391,798

<table>
<tr><td>Monitoring equipment</td><td>
<table>
<tr><td>Type</td><td>Differential pressure</td></tr>
<tr><td>Accuracy Class</td><td>±2.0%</td></tr>
<tr><td>Name</td><td>FQ_7106</td></tr>
<tr><td>Serial Number</td><td>91L751790</td></tr>
<tr><td>Calibration frequency</td><td>Every year</td></tr>
<tr><td>Date and validity of the meter`s the mos trecent calibration during the monitoring period</td><td>16-Apr-2016
(16-Apr-2016 to 15-Apr-2017)</td></tr>
<tr><td>Date and validity of the meter`s the 2nd r ecent calibration during the monitoring p eriod</td><td>15-Nov-2015
(15-Nov-2015 to 14-Nov-2016)</td></tr>
<tr><td>Date and validity of the meter`s the 3rd r ecent calibration during the monitoring p eriod</td><td>29-Oct-2014
(29-Oct-2014 to 28-Oct-2015)</td></tr>
<tr><td>Date and validity of the meter`s the 4th r ecent calibration during the monitoring p eriod</td><td>4-Nov-2013
(4-Nov-2013 to 3-Nov-2014)</td></tr>
<tr><td>Date and validity of the meter`s the 5th r ecent calibration during the monitoring p eriod</td><td>10-Sep-2012
(10-Sep-2012 to 9-Sep-2013)</td></tr>
<tr><td>Date and validity of the meter`s the 6th r ecent calibration during the monitoring p eriod</td><td>26-Sep-2011
(26-Sep-2011 to 25-Sep-2012)</td></tr>
<tr><td>Date and validity of the meter`s the 7th r ecent calibration during the monitoring p eriod</td><td>6-Nov-2010
(6-Nov-2010 to 5-Nov-2011)</td></tr>
</table>
</td></tr>
<tr><td>Measuring/reading/recording frequency</td><td>Continuous</td></tr>
<tr><td>Calculation method
(if applicable)</td><td>N/A</td></tr>
<tr><td>QA/QC procedures</td><td>The revised monitoring plan on PDD does not specify a calibration frequency of the meter (Tag No. 7106), but the calibration has conducted yearly with previous monitoring report. The yearly calibration frequency for the purge gas meter is satisfied with “Law of measurement” approved by Korean Government.

The meter (Tag No. 7106) has been calibrated periodically and a calibration certificate has been issued. The meter was calibrated on 6 November 2010, 26 September 2011, 10 September 2012, 4 November 2013, 29 October 2014, 15 November 2015, and 16 April 2016.

To take into consideration of its calibration frequeancy, some delayed calibration occurred during this monitoring period. LG Chem applied corrected data from 24 February 2011(Start date of this monitoring period) to 05 November 2011(End date of previous calibration validity), from 10 September 2013 to 3 November 2013 and from 29 October 2015 to 14 November 2015 with previous calibration report as a conservative manner.

- 01 Feb 2011 to 30 Nov 2011 : 2.0% (Applied maximum permissible error)
- 01 Sep 2013 to 30 Nov 2013 : 2.0% (Applied maximum permissible error)
- 01 Oct 2015 to 30 Nov 2015 : 2.0% (Applied maximum permissible error)

The thermometer(Tag No. TE-7106) for the purge gas temperature was managed through comparative testing according to internal standards by LG Chem. Both have no erroneous measurement or malfunction detected during the monitoring period.</td></tr>
<tr><td>Purpose of data/parameter</td><td>Project emission calculations</td></tr>
<tr><td>Additional comments</td><td>-</td></tr>
</table>

Data/parameter:	**LF_y**
Unit	Liter
Description	Quantity of by-product liquid fuel combusted in the project boiler during the year, y
Measured/calculated/default	Measured
Source of data	On-site measurement
Value(s) of monitored parameter	Before 2013 : 17,694,695 After 2013 : 33,831,742 Sum : 51,526,436
Monitoring equipment	Type: Positive displacement Accuracy Class: ±0.5% Name: FQ_7104 Serial Number: B-153-6985 Calibration frequency: Every 3 years Date and validity of the meter`s the most recent calibration during the monitoring period: 22-Oct-2014 (22-Oct-2014 to 21-Oct-2017) Date and validity of the meter`s the 2nd recent calibration during the monitoring period: 27-Sep-2011 (27-Sep-2011 to 26-Sep-2014)
Measuring/reading/recording frequency	Continuous
Calculation method (if applicable)	N/A
QA/QC procedures	The meter (Tag No. 7104) has been calibrated periodically and a calibration certificate has been issued. According to the PDD monitoring plan, the meter was calibrated on 27 September 2011, 22 October 2014. The meter (Tag No. FQ-7104) has been calibrated at least every 3 years and calibration certificates have been issued. The revised monitoring plan on PDD does not specify a calibration frequency, but the calibration has conducted every 3 years with previous monitoring report. The calibration frequency for the by-product liquid fuel meter is satisfied with “Law of measurement” approved by Korean Government. To take into consideration of its calibration frequeancy, some delayed calibration occurred during this monitoring period. LG Chem applied corrected data from 24 February 2011(Start date of this monitoring period) to 26 September 2011(End date of previous calibration validity) and from 27 September 2014 to 21 October 2014 with previous calibration report as a conservative manner. - 01 February 2011 to 30 September 2011 : 3.66% (Applied calibration error) - 01 September 2014 to 31 October 2014 : 3.28% (Applied calibration error)
Purpose of data/parameter	Project emission calculations
Additional comments	

Data/parameter:	**$NCV_{WG,y}$**
Unit	TJ/Nm^3
Description	Net calorific value of purge gas
Measured/calculated/default	Measured
Source of data	On-site measurement

Value(s) of monitored parameter

Before 2013, weighted average : 57.68 X 10^{-6}

Year	Quater	Net calorific Value(TJ/Nm^3)
2011	1Q	60.67 X 10^{-6}
	2Q	61.20 X 10^{-6}
	3Q	62.70 X 10^{-6}
	4Q	61.55 X 10^{-6}
2012	1Q	59.85 X 10^{-6}
	2Q	59.16 X 10^{-6}
	3Q	55.23 X 10^{-6}
	4Q	43.84 X 10^{-6}
Weighted average		57.68 X 10^{-6}

After 2013, weighted average : 39.06 X 10^{-6}

Year	Quater	Net calorific Value(TJ/Nm^3)
2013	1Q	47.55 X 10^{-6}
	2Q	52.00 X 10^{-6}
	3Q	53.11 X 10^{-6}
	4Q	52.44 X 10^{-6}
2014	1Q	53.64 X 10^{-6}
	2Q	34.42 X 10^{-6}
	3Q	35.44 X 10^{-6}
	4Q	36.60 X 10^{-6}
2015	1Q	33.28 X 10^{-6}
	2Q	33.92 X 10^{-6}
	3Q	36.50 X 10^{-6}
	4Q	35.40 X 10^{-6}
2016	1Q	30.35 X 10^{-6}
	2Q	37.36 X 10^{-6}
	3Q	38.92 X 10^{-6}
	4Q	35.79 X 10^{-6}
Weighted average		39.06 X 10^{-6}

Purge gas is consisted of C_3H_6, C_3H_8, H_2 and is generated by product of Octanol. Its composition can be able to change, accordingly, its net calorific value could be changed. The quantity of purge gas has been increased since April, 2014 through internal project conducted on 8th of April 2014, "PSA Purge gas fuel project". As the composition of purge gas increased is almost H_2, its net calorific value has been rapidly decreased.

Monitoring equipment	<table><tr><td>Type</td><td>Agilent 7890A Network Gas Chromatograph</td></tr><tr><td>Accuracy Class</td><td>· Inlet modules: Pressure sensors: Accuracy: <±2% full scale, Repeatability: <±0.05 psi, Temperature coefficient: <±0.01 psi/°C, Drift: <±0.1 psi/6 months Flow sensors: Accuracy <±5% depending on carrier gas, Repeatability: <±0.35% of setpoint, normalized temperature and pressure (NTP, 25°C, 1atm) per °C for He or H_2, <0.05mL/min NTP per °C for N_2 or Ar/CH_4. · Detector modules: Accuracy: <± 3mL/min NTP or 7% of setpoint Repeatability: <±0.35% of setpoint</td></tr></table>
Measuring/reading/recording frequency	Quarterly
Calculation method (if applicable)	Measured quarterly and weighted average yearly.
QA/QC procedures	The NCV of purge gas was analysed using standard gas (reference material) as per ASTM D 3588 (Standard practice for calculating heat value, compressibility factor and relative density (specific gravity) of gaseous fuels) widely using for NCV of gaseous fuels. GC (Gas chromatograph) maintenance is entrusted to specialized companies and is managed periodically. NCV for Purge gas can be crosschecked with the values are verified by 3rd verification body under K-ETS. can be crosschecked with the values are verified by 3rd verification body under K-ETS. The NCV value calculation method also conforms to the criteria set out in the regulation such as “Guideline for Greenhouse Gas and Energy Target Management Scheme” approved by Korean Government.
Purpose of data/parameter	Project emission calculations
Additional comments	

Data/parameter:	**$NCV_{LF,y}$**
Unit	TJ/Liter
Description	Net calorific value of by-product liquid fuel
Measured/calculated/default	Measured
Source of data	On-site measurement

Value(s) of monitored parameter	Before 2013, weighted average : 29.26 X 10^{-6}

Year	Quater	Net calorific Value(TJ/Nm^3)
2011	1Q	29.09 X 10^{-6}
	2Q	28.84 X 10^{-6}
	3Q	28.78 X 10^{-6}
	4Q	29.58 X 10^{-6}
2012	1Q	31.25 X 10^{-6}
	2Q	27.60 X 10^{-6}
	3Q	29.37 X 10^{-6}
	4Q	29.50 X 10^{-6}
Weighted average		29.26 X 10^{-6}

After 2013, weighted average : 27.77 X 10^{-6}

Year	Quater	Net calorific Value(TJ/Nm^3)
2013	1Q	27.13 X 10^{-6}
	2Q	27.30 X 10^{-6}
	3Q	28.58 X 10^{-6}
	4Q	27.54 X 10^{-6}
2014	1Q	28.77 X 10^{-6}
	2Q	27.19 X 10^{-6}
	3Q	25.10 X 10^{-6}
	4Q	26.21 X 10^{-6}
2015	1Q	27.97 X 10^{-6}
	2Q	28.07 X 10^{-6}
	3Q	27.41 X 10^{-6}
	4Q	28.98 X 10^{-6}
2016	1Q	28.64 X 10^{-6}
	2Q	28.90 X 10^{-6}
	3Q	29.39 X 10^{-6}
	4Q	28.53 X 10^{-6}
Weighted average		27.77 X 10^{-6}

Monitoring equipment	N/A
Measuring/reading/recording frequency	Quarterly
Calculation method (if applicable)	Measured quarterly and weighted average yearly.
QA/QC procedures	For the reliable value from the quarterly measurement, NCV for by-product liquid fuel were measured by the 3rd party under KOLAS quarterly. NCV for by-product liquid fuel can be crosschecked with the values are verified by 3rd verification body under K-ETS. The NCV value calculation method also conforms to the criteria set out in the regulation such as “Guideline for Greenhouse Gas and Energy Target Management Scheme” approved by Korean Government.
Purpose of data/parameter	Project emission calculations
Additional comments	

Data/parameter:	$\varepsilon_{projcet,y}$
Unit	%
Description	Energy efficiency of the boiler during the year, y
Measured/calculated/default	Calculated
Source of data	Calculated using measured data

Value(s) of monitored parameter	

Year	Quarter	Quarterly	Yearly
2011	1Q 2Q 3Q 4Q	81.75 % 83.78 % 85.04 % 84.37 %	84.14 %
2012	1Q 2Q 3Q 4Q	86.46 % 89.35 % 90.41 % 81.46 %	86.03 %
2013	1Q 2Q 3Q 4Q	94.65 % 96.33 % 94.97 % 92.77 %	94.81 %
2014	1Q 2Q 3Q 4Q	93.97 % 91.48 % 91.59 % 89.73 %	91.67 %
2015	1Q 2Q 3Q 4Q	88.36 % 88.68 % 90.26 % 86.76 %	88.48 %
2016	1Q 2Q 3Q 4Q	86.19 % 91.84 % 93.89 % 93.05 %	90.65 %
Weighted Average			89.28 %

Monitoring equipment	N/A
Measuring/reading/recording frequency	Quarterly
Calculation method (if applicable)	The energy efficiency of the boiler was calculated by the direct method (dividing the net heat generation by the energy content of the fuels fired) at least quarterly.
QA/QC procedures	The meters used for monitoring of the relevant parameters (steam generation, fuel consumption) will be calibrated periodically. Once the erroneous measurement or malfunction is detected, corrective actions will be taken by LG Chem.
Purpose of data/parameter	Project emission calculations
Additional comments	

D.3. Implementation of sampling plan

A sampling approach was not employed.

SECTION E. Calculation of emission reductions or net anthropogenic removals

E.1. Calculation of baseline emissions or baseline net removals

$$EF_{baseline} = FF_{baseline} \times EF_{baseline,CO2} \times NCV_{baseline} / Q_{baseline}$$

$$= 70,730,291(liter) \times 77.4(tCO_2/TJ) \times 39.1 \times 10^{-6}(TJ/liter) / 2,403.73(TJ)$$

$$= 89.05\ tCO_2e/TJ$$

Where:

$FF_{baseline}$	Quantity of bunker fuel oil C combusted in the baseline situation (liter)
$EF_{baseline,CO2}$	CO_2 emission factor of bunker fuel oil C (tCO_2/TJ)
$NCV_{baseline}$	Net calorific value of bunker fuel oil C (TJ/liter)
$Q_{baseline}$	Quantity of steam generated by bunker fuel oil C in the baseline situation (TJ)

For quantity of bunker fuel oil C combusted, $FF_{baseline}$, and quantity of steam generated by bunker fuel oil C, $Q_{baseline}$, 3 years data prior to project implementation (from 1_{st}, November, 2003 to 31_{st}, October 2006) is used.

$$Q_{baseline} = Q_{total,baseline} \times \frac{FF_{baseline} \times NCV_{baseline}}{(FF_{baseline} \times NCV_{baseline} + PG_{baseline} \times NCV_{PG,baseline} + LF_{baseline} \times NCV_{LF,baseline})}$$

= 3,701.09(TJ)×[70,730,291(liter)×39.1×10^{-6}(TJ/liter)]/[70,730,291(liter)×39.1×10^{-6} (TJ/liter)
×13,203,959(Nm^3)×52.15(TJ/liter)×26,297,017(liter)×30.576×10^{-6}(TJ/liter)]

= 2,403.73 TJ

Where:

$Q_{total,baseline}$	Total quantity of steam generated by bunker fuel oil C, waste gas and by-product liquid fuel in the baseline situation (TJ)
$PG_{baseline}$	Quantity of purge gas combusted in the boiler in the baseline situation (Nm^3)
$NCV_{PG,baseline}$	Net calorific value of purge gas (TJ/Nm^3)
$LF_{baseline}$	Quantity of by-product liquid fuel combusted in the boiler in the baseline situation (liter)
$NCV_{LF,baseline}$	Net calorific value of by-product liquid fuel (TJ/liter)

Quantity of steam generated by natural gas, Q_y

Since purge gas and by-product liquid fuel are also combusted in the boiler, the quantity of steam generated by natural gas, Q_y, is calculated based on the proportion of fuel used as follows:

$$Q_y = Q_{total,y} \times \frac{FF_{project,y} \times NCV_{NG,y}}{(FF_{project,y} \times NCV_{NG,y} + PG_y \times NCV_{WG,y} + LF_y \times NCV_{LF,y})}$$

▣ Monitoring period : from 24 February 2012 to 31 December 2012

= 2,123.35(TJ)×[30,902,352(Nm^3)×39.65×10^{-6}(TJ/Nm^3)]/[30,902,352(Nm^3)×39.65×10^{-6} (TJ/Nm^3)
+12,825,597(Nm^3)×57.68×10^{-6}(TJ/Nm^3)+17,694,695(liter)×29.26×10^{-6}(TJ/liter)]
= 1,047.91 TJ

▣ Monitoring period : from 1 January 2013 to 31 October 2016

= 4,128.57(TJ)×[56,601,999(Nm^3)×39.4×10^{-6}(TJ/Nm^3)]/[56,601,999(Nm^3)×39.4×10^{-6} (TJ/Nm^3)
+34,566,201(Nm^3)×39.06×10^{-6}(TJ/Nm^3)+33,831,742(liter)×27.77×10^{-6}(TJ/liter)]
= 2,037.03 TJ

Where:

$Q_{total,y}$	Total quantity of steam generated by natural gas, purge gas and by-product liquid fuel during year, y (TJ)
$FF_{project,y}$	Quantity of natural gas combusted in the project boiler during the year, y (Nm^3)
PG_y	Quantity of purge gas combusted in the boiler during year, y (Nm^3)
$NCV_{PG,y}$	Net calorific value of purge gas (TJ/Nm^3)
LF_y	Quantity of by-product liquid fuel combusted in the boiler during year, y (liter)
$NCV_{LF,y}$	Net calorific value of by-product liquid fuel (TJ/liter)

Baseline emission, BE_y

$$BE_y = EF_{baseline} \times Q_y$$

▣ Monitoring period : from 24 February 2012 to 31 December 2012

= 89.05(tCO_2e/TJ)×1,047.91(TJ)
= 93,316.57 tCO_2e

▣ Monitoring period : from 1 January 2013 to 31 October 2016

= 89.05(tCO_2e/TJ)×2,037.03(TJ)
= 181,397.72 tCO_2e

Where:

BE_y	Baseline emission during the year y (tCO_2e)
$EF_{baseline}$	Baseline emission factor for the baseline situation (tCO_2/TJ)
Q_y	Quantity of steam generated by natural gas (TJ)

E.2. Calculation of project emissions or actual net removals

Project emissions consist of those emissions related with the use of fossil fuel after the fuel switch. Project emissions are calculated as follows:

$$PE_y = FF_{project,y} \times NCV_{NG,y} \times EF_{NG,CO2}$$

▣ Monitoring period : from 24 February 2012 to 31 December 2012

$= 30,902,352(Nm^3) \times 39.65 \times 10^{-6}(TJ/Nm^3) \times 56.10(tCO_2/TJ)$

$= 68,743.53\ tCO_2e$

▣ Monitoring period : from 1 January 2013 to 31 October 2016

$= 56,601,999(Nm^3) \times 39.4 \times 10^{-6}(TJ/Nm^3) \times 56.10(tCO_2/TJ)$

$= 125,109.66\ tCO_2e$

Where:

PE_y	Project emissions during the year, y (tCO_2e)
$FF_{project,y}$	Quantity of natural gas combusted in the project boiler during the year, y (Nm^3)
$NCV_{NG,y}$	Net calorific value of the natural gas combusted in year, y (TJ/Nm^3)
$EF_{NG,CO2}$	CO_2 emission factor of the natural gas combusted in the project boiler (tCO_2/TJ)

E.3. Calculation of leakage emissions

As described in AMS-III.B, no leakage calculation is required.

E.4. Calculation of emission reductions or net anthropogenic removals

	Baseline GHG emissions or baseline net GHG removals (t CO_2e)	Project GHG emissions or actual net GHG removals (t CO_2e)	Leakage GHG emissions (t CO_2e)	GHG emission reductions or net anthropogenic GHG removals (t CO_2e)		
				Before 01/01/2013	From 01/01/2013	Total amount
Total	274,714.29	193,853.19	0	24,573	56,288	80,861

E.5. Comparison of emission reductions or net anthropogenic removals achieved with estimates in the registered PDD

Amount achieved during this monitoring period (t CO_2e)	Amount estimated ex ante (t CO_2e)
80,861 t CO_2e	111,632 tCO_2e

E.6. Remarks on increase in achieved emission reductions

The actual emission reductions achieved during the monitoring period is only 72.4% of the value calculated ex ante in the PDD due to following reasons:

1. Fuel mix of $FF_{project,y}$, PG_y and LF_y was changed. Compared with the ex-ante estimation, the share of PG_y and LF_y have increased, resulting in a change to the baseline as well as the project emission.

2. Steam generation (Q_y) from the system has decreased, due to lower demand of steam at the factory.

3. Increase of down time. Due to various reasons, the boiler was down for 182 days, during the total 2,075 days monitoring period, as indicated in Section B.1 Table 4