Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers

Polyoxymethylene (POM)

PlasticsEurope

February 2014

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Environmental Product Declaration

Introduction

This Environmental Product Declaration (EPD) is based upon life cycle inventory (LCI) data from PlasticsEurope's Eco-profile programme. It has been prepared according to **PlasticsEurope's Eco-profiles and Environmental Declarations – LCI Methodology and PCR for Uncompounded Polymer Resins and Reactive Polymer Precursors** (Product Category Rules version 2.0, April 2011). EPDs provide environmental performance data, but no information on the economic and social aspects which would be necessary for a complete sustainability assessment. Further, they do not imply a value judgment between environmental criteria.

This EPD describes the production of Polyoxymethylene (POM) polymer from cradle to gate (from resource extraction to polymer pellet at plant).

Please keep in mind that comparisons cannot be made on the level of the polymer material alone: it is necessary to consider the full life cycle of an application in order to compare the performance of different materials and the effects of relevant life cycle parameters. This EPD is intended to be used by member companies, to support product-orientated environmental management; by users of plastics, as a building block of life cycle assessment (LCA) studies of individual products; and by other interested parties, as a source of life cycle information.

Meta Data

Data Owner	PlasticsEurope, Product Group Engineering Plastics
LCA Practitioner	PricewaterhouseCoopers
Programme Owner	PlasticsEurope aisbl
Programme Manager, Reviewer	DEKRA Consulting GmbH
Number of plants included in data collection	2
Representativeness	>80%
Reference year	2010–2011
Year of data collection and calculation	2013
Expected temporal validity	2016
Cut-offs	No significant cut-offs
Data Quality	Good
Allocation method	No allocation in foreground process

Description of the Product and the Production Process

Polyoxymethylene (POM), a semi-crystalline thermoplastic, belongs to the polyacetals family of polymers. POM exists in two different forms: homopolymer (POM-h) and copolymer (POM-c). POM has mechanical properties which are suitable for high-performance applications, such as injection-moulded parts for household appliances. This EPD is for both POM-h and POM-c, as the difference in terms of LCA is small.

Production Process

POM is produced through the polymerisation of formaldehyde (for POM-h) or of trioxane with a smaller quantity of co-monomer (for POM-c). Formaldehyde is produced through the oxidation of methanol. The reference flow, to which all data given in this EPD refer, is 1 kg of POM in pellet form.

Data Sources and Allocation

The main data source was a data collection from European producers of POM. Primary data on gate-to-gate POM production is derived from site-specific information for processes under operational control supplied by the participating companies of this study. Two different POM producers with plants in two European countries were participating in the primary data collection. They rare expected to epresent >80% of POM production in Europe (EU27) in 2010–2011. In order to enhance representativeness and to protect confidentiality of producer data, a third dataset was put together by PwC from literature sources and specialist expertise and used in the vertical average. Background data for the upstream supply chain up to the precursors were obtained from the *DEAM*, *GaBi*, PlasticsEurope, and *Ecoinvent* databases.

Use Phase and End-of-Life Management

Used mainly in industrial, automotive and consumer applications, POM resin is used to produce injection-moulded mechanical and electrical parts such as gears, sliding and guide elements, screwing and assembly pieces, insulators and connectors etc.

Environmental Performance

The tables below show the environmental performance indicators associated with the production of 1 kg of POM.

Input Parameters

Indicator	Unit	Value
Non-renewable energy resources[1]		85.1
• Fuel energy	MJ	65.7
• Feedstock energy	MJ	19.3
Renewable energy resources (biomass)[1]		0.94
• Fuel energy	MJ	0.86
• Feedstock energy	MJ	0.08
Abiotic Depletion Potential		
• Elements	kg Sb eq	1.6E-06
• Fossil fuels	MJ	84.9
Renewable materials (biomass)	kg	8.6E-03
Water use	kg	544
• for process	kg	33
• for cooling	kg	512
[1] Calculated as upper heating value (UHV)		

Output Parameters

Indicator	Unit	Value
GWP	kg CO_2 eq	3.2
ODP	g CFC-11 eq	1.6E-04
AP	g SO_2 eq	5.4
POCP	g Ethene eq	0.5
EP	g PO_4 eq	1.2
Dust/particulate matter[2]	g PM10	0.35
Total particulate matter[2]	g	0.35
Waste (foreground process)		
• Non-hazardous	kg	1.05
• Hazardous	kg	2.2E-03
[2] Including secondary PM10		

Additional Environmental and Health Information

POM is inert under use phase conditions. However, during processing, when heated for extrusion or moulding, small quantities of formaldehyde may be released. Occupational health protection must be in place. The manufacturers of polyacetals are working through PlasticsEurope, the American Chemistry Council (ACC) and other industry groups to foster product safety and to actively engage with stakeholders.

Additional Technical Information

POM combines high stiffness and strength with outstanding resilience: low friction coefficient, high abrasion and heat resistance, and excellent dimensional stability, even under the effect of mechanical forces, in contact with numerous chemicals, fuels and other media as well as at elevated temperatures. It also has good electrical insulating properties.

Information

Data Owner

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Programme Manager & Reviewer

DEKRA Consulting GmbH

This Environmental Product Declaration has been reviewed by DEKRA Consulting GmbH. It was approved according to the Product Category Rules PCR version 2.0 (2011-04) and ISO 14025:2006. Registration number: PlasticsEurope 2013-002, validation expires on 31 December 2016 (date of next revalidation review).

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For copies of this EPD, for the underlying LCI data (Eco-profile), and for additional information, please refer to http://www.plasticseurope.org/.

References

- PlasticsEurope: Eco-profiles and environmental declarations – LCI methodology and PCR for uncompounded polymer resins and reactive polymer precursors (version 2.0, April 2011).
- Cover image with kind permission by DuPont International Operations Sàrl.

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The Material for the 21st Century

Goal & Scope

Intended Use & Target Audience

➢ *Eco-profiles (LCIs) and EPDs from this programme are intended to be used as "cradle-to-gate" building blocks of life cycle assessment (LCA) studies of defined applications or products. LCA studies considering the full life cycle ("cradle-to-grave") of an application or product allow for comparative assertions to be derived. It is essential to note that comparisons cannot be made at the level of the polymer or its precursors. In order to compare the performance of different materials, the whole life cycle and the effects of relevant life cycle parameters must be considered.*

PlasticsEurope Eco-profiles and EPDs represent polymer production systems with a defined output. They can be used as modular building blocks in LCA studies. However, these integrated industrial systems cannot be disaggregated further into single unit processes, such as polymerisation, because this would neglect the interdependence of the elements, e.g. the internal recycling of feedstocks and precursors between different parts of the integrated production sites.

PlasticsEurope Eco-profiles and EPDs are prepared in accordance with the stringent ISO 14040–44 requirements. Since the system boundary is "cradle-to-gate", however, their respective reference flows are disparate, namely referring to a broad variety of polymers and precursors. This implies that, in accordance with ISO 14040–44, a direct comparison of Eco-profiles is impossible. While ISO 14025, Clause 5.2.2 does allow EPDs to be used in comparison, PlasticsEurope EPDs are derived from Eco-profiles, i.e. with the same "cradle-to-gate" system boundaries.

As a consequence, a direct comparison of Eco-profiles or EPDs makes no sense because 1 kg of different polymers are not functionally equivalent.

Once a full life cycle model for a defined polymer application among several functionally equivalent systems is established, and only then, can comparative assertions be derived. The same goes for EPDs, for instance, of building product where PlasticsEurope EPDs can serve as building blocks.

Eco-profiles and EPDs are intended for use by the following target audiences:

- member companies, to support product-orientated environmental management and continuous improvement of production processes (benchmarking);
- downstream users of plastics, as a building block of life cycle assessment (LCA) studies of plastics applications and products; and
- other interested parties, as a source of life cycle information.

Product Category and Declared Unit

Product Category

The core product category is defined as **uncompounded polymer resins, or reactive polymer precursors**. This product category is defined "at gate" of the polymer or precursor production and is thus fully within the scope of PlasticsEurope as a federation. In some cases, it may be necessary to include one or several additives in the Eco-profile to represent the polymer or precursor "at gate". For instance, some polymers may require a heat stabiliser, or a reactive precursor may require a flame retardant. This special case is distinguished from a subsequent compounding step conducted by a third-party downstream user (outside PlasticsEurope's core scope).

Functional Unit and Declared Unit

The default Functional Unit and Declared Unit of PlasticsEurope Eco-profiles and EPDs are (unless otherwise specified[1]):

1 kg of primary POM "at gate" (production site output) representing a European industry production average, in pellet form.

Product and Producer Description

Product Description

Polyoxymethylene (POM) is a semi-crystalline thermoplastic polymer, existing in homopolymer (POM-h) and co-polymer (POM-c) forms. POM homopolymer chains are made solely of $–CH_2O–$ units while copolymer units have the following general structure: $–[(CH_2O)_p–/–CH_2CH_2O]_n$.

- IUPAC name: none, both POM-h and POM-c forms are covered by the name POM; a synonym for POM-h is poly(oxymethylene) glycol.
- CAS no. 9002-81-7 (POM-h); CAS no. 24969-26-4 (POM-c).
- Density: 1.42 g/cm^3 (POM-h); 1.41 g/cm^3 (POM-c).
- Chemical formula: $–[CH_2O]_n–$ (homopolymer); $–[(CH_2O)_p–/–CH_2CH_2O]_n–$ (copolymer).

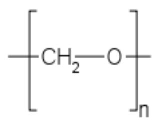

Figure 1: Structure of the repeated unit in POM-h

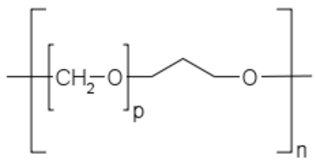

Figure 2: Structure of the repeated unit in POM-c

POM belongs to the family of polyacetals. The homopolymer chains are made only of carbon-oxygen bonds, whereas the chains of the POM copolymer also comprise carbon-carbon bonds.

POM was first synthesised in the 1950's and the first consumer-products made from POM were put on the market in 1959. It has many applications thanks to its mechanical and physical properties: low friction, excellent abra-

[1] Exceptions can occur when reporting Eco-profiles of, for instance, process energy, such as on-site steam, or conversion processes, such as extrusion.

sion and wear resistance, excellent creep resistance, and durability. It may be processed by injection moulding or extrusion to form mechanical components.

POM-h is produced through polymerisation of formaldehyde, which in turn is derived from oxidation of methane via methanol:

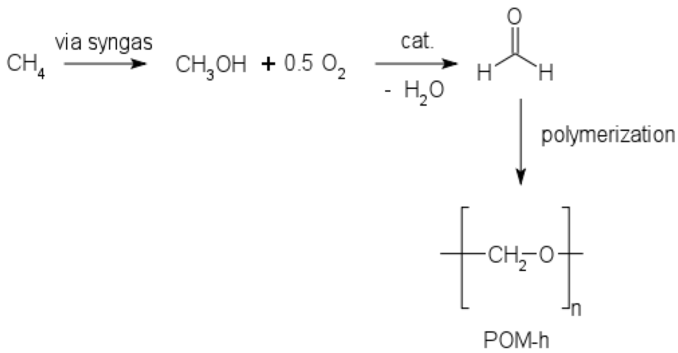

Figure 3: POM-h synthesis overview

POM-c is obtained through the polymerisation of trioxane, a derivative of formaldehyde, with a copolymer:

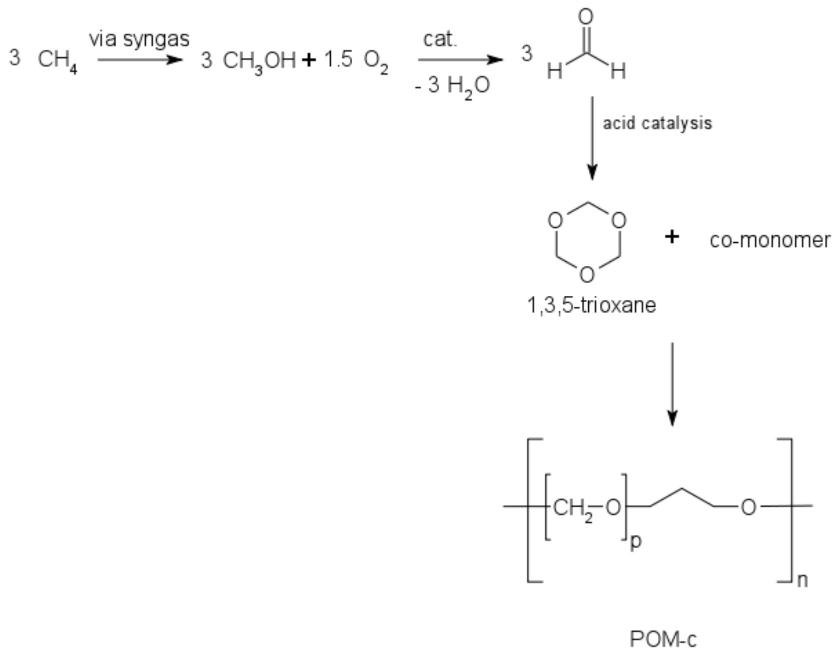

Figure 4: POM-c synthesis overview

where the syngas reactions are as follows:

$CO + 2H_2 \leftrightarrow CH_3OH$
$CO_2 + 3H_2 \leftrightarrow CH_3OH + H_2O$
$CO_2 + H_2 \leftrightarrow CO + H_2O$.

The processes described here, including supplementary materials (catalysts for instance), energy and utilities needed, are referred to as “foreground processes” as they are under direct management control. Related upstream processes (raw materials or chemicals production, fuels production, etc) are referred to as “background processes”.

Producer Description

PlasticsEurope Eco-profiles and EPDs represent European industry averages within the scope of PlasticsEurope as the issuing trade federation. Hence they are not attributed to any single producer, but rather to the European plastics industry as represented by PlasticsEurope’s membership and the production sites participating in the Eco-profile data collection. The following companies contributed data to this Eco-profile and EPD of POM:

- DuPont
- Celanese Engineered Materials (CEM)
- Third dataset from literature information.

Eco-profile – Life Cycle Inventory

System Boundaries

PlasticsEurope Eco-profiles and EPDs refer to the production of polymers as a cradle-to-gate system (Figure 4).

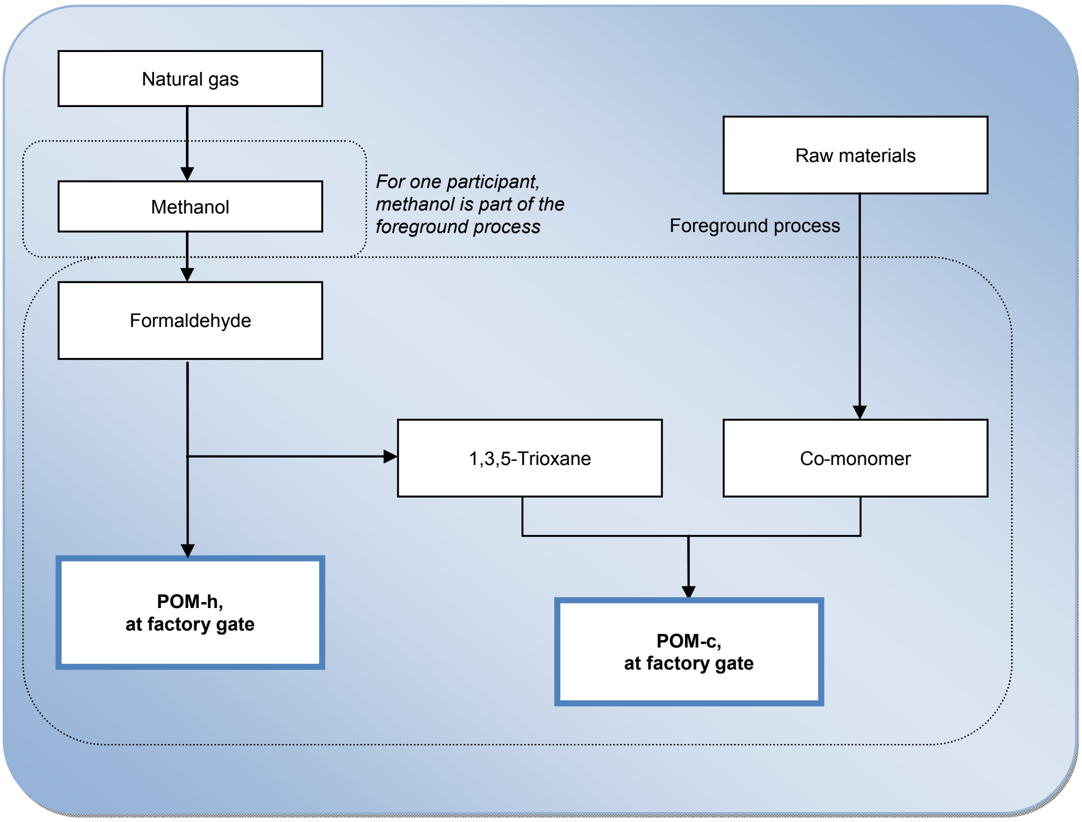

Figure 4: Cradle-to-gate system boundaries

Technological Reference

The production processes were modelled using specific values from a primary data collection at site, representing the specific technologies in use with the two producers having participated in the project. Primary data were used for all foreground processes (under operational control), whereas secondary data was used for background processes (under indirect management control). In order to enhance representativeness and to protect confidentiality of producer data, a third dataset was put together by PwC from literature sources and specialist expertise and used in the vertical average. Production capacity for POM was around 250 ktonnes in 2006 (production volume around 180 ktonnes); with current production above 240 ktonnes reported by participating producers, the representativeness – even in absence of current Europan totals – is expected to exceed 80%.

Temporal Reference

The LCI data for production was collected as 12 month averages representing the years 2010 for one producer and 2011 for the other. The overall reference year for this Eco-profile is 2010–2011 with a maximal temporal validity until 2016; this conservative validity period takes the lower representativeness (see below) into consideration.

Geographical Reference

Primary production data for POM are from two different European producers. Fuel and energy inputs in the system reflect average European conditions and whenever applicable, site specific conditions were applied, to reflect representative situations. Therefore, the study results are intended to be applicable within EU27+2 boundaries – in order to be applied in other regions, adjustments might be required. Formaldehyde imported into Europe was not considered in this Eco-profile.

Cut-off Rules

In the foreground processes all relevant flows were considered, trying to avoid any cut-off of material and energy flows. At least 95 % of mass and energy of the input and output flows were covered and 98 % of their environmental relevance (according to expert judgment) was considered, hence an influence of cut-offs less than 2 % on the total is expected.

Data Quality Requirements

Data Sources

Eco-profiles developed by PlasticsEurope use average data representative of the respective foreground production process, both in terms of technology and market share. The primary data are derived from site-specific information for processes under operational control supplied by the participating member companies of PlasticsEurope (see Producer Description).

Relevant foreground data for the third dataset was taken from literature (patents and process descriptions) and specialist input on precursor properties, specifics of involved chemical reactions, and chemical engineering processes.

All relevant background data such as energy and auxiliary material are from the *DEAM*, *PlasticsEurope* and *Ecoinvent 2.2* databases; formaldehyde as a background process is from the *GaBi* database. Most of the background data and the pertinent documentation are publicly available.

Relevance

With regard to the goal and scope of this Eco-profile, the collected primary data of foreground processes are of high relevance. However, primary data were available from only two European producers. Further, the dominance analysis (Table 18) showed that there is a substantial contribution of background datasets on impact indicators.

Representativeness

The participating companies represent more than 80% of POM production volume in Europe in 2011. The selected background datasets can be regarded as representative for the intended purpose.

Consistency

To ensure consistency, only primary data of the same level of detail and background data from the *DEAM* and *PlasticsEurope* databases were used; failing that, data from *Ecoinvent* were used. While building up the model, cross-checks concerning the plausibility of mass and energy flows were continuously conducted. The methodological framework is consistent throughout the whole model as the same methodological principles are used both in foreground and background system.

Reliability

Data reliability ranges from measured to estimated data. Data of foreground processes provided directly by producers were predominantly measured. Data of relevant background processes were measured or derived from literature; qualified estimates were used for some flows.

Completeness

Primary data used for the gate-to-gate production of POM covers all related flows in accordance with the cut-off criteria (i.e. considering mass, energy, and environmental relevance). Thus, all relevant flows were quantified and data is considered complete.

Precision and Accuracy

As the relevant foreground data is primary data or modelled based on primary information, precision is considered sufficient within this goal and scope.

Reproducibility

All data and information used are either documented in this report or they are available from the processes and process plans designed within the *TEAM®* software. The reproducibility is given for internal use since the owners of the technology provided the data and the models are stored and available in a database. Sub-systems are modelled by state of the art technology using data from a publicly available and internationally used database. It is worth noting that for external audiences, full reproducibility cannot be fully ensured due to the confidentiality of some primary information. However, experienced experts are able to recalculate and reproduce suitable parts of the system as well as key indicators.

Data Validation

Primary data collected from project partners was validated by the data providers in an iterative process several times, using existing data from published sources and expert knowledge. The background information from the databases is updated regularly and validated through regular feedback by users worldwide.

Life Cycle Model

The study has been performed with the LCA software *TEAM®*. The associated database complies with ISO 14040/44 requirements. Due to confidentiality reasons, details on software modelling and methods used cannot be shown here.

Calculation Rules

Vertical Averaging

As only two member companies participated, a horizontal average calculation was used for formaldehyde (intermediate). A vertical average was calculated from formaldehyde until POM (Figure 5).

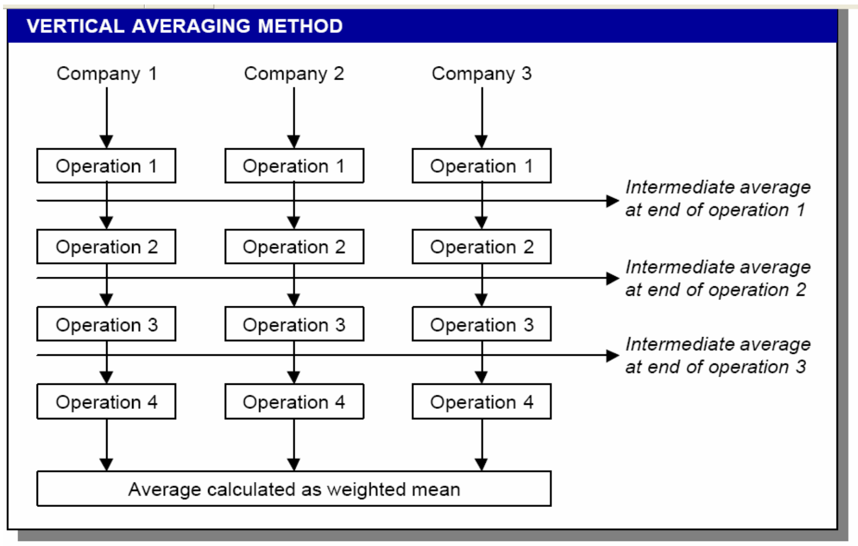

Figure 5: Vertical Averaging (source: Eco-profile of high volume commodity phthalate esters, ECPI European Council for Plasticisers and Intermediates, 2001)

Allocation Rules

Production processes in chemical and plastics industry are usually multi-functional systems, i.e. they have not one, but several valuable product and co-product outputs. Wherever possible, allocation should be avoided by expanding the system to include the additional functions related to the co-products. Often, however, avoiding allocation is not feasible. In such cases, the aim of allocation is to find a suitable partitioning parameter so that the inputs and outputs of the system can be assigned to the specific product sub-system under consideration. Within the scope of this Eco-profile, allocation was unnecessary in the foreground system; background datasets were used without changes.

Life Cycle Inventory (LCI) Results

Formats of LCI Dataset

The Eco-profile is provided in three electronic formats:

- As input/output table in Excel®
- As XML document in EcoSpold format (www.ecoinvent.org)
- As XML document in ILCD format (http://lct.jrc.ec.europa.eu)

Key results are summarised below.

Energy Demand

As a key indicator on the inventory level, the **primary energy demand** (system input) of 87.8 MJ/kg indicates the cumulative energy requirements at the resource level, accrued along the entire process chain (system boundaries), quantified as gross calorific value (upper heating value, UHV). As a measure of the share of primary energy incorporated in the product, and hence indicating a recovery potential, the **energy content in the polymer** (system output), quantified as the gross calorific value (UHV), is approximately 19 MJ/kg.

Table 1: Primary energy demand (system boundary level) per 1kg POM

Primary Energy Demand	Value [MJ]
Energy content in polymer (energy recovery potential, quantified as gross calorific value of polymer)	19.4
Process energy (quantified as difference between primary energy demand and energy content of polymer)	66.6
Total primary energy demand	**86.0**

Consequently, the difference (Δ) between primary energy input and energy content in polymer output is a measure of **process energy** which may be either dissipated as waste heat or recovered for use within the system boundaries. Useful energy flows leaving the system boundaries were removed during allocation.

Table 2 shows how the total energy input (primary energy demand) is used as fuel or feedstock. Fuel use means generating process energy, whereas feedstock use means incorporating hydrocarbon resources into the polymer. Note that some feedstock input may still be valorised as energy; furthermore, process energy requirements may also be affected by exothermal or endothermal reactions of intermediate products. Hence, there is a difference between the feedstock energy input and the energy content of the polymer (measurable as its gross calorific value). Considering this uncertainty of the exact division of the process energy as originating from either fuels or feedstocks, as well as the use of average data (secondary data) in the modelling with different country-specific grades of crude oil and natural gas, the feedstock energy has 20% of uncertainty.

Table 2: Analysis by primary energy resources (system boundary level), expressed as energy and/or mass (as applicable) per 1kg POM

Primary energy resource input	Total Energy Input [MJ]	Total Mass Input [kg]	Feedstock Energy Input* [MJ]	Fuel Energy Input [MJ]
Coal	5.2	0.19	0.0	5.2
Oil	2.2	0.05	0.0	2.2
Natural gas	71.8	1.3	19.3	52.5
Lignite	1.7	0.12	0.0	1.7
Nuclear	4.1	7.3E-06	0.0	4.1
Biomass	0.08	4.5E-03	0.0	8.2E-02
Hydro	0.3	0.0	0.0	0.3
Solar	0.2	0.0	0.0	0.2
Geothermics	0.00	0.0	0.0	0.0
Waves	0.00	0.0	0.0	0.0
Wood	0.08	4.1E-03	0.08	0.0
Wind	0.2	0.0	0.0	0.2
Other renewable fuels	0.0	0.0	0.0	0.0
Sub-total renewable	**0.94**	**0.01**	**0.08**	**0.86**
Sub-total Non-renewable	**85.1**	**1.7**	**19.3**	**65.7**
Total	**86.0**	**1.7**	**19.4**	**66.6**

*) the partitioning for feedstock is based on expertise and subject to an uncertainty of about 20%.

Table 3 shows that nearly all of the primary energy demand is from non-renewable resources. Since the scope of PlasticsEurope and their member companies is the polymer production, Table 4 analyses the types of useful energy inputs in the polymerisation: electricity has a minor contribution, whereas the majority is thermal energy (heat). This represents the share of the energy requirement that is under operational control of the polymer producer. Accordingly, Table 5 shows that the majority (about 75%) of the primary energy demand is accounted for by upstream processes. Finally, Table 6 provides a more detailed overview of the key processes along the production system, their contribution to primary energy demand and how this is sourced from the respective energy resources. This puts the predomimant contribution of the production into perspective with the precursors (»other chemicals«). In order to analyse these upstream operations more closely, please refer to the Eco-profiles of the respective precursors. It should be noted, however, that the LCI tables in the annex account for the entire cradle-to-gate primary energy demand of the POM system.

Table 3: Primary energy demand by renewability per 1kg POM

Fuel/energy input type	Value [MJ]	%
Renewable energy resources	0.9	1%
Non-renewable energy resources	85.1	99%
Total	86.0	100%

Table 4: Analysis by type of useful energy (POM production – unit process level) per 1kg POM

Type of useful energy in process input	Value [MJ]
Electricity	10–15
Heat, thermal energy	0–10
Other types of useful energy (relevant contributions to be specified)	0
Total (for selected key process)	20–30

Table 5: Contribution to primary energy demand (dominance analysis) per 1kg POM

Contribution to Primary Energy per segment	Value [MJ]	%
Production (electricity, steam, unit process, utilities, waste treatment)	61–69	approx. 80%
Pre-chain	17–25	approx. 20%
Total	86.0	100%

Table 6: Contribution of life cycle stages to total primary energy demand (gross calorific values) per 1kg POM

Total Primary Energy [MJ]	Formal-dehyde	POM	Others	Utilities	Electricity	Thermal Energy	Transport (fore-ground)
Coal			1.83	0.01	1.06	0.01	8.6E-04
Oil			0.28	0.00	4.1E-02	2.4E-03	9.6E-04
Natural gas	+++	++	40.78	0.00	0.97	0.5	5.4E-04
Lignite			0.30	0.00	7.4E-04	5.3E-10	6.0E-04
Nuclear		+	1.42	0.01	0.29	0.02	1.0E-03
Biomass			3.2E-02	2.6E-04	0.0	8.9E-04	0.0
Hydro			9.8E-02	0.00	0.0	0.0	0.0
Solar			1.2E-04	1.7E-06	0.0	0.0	0.0
Geothermics			0.0	0.0	0.0	0.0	0.0
Waves			0.0	0.0	0.0	0.0	0.0
Wood			2.6E-02	3.1E-04	3.7E-03	6.0E-11	4.3E-05
Wind			8.6E-03	1.2E-04	0.0	0.0	0.0
Other renewable fuels			0.0	0.0	0.0	0.0	0.0

Water Consumption

The evaporated water from cooling system can be estimated. The ratio between the input water amount for cooling system and the evaporated water amount is approximately 3% (based on public documentation). In the scope of this project, it was not feasible anymore to implement the emerging methodology for water inventory. Therefore, only a differentiation by source is provided (Table 7). Note that this gross water consumption data cannot be used for purposes of water footprinting.

Table 7: Gross water resources per 1kg POM

Source	Process water [kg]	Cooling water [kg]	Total [kg]
Public supply	0.2	1.5	1.7
River/canal	6.0	510	516
Sea	3.6		3.6
Unspecified	1.0		1.0
Well	10.9		10.9
Lake	11.3		11.3
Totals	**32.9**	**512**	**544**
Turbined water (unspecified source, directly released to environment)			**1620**

Air Emission Data

Table 8 shows a few selected air emissions which are commonly reported and used as key performance indicators; for a full inventory of air emissions, please refer to the complete LCI table in the annex of this report.

Table 8: Selected air emissions per 1kg POM

Air emissions	kg
Carbon dioxide, fossil (CO_2, fossil)	2.9
Carbon monoxide (CO)	1.5E-03
Sulphur dioxide (SO_2)	3.2E-03
Nitrogen oxides (NO_x)	2.9E-03
Particulate matter ≤ 10 µm (PM 10)	3.5E-04

Wastewater Emissions

Table 9 shows a few selected wastewater emissions which are commonly reported and used as key performance indicators; for a full inventory of wastewater emissions, please refer to the complete LCI table in the annex of this report.

Table 9: Selected water emissions per 1kg POM

Water emissions	**kg**
Biological oxygen demand after 5 days (BOD_5)	1.1E-03
Chemical oxygen demand (COD)	1.7E-03
Total organic carbon (TOC)	5.7E-04

Solid Waste

Table 10: Solid waste generation per 1kg POM (key foreground process level)

Waste for –	Incineration kg	Landfill kg	Recovery kg	Unspecified kg	Total kg
Non-hazardous	6.4E-04	0	1.3E-03	1.05*	1.05
Hazardous	9.4E-04	0	2.5E-05	1.2E-03	2.2E-03
Unspecified	5.8E-06	4.3E-03	0	1.7E-02	0.02
Total	1.6E-03	4.3E-03	1.3E-03	1.07	**1.08**

*) Waste tailings or overburden (deposited) are included in this figure. Note that this is waste for disposal and not after disposal. The high contribution is from the literature dataset.

Life Cycle Impact Assessment

Input

Natural Resources

Table 11: Abiotic Depletion Potential per 1kg POM

Natural resources	Value
Abiotic Depletion Potential (ADP), elements [kg Sb eq]	1.6E-06
Abiotic Depletion Potential (ADP), fossil fuels [MJ] (ultimate reserves)	84.9

Output

Climate Change

Table 12: Global Warming Potential (100 years) per 1kg POM

Climate change	kg CO_2 eq.
Global Warming Potential (GWP)	3.2

Acidification

Table 13: Acidification Potential per 1kg POM

Acidification of soils and water bodies	g SO_2 eq.
Acidification Potential (AP)	5.4

Eutrophication

Table 14: Eutrophication Potential per 1kg POM

Eutrophication of soils and water bodies	g PO_4^{3-} eq.
Eutrophication Potential (EP), total	1.2

Ozone Depletion

Table 15: Ozone Depletion Potential per 1kg POM

	g CFC-11 eq.
Ozone Depletion Potential (ODP)	1.6E-04

Summer Smog

Table 16: Photochemical Ozone Creation Potential per 1kg POM

	g Ethene eq.
Photochemical Ozone Creation Potential (POCP)	0.5

Dust & Particulate Matter

Table 17: PM10 emissions per 1kg POM

Particulate matter	g PM10 eq.
Particulate matter ≤ 10 µm. total	0.35
Particulate matter ≤ 10 µm (direct emissions)	0
Particulate matter ≤ 10 µm. secondary	0.35

Dominance Analysis

Table 18 shows the main contributions to the results presented above. Only a qualitative rating is used to protect the confidentiality of the two primary datasets, whereas the third dataset from literature is aggregated. In all analysed environmental impact categories, intermediates make a substantial contribution, the only exceptions being the indicators AP and EP.

Table 18: Dominance analysis of impacts per 1kg POM

	Total Primary Energy [MJ]	ADP Elements [kg Sb eq.]	ADP Fossil [MJ]	GWP [kg CO_2 eq.]	AP [g SO_2 eq.]	EP [g PO_4^{3-} eq]	POCP [g Ethene eq.]
Formaldehyde	+++	+	+++	+++	++	+	++
POM	++	++++	++	++	++	++++	++
Transport (foreground)							
Other chemicals	++++	+++	++++	+++	+++	+++	+++
Utilities		+				+	
Electricity	+		+	+	+	+	+
Thermal energy	+		+	+			

Review

Review Details

The project included regular milestone meetings with representatives of all participating producers and PlasticsEurope as system operator. The reviewer participated in these meetings. In addition, a review meeting between the LCA practitioner and the reviewer was held, including a model and database review, and spot checks of data and calculations.

This project presented a particular challenge because, contrary to goal and scope, the inclusion of a third major producer with a primary dataset became impossible at a late stage. Consequently, the practitioner had to develop a literature dataset to enable the preparation of this Eco-profile at all. Limitations on data quality arising from this decision are thus not attributable to the practitioner nor to the quality of the primary data provided by the two remaining companies; they are rather an upshot of the amalgamated life cycle model.

Specific comments on the results include:

- Proxy datasets needed to be developed to represent auxiliaries of trioxane and co-monomer production. The impact of these proxy data was assessed and, also due to their mass contributions of less than 1%, found to be negligible.
- The differentiation of the water inventory by source and destination (allowing for a water balance and supporting water footprints) should be included in future updates.

Compliance with ILCD Entry-level Requirements

Table 19: General review reporting items (reproduced with kind permission of JRC)

REVIEW REPORTING			
General information			
Data set name	**Polyoxymethylene (POM)**		
Data set UUID and version number	n/a		
Data set locator (e.g. Permanent URI, URL, contact point, or database name and version, etc.)	n/a		
Data set owner	PlasticsEurope aisbl		
Review commissioner(s)	PlasticsEurope aisbl		
Reviewer name(s) and affiliation(s), contact	Dr.-Ing. Ivo Mersiowsky, DEKRA Consulting GmbH		
Review type applied	Independent external		
Date of review completion (DD/MM/YYYY)	13/12/2013		
Reviewed against / Compliance system name	ILCD Data Network – Entry-level requirements		
Reviewer assessment:			
Aspect	**Yes**	**No**	**Comments**
Quality compliance (ISO 14040 & 14044) fulfilled (see Table 20)	X		
Method compliance (ISO 14040 & 14044) fulfilled and documented in data set	X		
Nomenclature compliance (see Table 21) fulfilled	X		
Documentation compliance (see Table 21) fulfilled	X		
Review compliance (Independent external review report) fulfilled	X		
Compliant with ISO 14040 & 14044	X		
Overall compliant with compliance system	X		
Date, location, reviewer signature	13 December 2013, Stuttgart, Germany		

Table 20: Specific/detailed review reporting items for LCI data set: quality compliance (ISO 14040 & 14044; reproduced with kind permission of JRC)

ITEMs	Comments
Time-related coverage/representativeness: "age of data and the minimum length of time over which data should be collected" "qualitative assessment of the degree to which the data set reflects the true population of interest"	**Good** Foreground: 12 month averages representing the years 2010 (producer 1) and 2011 (producer 2). Background: wide range from 1990s to 2000s. Substantial contribution expected from natural gas (2005). Maximum temporal validity until 2016. (p.10)
Geographical coverage/representativeness: "geographical area from which data for unit processes should be collected to satisfy the goal of the study" "qualitative assessment of the degree to which the data set reflects the true population of interest"	**Good** European production average (data from two producers in two different European countries; supplemented by average from literature). (p.11)
Technology coverage/representativeness: "specific technology or technology mix" "qualitative assessment of the degree to which the data set reflects the true population of interest"	**Good** Technology mix representing European production (see above). >80 % of the European production capacity (EU-27) in 2010–2011. Two specific technologies supplemented by average from literature. (p.10)
Precision: "measure of the variability of the data values for each data expressed (e.g. variance)"	**n/a** Relevant foreground data is primary data, or modelled based on primary information sources of the owners of the technologies. See Uncertainty below for explanation of "n/a" rating. (p. 11)
Completeness: "percentage of flow that is measured or estimated"; assessed on level of process	**Very good** Primary data used for the gate-to-gate production covered all relevant flows in accordance with the cut-off criteria, i.e. at least 95 % of mass and energy of the input and output flows, and 98 % of their environmental relevance (according to expert judgment) were considered. (p.12)
Consistency: "qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis"	**Good** Primary data of the same level of detail and background data from DEAM and other databases were used. While building up the model, cross-checks ensured the plausibility of mass and energy flows. Due to the relevance of background datasets from different databases and the inclusion of literature data, the overall consistency rating is reduced. (p.11)
Sources of the data; Appropriateness of use primary/secondary data source	The main data source was a primary data collection from European producers, providing site-specific gate-to-gate production data for processes under operational control of the participating companies. Data for the upstream supply chain until the precursors are taken from several databases (DEAM, PlasticsEurope, GaBi, ecoinvent). (p. 11)
Uncertainty of the information (e.g. data, models and assumptions).	Variation of single data was not recorded. Variation of the model/dataset not applicable due to vertical average of production lines and technologies. The critical aspect within this model is the inclusion of literature data as a proxy for a third original dataset. Hence, Precision above was rated "n/a". (p.12)

Table 21 Specific/detailed review reporting items for LCI data set: nomenclature and documentation (reproduced with kind permission of JRC)

ITEMs	Comments
Nomenclature	
Correctness and consistency of applied nomenclature	Yes
Documentation	
Appropriateness of documentation extent (see document "Documentation of LCA data sets")	Yes
Appropriateness of documentation form (ILCD Format)	Yes

Review Summary

This Eco-profile has a noticeably lower representativeness than other reports from the PlasticsEurope programme: this is because only two primary datasets were available. Through inclusion of literature data, the resulting dataset is still considered reliable and good quality representation of POM production in Europe. Once a third original dataset, with a substantial contribution to the European production volume, becomes available an expansion and recalculation is highly recommended to improve the achievable data quality ratings. The critical review confirms that this Eco-profile adheres to the rules set forth in the PlasticsEurope's Eco-profiles and Environmental Declarations – LCI Methodology and PCR for Uncompounded Polymer Resins and Reactive Polymer Precursors (PCR version 2.0, April 2011).

Reviewer Name and Institution

Dr.-Ing. Ivo Mersiowsky, Business Line Manager Sustainability Leadership, DEKRA Consulting GmbH, Stuttgart, Germany

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ISO 14044: 2006	ISO 14044 Environmental management -- Life cycle assessment -- Requirements and guidelines. Geneva, 2006
ILCD 2010	European Commission (2010): ILCD Handbook – General guide for Life Cycle As-sessment (LCA) – Detailed guidance
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