

REDUCTION OF GHG EMISSIONS IN PROPYLENE OXIDE PRODUCTION AT MTP HPPO MANUFACTURING CO., LTD.



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Project Title	REDUCTION OF GHG EMISSIONS IN PROPYLENE OXIDE PRODUCTION AT MTP HPPO MANUFACTURING CO., LTD.
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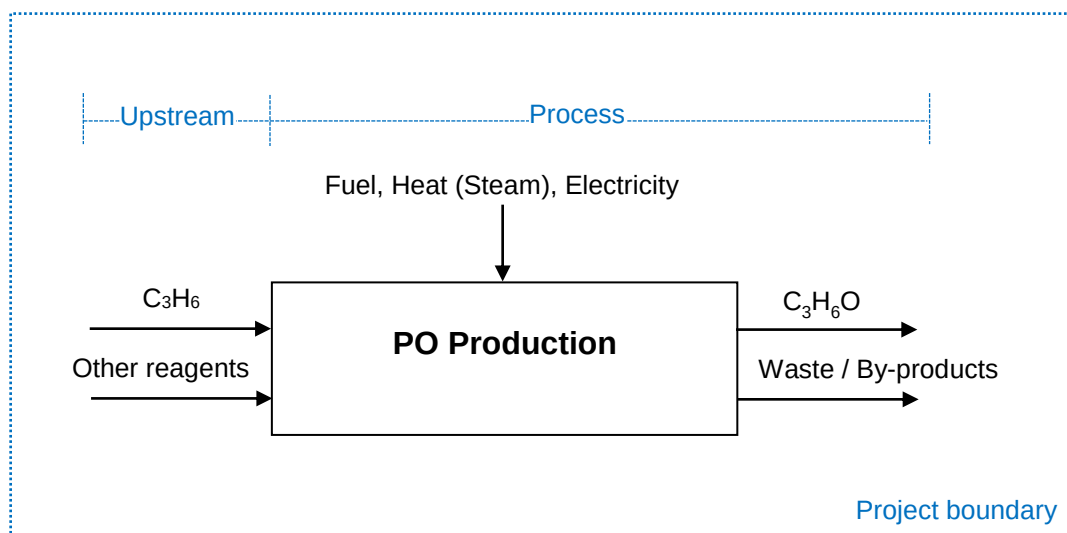
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1 PROJECT DETAILS

1.1 Summary Description of the Implementation Status of the Project

The project involves a new process installation at a production facility of Propylene Oxide (PO) at MTP HPPO Manufacturing Co., Ltd, a joint venture between The Siam Cement Public Co., Ltd and The Dow Chemical Company, which is Hydrogen Peroxide-based Propylene Oxide (HPPO) technology instead of the conventional Chlorohydrin process. The conventional Chlorohydrin process is one of the typical processes in the Propylene Oxide industry that involves hydrochlorination process. In the Chlorohydrin process, Propylene (C_3H_6) is combined to hypochlorous acid to form a Chlorohydrin intermediate which is subsequently dechlorohydrinated to PO and leads to the formation of salts. While in the HPPO process, Propylene and Hydrogen peroxide is combined to produce PO.

The spatial extent of the project boundary encompasses PO manufacturing plant from reagents admission to the treatment of by-products and waste from process.



The project boundary encompasses also the project electricity system(s) and heat/steam generation system that the PO plant is connected to. The spatial extent of the project electricity system consists of the power plants that are physically connected through transmission and distribution lines to the project activity and that can be dispatched without significant transmission constraints. The project is connected to the Glow grid which in turn is connected to the national grid. Therefore, the national grid is considered as the ultimate connected grid.

The spatial extent for the heat (steam) system is similar, including the heat/steam generating systems that are physically connected to the project activity and that can be displaced without significant constraints. The heat (steam) requirements of the project are met by the steam extracted from the cogeneration plants of Glow grid. As the emissions get accounted in the electricity component therefore to avoid double counting and applying conservative principle the emission factor for steam has been considered as zero. The fuel requirement is for incineration purpose. Natural gas is being used as the fuel.

As compared to the conventional processes based on Chlorohydrin technology, the HPPO technology reduces overall energy consumption, thus resulting in significant emission reductions. Furthermore, the HPPO technology diminishes the waste volume also significantly, and decreases the infrastructure requirements and physical footprint by using simpler raw material and avoiding co-products.

The summary of implementation status of the project activity is as follow:

Events	Date
Commission of the project activity	04/10/2011
Registration date under VCS	05/01/2016
First monitoring period	04/10/2011 - 31/03/2014

This monitoring report is for the second verification of the first crediting period. The project has achieved 720,991 tCO₂e in this monitoring period. Further background information on this project can be found in the VCS website: http://www.vcsprojectdatabase.org/#/project_details/1502

1.2 Sectoral Scope and Project Type

The project activity falls under the category 5, chemical industry. The project is a single project activity and not a grouped project.

1.3 Project Proponent

Organization name	MTP HPPO Manufacturing Co.,Ltd.
Contact person	Mr. Chatchai Luanpolcharoenchai
Title	Thailand Country President
Address	15th Floor, White Group Building II, 75 Soi Rubia, Sukumvit 42 Road, Prakanong, Klongtoey, Bangkok, Thailand.
Telephone	+66 2 365 7000
Email	

1.4 Other Entities Involved in the Project

Organization name	South Pole Carbon (Thailand) Co.,Ltd.
Role in the project	Consultant
Contact person	Ms. Ladaporn Khunikakorn
Title	Regional Director Southeast Asia
Address	2/22 Iyara Building, 6 th Floor, Chan Road, Thungwatdon Sathorn, Bangkok 10120, Thailand
Telephone	+66 2 678 8979
Email	registration@southpole.com

1.5 Project Start Date

The project start date is 04/10/2011 which is the actual commissioning date of the new HPPO technology at MTP HPPO Manufacturing Co.,Ltd.

1.6 Project Crediting Period

This crediting period of this project is 10 years. Starting from 04/10/2011 to 03/10/2021. The crediting period may be renewed twice.

1.7 Project Location

The project activity is located at 10 Moo 2, Asia Industrial Estate, Banchang, Rayong, Thailand (<http://www.dow.com/thailand/about/locations.htm>). The coordinate of the production facility are:

Latitude: 12.702612; Longitude 101.095079

The project location is also shown in the following figure.





Figure 1: Project Location

1.8 Title and Reference of Methodology

The emission reduction calculations and the monitoring plan are based on the approved VCS methodology;

VM0023 : Reduction of GHG emissions in Propylene Oxide production
Sectoral scope : 5
Version : 1.0

The methodology can be found on the VERRA's website at the following address:

<https://verra.org/methodology/vm0023-reduction-of-ghg-emissions-in-propylene-oxide-production-v1-0/>

The above selected methodology also refers to the approved versions of the following methodological tools:

- Tool to calculate the emission factor for an electricity system, Version 4.0;
- Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion, Version 2.

The methodological tools can be found on the UNFCCC's website at the following address:

<http://cdm.unfccc.int/methodologies/SSCmethodologies/approved>

1.9 Other Programs

- Emission Trading Programs and Other Binding Limits:

The project is registered under VCS and does not reduce GHG emissions from activities that are included in an emissions trading program or any other mechanism that included GHG allowance.

- Other Forms of Environmental Credit

The project does not seek or receive another form of GHG-related environmental credit including renewable energy certificates during this monitoring period.

- Participation under Other GHG Programs

The project is registered under VCS and will not be registered under any other GHG programs.

1.10 Sustainable Development

The proposed project activity has been assessed in line with the sustainable development per as

1. National Resource and Environmental Dimension

As compared to the conventional processes based on Chlorohydrin technology, the HPPO technology reduces overall energy consumption, thus resulting in significant emission reductions. Furthermore, the HPPO technology diminishes the wastewater volume also significantly, and decreases the infrastructure requirements and physical footprint by using simpler raw material and avoiding co-products.

2. Social Dimension

The project activity provides direct and indirect employment to the local community. The involvement of local employees in the project activity helps to enhance the skills of the labour in the region by training them in different technical areas. In addition, the close collaboration between external experts and local counterparts is expected to promote long-term sustainable partnerships, benefiting the local stakeholders. The safety aspects of operating the biogas plant are sufficiently addressed.

3. Development/ Transfer of Technology

The project involves the use of some imported components and hence the transfer of technology from outside the country which provides an opportunity to promote and disseminate the successful application and integration of technologies for replication across Thailand. Also, the locally produced equipment may be put to use in other parts of Thailand for similar purposes. Geographically, transfer of technology and know-how has occurred mainly from urban to rural areas.

4. Economic Dimension

The project activity increases the employment opportunities for the local people by setting up an industrial unit in the area. The project activity contributed to the employment of local people both in the skilled and semi-skilled category during the construction phase. Regional economic development can foster through contracts to local firms.

2 IMPLEMENTATION STATUS

2.1 Implementation Status of the Project Activity

During June 2008, SCG-Dow Group, a joint venture between The Dow Chemical Company and The Siam Cement Group (SCG) broke ground on a 390,000 tonnes per annum of propylene oxide (PO) plant. Full capacity run was achieved in November 2011. The plant fulfilled all quality and production parameters.

Within this monitoring period, there were no significant occurrences of events, which affected the project activity within the project boundary.

2.2 Deviations

2.2.1 Methodology Deviations

There is no methodology deviations.

2.2.2 Project Description Deviations

Description of deviation

The accuracy of the installed flow meter for monitoring the amount of Sol_y is not consistent with the accuracy identified in the registered PD, which is +/- 0.15% of reading.

The actual accuracy in the technical specification document is +/-0.65% of reading for the same type and model of meter.

This model of flow meter has been installed since the commissioning of project activity and used for measuring the amount of Sol_y for this entire monitoring period. This flow meter was checked during the validation site visit. The value mentioned in the registered PD may be a typographical error.

Justification for project description deviation

The technical specification of the installed flow meters provided by the manufacturer's is;

Brand	Rosemount
Type	Vortex
Model	8800DF020SA1N2D1E5T1CNQ4
Accuracy	+/- 0.65% of reading

Source : [Product Data Sheet](#)

The accuracy of this type of flow meter reported in this monitoring report is changed from +/- 0.15% to be +/- 0.65%.

This deviation does not impact the applicability of the methodology, additionality or the appropriateness of the baseline scenario, and the project remains in compliance with the applied methodology.

2.3 Grouped Project

This is not a grouped project.

2.4 Safeguards

2.4.1 No Net Harm

There is no negative environmental and socio-economic impact.

2.4.2 Local Stakeholder Consultation

A stakeholder consultation was conducted before the implementation of the proposed VCS project activity on the 3rd of February 2010 as part of the EIA. The invitation letter was sent out as well as announcement made publicly. In addition, the project also organized several following up group consultation in order to make sure that most of relevant stakeholders had expressed their opinion and concern on the project. The results of such public hearings were positive.

Invitation letter

เรื่อง ขอเข้าพบสนทนากลุ่ม เพื่อรับฟังความคิดเห็นในขั้นตอนการประเมินผลกระทบ
และจัดทำรายงานการวิเคราะห์ผลกระทบสิ่งแวดล้อมและสุขภาพ

เรียน นายกเทศมนตรีตำบลบ้านฉาง

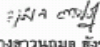
สิ่งที่ส่งมาด้วย ประเด็นการสนทนากลุ่มย่อย

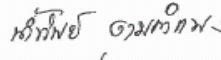
ตามที่ บริษัท ยูไนเต็ด แอนนาลิสต์ แอนด์ เอ็นจิเนียริง คอนซัลแตนท์ จำกัด ซึ่งเป็นหนึ่งในกลุ่มบริษัทที่ปรึกษาที่ได้รับการว่าจ้างจากกลุ่มบริษัท ดาว ในประเทศไทย และ กลุ่มบริษัท โซลเวย์ ให้เป็นที่ปรึกษาในการดำเนินการประเมินผลกระทบต่อสุขภาพ โครงการก่อสร้างและขยายโรงงานอุตสาหกรรมปิโตรเคมี ในพื้นที่นิคมอุตสาหกรรมเอเชีย อำเภอบ้านฉาง จังหวัดระยอง ซึ่งได้ดำเนินการจัดประชุมรับฟังความคิดเห็นในเวทีกำหนดขอบเขตและแนวทางการประเมินผลกระทบด้านสิ่งแวดล้อมและสุขภาพโดยสาธารณะ (Public Scoping) ของโครงการ เมื่อวันที่ 3 กุมภาพันธ์ 2553 แล้วนั้น

ในการนี้ บริษัท ยูไนเต็ด แอนนาลิสต์ แอนด์ เอ็นจิเนียริง คอนซัลแตนท์ จำกัด ขอเข้าพบสนทนากลุ่ม เพื่อรวบรวมข้อมูลการจัดการอนามัยสิ่งแวดล้อม และการจัดการด้านสาธารณสุข รวมทั้ง นำเสนอการประเมินผลกระทบสิ่งแวดล้อมและสุขภาพ และมาตรการป้องกัน แก้ไขผลกระทบสิ่งแวดล้อมและสุขภาพของโครงการ (รายละเอียดสิ่งที่ส่งมาด้วย) จึงขอเชิญ ในวันที่ 15 มีนาคม 2553 เวลา 13.30 - 15.30 น. ณ เทศบาลตำบลบ้านฉาง ทั้งนี้ขอความอนุเคราะห์ในการเชิญผู้แทนของสาธารณสุขและสิ่งแวดล้อม และผู้แทนฝ่ายป้องกันและบรรเทาสาธารณภัยของเทศบาลฯ เข้าร่วมประชุม ตามวันและเวลาดังกล่าว เพื่อร่วมแสดงความคิดเห็นและข้อเสนอแนะที่จะเป็นประโยชน์สำหรับให้บริษัทฯ ให้นำมาปรับปรุงแนวทางการประเมินผลกระทบด้านสุขภาพให้ครอบคลุมประเด็นวิกฤตกังวลให้มากที่สุด พร้อมทั้ง ขออนุเคราะห์ห้องประชุมของเทศบาลตำบลบ้านฉาง เป็นสถานที่จัดสนทนากลุ่มในครั้งนี้ ซึ่งคาดว่าจะมีผู้เข้าร่วมประชุมประมาณ 8-10 คน

จึงเรียนมาเพื่อโปรดพิจารณา และขอขอบคุณ ณ โอกาสนี้

ขอแสดงความนับถือ


(นางสาวนฤมล ตั้งประเสริฐ)
ผู้จัดการโครงการ


ส.ค. 53

ผู้ประสานงาน นางสาวอริฎา อุบัติทอง
ฝ่ายศึกษาและจัดการสิ่งแวดล้อม
โทร. 02-7632828 ต่อ 2903 โทรสาร 02-7632839

Public announcement (in 4 areas)



Stakeholder consultation



Registration form

[illegible]

3 DATA AND PARAMETERS

3.1 Data and Parameters Available at Validation

Data / Parameter	EC _{Chlor-Alkali, y}
Data unit	MWh/tCl ₂
Description	Energy consumption per tonne of Cl ₂ production in year y
Source of data	Independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.
Value applied	2.2
Justification of choice of data or description of measurement methods and procedures applied	The membrane cell process is the preferred process for new PO production facilities. Thus, it is assumed that production of chlor-alkali in the baseline PO production facility is through the membrane cell process ¹ .
Purpose of the data	Calculation of baseline emissions
Comments	-

Data / Parameter	SSC _{CHPO}
Data unit	TJ/tonne of PO
Description	Specific thermal energy consumption ratio in PO production through the CHPO-chlor-alkali process.
Source of data	Independent third party report
Value applied	0.003864
Justification of choice of data or description of measurement methods and procedures applied	Steam consumption is converted conservatively into energy terms using enthalpy values and accounting for any condensate return
Purpose of the data	Calculation of baseline emissions
Comments	Nexant report on HPPO, Table 4.3 and 4.5 This parameter is not considered in both baseline scenario and is conservative since baseline thermal energy consumption is higher as compared to project.

¹ <http://www.miga.org/documents/ChlorAlkali.pdf>

Data / Parameter	SEC _{CHPO}
Data unit	MWh/tonne of PO
Description	Specific electrical energy consumption ratio in PO production through the CHPO-chlor-alkali process.
Source of data	Independent third party report
Value applied	0.100
Justification of choice of data or description of measurement methods and procedures applied	Electrical energy required per ton of the PO in the CHPO process excluding the chlor-alkali production
Purpose of the data	Calculation of baseline emissions
Comments	Nexant report on HPPO, Table 4.5

Data / Parameter	pe _{HP}
Data unit	tCO ₂ /tH ₂ O ₂
Description	Quantity of CO ₂ that would be emitted per tonne of H ₂ O ₂
Source of data	Independent third party report
Value applied	0.533
Justification of choice of data or description of measurement methods and procedures applied	Amount of CO ₂ expected to be released per ton of the H ₂ O ₂ production based on Life Cycle Assessment (LCA) study
Purpose of the data	Calculation of baseline emissions
Comments	Sourced from certified environmental product declaration (EPD) for hydrogen peroxide

Data / Parameter	pe _{Sol}
Data unit	tCO ₂ /tonne of solvent
Description	Quantity of CO ₂ emitted per tonne of solvent
Source of data	Table 3.12, Chapter 3: Chemical Industry Emissions, IPCC 2006 report
Value applied	0.310
Justification of choice of data or description of measurement methods and procedures applied	-

Purpose of the data	Calculation of project emissions
Comments	-

Data / Parameter	$Ca_{Waste,Baseline}$
Data unit	tC/tonne of PO
Description	Carbon amount in the waste stream combusted in the incinerator in the baseline per tonne of PO
Source of data	-
Value applied	-
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of the data	Calculation of baseline emissions
Comments	Excluded for simplification

Data / Parameter	$f_{Ci,Baseline}$
Data unit	Ratio
Description	Quantity of fossil fuel combusted in the incinerator in the baseline per tonne of PO production
Source of data	-
Value applied	-
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of the data	Calculation of baseline emissions
Comments	Excluded for simplification

Data / Parameter	$EF_{EL,y}$
Data unit	tCO ₂ /MWh
Description	Emission factor for electricity generation in year y
Source of data	Electricity Generating Authority of Thailand (EGAT)
Value applied	0.5113
Justification of choice of	The emission factor is calculated according to the latest 'Tool to

data or description of measurement methods and procedures applied	calculate the emission factor for an electricity system' Version 4.0 provided by Thailand Greenhouse Gas Management Organization (Public Organization).
Purpose of the data	Calculation of baseline and project emissions
Comments	Although the emission factor provided by the Thai DNA refers to version 2.2.1 of the tool. However, the changes from version 2.2.1 to version 4.0 of the tool do not impact the computation in the context of Thailand.

3.2 Data and Parameters Monitored

Data / Parameter	PO _y																							
Data unit	tonnes																							
Description	Quantity of PO produced in year y																							
Source of data	Plant records																							
Description of measurement methods and procedures to be applied	Continuous measurement using flowmeter and cross-checking the data with stock verification records																							
Frequency of monitoring/recording	Continuous monitoring, integrated daily and at least monthly recordings																							
Value monitored	The lower and higher values from the plant records and stock records were applied in the calculation of baseline and project emissions for conservativeness. <table><tr><th rowspan="2">Monitoring period</th><th colspan="3">Value</th></tr><tr><th>Monitored</th><th>Lower</th><th>Higher</th></tr><tr><td>01/04/2014 to 31/12/2014</td><td>211,033</td><td>210,716</td><td>211,556</td></tr><tr><td>01/01/2015 to 31/12/2015</td><td>423,741</td><td>423,106</td><td>424,682</td></tr><tr><td>01/01/2016 to 31/12/2016</td><td>422,222</td><td>421,589</td><td>422,855</td></tr><tr><td>01/01/2017 to 31/12/2017</td><td>426,048</td><td>425,271</td><td>426,687</td></tr></table>	Monitoring period	Value			Monitored	Lower	Higher	01/04/2014 to 31/12/2014	211,033	210,716	211,556	01/01/2015 to 31/12/2015	423,741	423,106	424,682	01/01/2016 to 31/12/2016	422,222	421,589	422,855	01/01/2017 to 31/12/2017	426,048	425,271	426,687
Monitoring period	Value																							
	Monitored	Lower	Higher																					
01/04/2014 to 31/12/2014	211,033	210,716	211,556																					
01/01/2015 to 31/12/2015	423,741	423,106	424,682																					
01/01/2016 to 31/12/2016	422,222	421,589	422,855																					
01/01/2017 to 31/12/2017	426,048	425,271	426,687																					

Monitoring equipment	Tag no.	FT-4262-01
	Equipment type	Coriolis mass flowmeter
	Manufacturer	Endress+Hauser
	Model	PROMASS 80F
	Maximum permissible error	$\pm 0.15\%^2$
	Serial no.	D3037716000
	Date of calibration	08/01/2019
	Validity	07/01/2024
QA/QC procedures to be applied	Meters are calibrated every 5 years according to the shutdown plan of HPPO plant. Cross-checking data with stock inventory.	
Purpose of the data	Calculation of baseline and project emissions	
Calculation method	Not applicable	
Comments	Since the calibration of the equipment was conducted on 08/01/2019 which was not in line with the calibration frequency, the measured values from 01/04/2014 to 31/12/2017 have been adjusted by applying the maximum permissible error ($\pm 0.15\%$) in a conservative manner. The details can be found in the calculation sheet.	

Data / Parameter	Soly
Data unit	tonnes
Description	Quantity of make-up solvent used in year y.
Source of data	PO production facility records.
Description of measurement methods and procedures to be applied	Continuous measurement using flowmeter and cross-checking the data with stock verification records
Frequency of monitoring/recording	Data monitoring was continuous and aggregate recording must be performed at least monthly.
Value monitored	The higher value between the plant records and stock records was applied in the calculation of project emissions for conservativeness.

² https://portal.endress.com/wa001/dla/5000275/1921/000/01/TI101DEN_0210.pdf

	Monitoring period	Value	
		Monitored	Higher
	01/04/2014 to 31/12/2014	10,986	11,224
	01/01/2015 to 31/12/2015	20,278	20,327
	01/01/2016 to 31/12/2016	21,068	21,205
	01/01/2017 to 31/12/2017	18,098	18,615
Monitoring equipment			
	Tag no.	FT-7409-02	
	Equipment type	Vortex flowmeter	
	Manufacturer	ROSEMOUNT	
	Model	8800DF020SA1N2D 1E5T1CNQ4	
	Maximum permissible error	±0.65% ³	
	Serial no.	06015616	
	Date of calibrations	05/08/2010 08/12/2018	
	Validity	07/12/2023	
QA/QC procedures to be applied	Meters are calibrated every 5 years according to the shutdown plan of HPPO plant. Cross-checking data with stock inventory.		
Purpose of the data	Calculation of project emissions		
Calculation method	Not applicable		
Comments	The sol _y as found in equation 12 was used only for ex-ante estimations. For ex-post calculations, “sol _y x PO _y ” is represented by Sol _y in equation 12, the value of which was monitored in accordance with the procedures described above.		
	Since the calibration of the equipment was conducted on		

³ Page no.29 of the [technical specification](#)

	08/12/2018 which was not in line with the calibration frequency, the measured values from 01/08/2015 ⁴ to 31/12/2017 have been adjusted by applying the maximum permissible error ($\pm 0.65\%$) in a conservative manner. The details can be found in the calculation sheet.
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Data / Parameter	EF _{CO₂,i,y}				
Data unit	tCO ₂ /TJ				
Description	Weighted average CO ₂ emission factor of fossil fuel used during year y				
Source of data	Default value from IPCC Table 2.3: Default emission factors for stationary combustion in manufacturing industries and construction ⁵				
Description of measurement methods and procedures to be applied	Onsite observation				
Frequency of monitoring/recording	Annually				
Value monitored	<table border="1"> <thead> <tr> <th>Fuel type</th><th>Value</th></tr> </thead> <tbody> <tr> <td>Natural gas</td><td>56.1</td></tr> </tbody> </table>	Fuel type	Value	Natural gas	56.1
Fuel type	Value				
Natural gas	56.1				
Monitoring equipment	-				
QA/QC procedures to be applied	-				
Purpose of the data	Calculation of baseline and project emissions				
Calculation method	-				
Comments	International publicly available data				

Data / Parameter	$\eta_{\text{Boiler},y}$
Data unit	%
Description	Efficiency of the steam generating system
Source of data	-
Description of measurement methods and procedures to be applied	-

⁴ The actual gap started from 05/08/2015. However, since the data was recorded as monthly basis, the error applied for the whole month of August 2015.

⁵ http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

applied	
Frequency of monitoring/recording	-
Value monitored	-
Monitoring equipment	-
QA/QC procedures to be applied	-
Purpose of the data	Calculation of baseline and project emissions
Calculation method	-
Comments	This parameter is not considered in both baseline and project scenario and is conservative since baseline energy consumption is higher as compared to project. Source: Nexant report on HPPO, Table 4.3 & 4.5

Data / Parameter	SC _{HPPO,y}											
Data unit	TJ											
Description	Thermal energy consumption in the PO production through HPPO process in year y											
Source of data	Plant records											
Description of measurement methods and procedures to be applied	Steam consumption would be converted conservatively into energy terms using enthalpy values and accounting for any condensate return.											
Frequency of monitoring/recording	Calculated											
Value monitored	As per the registered PD, the parameter was not considered in both baseline and project scenario. <table><tr><th>Monitoring period</th><th>Value</th></tr><tr><td>01/04/2014 to 31/12/2014</td><td>582</td></tr><tr><td>01/01/2015 to 31/12/2015</td><td>1,178</td></tr><tr><td>01/01/2016 to 31/12/2016</td><td>1,183</td></tr><tr><td>01/01/2017 to 31/12/2017</td><td>1,151</td></tr></table>		Monitoring period	Value	01/04/2014 to 31/12/2014	582	01/01/2015 to 31/12/2015	1,178	01/01/2016 to 31/12/2016	1,183	01/01/2017 to 31/12/2017	1,151
Monitoring period	Value											
01/04/2014 to 31/12/2014	582											
01/01/2015 to 31/12/2015	1,178											
01/01/2016 to 31/12/2016	1,183											
01/01/2017 to 31/12/2017	1,151											
Monitoring equipment	<table><tr><td>Tag no.</td><td>FT-9500-01</td></tr><tr><td>Equipment type</td><td>Annubar flowmeter</td></tr><tr><td>Manufacturer</td><td>ROSEMOUNT</td></tr></table>		Tag no.	FT-9500-01	Equipment type	Annubar flowmeter	Manufacturer	ROSEMOUNT				
Tag no.	FT-9500-01											
Equipment type	Annubar flowmeter											
Manufacturer	ROSEMOUNT											

	Model	3051SFADS240ZCHFS3A3D 0072AA1B2G9E1F2F0052
	Maximum permissible error	$\pm 0.8\%$ ⁶
	Serial no.	02209215
	Date of calibration	05/01/2011
	Tag no.	TT-9500-01
	Equipment type	RTD (PT100)
	Manufacturer	ABB
	Model	A5Y0W9S3D1D6P3D2L1H4 /OPT
	Maximum permissible error	$\pm 0.06\%$
	Serial no.	210000853587001
	Date of calibration	17/05/2011
	Tag no.	PT-9500-01
	Equipment type	Pressure transmitter
	Manufacturer	ROSEMOUNT
	Model	3051CA3A02A1BK6H2L4 T1P1CN
	Maximum permissible error	$\pm 1.0\%$
	Serial no.	2284871
	Date of calibration	17/05/2011
QA/QC procedures to be applied	Cross-checking with thermal energy purchase receipt from the thermal supplier	
Purpose of the data	Calculation of project emissions	
Calculation method	The respective enthalpies should be determined based on the mass (or volume) flows, the temperatures and, in case of superheated steam, the pressure. Steam tables or appropriate thermodynamic equations may be used to calculate the enthalpy as a function of temperature and pressure.	
Comments	This parameter was not considered in both baseline and	

⁶ Page 4 of the [technical specification](#)

	project scenario and was conservative since baseline thermal energy consumption was higher as compared to project. Source: Nexant report on HPPO, Table 4.3 & 4.5
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Data / Parameter	EC _{HPPO,y}																			
Data unit	MWh																			
Description	Electrical energy consumption in the PO production through HPPO process in year y																			
Source of data	Plant records																			
Description of measurement methods and procedures to be applied	Electrical consumption to be monitored continuously and the average specific electrical energy consumption to be calculated based on PO production																			
Frequency of monitoring/recording	Continuous monitoring, integrated daily and at least monthly recordings																			
Value monitored	The higher value between the plant records and invoices was applied in the calculation of project emissions for conservativeness. <table><tr><th rowspan="2">Monitoring period</th><th colspan="2">Value</th></tr><tr><th>Monitored</th><th>Higher</th></tr><tr><td>01/04/2014 to 31/12/2014</td><td>125,680</td><td>125,680</td></tr><tr><td>01/01/2015 to 31/12/2015</td><td>246,537</td><td>247,370</td></tr><tr><td>01/01/2016 to 31/12/2016</td><td>247,908</td><td>249,148</td></tr><tr><td>01/01/2017 to 31/12/2017</td><td>247,077</td><td>248,312</td></tr></table>			Monitoring period	Value		Monitored	Higher	01/04/2014 to 31/12/2014	125,680	125,680	01/01/2015 to 31/12/2015	246,537	247,370	01/01/2016 to 31/12/2016	247,908	249,148	01/01/2017 to 31/12/2017	247,077	248,312
Monitoring period	Value																			
	Monitored	Higher																		
01/04/2014 to 31/12/2014	125,680	125,680																		
01/01/2015 to 31/12/2015	246,537	247,370																		
01/01/2016 to 31/12/2016	247,908	249,148																		
01/01/2017 to 31/12/2017	247,077	248,312																		
Monitoring equipment	There are 4 power meters for measurement of electrical energy consumption. <table><tr><td>Tag no. / Serial no.</td><td>1) JT700211ACalc / BF0908074311 2) JT700214ACalc / BF0908074313</td></tr></table>			Tag no. / Serial no.	1) JT700211ACalc / BF0908074311 2) JT700214ACalc / BF0908074313															
Tag no. / Serial no.	1) JT700211ACalc / BF0908074311 2) JT700214ACalc / BF0908074313																			

		3) JT700220ACalc / BF0908074317 4) JT700223ACalc / BF0908074314
	Equipment type	7KG7750-0GA01-0AA0
	Manufacturer	SIEMENS
	Model	SIMEAS P50
	Maximum permissible error	±0.5%
	Date of calibrations	14/05/2010 13/07/2018
	Validity	12/07/2023
QA/QC procedures to be applied	Meters are calibrated regularly every 5 years according to the shutdown plan of HPPO plant.	
Purpose of the data	Calculation of project emissions	
Calculation method	-	
Comments	Since the calibration of the equipment was conducted on 13/07/2018 which was not in line with the calibration frequency, the measured values from 01/05/2015 ⁷ to 31/12/2017 have been adjusted by applying the maximum permissible error (±0.50%) in a conservative manner. The details can be found in the calculation sheet.	

Data / Parameter	Q _{Propylene,y}
Data unit	Tonnes
Description	Quantity of propylene used in year y
Source of data	PO production facility records
Description of measurement methods and procedures to be applied	Continuous measurement using flowmeter and cross-checking the data with stock verification records
Frequency of monitoring/recording	Data monitoring was continuous and aggregate recording must be performed at least monthly
Value monitored	The higher value between the plant records and stock

⁷ The actual gap started from 14/05/2015. However, since the data was recorded as monthly basis, the error applied for the whole month of May 2015.

	records was applied in the calculation of project emissions for conservativeness.		
	Monitoring period	Value	
		Monitored	Higher
	01/04/2014 to 31/12/2014	168,009	168,009
	01/01/2015 to 31/12/2015	332,487	332,785
	01/01/2016 to 31/12/2016	333,681	334,964
	01/01/2017 to 31/12/2017	335,963	337,443
Monitoring equipment			
	Tag no.	FT-1164-01	
	Equipment type	Coriolis mass flowmeter	
	Manufacturer	Endress+Hauser	
	Model	PROMASS 80F	
	Maximum permissible error	±0.15% ⁸	
	Serial no.	D3036216000	
	Date of calibration	04/06/2010 10/03/2018	
Validity	09/03/2023		
QA/QC procedures to be applied	Meters are calibrated every 5 years according to the shutdown plan of HPPO plant. Cross-checking data with stock inventory		
Purpose of the data	Calculation of project emissions		
Calculation method	-		
Comments	Since the calibration of the equipment was conducted on 10/03/2018 which was not in line with the calibration frequency, the measured values from 01/06/2015 ⁹ to 31/12/2017 have been adjusted by applying the maximum permissible error (±0.15%) in a conservative manner. The details can be found in the calculation		

⁸ Page no.17 of the [technical specification](#)

⁹ The actual gap started from 04/06/2015. However, since the data was recorded as monthly basis, the error applied for the whole month of June 2015.

	sheet.
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Data / Parameter	Q _{By-product,y}		
Data unit	Tonnes		
Description	Quantity of by-product produced in year y		
Source of data	PO production facility records		
Description of measurement methods and procedures to be applied	Continuous measurement using flowmeter and cross-checking the data with stock verification records		
Frequency of monitoring/recording	Data monitoring is continuous and aggregate recording must be performed at least monthly.		
Value monitored	The lower value between the plant records and stock records was applied in the calculation of project emissions for conservativeness.		
	Monitoring period	Value	
		Monitored	Lower
	01/04/2014 to 31/12/2014	1,478	1,408
	01/01/2015 to 31/12/2015	4,503	3,942
	01/01/2016 to 31/12/2016	4,631	4,542
	01/01/2017 to 31/12/2017	5,318	5,244
Monitoring equipment			
	Tag no.	FIT-7220-01	
	Equipment type	Ultrasonic	
	Manufacturer	KROHNE	
	Model	UFS3000	
	Maximum permissible error	±0.5% ¹⁰	
	Serial no.	A1071567	
Date of calibration	17/05/2010 06/12/2018		

¹⁰ Page no.4 of the [technical specification](#)

	Validity	05/12/2023
QA/QC procedures to be applied	Meters are calibrated every 5 years according to the shutdown plan of HPPO plant. Cross-checking data with stock inventory	
Purpose of the data	Calculation of project emissions	
Calculation method	-	
Comments	Since the calibration of the equipment was conducted on 06/12/2018 which was not in line with the calibration frequency, the measured values from 01/05/2015 ¹¹ to 31/12/2017 have been adjusted by applying the error identified in calibration test ($\pm 1.406\%$) in a conservative manner. The details can be found in the calculation sheet.	

Data / Parameter	FC _{i,y}																
Data unit	MMBTU (volume unit)																
Description	Quantity of NG combusted in the incinerator during the year y																
Source of data	NG supplied by PTT																
Description of measurement methods and procedures to be applied	Measured through turbine meter																
Frequency of monitoring/recording	-																
Value monitored	The higher value between the plant records and stock records was applied in the calculation of project emissions for conservativeness. <table><tr><th rowspan="2">Monitoring period</th><th colspan="2">Value</th></tr><tr><th>Monitored¹²</th><th>Higher</th></tr><tr><td>01/04/2014 to 31/12/2014</td><td>104,727</td><td>143,227</td></tr><tr><td>01/01/2015 to 31/12/2015</td><td>302,713</td><td>384,265</td></tr><tr><td>01/01/2016 to 31/12/2016</td><td>278,475</td><td>363,932</td></tr></table>			Monitoring period	Value		Monitored ¹²	Higher	01/04/2014 to 31/12/2014	104,727	143,227	01/01/2015 to 31/12/2015	302,713	384,265	01/01/2016 to 31/12/2016	278,475	363,932
Monitoring period	Value																
	Monitored ¹²	Higher															
01/04/2014 to 31/12/2014	104,727	143,227															
01/01/2015 to 31/12/2015	302,713	384,265															
01/01/2016 to 31/12/2016	278,475	363,932															

¹¹ The actual gap started from 17/05/2015. However, since the data was recorded as monthly basis, the error applied for the whole month of May 2015.

¹² The value was monitored in Nm³ unit. The factor of 0.0411 MMBTU/Nm³ is used to convert the value in Nm³ to MMBTU unit.

	01/01/2017 to 31/12/2017	241,549	338,891	
Monitoring equipment	There are 2 meters belongs to PTT company (natural gas supplier)			
	Tag no. / Serial no.	1) 330-FY-6502A / 3401877930 2) 330-FY-6502B / 3401117178		
	Equipment type	Turbine meter with gas volume converter		
	Manufacturer	Itron		
	Maximum permissible error	±0.2% ¹³		
	Date of calibrations	20/07/2017 19/07/2018		
QA/QC procedures to be applied	The meter belongs to PTT and installed on PTT skid.			
Purpose of the data	Calculation of project emissions			
Calculation method	-			
Comments	Since the calibration of the equipment was conducted on 20/07/2017 which was not in line with the calibration frequency, the measured values from 01/04/2014 to 31/07/2017 ¹⁴ have been adjusted by applying the maximum permissible error (±0.2%) in a conservative manner. The details can be found in the calculation sheet.			

Data / Parameter	COEF _{i,y}
Data unit	tCO ₂ /t of Natural gas
Description	CO ₂ emission coefficient of Natural gas
Source of data	IPCC
Description of measurement methods and procedures to be applied	Publicly available national data
Frequency of monitoring/recording	As per the "Tool to calculate project or leakage CO ₂

¹³ Page no.2 of the [technical specification](#)

¹⁴ The actual gap was up to 19/07/2017. However, since the data was recorded as monthly basis, the error applied for the whole month of July 2017.

	emissions from fossil fuel combustion", Version 2
Value monitored	2.6928
Monitoring equipment	-
QA/QC procedures to be applied	-
Purpose of the data	Calculation of project emissions
Calculation method	Based on option B, equation 4 of the tool. NCV = 48.0 TJ/Gg (IPCC 2006, Energy volume: Overview, Table 1.2) EF = 56.1 Tons/TJ (IPCC 2006, Energy volume: Overview, Table 1.4)
Comments	Conversion of volume units to energy units: $1 \text{ Nm}^3 = 0.0433 \text{ GJ}^{15}$

3.3 Monitoring Plan

Monitoring Management

The required monitoring equipment are installed and monitoring procedures followed as mentioned in section 4.2 of the VCS-PD. The data is recorded on a continuous basis or as indicated in section 4.2 and recorded in the logs. The data is kept in both soft and hard copy format and proper data backups maintained. The calibration of monitoring equipment is done on regular intervals at site, based on master equipments traceable to industry/national standards.

All the staff are trained by the company on how to operate the plant as well as monitor the required data under the VCS methodology. General outline of operation and management of the project activity is as follows:

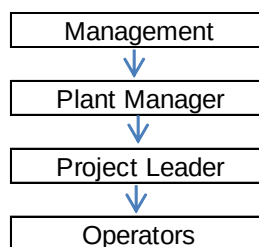


Figure 2: Monitoring diagram

¹⁵ Source: http://agnatural.pt/documentos/ver/natural-gas-conversion-guide_cb4f0ccd80ccaf88ca5ec336a38600867db5aaf1.pdf

The above flow diagram from the registered PD has been followed as monitoring plan, as well as for plant's routine monitoring system.

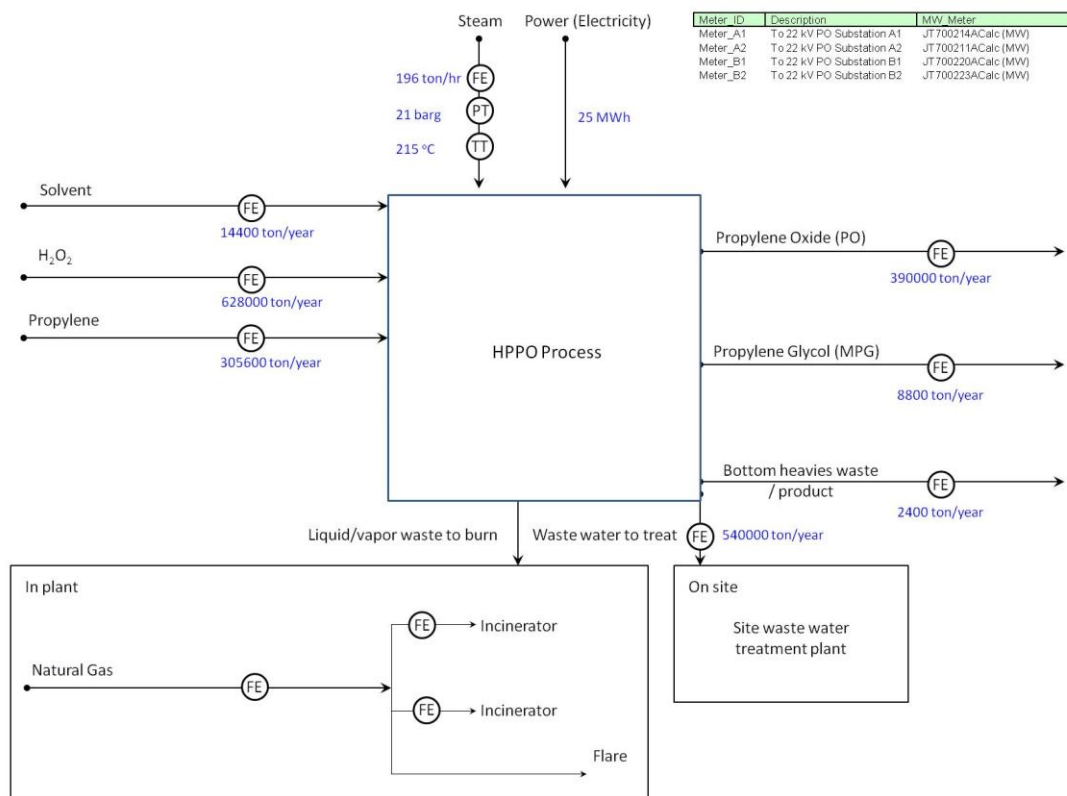


Figure 3: Monitoring diagram

Monitoring System

All meters are recorded under MES (Manufacturing Execution Suit/IP21) server according to DOW standard.

ARCHIVING

- Archiving is the process to save the IP21 process data and retain it for 5 or 75 years
- Archiving jobs are run by the IBM BUR (Backup & Restore) team every two weeks
- Archive jobs are monitored for failure and Service Request cases are submitted for investigation
- Random archive restores to verify that the process works are not performed
- The MES Archiving website at the link below has details on the archive data restore procedures

BACKUPS

- Backups are performed to restore the system in the event of a catastrophic failure
- Backups of the server are performed daily by the IBM BUR (Backup & Restore) team

- Backups are done on the C, D, E drives (the other drives can be rebuilt and restored)
- Backups are retained for 30 days
- Backup jobs are monitored for failure by the BUR team and Service Request cases are submitted for investigation

Quality assurance and quality control

The project leader monitors the overall plant's performance, ensuring proper and timely calibration (in accordance with the manufacturer specifications or national standard) of systems, data acquisition and storage. Erroneous data or uncertainties found in measurement of the monitoring devices for the project (i.e. flow rate, electricity meters, etc.) are included in the quality assurance and quality control procedures for individual monitoring parameters as per Section 4.2 of VCS PD.

Data storage and filling

All monitoring data are stored in logs and in electronic format as excel sheets. Primary source of data for emission reduction calculation is derived from the electronic system while in case of emergency or data error, support monitoring data from the log book is used instead. The monitoring records shall be archived for a period of the crediting period plus two years.

Emergency procedure

The project activity is not expected to result in any emergency that can result in substantial emissions.

- The recorded data is stored and backed up via MES system to prevent the loss of historical data.
- The hard copies are collected and controlled as per the ISO 9001 requirements.

However, since unexpected emergency situations might affect the completeness or accuracy of monitored data. Apart from general provisions described topic above and below of this section, the operator also take measures to avoid data loss and inaccuracies under such circumstances. Following an emergency situation, the staff responsible for operation and monitoring of the plant shall be made aware of any event from the previous day or previous shift and plan to promptly rectify the situation. In case of problems with any equipment or machines, immediate action shall be taken to restore regular operation of such affected devices.

Uncertainty in data

Some uncertainties may result due to malfunction of meters, calibration issues and wrong data collection (gaps in manual log sheets, human errors by plant operators). The operator is expected to put best efforts to prevent such errors, however regular internal audits shall rectify any such uncertainty in the monitored data.

4 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

4.1 Baseline Emissions

Baseline emissions for the chosen baseline scenario are calculated as follows:

$$BE_y = BE_{Upstream,y} + BE_{Process,y} \quad (1)$$

Where:

BE_y	Baseline emission in year y (tCO ₂)
$BE_{Upstream,y}$	Emissions associated with the baseline reagents required for the production of PO in year y (tCO ₂)
$BE_{Process,y}$	Emissions due to energy usage (heat and electricity) for transforming the baseline reagents into the final product (PO) and also for waste and by-product treatment in year y (tCO ₂)

Up-stream emissions ($BE_{Upstream,y}$):

The up-stream emissions are on account of the various reagents used in the process. The reagents used in the baseline (CHPO-Chlor-Alkali process) are C₃H₆, Cl₂ and NaOH. The emissions associated with C₃H₆ has however not been accounted as its usage would be essentially the same as in the project activity. The emissions associated with Chlor-Alkali production have been accounted as these are generally not found naturally and are to be produced in an industrial facility.

The emissions associated with Chlor-Alkali production are calculated as follows:

$$BE_{Upstream,y} = be_{Chlor-Alkali,y} \times PO_y \quad (2)$$

Where:

$be_{Chlor-Alkali,y}$	Quantity of CO ₂ that would be emitted from Chlor-Alkali production per unit of PO in year y (tCO ₂ /tonne of PO)
PO_y	Quantity of PO produced in year y (tonnes)

The Chlor-Alkali process involves the electrolysis of aqueous sodium chloride (brine) in a membrane cell. The CO₂ emissions associated with Chlor-Alkali production are calculated as follows:

$$be_{Chlor-Alkali,y} = \left(\frac{71}{58} \right) \times ec_{Chlor-Alkali,y} \times EF_{EL,y} \quad (3)$$

Where:

$ec_{Chlor-Alkali,y}$	Energy consumption per ton of Cl ₂ production in year y (MWh/tCl ₂)
$EF_{EL,y}$	Emission factor for electricity generation in year y (tCO ₂ /MWh)
71/58	Ratio between the molecular weights of Cl ₂ and C ₃ H ₆ O (mass units/mass units)

Process emissions ($BE_{Process,y}$):

The process emissions would arise due to energy usage (heat, electricity etc.) for transforming the reagents into the final product and also from waste treatment.

The emissions associated with energy usage will be calculated as follows:

$$BE_{Process,y} = BE_{Heat,y} + BE_{Elec,y} + BE_{Waste,y} \quad (4)$$

Where:

$BE_{Heat,y}$ Emissions due to thermal energy (heat/steam) for transforming the baseline reagents into the final product (PO) and also for waste treatment in year y (tCO₂)

$BE_{Elec,y}$ Emissions due to electrical energy for transforming the baseline reagents into the final product (PO) and also for waste treatment in year y (tCO₂)

$BE_{Waste,y}$ Emissions due to treatment of waste products in year y (tCO₂)

The CO₂ emissions from thermal energy (heat/steam) will be calculated as follows:

$$BE_{Heat,y} = SSC_{CHPO} \times PO_y \times EF_{Steam,y} \quad (5)$$

Where:

SSC_{CHPO} Specific thermal energy consumption ratio in the PO production through CHPO process (TJ/tonne of PO).

$EF_{Steam,y}$ Emission factor for thermal energy generation in year y (tCO₂/TJ)

The emission factor for thermal energy generation would be calculated as follows:

$$EF_{Steam,y} = EF_{CO_2,i,y} / \eta_{Boiler,y} \quad (6)$$

Where:

$EF_{CO_2,i,y}$ Weighted average CO₂ emission factor of fuel type i in year y (tCO₂/TJ)

$\eta_{Boiler,y}$ Efficiency of the steam generating system

The CO₂ emissions from electrical energy will be calculated as follows:

$$BE_{Elec,y} = SEC_{CHPO} \times PO_y \times EF_{El,y} \quad (7)$$

Where:

SEC_{CHPO} Specific electrical energy consumption ratio in the PO production through CHPO process (MWh/tonne of PO).

$EF_{El,y}$ Emission factor for electricity generation in year y (tCO₂/MWh)

The specific energy consumption ratios (thermal/electrical) will be sourced from independent third party reports.

The CO₂ emissions from waste treatment will be calculated as follows:

$$BE_{Waste,y} = \left(\frac{44}{12}\right) \times (CA_{Waste,Baseline}) + FC_{i,Baseline} \times COEF_i \quad (8)$$

Where:

$CA_{Waste, Baseline}$ Carbon amount in the waste stream derived from the carbon amount in the Propylene feed, PO and by-products in the baseline (tonnes)

44/12 Ratio between the molecular weights of CO₂ and Carbon (mass units/mass units)

$FC_{i,Baseline}$ Quantity of fuel type i combusted in the incinerator in the baseline (mass or volume unit/year)

$COEF_i$ CO₂ emission coefficient of fuel type i (tCO₂/mass or volume unit)

The “Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion” should be referred to calculate the CO₂ emission coefficient.

The carbon amount in the waste stream and fuel combusted in the incinerator could be presented in terms of PO output.

For simplification and as a conservative approach, the emissions linked to waste and by-products will be neglected.

The summary of the baseline emissions shows in the table below.

BE_y	Unit	2014	2015	2016	2017
$BE_{Upstream,y}$	tCO ₂	290,153	582,609	580,520	585,590
$BE_{Process,y}$	tCO ₂	10,773	21,633	21,555	21,744
BE_y	tCO ₂	300,926	604,242	602,075	607,334

4.2 Project Emissions

Project emissions are calculated as follows:

$$PE_y = PE_{Upstream,y} + PE_{Process,y} \quad (9)$$

Where:

PE_y	Project emissions in the year y (tCO ₂)
$PE_{Upstream,y}$	Emissions associated with the project reagents for the production of PO in year y (tCO ₂)
$PE_{Process,y}$	Emissions due to energy usage (heat, electricity etc.) for transforming the project reagents into the final product (PO) and also for waste treatment in year y (tCO ₂)

Up-stream emissions ($PE_{Upstream,y}$):

The upstream emissions are based on the various reagents used in the PO production process. The reagents used in the project scenario (HPPO process) are C₃H₆ and H₂O₂. However, the emissions associated with C₃H₆ are not accounted for as its usage would be essentially the same as in the baseline activity. The emissions associated with H₂O₂ production have been included as this compound is generally not found naturally and is produced in an industrial facility. Further, since the reaction is carried out in solvents¹⁶, the emissions associated with the make-up solvent are considered as well.

The upstream emissions are calculated as follows:

$$PE_{Upstream,y} = PE_{Upstream,H_2O_2,y} + PE_{Upstream,Solvent,y} \quad (10)$$

The emissions associated with H₂O₂ production are calculated as follows:

$$PE_{Upstream,H_2O_2,y} = \left(\frac{34}{58} \right) \times pe_{HP} \times PO_y \quad (11)$$

Where:

pe_{HP}	Quantity of CO ₂ that would be emitted per tonne of H ₂ O ₂ (tCO ₂ /tH ₂ O ₂)
PO_y	Quantity of PO produced in year y (tonnes)
34/58	Ratio between the molecular weights of H ₂ O ₂ and C ₃ H ₆ O (mass units/mass units)

The emissions associated with make-up solvent are calculated as follows:

$$PE_{Upstream,Solvent,y} = pe_{Sol} \times sol_y \times PO_y \quad (12)$$

¹⁶ Typically solvents of polar nature are used, such as alcohols, ketones, ethers, etc.

Where:

pe_{Sol}	Quantity of CO ₂ that is emitted per tonne of solvent (tCO ₂ /tonne of solvent)
sol_y	Quantity of solvent required per tonne of PO in year y (tonnes)
PO_y	Quantity of PO produced in year y (tonnes)

Note that sol_y , as found in equation 12 above, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, “ $sol_y \times PO_y$ ” is represented by Sol_y in equation 12 above, the value of which is monitored.

Process emissions ($PE_{Process,y}$):

The process emissions arise from the energy usage (e.g. heat and electricity) required for transforming the reagents into the final product, and for by-product and waste treatment.

The process emissions are calculated as follows:

$$PE_{Process,y} = PE_{Heat,y} + PE_{Elec,y} + PE_{Waste,y} \quad (13)$$

Where:

$PE_{Heat,y}$	Emissions due to thermal energy (heat/steam) for transforming the project reagents into the final product in year y (tCO ₂)
$PE_{Elec,y}$	Emissions due to electrical energy for transforming the project reagents into the final product in year y (tCO ₂)
$PE_{Waste,y}$	Emissions due to treatment of waste products in year y (tCO ₂)

The CO₂ emissions from thermal energy (heat/steam) are calculated as follows:

$$PE_{Heat,y} = SSC_{HPPO,y} \times PO_y \times EF_{Steam,y} \quad (14)$$

Where:

$SSC_{HPPO,y}$	Specific thermal energy consumption ratio in PO production through the HPPO process in year y (TJ/tonne of PO)
$EF_{Steam,y}$	Emission factor for thermal energy generation in year y (tCO ₂ /TJ)

Note that $SSC_{HPPO,y}$, as found in equation 14 above, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, “ $SSC_{HPPO,y} \times PO_y$ ” is represented by SC_{HPPO} in equation 14 above, the value of which is monitored.

The emission factor for thermal energy generation is the same as calculated for the baseline emissions.

The CO₂ emissions from electrical energy are calculated as follows:

$$PE_{El,y} = SEC_{HPPO,y} \times PO_y \times EF_{El,y} \quad (15)$$

Where:

$SEC_{HPPO,y}$ Specific electrical energy consumption ratio in PO production through the HPPO process in year y (MWh/tonne of PO)

$EF_{El,y}$ Emission factor for electricity generation in year y (tCO₂/MWh)

Note that SEC_{HPPO} , as found in equation 15 above, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, " $SEC_{HPPO} \times PO_y$ " is represented by EC_{HPPO} in equation 15 above, the value of which is monitored.

The emission factor for electricity generation is the same as calculated for the baseline emissions.

The CO₂ emissions from waste treatment are calculated as follows:

$$PE_{Waste,y} = \left(\frac{44}{12} \right) \times (CA_{Waste,y}) + FC_{i,y} \times COEF_{i,y} \quad (16)$$

Where:

$CA_{Waste,y}$ Carbon amount in the waste stream derived from the carbon amount in the propylene feed, solvent, PO and by-products in year y (tonnes)

44/12 Ratio between the molecular weights of CO₂ and carbon (mass units/mass units)

$FC_{i,y}$ Quantity of fuel type i combusted in the incinerator in year y (mass or volume unit/year)

$COEF_{i,y}$ CO₂ emission coefficient of fuel type i in year y (tCO₂/mass or volume unit)

The CDM Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion must be used to calculate the CO₂ emission coefficient.

The carbon amount in the waste stream must be calculated as follows:

$$CA_{Waste,y} = CA_{Propylene,y} + CA_{Solvent,y} - (CA_{PO,y} + CA_{Byproducts,y}) \quad (17)$$

Where:

$CA_{Propylene,y}$ Carbon amount in the propylene feed in year y (tonnes)

$CA_{Solvent,y}$ Carbon amount in the solvent used in year y (tonnes)

$CA_{PO,y}$ Carbon amount in PO produced in year y (tonnes)

$CA_{Byproducts,y}$ Carbon amount in the by-products in year y (tonnes)

The total amount of carbon in a particular product is a function of the respective carbon fraction and the quantity of the product, expressed as follows:

$$CA_{x,y} = ca_{x,y} \times Q_{x,y} \quad (18)$$

Where:

$CA_{x,y}$ Carbon amount in the product x in year y (tonnes)

$ca_{x,y}$ Carbon fraction in the product x in year y (mass units/mass units)

$Q_{x,y}$ Quantity of the product x in year y (tonnes)

x propylene, solvent, PO, by-product, waste

The summary of the project emissions shows in the table below.

PE_y	Unit	2014	2015	2016	2017
$PE_{Upstream,y}$	tCO ₂	69,581	138,994	138,695	139,089
$PE_{Process,y}$	tCO ₂	134,206	253,318	263,491	256,212
PE_y	tCO ₂	203,787	392,312	402,186	395,301

4.3 Leakage

No leakage emissions are considered. The main emissions potentially giving rise to leakage in the context of the project are emissions arising due to construction of the PO production facility and transportation of reagents. These emissions sources are excluded as these would be higher in the baseline scenario as compared to project scenario.

4.4 Net GHG Emission Reductions and Removals

Year	Baseline emissions or removals (tCO ₂ e)	Project emissions or removals (tCO ₂ e)	Leakage emissions (tCO ₂ e)	Net GHG emission reductions or removals (tCO ₂ e)
01/04/2014 to 31/12/2014	300,926	203,787	0	97,139
01/01/2015	604,242	392,312	0	211,930

to 31/12/2015				
01/01/2016 to 31/12/2016	602,075	402,186	0	199,889
01/01/2017 to 31/12/2017	607,334	395,301	0	212,033
Total	2,114,577	1,393,586	0	720,991

As per the table below, the net GHG emission reductions achieved during this monitoring period is less than the values estimated in ex-ante calculation of the registered PD.

Net GHG emission reductions (tCO ₂ e)	Amount estimated ex ante (tCO ₂ e)
720,991	897,585 ¹⁷

¹⁷ The estimation has been provided in the emission reduction calculation sheet