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Sectoral Scope 5

Reduction of GHG Emissions in Propylene Oxide Production

Methodology developed by:

South Pole Carbon Asset Management Ltd.

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1 SOURCES

CDM *Tool for the demonstration and assessment of additionality*

CDM *Tool to calculate baseline, project and/or leakage emissions from electricity consumption*

CDM *Tool to determine the baseline efficiency of thermal or electric energy generation systems*

CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology quantifies the GHG emission reductions resulting from the use of Hydrogen Peroxide-based Propylene Oxide (HPPO) technology, which requires less GHG-intensive reagents and requires less energy for the production of Propylene Oxide (PO) compared to other production processes.

This methodology is based on the project being developed by MTP HPPO Manufacturing Co., Ltd, a joint venture between The Siam Cement Public Co., Ltd and The Dow Chemical Company. The project involves the construction of a PO production facility that will use HPPO technology instead of the conventional Chlorohydrin (CHPO)-chlor-alkali process.

PO is an organic compound with the molecular formula CH_3CHCH_2O. This colorless volatile liquid is produced on a large scale industrially. PO is a very common chemical building block used to produce commercial and industrial products including polyether polyols, propylene glycols and propylene glycol ethers. It is among the most diffused chemical intermediates in the world and its production continues to grow.

There are many processes (or chemical routes) that are used in the industry to synthesize PO. Industrial production of PO generally starts from propylene. Two general approaches are then employed, one involving hydrochlorination and the other involving oxidation. The hydrochlorination route, which uses chlorohydrin technology, is the traditional route and proceeds via the conversion of propylene to PO. There are also other possible routes to produce PO based on co-oxidation of the organic chemicals isobutene or ethylbenzene. However, these alternative routes are characterized by substantial production of co-products, such as *t*-butyl alcohol or styrene, respectively.

This methodology is not designed to address all types of PO production processes. Its application is limited to projects wherein PO is the only output expected (ie, no co-products are produced in the process). The methodology is applicable only to greenfield projects where the project activity is the implementation of the HPPO process and where implementation of the CHPO-chlor-alkali process is identified as the baseline scenario.

In this methodology, the GHG emissions produced by different chemical manufacturing processes using different reagents are being compared. Comparing two processes that do not use the same input materials not only entails a comparison of emissions that occur in the PO production facility but requires a broader approach, similar to a life cycle assessment where emissions due to reagent production are also taken into account. The methodology therefore distinguishes (for both baseline and project processes) between two classes of emissions:

- **Upstream emissions**: includes emission sources linked to the reagents being used in the PO production process.

- **Process emissions**: includes emission sources located within the PO production facility and include emissions associated with the synthesis of the PO as well as emissions associated with by-product and waste treatment.

Since the product is the same in both the baseline and project scenarios, downstream emissions would be the same and have therefore not been considered. The emissions associated with the construction of the PO production facility are also ignored as they are not expected to be significantly different in the baseline and project scenarios. As such, this methodology considers only upstream and process emissions.

The methodology quantifies emission reductions from a more energy efficient PO production process, which has significant capital and recurring costs estimated to be over US$1,500 per tonne of PO. As a result, the methodology does not create any incentives for producing PO for the sole purpose of earning carbon credits.

The key elements of this methodology are as follows:

- **Applicability conditions:** The methodology is applicable to greenfield projects where PO is the only expected output (ie, no co-products are produced in the production process). Nevertheless, in practice, due to selectivity of the catalysts, by-products may be produced in the production process. Such by-products must not be more than 10% (in mass terms) relative to the PO output. As a consequence, the methodology is applicable only to projects where the project activity is the implementation of the HPPO process and where implementation of the CHPO-chlor-alkali process is identified as the baseline scenario.

- **Project boundary:** The project boundary includes upstream emissions from reagent production and process emissions from the synthesis of PO and from by-product and waste treatment.

- **Baseline scenario:** The baseline scenario is determined through an evaluation of the likely alternatives, accounting for local/national regulations and laws, investment analyses and/or barriers. A list of pre-defined alternatives is included in this methodology; this list is non-exhaustive and additional alternatives may be proposed by project proponents.

- **Additionality:** Additionality must be demonstrated through the application of the latest version of the CDM *Tool for the demonstration and assessment of additionality*.

- **Baseline emissions:** Baseline emissions include upstream emissions and process emissions.

  Upstream emissions include emissions associated with the baseline reagents. For simplification, and as a conservative approach, the following upstream emission sources are excluded:

  - Emissions associated with raw materials that are in an unprocessed or minimally processed state;
  - Raw material extraction;
  - Catalysts;
  - Transportation; and
  - Reagents common in quantity and quality to the project activity.

  Process emissions include emissions resulting from energy usage (eg, heat and electricity) for transforming the reagents into the final product and also for waste and by-product treatment. For simplification, and as a conservative approach, emissions linked to waste and by-products may be neglected if credible data to estimate same is not available. Process emissions due to energy usage are calculated based upon the specific energy required per tonne of PO production, and the associated emission factor for the thermal/electrical energy generation, respectively.

- **Project emissions:** Project emissions include upstream emissions and process emissions.

  Upstream emissions include emissions associated with the project reagents. For simplification, and as a conservative approach, the same upstream emission sources as under the baseline scenario are excluded for the project scenario.

  Process emissions include emissions resulting from energy usage (eg, heat and electricity) for transforming the reagents into the final product and also for waste and by-product treatment.

  Emissions linked to energy, electricity and steam are calculated using the latest versions of the CDM *Tool to calculate baseline, project and/or leakage emissions from electricity consumption* and the CDM *Tool to calculate project or leakage CO2 emissions from fossil fuel combustion,* respectively.

  Apart from waste contained in wastewater streams, most of the waste generated on-site is usually incinerated. Emissions from the incineration of such waste streams must be estimated by considering the carbon content of the waste stream (based on their chemical

formula). By-products that can be recovered from the process and used for other processes within the project boundary are considered as carbon neutral since all emissions linked to their treatment are included in the project boundary and are already taken into account. Incineration of waste streams often involves co-firing of fossil fuels. Emissions from fossil fuel consumption are also considered.

- **Leakage:** Leakage is not considered an issue under this methodology.
- **Emission reductions:** The emission reductions are calculated as baseline emissions minus project emissions.
- **Monitoring:** As all parameters are related to the production process, monitoring must follow standard industrial practice.

Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS

For the purposes of this methodology, the following definitions apply:

By-Products: Incidental (ie, undesired) products deriving from chemical processes. Water is not considered to be a by-product.

Chlorohydrin Process (CHPO Process): Process whereby propylene is combined with hypochlorous acid to form a chlorohydrin intermediate, which is subsequently dechlorohydronated to PO. This process leads to the formation of salts.

CHPO-Chlor-Alkali Process: A specific CHPO process where caustic soda facilitates a dechlorohydronation reaction, leading to large quantities of NaCl brine.

CHPO-Lime Process: A specific CHPO process where lime is used as a chlorine absorber. Quick-lime (CaO) is mixed with water to form calcium hydroxide which is mixed with a chlorohydrin solution. This process leads to large quantities of effluent with $CaCl_2$ loads.

Co-Oxidation: PO production process that co-produces styrene (POSM) and t-butyl (POTBA).

Co-Products: Products deriving from the chemical process which is not the primary product. Water is not considered to be a co-product.

Cumene Hydroperoxide Process (CHP Process): Process where CHP is used for the epoxidation of propylene[1]. This route produces DMBA as a co-product which may be further recycled to cumene.

Hydrogen Peroxide-Based PO Process (HPPO Process): Process consisting of the production of PO from propylene and hydrogen peroxide[2].

Oxidation: PO production process that does not lead to co-products.

Propylene Oxide Styrene Monomer Process (POSM Process): Hydroperoxidation production route to PO that co-produces styrene monomer. This process involves the co-oxidation of ethylbenzene and styrene, and produces PO and styrene.

Propylene Oxide Tertiary Butyl Alcohol Process (POTBA Process): Hydroperoxidation production route to PO that co-produces t-butyl. This process involves the co-oxidation of isobutene and styrene, and produces PO and t-butyl.

Propylene Oxide (PO): An organic compound with the molecular formula CH_3CHCH_2O. This colourless volatile liquid is produced on a large scale industrially, its major application being its use in the production of polyether polyols, which are used for making polyurethane plastics.

Waste: Material generated by the production process which is not sold or re-used in other processes on-site. Waste streams may be incinerated on-site, treated within the project boundary (eg, wastewater) or disposed of (eg, at solid disposal site).

4 APPLICABILITY CONDITIONS

This methodology is applicable under the following conditions:

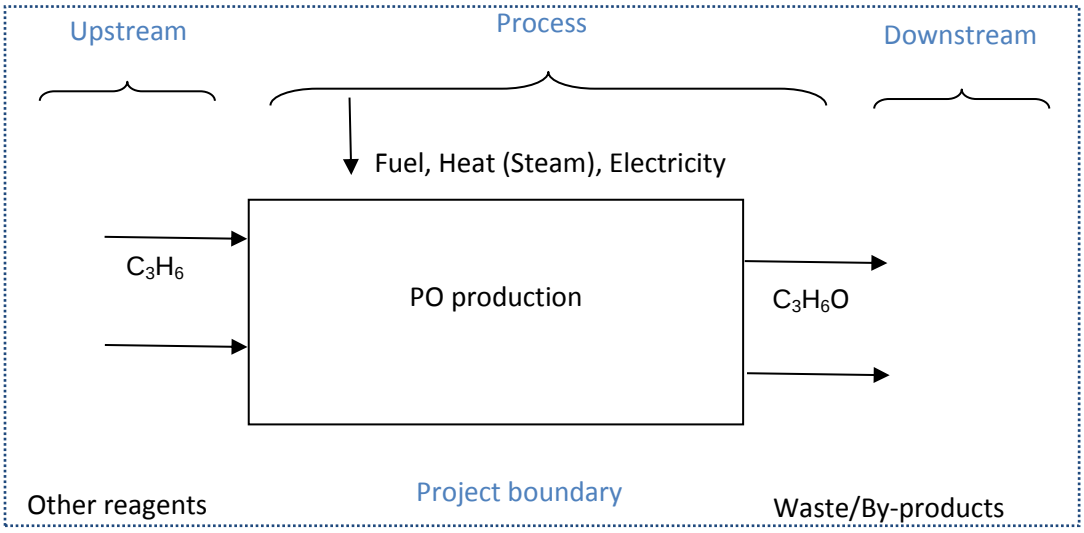
- The methodology is limited to greenfield projects (ie, new PO production facilities) wherein PO is the only output.
- The PO production process must not produce any co-products. There may be by-products produced in the PO production process, due to the selectivity of catalysts.
- The PO production process must not create more than 10% (in mass terms) by-product, relative to PO output.
- The methodology is applicable only to projects where the project activity is the implementation of the HPPO process and where implementation of the CHPO-chlor-alkali process is identified as the baseline scenario.

[1] Patented by Sumitomo (World patent 01/05778 A1).
[2] There are two patents linked to this process. One is owned by DOW (US patent 7,138,534), and the other by Degussa (6,878,836).

- The project may be located in any geographic region of the world.
- The applicability conditions of the tools referenced in this methodology also apply.

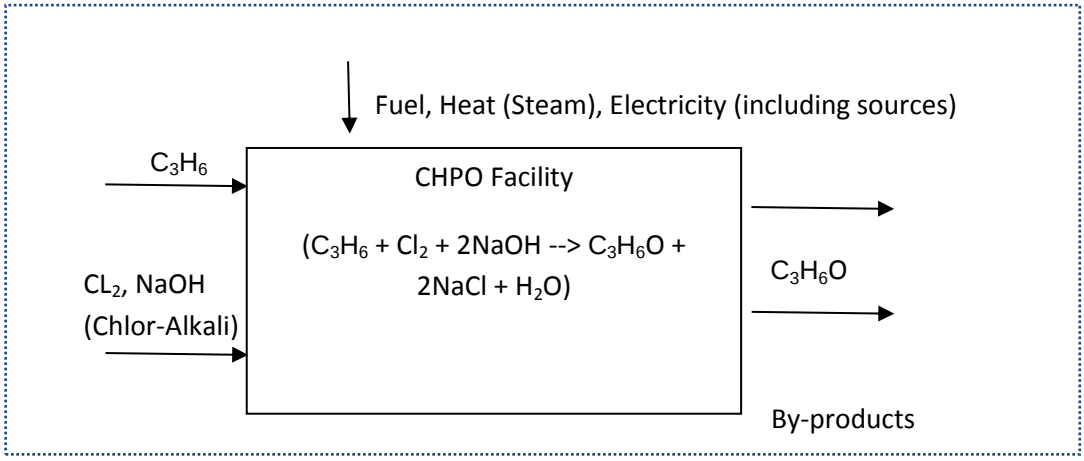
5 PROJECT BOUNDARY

The spatial extent of the project boundary encompasses (1) the upstream emissions from reagent production and (2) the emissions from the PO production facility (ie, the cumulative emissions beginning from reagents admission and synthesis of PO through to the treatment of by-products and waste from the production process).

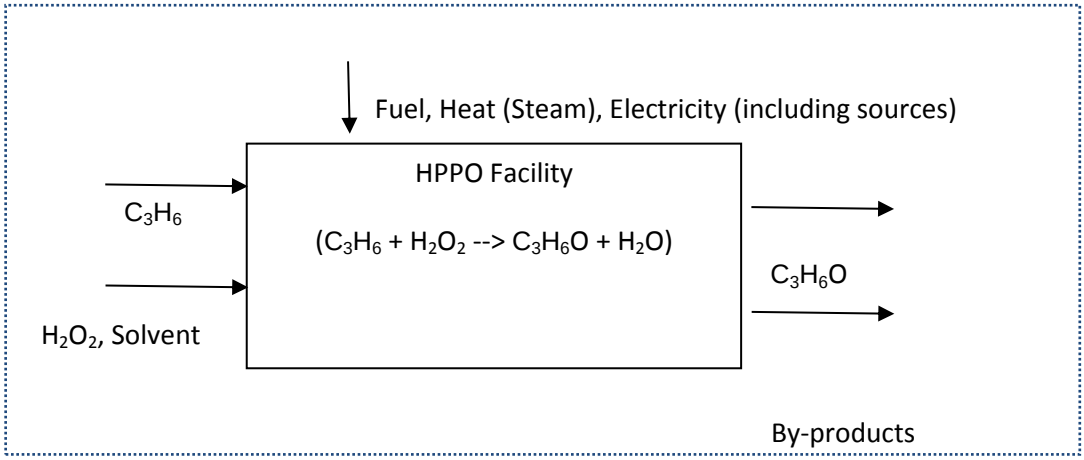


The project boundary also encompasses the project's electricity system(s) and the heat/steam generation system that the PO production facility is connected to. The spatial extent of the project electricity system consists of the power plants that are physically connected through transmission and distribution lines to the project activity and that can be dispatched without significant transmission constraints. The 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.

For the CHPO-chlor-alkali process (baseline scenario), the spatial extent of the project boundary is defined as follows:



For the HPPO process (project activity), the spatial extent of the project boundary is defined as follows:



The greenhouse gases included in, or excluded from, the project boundary are shown in the table below:

Source		Gas	Included?	Justification/Explanation
Baseline	Emissions associated with the production of baseline reagents	CO_2	Yes	The emissions associated with Cl_2 and NaOH (chlor-alkali) production are accounted for as these are generally not found naturally and are produced in an industrial facility. The emissions associated with C_3H_6 have, however, not been accounted for as its usage would be essentially the same as in the project activity.
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.
	Emissions associated with steam and electricity requirements of the production process	CO_2	Yes	Emissions could arise from the combustion of fossil fuels for providing steam and/or electricity to the PO production facility.
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.
	Emissions associated with treatment of waste produced by the production process	CO_2	Yes	Emissions could arise from the incineration of waste.
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.

Source		Gas	Included?	Justification/Explanation
Project	Emissions associated with the production of project reagents	CO_2	Yes	The emissions associated with H_2O_2 production and methanol as a solvent (make-up) have been accounted for as these reagents are generally not found naturally and are produced in an industrial facility. The emissions associated with C_3H_6 have, however, not been accounted for as its usage would be essentially the same as in the baseline activity.
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.
	Emissions associated with steam and electricity requirements of the production process	CO_2	Yes	Emissions could arise from the combustion of fossil fuels for providing steam and/or electricity to the PO production facility
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.
	Emissions associated with treatment of waste produced by the production process	CO_2	Yes	Emissions could arise from the incineration of waste (eg, low boils, waste gas, etc.).
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

Project proponents must apply the following steps to identify the baseline scenario:

Step 1: Identification of plausible alternative scenarios

This step serves to identify all alternative scenarios to the project activity which could qualify as the baseline scenario. Alternatives must be able to deliver outputs or services[3] that are equivalent to what has been implemented previously, or is currently being implemented in the relevant country/region. Given that the only output intended from production is PO (ie, no co-products), identified alternatives must therefore consist of all commercially available PO technologies. The list of alternatives must therefore consist of at least (but not limited to):

P1: The project activity without carbon revenues;

P2: A PO production facility with comparable capacity using a CHPO process (CHPO-lime or CHPO-chlor-alkali processes);

P3: A PO production facility with comparable capacity using any other commercially available technology.

Step 2: Consistency with mandatory applicable laws and regulations

This step serves to eliminate alternatives that are not in compliance with all applicable mandatory legal and regulatory requirements.

Step 3: Barrier analysis

This step serves to identify barriers and to assess which alternative scenarios are prevented by these barriers. Scenarios that face prohibitive barriers must be eliminated by applying Step 3 of the latest version of the CDM *Tool for demonstration and assessment of additionality*.

If only one alternative remains, this must be considered the baseline scenario. If more than one alternative remains, proceed to Step 4.

Step 4: Economic analysis

This step serves to compare the economic or financial attractiveness of all alternatives that are remaining and identify the scenario that is the most economically and/or financially attractive. The economic analysis must be completed by applying Step 2 of the latest approved version of the CDM *Tool for the demonstration and assessment of additionality*.

[3] The processes wherein co-products are produced (eg, CHP, POSM and POTBA processes) are not considered as likely alternatives.

This methodology is only applicable if implementation of the CHPO-chlor-alkali process is identified as the baseline scenario.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

The additionality of the project activity must be demonstrated and assessed using the latest version of the CDM *Tool for the demonstration and assessment of additionality*. While demonstrating the additionality of the project activity, the project proponent must consider the different baseline alternatives described in the section above.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Baseline emissions are calculated as follows:

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

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)

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

The upstream emissions are based on the various reagents used in the process. The reagents used in the baseline (CHPO-chlor-alkali process) are C_3H_6, Cl_2 and NaOH. The emissions associated with C_3H_6, however, are not accounted for as usage would be essentially the same as in the project activity. The emissions associated with Cl_2 and NaOH (chlor-alkali) production have been included as these are generally not found naturally and are be produced in an industrial facility.

The emissions associated with chlor-alkali production are calculated as follows:

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

Where:

$be_{Chlor\text{-}Alkali,\ y}$	Quantity of CO_2 emitted from chlor-alkali production per unit of PO in year y (tonnes)
PO_y	Quantity of PO produced in year y (tonnes)

The chlor-alkali production process involves the electrolysis of aqueous sodium chloride (brine) in a membrane cell. The CO_2 emissions associated with chlor-alkali production are calculated as follows[4]:

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

Where:

$ec_{Chlor\text{-}Alkali,\ y}$	Energy consumption per tonne 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_3H_6O (mass units/mass units)

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

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

The emissions associated with energy usage are calculated as follows:

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

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 (tCO_2)
$BE_{Elec,y}$	Emissions due to electrical energy for transforming the baseline reagents into the final product (PO) and also for waste treatment in year y (tCO_2)
$BE_{Waste,y}$	Emissions due to treatment of waste in year y (tCO_2)

[4] The equation has been presented in terms of chlorine and PO, and so the energy consumption is also linked to chlorine.

The CO_2 emissions from thermal energy (heat/steam) are calculated as follows:

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

Where:

SSC_{CHPO}	Specific thermal energy consumption ratio in PO production through the CHPO-chlor-alkali process (TJ/tonne of PO)
$EF_{Steam,y}$	Emission factor for thermal energy generation in year y (tCO_2/TJ)

The emission factor for thermal energy generation is calculated as follows:

$$EF_{Steam,y} = EF_{CO2,i,y} / \eta_{Boiler,y} \quad \textbf{(6)}$$

Where:

$EF_{CO2, I, y}$	Weighted average CO_2 emission factor of fuel type i in year y (tCO_2/TJ)
$\eta_{Boiler,y}$	Efficiency of the steam generating system in year y

The CO_2 emissions from electrical energy are calculated as follows:

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

Where:

SEC_{CHPO}	Specific electrical energy consumption ratio in PO production through the CHPO-chlor-alkali process (MWh/tonne of PO)
$EF_{El,y}$	Emission factor for electricity generation in year y (tCO_2/MWh)

For the specific thermal energy consumption ratio in PO production through the CHPO-chlor-alkali process, data must be derived from an 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.

The CO_2 emissions from waste treatment are calculated as follows:

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

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 CO_2 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)
$COEF_i$	CO_2 emission coefficient of fuel type i (tCO_2/mass or volume unit)

The carbon amount in the waste stream derived from the carbon amount in the propylene feed, PO and by-products in the baseline must be determined by applying equations 17 and 18.

The CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion* must be used to calculate the CO_2 emission coefficient.

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

For simplification, and as a conservative approach, the emissions linked to waste and by-products may be neglected if data from an independent third party report from a recognized, credible source (reviewed by an appropriately qualified, independent organization or appropriate peer review group) or published by a government agency, to estimate same is not available.

8.2 Project Emissions

Project emissions are calculated as follows:

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

Where:

PE_y	Project emissions in 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 and electricity) for transforming the

project reagents into the final product (PO) and also for waste treatment in year y (tCO_2)

Upstream 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 C_3H_6 and H_2O_2. However, the emissions associated with C_3H_6 are not accounted for as its usage would be essentially the same as in the baseline activity. The emissions associated with H_2O_2 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 solvents[5], the emissions associated with the make-up solvent (in this case methanol) are considered as well.

The upstream emissions are calculated as follows:

$$PE_{Upstream,y} = PE_{Upstream,H2O2,y} + PE_{Upstream,Solvent,y} \quad \textbf{(10)}$$

The emissions associated with H_2O_2 production are calculated as follows:

$$PE_{Upstream,H2O2,y} = \left(\frac{34}{58}\right) \times pe_{HP} \times PO_y \quad \textbf{(11)}$$

Where:

pe_{HP}	Quantity of CO_2 that would be emitted per tonne of H_2O_2 (tCO_2/tH_2O_2)[6]
PO_y	Quantity of PO produced in year y (tonnes)
34/58	Ratio between the molecular weights of H_2O_2 and C_3H_6O (mass units/mass units)

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

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

Where:

pe_{Sol}	Quantity of CO_2 that is emitted per tonne of solvent (tCO_2/tonne of solvent)

[5] Typically solvents of polar nature are used, such as alcohols, ketones, ethers, etc.

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 X PO_y" is represented by Sol_y in equation 12 above, the value of which is monitored in accordance with the procedures described in Section 9.2.

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

The process emissions arise from the energy usage (eg, 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:

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

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 CO_2 emissions from thermal energy (heat/steam) are calculated as follows:

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

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}, 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, "$SSC_{HPPO,y}$ X PO_y" is represented by SC_{HPPO} in equation 14 above, the value of which is monitored in accordance with the procedures described in Section 9.2.

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

The CO_2 emissions from electrical energy are calculated as follows:

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

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 (tCO_2/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} X PO_y" is represented by EC_{HPPO} in equation 15 above, the value of which is monitored in accordance with the procedures described in Section 9.2.

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

The CO_2 emissions from waste treatment are calculated as follows:

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

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 CO_2 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)
$COEF_{i,y}$	CO_2 emission coefficient of fuel type i in year y (tCO_2/mass or volume unit)

The CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion* must be used to calculate the CO_2 emission coefficient.

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

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

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:

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

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

For example, where methanol is being used as a solvent, which gives the by-product monopropyleneglycol ($C_3H_8O_2$), equation 17 is represented as follows:

$$CA_{Waste,y} = \left(\frac{36}{42}\right) \times Q_{Propylene,y} + \left(\frac{12}{32}\right) \times Sol_y - \left(\frac{36}{58}\right) \times PO_y - \left(\frac{36}{76}\right) \times Q_{Byproduct,y} \quad \textbf{(19)}$$

Where:

36/42	Carbon fraction in propylene (mass units/mass units)
12/32	Carbon fraction in methanol (mass units/mass units)
36/58	Carbon fraction in PO (mass units/mass units)
36/76	Carbon fraction in monopropyleneglycol (mass units/mass units)
$Q_{Propylene, y}$	Quantity of propylene used in year y (tonnes)

Sol_y	Quantity of make-up methanol used in year y (tonnes)
PO_y	Quantity of PO produced in year y (tonnes)
$Q_{Byproduct,\ y}$	Quantity of monopropyleneglycol produced in year y (tonnes)

8.3 Leakage

Leakage is not considered an issue under this methodology. 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.

8.4 Summary of GHG Emission Reduction and/or Removals

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad \textbf{(20)}$$

Where:

ER_y	Emission reductions in year *y* (tCO_2e/yr)
BE_y	Baseline emissions in year *y* (tCO_2/yr)
PE_y	Project emissions in year *y* (tCO_2e/yr)
LE_y	Leakage emissions in year y (tCO_2e/yr)

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter:	$ec_{Chlor\text{-}Alkali,\ y}$
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.
Justification of choice of data or description	The membrane cell process is the preferred

of measurement methods and procedures applied:	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[7].
Any comment:	-

Data Unit / 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 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.
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.
Any comment:	-

Data Unit / 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 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.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

[7] http://www.miga.org/documents/ChlorAlkali.pdf

Data Unit / Parameter:	pe_{HP}
Data unit:	tCO_2/tH_2O_2
Description:	Quantity of CO_2 emitted per tonne of H_2O_2.
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.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

Data Unit / Parameter:	pe_{Sol}
Data unit:	tCO_2/tonne of methanol solvent
Description:	Quantity of CO_2 emitted per tonne of methanol.
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.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

Data Unit / 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:	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.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

Data Unit / Parameter:	$fc_{i,Baseline}$
Data unit:	Mass or volume unit in baseline per tonne of PO
Description:	Quantity of fuel type i combusted in the incinerator in the baseline per tonne of PO.
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.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

9.2 Data and Parameters Monitored

Data Unit / Parameter:	PO_y
Data unit:	Tonnes
Description:	Final quantity of PO produced in year y.
Source of data:	PO production facility records.
Description of measurement methods and procedures to be applied:	Flow-rate meters, mass meters, cross-check with stock verification records.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly.
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards, and cross-checked with production stock inventory.
Any comment:	-

Data Unit / Parameter:	Sol_y
Data unit:	Tonnes
Description:	Quantity of make-up methanol solvent used in year y.
Source of data:	PO production facility records.
Description of measurement methods and procedures to be applied:	Flow-rate meters, mass meters, cross-check with stock verification records.

Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly.
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards, and cross-checked with stock inventory.
Any comment:	Note that sol_y, as found in equation 12, 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 x PO_y" is represented by Sol_y in equation 12, the value of which is monitored in accordance with the procedures described above.

Data Unit / Parameter:	$EF_{EL,y}$
Data unit:	tCO_2/MWh
Description:	Emission factor for electricity generation in year y.
Source of data:	Calculate the emission factor using the procedures in the latest approved version of the CDM *Tool to calculate the emission factor for an electricity system*.
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to calculate the emission factor for an electricity system.*
Frequency of monitoring/recording:	As per the CDM *Tool to calculate the emission factor for an electricity system.*
QA/QC procedures to be applied:	As per the CDM *Tool to calculate the emission factor for an electricity system.*
Any comment:	-

Data Unit / Parameter:	$EF_{CO2,\ I,\ y}$
Data unit:	tCO_2/TJ
Description:	Weighted average CO_2 emission factor of fuel type i in year y.
Source of data:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Frequency of monitoring/recording:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel*

	combustion.
QA/QC procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Any comment:	-

Data Unit / Parameter:	$\eta_{Boiler,y}$
Data unit:	-
Description:	Efficiency of the steam generating system in year y.
Source of data:	As per the CDM *Tool to determine the baseline efficiency of thermal or electric energy generation systems.*
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to determine the baseline efficiency of thermal or electric energy generation systems.*
Frequency of monitoring/recording:	As per the CDM *Tool to determine the baseline efficiency of thermal or electric energy generation systems.*
QA/QC procedures to be applied:	As per the CDM T*ool to determine the baseline efficiency of thermal or electric energy generation systems.*
Any comment:	-

Data Unit / Parameter:	$SC_{HPPO,\ y}$
Data unit:	TJ
Description:	Thermal energy consumption in PO production through the HPPO process in year y.
Source of data:	PO production facility records.
Description of measurement methods and procedures to be applied:	This parameter must be determined as the difference of the enthalpy of the process heat (steam) supplied to PO production process in the project method, minus the enthalpy of the feed-water, the boiler blow-down and any condensate return. The respective enthalpies are 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.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly.
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines, and cross-checked with other PO production facility records.
Any comment:	Note that SSC_{HPPO}, as found in equation 14, 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, "$SSC_{HPPO,y}$ x PO_y" is represented by SC_{HPPO} in equation 14, the value of which is monitored in accordance with the procedures described above.

Data Unit / Parameter:	$EC_{HPPO, y}$
Data unit:	MWh
Description:	Electrical energy consumption in PO production through the HPPO process in year y.
Source of data:	PO production facility records.
Description of measurement methods and procedures to be applied:	Electrical consumption is monitored continuously and the average specific electrical energy consumption is calculated based on PO production.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly.
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards.
Any comment:	Note that SEC_{HPPO}, as found in equation 15, 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} x PO_y" is represented by EC_{HPPO} in equation 15, the value of which is monitored in accordance with the procedures described above.

Data Unit / 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:	Flow-rate meters, mass meters, cross-check with stock verification records.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards, and cross-checked with stock inventory.
Any comment:	-

Data Unit / Parameter:	$Q_{By\text{-}product,y}$
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:	Flow-rate meters, mass meters, cross-check with stock verification records.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards, and cross-checked with stock inventory.
Any comment:	-

Data Unit / Parameter:	$FC_{i,y}$
Data unit:	Mass or volume unit/year
Description:	Quantity of fuel type i combusted in the incinerator in year y.
Source of data:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Frequency of monitoring/recording:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
QA/QC procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*

Any comment:	-

Data Unit / Parameter:	$COEF_{i,y}$
Data unit:	tCO_2/mass or volume unit
Description:	CO_2 emission coefficient of fuel type i in year y.
Source of data:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Frequency of monitoring/recording:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
QA/QC procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Any comment:	-

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions relevant for the project and baseline scenario. Monitoring procedures must address the following:

a) Types of data and information to be reported;

b) Units of measurement;

c) Origin of the data;

d) Monitoring methodologies (eg, estimation, measurement, calculation);

e) Type of equipment used, if any;

f) Monitoring times and frequencies;

g) QA/QC procedures;

h) Monitoring roles and responsibilities; and

i) GHG information management systems, including the location, back up, and retention of stored data.

Where measurement and monitoring equipment is used, the project proponent must ensure the equipment is calibrated according to current good practice (eg, relevant industry standards). All data collected as part of monitoring must be archived electronically and kept at least for two years after the end of the last project crediting period.

QA/QC procedures include, but are not limited to:

Data Gathering, Input and Handling Measures

- Input data checked for typical errors, including inconsistent physical units, unit conversion errors, typographical errors caused by data transcription from one document to another and missing data for specific time periods or physical units.
- Input time series data checked for large unexpected variations (eg, orders of magnitude) that could indicate input errors.
- All electronic files use version control to ensure consistency.
- Physical protection of monitoring equipment (eg, sealed meters and data loggers).
- Physical protection of records of monitored data (eg, hard copy and electronic records).

Data Documentation

- Input data units checked and documented.
- All sources of data, assumptions and emission factors documented.
- Changes to data, assumptions and emission factors documented.
- Documented assumptions and algorithms validated based on best practices.

Calculations

- Units for input data and conversion factors documented.
- Units for all intermediate calculations and final results documented.
- Input data and calculated data clearly differentiated.
- Comparison to previous results to identify potential inconsistencies.
- Results aggregated in various ways to identify potential inconsistencies.

10 REFERENCES AND OTHER INFORMATION

The latest approved versions of CDM tools referenced by this methodology are available at:

http://cdm.unfccc.int/Reference/tools/index.html

DOCUMENT HISTORY

Version	Date	Comment
v1.0	9 Sep 2013	Initial version released