



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

# Polyamide 6 (PA6)

PlasticsEurope  
February 2014

# 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** (PCR 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 the Polyamide 6 (PA6) polymer from cradle to gate (from crude oil extraction to granules or resin 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 Polymers
LCA Practitioner	PricewaterhouseCoopers
Programme Owner	PlasticsEurope aisbl
Programme Manager, Reviewer	DEKRA Consulting GmbH
Number of plants included in data collection	7
Representativeness	57%
Reference year	2010–2012
Year of data collection and calculation	2012–2013
Expected temporal validity	2016
Cut-offs	No significant cut-offs
Data Quality	Very good
Allocation method	No allocation; substitution method is used for co-products

## Description of the Product and the Production Process

Polyamides are a group of polymers characterised by a carbon chain with  $-C=O-NH-$  groups interspersed at regular intervals along it. They are commonly referred to by the generic name Nylon and are usually identified by a numbering system that indicates the number of carbon atoms between successive nitrogen atoms in the main chain. This EPD is for Polyamide 6 (PA6), a polymer formed by ring-opening polymerisation of caprolactam, a cyclic monomer. Caprolactam has a peptide bond which is broken during polymerisation, after which new peptide bonds are formed at each end of the monomer. This leads to a backbone polymer.

## Production Process

PA6 is formed by polymerisation of caprolactam. Caprolactam is produced from cyclohexanone, which reacts with hydroxylamine to form an oxime which undergoes a Beckmann rearrangement with an acid to form the bisulphate salt of caprolactam. The latter is neutralised with an alkali compound to form caprolactam. A byproduct of caprolactam production is ammonium sulphate. As for cyclohexanone, there are two ways to produce it using benzene as a starting chemical: one route is the hydrogenation of benzene to produce cyclohexane, which is then oxygenated to give cyclohexanone. The alternative route uses the reaction of benzene with propylene. This gives cumene that can be further oxygenated to phenol, giving acetone as by-product. Phenol can then be hydrogenated to form cyclohexanone.

The reference flow, to which all data given in this EPD refer, is 1 kg of PA6 in pellet form.

## Data Sources and Allocation

The main data source was a data collection from European producers of polyamide 6 (PA6). Primary data on gate-to-gate PA6 production is derived from site-specific information for processes under operational control supplied by the participating companies of this study. Four different PA6 producers with plants in four European countries were participating

in the primary data collection. They represent approximately 57% of European PA6 production (EU27) in 2012. Unless primary data were provided, data for the upstream supply chain until the precursors as well as relevant background data, such as energy and auxiliary material, are from the *DEAM*, *PlasticsEurope* and *Ecoinvent* databases. For caprolactam, three caprolactam producers with plants in three European countries participated in the primary data collection.

### Use Phase and End-of-Life Management

PA6 can be extruded, granulated and moulded in a wide range of textile, packaging and engineering applications. The main uses include fibers, films and engineering plastics. Applications range from automotive and electrical to food packaging. It should be noted that PA6 (polycaprolactam or Nylon 6) and PA6.6 (Nylon 6.6) are used for similar purposes. PA6 can be recycled mechanically or for feedstock; chemical recycling back to the monomer is commercially exploited.

### Environmental Performance

The tables below show the environmental performance indicators associated with the production of 1 kg of PA6.

#### Input Parameters

Indicator	Unit	Value
Non-renewable energy resources <sup>1)</sup>	MJ	128.8
• Fuel energy	MJ	90.3
• Feedstock energy	MJ	38.5
Renewable energy resources (biomass) <sup>1)</sup>	MJ	0.36
• Fuel energy	MJ	0.35
• Feedstock energy	MJ	0.01
Abiotic Depletion Potential		
• Elements	kg Sb eq	1.7E-08
• Fossil fuels	MJ	115.9
Renewable materials (biomass)	kg	8.3E-03
Water use	kg	1647
• for process	kg	10
• for cooling	kg	1637

<sup>1)</sup> Calculated as upper heating value (UHV)

#### Output Parameters

Indicator	Unit	Value
GWP	kg CO <sub>2</sub> eq	6.7
ODP	g CFC-11 eq	1.2E-04
AP	g SO <sub>2</sub> eq	12.0
POCP	g Ethene eq	0.6
EP	g PO <sub>4</sub> eq	4.2
Dust/particulate matter <sup>2)</sup>	g PM10	1.2
Total particulate matter <sup>2)</sup>	g	1.2
Waste		
• Non-hazardous	kg	0.06
• Hazardous	kg	0.03

<sup>2)</sup> Including secondary PM10

### Additional Environmental and Health Information

PA6 is not classified as dangerous according to CLP legislation (EC 1272/2008). It does not require a hazard label in accordance with EC Directives. Under certain circumstances (temperature >300°C), thermal degradation can give rise to toxicologically relevant HCN and CO emissions. The manufacturers of polyamides 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

Among the intrinsic properties of PA6 are: high tensile strength, good abrasion resistance, elasticity, barrier properties of films, durability, flexible design, and easy processing. It is also resistant to acid and alkali chemicals as well as to hydrocarbons, solvents, fuels, waxes, and oils. In addition, PA6 is an electrical isolator.

### Additional Economic Information

Weight reduction in automobiles and increased shelf life of fresh food are examples where PA6 applications contribute to reduction of carbon footprint and costs in the use phase compared with standard solutions.

## 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 1.2 (2010-06) and ISO 14025:2006.

Registration number: PlasticsEurope 2013-003, 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)
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