Greenhouse Gas Capture and Utilization in Plastic Materials

Title	Greenhouse Gas Capture and Utilization in Plastic Materials
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Sectoral Scope	3. Energy Demand
Developer	Newlight Technologies, Inc. and Carbonomics, LLC
Prepared By	Carbonomics, LLC
Contact	Seth Baruch, 5077 Blackhawk Drive, Danville, CA 94506; (202) 236-5253, sbaruch@carbonomicsonline.com

Relationship to Approved or Pending Methodologies

Approved and pending methodologies under the VCS and approved GHG programs which fall under the same sectoral scope were reviewed to determine whether an existing methodology could be reasonably revised to meet the objective of the proposed methodology. 25 methodologies were identified under the same sectoral scope, and are set out in Table 1 below. No other similar methodologies under the VCS or any other approved GHG program are applicable to project activities which capture and use greenhouse gases to produce plastic materials, and thus no existing methodology can be reasonably revised to meet the objective of this methodology.

Table 1: Similar Methodologies

Methodology	Title	GHG Program	Comments
VM0008	Weatherization of Single Family and Multi-Family Buildings	VCS	Not applicable to project activities that produce plastic materials from greenhouse gases.
VM0013	Calculating Emission Reductions from Jet Engine Washing	VCS	Not applicable to project activities that produce plastic materials from greenhouse gases.
VM0018	Energy Efficiency and Solid Waste Diversion Activities within a Sustainable Community	VCS	Not applicable to project activities that produce plastic materials from greenhouse gases.
VM0020	Transport Efficiency from Lightweight Pallets	VCS	Not applicable to project activities that produce plastic materials from greenhouse gases.
VM0025	Campus Clean Energy and Energy Efficiency	VCS	Not applicable to project activities that produce plastic materials from greenhouse gases.
AM0017	Steam system efficiency improvements by replacing steam traps and returning condensate	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AM0018	Baseline methodology for steam optimization systems	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AM0020	Baseline methodology for water pumping efficiency/improvements	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AM0046	Distribution of efficient light bulbs to households	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.

AM0060	Power saving through replacement by energy efficient chillers	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AM0070	Manufacturing of energy efficient domestic refrigerators	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AM0086	Distribution of zero energy water purification systems for safe drinking water	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AM0105	Energy efficiency in data centres through dynamic power management	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AM0113	Distribution of compact fluorescent lamps (CFL) and light-emitting diode (LED) lamps to households	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.C.	Demand-side energy efficiency activities for specific technologies	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.G.	Energy efficiency measures in thermal applications of non-renewable biomass	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.J.	Demand-side activities for efficient lighting technologies	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.L.	Demand-side activities for efficient outdoor and street lighting technologies	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.M.	Demand-side energy efficiency activities for installation of low-flow hot water savings devices	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.N.	Demand-side energy efficiency activities for installation of energy efficient lighting and/or controls in buildings	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.O.	Dissemination of energy efficient household appliances	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.P.	Energy efficient pump-set for agriculture use	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.

AMS-II.R.	Energy efficiency space heating measures for residential buildings	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-II.S.	Energy efficiency in motor systems	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.
AMS-III.AV.	Low greenhouse gas emitting water purification systems	CDM	Not applicable to project activities that produce plastic materials from greenhouse gases.

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1 SOURCES

This methodology is informed primarily by CDM methodology AMS-III.BA, *Recovery and recycling of materials from E-Waste*, particularly the principle of using recycled materials to displace virgin materials production.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology is globally applicable to project activities that convert carbon dioxide and/or methane, which would have otherwise been emitted into the atmosphere, into a useful plastic material for sale into the plastics market. Such project activities reduce greenhouse gas emissions in two ways. First, project activities sequester carbon dioxide and/or methane into plastic material. Second, the process for manufacturing plastic material from sequestered carbon dioxide and/or methane is typically less emission-intensive than the traditional process for manufacturing plastic material.

Additionality and Crediting Method	
Additionality	Activity Method
Crediting Baseline	Project Method

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Feedstock
The greenhouse gases (i.e., CO_2 and/or CH_4) which are captured as part of project activities to be used along with other materials to produce plastic material

Non-Qualifying CH_4
Methane which is part of the GHG feedstock, but which would have been captured and destroyed in the baseline scenario (e.g., via a landfill collection system)

Plastic Material
Resins or pelletized material that can be molded into useful products. These materials include conventional plastics such as polypropylene (PP), polystyrene (PS), polyethylene (PE), thermoplastic urethane (TPU), acrylonitrile butadiene styrene (ABS), polycarbonate (PC) and polyethylene terephthalate (PET).

Qualifying CH_4
Methane which is part of the GHG feedstock that would have been emitted into the atmosphere in the baseline scenario

4 APPLICABILITY CONDITIONS

This methodology is globally applicable to project activities that convert carbon dioxide and/or methane, which would have otherwise been emitted into the atmosphere, into a useful plastic material for sale into the plastics market.

Project activities must meet the following conditions:

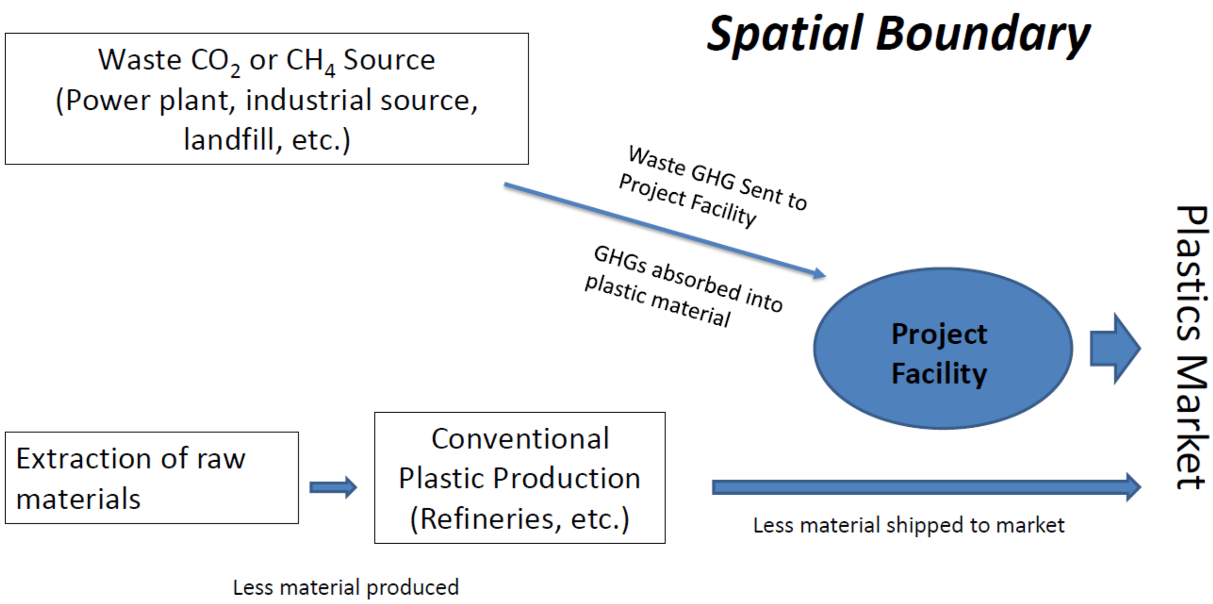
1) Project activities must produce a useful plastic material, with an expected lifetime (period of non-degradation) of at least 100 years[1], through a carbon capture and utilization technology which converts CO_2 and/or CH_4 into a long-chain thermopolymer.
2) Project activities must produce a plastic material that will be used to produce useful plastic products that are sold in the commercial market.
3) Project activities must produce one of the following plastic materials:
   - Polypropylene (PP)
   - Polystyrene (PS)
   - Polyethylene (PE), including high-density and low-density polyethylene (HDPE, LDPE) as well as linear low-density polyethylene
   - Thermoplastic urethane (TPU)
   - Acrylonitrile butadiene styrene (ABS)
   - Polycarbonate (PC)
   - Polyethylene terephthalate (PET)
   - Polyvinyl Chloride (PVC)

5 PROJECT BOUNDARY

As illustrated below, the spatial extent of the project boundary encompasses:

- The project facility where plastic materials are produced;
- The facilities from which the GHG feedstock is sourced (if not direct air capture);
- The facilities where displaced conventional plastic material is manufactured.

[1] Plastic materials produced by projects using this methodology must permanently sequester carbon (i.e., sequester carbon for a period of at least 100 years). Many plastic materials are well-known to have degradation times significantly greater than 100 years. See: *How Long Does it Take a Plastic Bottle to Biodegrade* (Postconsumers, 2011), *Plastic Recycling Facts and Figures* (Sleight, 2011), *A Whopping 91% of Plastic Isn't Recycled* (National Geographic, 2017).



The greenhouse gases included in or excluded from the project boundary are shown in Table 2 below.

Table 2: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Captured GHGs	CO_2	Optional	CO_2 is one of the main gases that can be captured by carbon capture and utilization technology. Note that some projects may use only CH_4 and not CO_2, in which case CO_2 may be excluded from the project boundary. Either CO_2 and/or CH_4 must be included within the project boundary.
		CH_4	Optional	CH_4 is one of the main gases that can be captured by carbon capture and utilization technology. Note that some projects may use only CO_2 and not CH_4, in which case CH_4 may be excluded from the project boundary. Either CO_2 and/or CH_4 must be included within the project boundary.
		N_2O	No	N_2O and any other GHGs are not gases that would be captured and utilized in plastic material with current technology.
		Other	No	N/A
	GHGs from displacement of traditional	CO_2	Yes	The use and combustion of fossil fuels is the primary source of emissions from the traditional process of manufacturing plastics, including the

Source		Gas	Included?	Justification/Explanation
	plastics production			refining of raw materials and process energy for production of plastics. See Appendix 1 for further detail. *Note: Transportation of plastic materials is not considered in either the baseline or project scenario because it is assumed that under either scenario, conventional plastics or GHG-captured plastics would require transport.*
		CH_4	No	Excluded for simplicity and to be conservative
		N_2O	No	Excluded for simplicity and to be conservative
		Other	No	N/A
Project	GHGs from the project facility	CO_2	Yes	Use of electricity and combusted natural gas are the primary energy sources that would be used to power a facility capturing GHGs and manufacturing plastic material, and thus CO_2 would be the primary emission from that combustion
		CH_4	No	Excluded for simplicity and to be conservative
		N_2O	No	Excluded for simplicity and to be conservative
		Other	No	Excluded for simplicity and to be conservative

6 BASELINE SCENARIO

The baseline scenario is the continuation of the manufacture of plastic material through traditional processes (i.e., not through the use of GHG capture and utilization technology).

7 ADDITIONALITY

This methodology uses an activity method for the demonstration of additionality.

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Positive List

The applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all applicability conditions, and in so doing, it is deemed as complying with the positive list and as being additional.

The positive list was established using the activity penetration option (Option A in the *VCS Standard*). Justification for the activity method is provided in Appendix I.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Emissions in the baseline scenario are associated with two components. The first component is the emissions from the GHG feedstock which would remain in the atmosphere or be released to the atmosphere in the absence of the project. The second component is the emissions associated with traditional plastics materials production processes.

Component 1: GHG feedstock

Where the project captures CO_2 from flue gases to produce plastics, CO_2 emissions in the baseline scenario are simply those that would otherwise stay in the flue gas or atmosphere, or be released to the atmosphere.

Where the project uses CH_4 as feedstock for plastic production, the CH_4 may be derived from two types of sources:

1) *Non-qualifying CH_4:* Methane that comes from a landfill or other source where it is required to be flared or otherwise destroyed in the baseline scenario. Where non-qualifying CH_4 is captured as part of project activities, emissions in the baseline scenario must only be attributed to the CO_2 that is released as a result of the CH_4 flaring or destruction process.

2) *Qualifying CH_4:* Methane that comes from a source where it is not required to be flared or otherwise destroyed in the baseline scenario (e.g., a small landfill or biogas facility). Where qualifying CH_4 is captured as part of project activities, emissions in the baseline scenario are attributed to the release of such CH_4 to the atmosphere.

Component 2: Plastic production

Emissions associated with the production of virgin plastic through traditional processes that are displaced by the plastic material manufactured by the project must also be accounted for in the baseline scenario. Appendix II provides default factors for GHG emissions per tonne of virgin plastic produced using traditional plastic production processes for different types of plastic materials. It may be assumed that for every tonne of plastic material manufactured at a project facility, a tonne of plastic material produced through traditional processes is displaced.

Baseline emissions in year *y* of the project crediting period (BE_y) is expressed as follows:

$$BE_y = BE_{cg,y} + BE_{tp,y} \quad (1)$$

Where:

$BE_{cg,y}$ = Baseline emissions from the GHG feedstock which would be released to the atmosphere in the absence of the project (metric tonnes CO_2eq) in year *y*.

$BE_{tp,y}$	= Baseline emissions from plastic material production via traditional manufacturing processes (metric tonnes CO_2eq) in year *y*; and

Baseline emissions from plastic material production via traditional manufacturing processes is calculated as follows:

$$BE_{tp,y} = \sum_i (Q_{p,i,y} * EF_i) \quad (2)$$

Where:

$Q_{p,i,y}$	= Quantity of plastic type *i* produced by the project in year *y* (metric tonnes); and
EF_i	= Emission factor associated with the production of virgin plastic materials via traditional manufacturing processes (tCO_2/metric tonne of plastic for plastic type *i*).

Baseline emissions from the GHG feedstock which would be released to the atmosphere in the absence of the project is calculated as follows:

$$BE_{cg,y} = [(Q_{CO2y} + Q_{CO2fl,y}) * (1-DF_{EL})] + (Q_{methane,y}) \quad (3)$$

Where:

Q_{CO2y}	= Amount of CO_2 captured in year *y* to produce plastic material by the project (metric tonnes).
$Q_{methane,y}$	= Amount of qualifying CH_4 captured in year *y* and used to produce long-lived plastic products (metric tonnes).
$Q_{CO2fl,y}$	= Amount of CO_2 that would have been emitted by the flaring of non-qualifying CH_4, such non-qualifying CH_4 being captured and used by the project to produce plastic material.
DF_{EL}	= Discount factor applied for volume of end-of-life plastic material that is expected to be incinerated, releasing CO_2 being. See additional guidance below.

$$Q_{methane,y} = [(Q_{CH4,y} * GWP_{CH4}) - (Q_{CH4,y} * DF_{EL} * GWP_{CO2})] \quad (4)$$

Where:

$Q_{CH4,y}$	= Amount of qualifying CH_4 captured in year *y* as part of the plastic production process (metric tonnes).
GWP_{CH4}	= Global Warming Potential of methane (tCO_2/tCH_4)
GWP_{C02}	= Global Warming Potential of CO_2 (tCO_2/tCO_2)

8.2 Project Emissions

Project emissions include emissions from electricity used or fossil fuels combusted at the project production facility.

Project emissions are calculated as follows:

$$PE_y = PE_{elec} + PE_{ffc} \quad (5)$$

Where:

PE_y = Project emissions for year *y* of the project crediting period (tCO_2e)

PE_{elec} = Project emissions from the use of electricity at the project production facility (tCO_2e)

PE_{ffc} = Project emissions from the combustion of fossil fuels at the project production facility (tCO_2e)

Project emissions from the use of electricity at the project production facility are calculated as:

$$PE_{elec} = Q_{elec,y} * EF_{elec} \quad (6)$$

Where:

$Q_{elec,y}$ = Quantity of electricity from the grid in year *y* used to power the project production facility in year *y* (MWH)

EF_{elec} = Emissions intensity of the electricity in tCO_2/MWH.

Project emissions from the combustion of fossil fuels at the project production facility are calculated as follows:

$$PE_{ffc} = Q_{ff,y} * FC_y * EF_{a,y} \quad (7)$$

Where:

$Q_{ff,y}$ = Quantity of fossil fuel used in year *y*

FC_y = Energy content of fuel type a combusted the year *y* (terajoule or TJ).

$EF_{a,y}$ = Emission factor of fuel in year *y* (tCO_2/TJ).

8.3 Leakage

No leakage is expected from project activities.

8.4 Net GHG Emission Reduction and Removals

Net GHG emission reductions and removals are calculated as follows:

$$ER_Y = BE_Y - PE_y \quad (8)$$

Where:

ER_Y	= Net GHG emissions reductions and removals in year y (tCO_2e)
BE_Y	= Baseline emissions in year y (tCO_2e)
PE_y	= Project emissions in year y (tCO_2e)

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	DF_{EL}
Data unit	Unitless
Description	Discount factor applied to account for the end of life of plastic material that is incinerated, releasing CO_2
Equations	2
Source of data	US EPA or similar source in other country (see Appendix II). The project proponent must use the global default for the discount factor for estimated plastic incineration levels, specified in Appendix II, unless the project proponent can provide evidence to demonstrate the proportion of plastic *products* made with plastic *material* produced through the project activity that are exported to different countries. Where data is used to create discount factors, the sources must be consistent with the current version of the *VCS Standard's* requirements for default factors (currently located in Section 4.5.6 of the *VCS Standard*, version 3.7).
Value applied	See Appendix II
Justification of choice of data or description of measurement methods and procedures applied	National environmental agencies or similar government and research institutions have accurate data on the percentage of plastic materials in conventional waste streams and what percentage of those waste stream that is incinerated.

Purpose of Data	Calculation of baseline emissions – if plastic is incinerated, the captured CO_2 is released, and reductions cannot be credited for this portion of the baseline emissions.
Comments	This discount factor is applied only to the CO_2 side of the equation because if the plastic is incinerated, it would not release CH_4, regardless of the feedstock used to produce the plastic material. Note also that the discount factor does not apply to plastic materials where CH_4 (which would have otherwise been vented) is captured in the plastic but that material is subsequently incinerated. This is due to the fact that the captured CH_4 would convert to CO_2 when the plastic is incinerated. In this case, only the CO_2 need be considered. To be updated each crediting period if new data exists.

Data / Parameter	EF_i
Data unit	tCO_2/tonne of plastic material type i produced
Description	The emissions factor for GHG's caused by the production of virgin plastic materials in tCO_2/tonne of plastic material.
Equations	2
Source of data	U.S. EPA or similar source in other country (see Appendix II for more information on the data used to calculate this variable in the U.S. below)
Value applied	See Appendix II
Justification of choice of data or description of measurement methods and procedures applied	National environmental agencies or similar government and research institutions have accurate data on energy requirements for each segment of the plastic production process including raw materials extraction and the production process itself. To be updated each crediting period if new data exists.
Purpose of Data	Calculation of baseline emissions
Comments	Different types of plastic material have different emission factors, and therefore, where the project produces more than one type of plastic material, the emissions from each type of plastic material must be summed. Default factors for different types of plastic are found in Appendix II.

Data / Parameter	GWP of CH_4
Data unit	tCO_2/tCH_4
Description	Global warming potential of methane

Equations	3
Source of data	IPCC defaults
Justification of choice of data or description of measurement methods and procedures applied	The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized, and the data provided in the guidelines is peer reviewed
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$FC_{,y}$
Data unit	TJ
Description	Energy content per unit of fuel type y
Equations	6
Source of data	IPCC defaults
Description of measurement methods and procedures to be applied	Use values from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, such as for net calorific value. The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed.
Frequency of monitoring/recording	Once per crediting period
QA/QC procedures to be applied	NA
Purpose of data	Calculation of project emissions
Comments	N/A

Data / Parameter	$EF_{a,y}$
Data unit	TCO_2/TJ
Description	Emission factor of fuel type y
Equations	6
Source of data	IPCC defaults
Description of measurement methods and procedures to be applied	Use values from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, such as for net calorific value. The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed.
Frequency of monitoring/recording	Once per crediting period, just to check if values have been updated.

QA/QC procedures to be applied	NA
Purpose of data	Calculation of project emissions
Comments	N/A

9.2 Data and Parameters Monitored

Data / Parameter	$Q_{p,i,y}$
Data unit	tonnes of plastic type *i*
Description	Quantity of plastic type *i* produced in year y
Equations	2
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	Plastic material must be weighed on scales that have available calibration procedures from the manufacturer.
Frequency of monitoring/recording	Daily or monthly
QA/QC procedures to be applied	Calibration of scales must be conducted according to the equipment manufacturer's specifications.
Purpose of data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	Q_{CO2y} and Q_{CH4y}
Data unit	tonnes of CO_2 or tonnes of CH_4
Description	The amount of CO_2 and qualifying CH_4 captured in year y to produce the products in the project activity (metric tonnes)
Equations	3
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	Use calibrated flow meters. Calibration must be conducted according to the equipment manufacturer's specifications. The amount of CO_2 or CH_4 must be metered before entering the plastic production process and must be subject to standard calibration and QA/QC procedures for the measurement of critical data variables. This data must be crosschecked with a pre-production estimate of GHG-to-product ratios to ensure that GHG feedstock

	is not released during the production process. For example, a process may take two pounds of CO_2 to manufacture one pound of plastic. Note that the quantity of any GHG captured in the process must be measured at the very point in which the GHGs are sequestered. In other words, in a multi-step process, GHGs may be captured but some may escape throughout each stage of the process. If these GHGs are thus not captured, they cannot be credited, so the meter for captured GHGs must be at the point where all GHGs will be captured and not escape.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least a daily basis.
QA/QC procedures to be applied	Calibration of meters must be conducted according to the equipment manufacturer's specifications.
Purpose of data	Calculation of baseline emissions
Comments	Note that the quantity of any GHG captured in the process must be measured at the very point in which the GHGs are sequestered. In other words, in a multi-step process, GHGs may be captured but some may escape throughout each stage of the process. If these GHGs are thus not captured, they cannot be credited, so the meter for captured GHGs must be at the point where all GHGs will be captured and not escape. In addition, at validation, project proponent should provide an estimated ratio of GHG-to-product ratios (eg: 2 lbs CO2 to 1 lb plastic). If actual verified ratios are significantly higher, project owner should provide an explanation or use the more conservative ratio provided at validation. For qualifying methane (CH4,y), this variable is necessary because if qualifying methane is captured but then a portion of the plastic is incinerated, what gets re-emitted would be CO2 and not methane. For example, if a project activity sequestered four metric tonnes of CH_4, and the discount factor were 25% -- meaning 25% of the plastic was expected to be incinerated – it can be assumed that one tonne of CO_2 (*NOT* CH_4) would be re-released. Thus baseline emissions in this case would be: (4 tonnes of methane * 25 GWP of CH4) – (4 tonnes * 25% DF * 1) = 99 tCO2eq. If the 25% discount factor were just applied to the 4 tonnes of methane captured – without any adjustment for the fact that what gets reemitted is CO2, not CH4 – baseline emissions would be an incorrect 75 tCO2eq: 4 tonnes * 25 GWP of CH4 * 75% = 75 tCO2eq.

Data / Parameter	$Q_{CO2fl,y}$
Data unit	Metric tonnes
Description	The amount of CO_2 that would have been emitted by the flaring of non-qualifying CH_4, which would – in the absence of the project – have been flared and thus emitting CO_2. But because that methane was captured instead of flared, that CO_2 was not emitted and can therefore be counted as a baseline emission. The project proponent must indicate that the captured methane would have otherwise been emitted in the absence of the project. In other words, where the captured and sequestered methane was sourced from a landfill that already has a landfill gas collection system or where LFG is required to be captured and flared, that amount of methane must be deducted from baseline emissions. For example, where half of the methane for a project facility was sourced from a landfill with an LFG collection system and half from an anaerobic digestion facility on a farm that is not required to capture methane, baseline emissions from the capture of methane must be reduced by 50 percent. For additional guidance on what does and what does not constitute qualified methane, project proponents should consult the most recent version of CDM methodology *ACM0001, Flaring or use of landfill gas*, specifically the variables relevant for quantifying baseline destruction of methane.
Equations	3
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	The project proponent should determine what percentage of the methane would have been collected in the absence of the project. For example, if half of the methane for a project facility were sourced from a landfill with an LFG collection system and half from an anaerobic digestion facility on a farm that is not required to capture methane, then baseline emissions from the capture of methane must be reduced by 50%. If that methane equaled 20 tonnes, assuming a conservative estimation for flare efficiency, the project proponent can convert that to tonnes of CO2 that would have otherwise been emitted.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least a daily basis.
QA/QC procedures to be applied	

Purpose of data	Calculation of baseline emissions
Comments	For additional guidance on what does and what does not constitute qualified methane may consult *ACM0001, Flaring or use of landfill gas*, specifically the variables that deal with quantifying the baseline destruction of methane. This document can be referenced as well for guidance on estimating flare efficiency.

Data / Parameter	$Q_{elec,y}$
Data unit	MWh/yr
Description	Quantity of electricity used by project facility supplied by the grid in year y
Equations	5
Source of data	Measurements at project facility or electric utility bills
Description of measurement methods and procedures to be applied	Use calibrated electricity meters. Calibration must be conducted according to the equipment manufacturer's specifications. Alternatively, utility billing data can be used.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least a daily basis. If utility data is used, monthly bills are acceptable
QA/QC procedures to be applied	The consistency of metered electricity generation should be cross-checked with receipts from electricity purchases where applicable
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	EF_{elec}
Data unit	tCO_2/MWH
Description	Emission intensity of electricity
Equations	5
Source of data	US eGrid or utility data or similar source if the project is in another country.
Description of measurement methods and procedures to be applied	In developing countries, standard CDM methodologies can be applied, specifically the "Tool to calculate the emission factor for an electricity system". In the US, eGrid emissions factor for the sub-region where the facility is located (latest available information) may be used.
Frequency of	Annual

monitoring/recording	
QA/QC procedures to be applied	As set out in the CDM Tool
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	$Q_{ff,y}$
Data unit	Gallons (oil fuels), cubic meters (natural gas), tonnes (solid fuels)
Description	Quantity of fossil fuel used by the project facility in year y
Equations	6
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	Use calibrated flow or gas meters. Calibration must be conducted according to the equipment manufacturer's specifications.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least a daily basis.
QA/QC procedures to be applied	The consistency of metered electricity generation should be cross-checked with receipts from fuel suppliers where applicable
Purpose of data	Calculation of project emissions
Comments	N/A

9.3 Description of the Monitoring Plan

The project must monitor all key variables, including the following:

- Quantity of CO_2 captured from the atmosphere as a GHG feedstock for the plastic material. The capture process will capture CO_2, which will then be run through a meter to measure the amount of CO_2 captured in pounds or kg.
- Quantity of methane that is collected (if CH_4 is part of the GHG feedstock) must be piped or shipped into the production facility. The amount of methane captured must be measured through traditional metering methods.

  Note that both the CO_2 and CH_4 captured must be crossed checked with pre-defined, estimated ratios of GHG input to plastic output, which must be included in the Quality Control section of the monitoring tables. In addition, the project proponent is required to account for any GHGs that escape during the manufacturing process (although the point of measurement should be the latest point just prior to when the GHG feedstock combines with other materials to form the plastic material and is thus sequestered). If it is known that the typical product requires two pounds of CO_2 per pound of plastic and if that ratio does do not correspond closely to the metered data – then there has been an error. The margin of error should be no greater than 10%.

- Production and sale of plastic material. This must be monitored through appropriate weighing techniques. Sales records must also be provided to ensure the plastic materials are entering the market and thus displacing traditional plastic products.
- Quantities of electricity and any fossil fuel used at the facility (for project emissions). Gas and electricity meter readings shall be the primary method for monitoring these data parameters. Utility-supplied data (gas and electricity bills) are acceptable.

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 scenarios. Monitoring procedures must address the following:

- Types of data and information to be reported;
- Units of measurement;
- Origin of the data;
- Monitoring methodologies (e.g., estimation, modeling, measurement and calculation);
- Type of equipment used;
- Monitoring times and frequencies;
- QA/QC procedures;
- Monitoring roles and responsibilities, including experience and training requirements;
- 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 (e.g., relevant industry standards).

All data collected as part of monitoring must be archived electronically and kept at least for 2 years after the end of the last project crediting period. QA/QC procedures must 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 (e.g., orders of magnitude) that could indicate input errors;
- All electronic files to use version control to ensure consistency;
- Physical protection of monitoring equipment;

- Physical protection of records of monitored data (e.g., hard copy and electronic records);
- Input data units checked and documented;
- All sources of data, assumptions and emission factors documented.

10 REFERENCES

1) CDM Methodology AMS III B.A.: Recovery and recycling of materials from E-Waste, UNFCCC.

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3) Postconsumers, 2011. How Long Does it Take a Plastic Bottle to Biodegrade (online at: http://www.postconsumers.com/2011/10/31/how-long-does-it-take-a-plastic-bottle-to-biodegrade/).

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7) Gourmelon, G, 2015. Global Plastic Production Rises. Worldwatch Institute (online at: http://vitalsigns.worldwatch.org/sites/default/files/vital_signs_trend_plastic_full_pdf.pdf, page 2.)

APPENDIX I: JUSTIFICATION FOR ACTIVITY METHOD

As of the writing of this methodology, there is no large-scale commercial application of the technology to capture and sequester GHGs in plastic material. There is limited activity in sequestering GHGs in concrete and other similar building materials. As of mid-2017, the company closest towards commercialization in the plastics sector has only a small pilot plant, operated by a start-up company called Newlight Technology. As a result, essentially 100 percent of all plastic materials in any market are produced using conventional, petroleum-based materials and processes, with the exception of some niche plastics made from food crops like corn or sugarcane. The use of these bioplastics is not eligible under this methodology because while these plastics do not use petroleum-based raw materials, their production does not sequester CO_2 or CH_4, one of the central tenets of this methodology.

Positive List

This project activity in particular, and carbon capture and utilization in general, is a completely new field with few if any fully commercial technologies. Thus, the methodology uses an activity method for demonstrating additionality, with this technology as the basis for a positive list. This approach stipulates that the total amount of plastic production from this alternative, GHG-capturing process does not amount to more than five percent of total plastic production worldwide. Five percent is the activity penetration threshold set by the *VCS Standard*, and is determined by taking the Observed Activity (OA) divided by the Maximum Adoption Potential (MAP). Where the result of this equation is less than five percent, the project activity may be considered additional.

In this case, as mentioned above, this project activity has not reached commercial scale. The one company, Newlight Technology, which produces the only known GHG-sequestering plastic material, has only a small pilot facility which has produced plastic for a few clients. However, this particular plastic used shipped CO_2 from another source, not a waste source like the flue gas from a power plant. Thus, the "total number of instances installed at a given date in year *y*" is zero, and thus OA can be considered to be zero.

The *VCS Standard* defines MAP as "the total adoption of a project activity that could currently be achieved given current resource availability, technological capability, level of service, implementation potential, total demand, market access and other relevant factors within the methodology's applicable geographically defined market." In this case, given the early stage of carbon capture and utilization technology, it is difficult to say exactly what the resource and other constraints are. The feedstocks, CO_2 and CH_4, are ubiquitous, and there are no particular barriers (e.g., market access or customer acceptance) that would limit the adoption of this technology. Thus, for the purposes of this methodology, the MAP can be considered the entire market for each specific type of plastic the project facility will produce, within the country where that facility is located. Therefore, clearly the activity penetration level of the project activity covered by this methodology is below the five percent threshold, and the project activity may be deemed additional.

APPENDIX II: EMISSION FACTORS

Data on emission factors from different parts of the plastic production process

Table 3 below is derived from EPA's Waste Reduction Model (WARM) section on plastics[2], which disaggregates the different sources of emissions associated with plastic production. It includes process energy (from the petroleum refining process) as well as non-process emissions and transportation. For the purposes of this methodology, only process and non-process emissions are included. Factors such as transportation that would occur in both the baseline and project scenarios (e.g., because traditional plastic or GHG-containing plastic both must be transported to their final destination) are not included because they are not expected to be different in the baseline and project scenarios.

In the analysis below, the default emission factor for each type of plastic is Column B + Column D. Thus, taking HDPE as an example, process energy is 1.19 tCO_2/short ton, non-process energy is 0.20 and adding them together provides the default equal to 1.39 tCO_2/short ton, as indicated in Table 4, below. Note that the tCO_2 in the table are expressed in short tons. These provided emission factors apply only to projects located in the United States. For projects located outside the U.S., the project proponent must derive and justify emission factors that are applicable to the project. For the purposes of calculating baseline emissions in Equation 2, the factors below must be converted into metric tonnes, which is provided in Table 4

Table 3: Raw Material Acquisition and Manufacturing Emission Factor for Virgin Production of Plastics ($MTCO_2e$/Short Ton)

(a) Material/Product	(b) Process Energy	(c) Transportation Energy	(d) Process Non-Energy	(e) Net Emissions (e = b + c + d)
HDPE	1.19	0.19	0.20	1.57
LDPE	1.40	0.19	0.21	1.80
PET	1.75	0.11	0.39	2.25
LLDPE	1.14	0.19	0.25	1.58
PP	1.17	0.17	0.21	1.55
PS	1.87	0.18	0.45	2.50
PVC	1.69	0.12	0.14	1.96

A few types of plastic material eligible to be produced through project activities are not included in the EPA report. These forms of plastic are

- Thermoplastic urethane (TPU)
- Acrylonitrile butadiene styrene (ABS)
- Polycarbonate (PC)

Emission factors for these plastic materials were derived from a different source, a report prepared for the City of Winnipeg and its South End Sewage Treatment Plant ("Winnipeg Sewage Treatment Program, Process Selection Report[3]. The emission factors included in this report are inclusive of emissions associated with transportation. Therefore, to calculate emission factors for ABS, TPU and PC that are

[2] *Waste Reduction Model (WARM), Version 13* (U.S. Environmental Protection Agency, 2015).

[3] *Process Selection Report* (Winnipeg Sewage Treatment Program, 2011).

equivalent to the emission factors for other eligible plastic materials, an estimate of transportation emissions was subtracted from the total emissions. The EPA data from the WARM Model specifies 0.19 short tons of CO_2 (equal to 0.17 metric tonnes of CO_2) as the highest (and therefore most conservative) value for emissions from transportation; this value was subtracted from total emissions for the emission factors for ABS, TPU and PC included in Table 4 below. It is reasonable to infer that transporting ABS, TPU and PC would be similar in cost and energy to all other types of plastics, a point reinforced by the fact that the transport figures in the WARM model (except for PVC) are all in a very small range. The emission factors for TPU and PC were derived from the "Other Plastics" emission factor.

Table 4: Default Emission Factors

Plastic Type	Emission Factor (tCO_2e/metric tonne of plastic material produced)
HDPE	1.26
LDPE	1.46
PET	1.94
LLDPE	1.26
PP	1.25
PS	2.10
PVC	1.66
ABS	3.29
TPU	2.53
PC	2.53

Data on percentage of plastics that are incinerated as opposed to landfilled or recycled

U.S. Environmental Protection Agency (EPA) has collected and reported data on the generation and disposition of waste in the United States for more than 30 years.

This information is used to measure the success of waste reduction and recycling programs across the country and characterize the U.S. national waste stream. The facts and figures are current through calendar year 2014.[4] The default for the U.S. is set at 15 percent for this methodology, meaning that 15 percent of the total plastics must be assumed to be incinerated with the subsequent release of CO_2. Therefore, the discount factor for the U.S. is 0.15. The source of this information in the following US EPA report: *Advancing Sustainable Materials Management: 2014 Fact Sheet Assessing Trends in Material Generation, Recycling, Composting, Combustion with Energy Recovery and Landfilling in the United States, November 2016.* On the table, this figure can be found under the category "Combustion as a percent of generation", which refers to the percent combusted as a percent of total waste generation for that category. This is based on survey and field data from the U.S. EPA.

[4] *Advancing Sustainable Materials Management: 2014 Fact Sheet* (U.S. Environmental Protection Agency, 2014).

For projects located in other countries, ministries or other government agencies that are responsible for solid waste management will likely have similar surveys. These surveys must estimate either (a) total amount of plastic disposal or (b) total plastic production and use in a country, as well as levels of reuse and recycling. In either case, independent market estimates from government, academic or trade association sources may be used to determine the level of plastics disposal in a particular country. Similarly, these same types of third-party sources must also provide estimates of the level of plastics that are included in waste streams that go to incineration. Tonnes of waste that go to municipal or private incinerators are typically available and often include the percentage of solid waste streams that are comprised of plastic materials. Taken together, these sources provide an estimate of the total percentage of disposed plastic materials that are destroyed. Where data is used to create discount factors, the sources must be consistent with the current version of the *VCS Standard's* requirements for default factors (currently located in Section 4.5.6 of the *VCS Standard*, version 3.7). The project proponent must calculate the selected discount factor in terms of tCO_2e/tonne of plastic material produced and apply this calculated discount factor to determine emissions in Equation 2.

Global Default

Where data is not available to determine a specific default factor a particular country, a "global default" may be used. A report from the WorldWatch Institute cites a U.N. Environmental Program report, describing averages in Europe. The report states, "In Europe, 26 percent, or 6.6 million tonnes, of the post-consumer plastic produced in 2012 was recycled, while 36 percent was incinerated for energy generation."[5] Based on research, Europe has the highest level of plastics incineration of any known country or region. Thus, for the purposes of the methodology, where a project proponent cannot find data on the level of baseline plastics incineration in a country where a project facility is located, a global default of 40 percent may be used as a conservative default.

[5] *Global Plastic Production Rises, Recycling Lags* (WorldWatch Instituate, 2015).