# Eco-profile

## of long and short chain polyether polyols for polyurethane products

April 2021

# CONTENTS

# 1 Summary

This Eco-profile has been prepared according to **Eco-profiles program and methodology –PlasticsEurope – V3.0 (2019)**.

It provides environmental performance data representative of the average European production of polyether polyols, from cradle to gate (from crude oil extraction to granulates or resin at plant).

**Please keep in mind that comparisons cannot be made on the level of the polyether polyols 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. It 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.

## 1.1 META DATA

| | |
|---|---|
| Data Owner | ISOPA |
| LCA Practitioner | Sphera Solutions GmbH. |
| Programme Owner | PlasticsEurope |
| Reviewer | DEKRA Assurance Services GmbH, Angela Schindler |
| Number of plants included in data collection | 6 (long chain polyether polyols)<br>4 (short chain polyether polyols) |
| Representativeness | 80 % (long chain polyether polyols), 80 % (short chain polyether polyols) coverage in terms of production volumes in the EU region |
| Reference year | 2018 |
| Year of data collection and calculation | 2020 |
| Expected temporal validity | 2026 |
| Cut-offs | No significant cut-offs |
| Data Quality | Very good |
| Allocation method | Not applicable (for polymerization step) |

## 1.2 DESCRIPTION OF THE PRODUCT AND THE PRODUCTION PROCESS

This EPD is for long chain polyether polyols (MW > 1000 g/mol) and short chain polyether polyols (MW < 1000 g/mol), used in the production of flexible and rigid polyurethanes (PU).

Polyether polyols are polymeric compounds containing ether groups (R-O-R) an OH- groups.

Polyether polyols are one of the precursors of polyurethane foam. This Eco-profile covers two types of polyether polyols; short chain polyether polyols and long chain polyether polyols. Short chain polyether polyols are mainly used to produce rigid PU foams while long chain polyether polyols are mainly used to produce flexible PU foams.

A combination of the different building blocks can be used for a variety of other polyurethane applications. (see Eco-profile of toluene diisocyanate (TDI) and methylene diphenyl diisocyanate (MDI))

The reference flows, to which all data given in this EPD refer, is 1 kg of long chain and 1 kg of short chain polyether polyols.

**Production Process**

Polyether polyols are produced by the alkoxylation process. An addition reaction takes place where ethylene oxide or propylene oxide reacts with an initiator containing OH- groups like glycerine, saccharose and other carbohydrates.  Typically, the reaction takes place with a catalyst (as a base) which is fed into the solution in a batch reactor.  Using a different catalyst, a continuous process can be followed. The reaction runs under elevated temperature and pressure and is strongly exothermic. When the reaction is complete, the polyether polyol products are separated from by-products and water if necessary. The amount of alkoxylation species can be varied to achieve different chain lengths and molecular weights.

## 1.3 DATA SOURCES AND ALLOCATION

The main data source was a data collection from European producers of polyether polyols. Primary data on gate-to-gate polyether polyol production is derived from site-specific information for processes under operational control supplied by the participating companies of this study.

Five different producers of long chain polyether polyols with six plants in two different European countries participated in the primary data collection.

Three different short chain polyether polyols producers with four plants in three different European countries participated in the primary data collection.

Regarding long chain polyether polyols about 80% of the European polyether polyol production (EU-28) in 2018 are covered and about 80% regarding the short chain polyether polyols respectively.

The data for the upstream supply chain until the precursors, as well as all relevant background data such as energy and auxiliary material are taken from the GaBi 2020 LCI database [SPHERA 2020]. Most of the background data used is publicly available and public documentation exists. For the main precursor propylene oxide primary data was collected.

For the main precursor propylene oxide price allocation was applied based on feedback from the producers. The sensitivity analysis has shown that even if mass allocation was applied the differences in the results would be 2-3 %.

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

Polyether polyols produced from glycerine and propylene oxide are typically used in polyurethane-foam production.

Flexible polyurethane foams produced from TDI or MDI and polyether polyols are typically used in upholstery, mattresses and automotive seats.

Rigid polyurethane foams produced from MDI and polyether polyols have good thermal insulation properties and are used in the manufacture of freezers and refrigerators, and in building and automotive applications.

Post-consumer recycling of polyurethane products becomes a practice in more and more countries for applications where high volumes are available and which could include collection and sorting. A range of mechanical (regrinding, bonding, pressing, and moulding) and chemical (glycolysis, hydrolysis, pyrolysis) recycling technologies are available to produce alternative products and chemical compounds for subsequent domestic, industrial and chemical applications.

For all post-consumer polyurethane waste, for which recycling has not proven to be economically feasible due to contamination and/or complex collection and/or dismantling steps (e.g. automotive shredding), energy recovery is still the option of choice. However, as society moves towards a circular economy in the coming decades the level of energy recovery will decrease and increasingly more sectors will initiate recycling projects for post-consumer PU waste.

## 1.4 ENVIRONMENTAL PERFORMANCE

The tables below show the environmental performance indicators associated with the production of 1 kg of long chain and short chain polyether polyol, respectively.

Please note that considering the 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 and fuel energy are presented as a range.

## 1.4.1 Input Parameters

| **Indicator** | **Unit** | **Value** | | **Impact method ref.** |
|---|---|---|---|---|
| | | **Long chain polyether polyols** | **Short chain polyether polyols** | |
| Non-renewable energy resources1) | | | | |
| • Fuel energy | MJ | 45.63 – 50.63 | 40.25 – 45.25 | - |
| • Feedstock energy | MJ | 35 -.40 | 35 - 40 | Gross calorific value- |
| Renewable energy resources (biomass)1) | | | | |
| • Fuel energy | MJ | 6.11 | 11.05 | - |
| • Feedstock energy | MJ | 0.00 | 0.00 | Gross calorific value-- |
| Abiotic Depletion Potential | | | | |
| • Elements | kg Sb eq. | 1.05E-05 | 1.00E-05 | CML 2016 |
| • Fossil fuels | MJ | 75.62 | 70.30 | CML 2016 |
| Renewable materials (biomass) | kg | 6.70E-12 | 7.91E-12 | |
| Water | kg | | | |
| • Use | kg | 2099.61 | 2302.02 | - |
| • Consumption | kg | 19.28 | 33.94 | - |
| 1) Calculated as upper heating value (UHV) | | | | |

## 1.4.2 Output Parameters

| **Indicator** | **Unit** | **Value** | | **Impact method ref.** |
|---|---|---|---|---|
| | | **Long chain polyether polyols** | **Short chain polyether polyols** | |
| GWP | kg CO$_2$ eq. | 2.93 | 2.82 | CML 2016 |
| ODP | g CFC-11 eq. | 4.08E-10 | 4.36E-10 | CML 2016 |
| AP | g SO$_2$ eq. | 4.34 | 4.23 | CML 2016 |
| POCP | g Ethene eq. | 0.60 | 0.52 | CML 2016 |
| EP | g PO$_4^{3-}$ eq. | 0.93 | 1.24 | CML 2016 |
| Dust/particulate matter2) | g PM10 | 0.17 | 0.19 | - |
| Total particulate matter2) | g | 0.25 | 0.28 | - |

| | | | | |
|---|---|---|---|---|
| Waste | | | | |
| • Non-hazardous | kg | 0.09 | 0.12 | - |
| • Hazardous | kg | 1.35E-03 | 1.40E-03 | - |
| 2) Including secondary PM10 | | | | |

## 1.5 ADDITIONAL ENVIRONMENTAL AND HEALTH INFORMATION

This part has been written under the responsibility of the Data owner only and is not part of the LCA practitioner and reviewer work.

The manufacturers of polyether polyols are working through ISOPA to promote Product Stewardship and responsible practice in the value chain. These activities include driver training, tank farm assessments and HSE training in the use of polyurethane raw materials through the “Walk the Talk” programme.

## 1.6 ADDITIONAL TECHNICAL INFORMATION

This part has been written under the responsibility of the Data owner only and is not part of the LCA practitioner and reviewer work.

Polyether polyols are raw materials for polyurethane materials. The intrinsic product qualities of polyurethanes are lightweight; strong; durable; resistant to abrasion and corrosion. In addition, polyurethane insulation materials in building applications, refrigerators and freezers enable very large energy savings in heating & cooling to be made.

## 1.7 ADDITIONAL ECONOMIC INFORMATION

This part has been written under the responsibility of the Data owner only and is not part of the LCA practitioner and reviewer work.

Polyether polyols are raw materials for polyurethane materials. Polyurethane materials find wide application as coatings, flexible foams, rigid foams and elastomers. Fields of application include construction, transport, clothing, shoes, bedding, furniture, refrigerators and freezers.

### 1.7.1 Programme Owner

**PlasticsEurope**

Rue Belliard 40

B-1040 Brussels, Belgium

E-mail: info@plasticseurope.org

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

### 1.7.2 Data Owner

**ISOPA Aisbl**

Rue Belliard 65

B-1040 Brussels, Belgium

E-mail: main@isopa.org

### 1.7.3 LCA practitioner

**Sphera Solutions GmbH**

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70771 Leinfelden-Echterdingen, Germany

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### 1.7.4 Reviewer

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# 2 ECO-PROFILE REPORT

## 2.1 FUNCTIONAL UNIT AND DECLARED UNIT

**1 kg of long chain respectively short chain polyether polyol »at gate« (production site output) representing a European industry production average.**

## 2.2 PRODUCT DESCRIPTION

Polyether polyols are polymeric organic compounds including ether groups (R-O-R) and hydroxyl groups (OH). They are liquids at short chain lengths (short chain polyether polyols, MW < 1000 g/mol) and waxy solids, when chains are longer (long chain polyether polyols, MW > 1000 g/mol).

Polyether polyols are one of the precursors of polyurethane foam. There are two main types of polyether polyols, short chain polyether polyols and long chain polyether polyols. Short chain polyether polyols combined with MDI are used to produce rigid foams, while long chain polyether polyols combined with TDI resulting in flexible foams. Later in this report, short chain and long chain polyether polyols are discussed separately. For this description an average of all polyether polyols is shown.

- IUPAC name: Polyether Polyol
- Due to the building block format, multiple different polyols can be produced with different CAS numbers. In this report, main representatives are being investigated. Due to competition law, no CAS numbers are included in this report.
- chemical formula: $HO\text{--}(AO)_m\ ZO\text{--}(BO)_n\ \text{–}H$ (A, Z, B…organic rest)
- gross calorific value: 35 – 40 MJ/kg

In average, about 23 % of the carbon containing raw materials used for the short chain polyether polyols have a renewable origin (from sugars)

## 2.3 MANUFACTURING DESCRIPTION

Polyether polyols are produced by the alkoxylation process. This is an addition reaction where ethylene oxide or propylene oxide reacts with an initiator containing OH-groups. Glycerine is a common initiator but other carbohydrates such as saccharose can be used as well. The alkoxylation process requires a catalyst and, in this case, a base like KOH is used for catalysis. The amount of alkoxylation species can be varied to achieve different chain lengths and molecular weights.

An example of a base catalyzed batch process reaction mechanism is shown below: . In the first step, the initiator is turned into an alcoholate-anion by the base. In the second step, the epoxide (propylene oxide) is added to the anion by ring opening. The resulting epoxide-based monomer then combines with other resulting monomers to achieve longer polymer chains.

The following equation shows the example of polypropylene glycol produced by propylene glycol and propylene oxide:

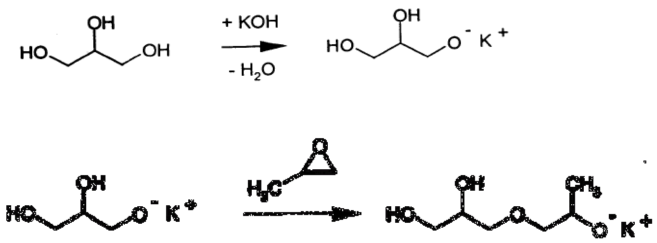

Figure 1 Example for the production of a polyether polyol

The process takes place in a batch reactor. It starts with the introduction of the initiator and the base into the reactor to start the first reaction step shown above. After this the epoxide is added. The reaction runs under elevated temperature (ca. 100- 130°C) and pressure (ca. 2-5bar) [SCIEN 2001] and is strongly exothermic so the heat given off has to be removed.

The final product (polyether polyol) has to be purified i.e. separated from the spent catalyst. To remove the catalyst, an acid is introduced which reacts with the base to form an insoluble salt which is easily removed by filtering.

The main process feedstocks, propylene oxide and ethylene oxide, are derived from propylene or ethylene, both of which are products of petroleum cracking.

## 2.4 PRODUCER DESCRIPTION

The following companies have participated in the data collection.

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

- BASF Polyurethanes GmbH

Elastogranstraße 60

PO Box 1140

D-49448 Lemförde

Germany

www.polyurethanes.basf.de

- Covestro

Covestro Deutschland AG
51373 Leverkusen
Gemany
https://www.covestro.com/

- Dow Europe GmbH

Bachtobelstrasse 3
CH-8810 Horgen
Switzerland
www.dow.com

- Huntsman

Everslaan 45
B-3078 Everberg
Belgium
www.huntsman.com/pu

- Deutsche Shell Chemie GmbH

Rheinland Raffinerie Wesseling
Ludwigshafener Straße
D-50389 Wesseling
Germany
www.shell.de

## 2.5 SYSTEM BOUNDARIES

Eco-profiles and EPDs refer to the production of polymers as a cradle-to-gate system (see Figure 2 for long chain polyether polyols and Figure 3 for short chain polyether polyols):

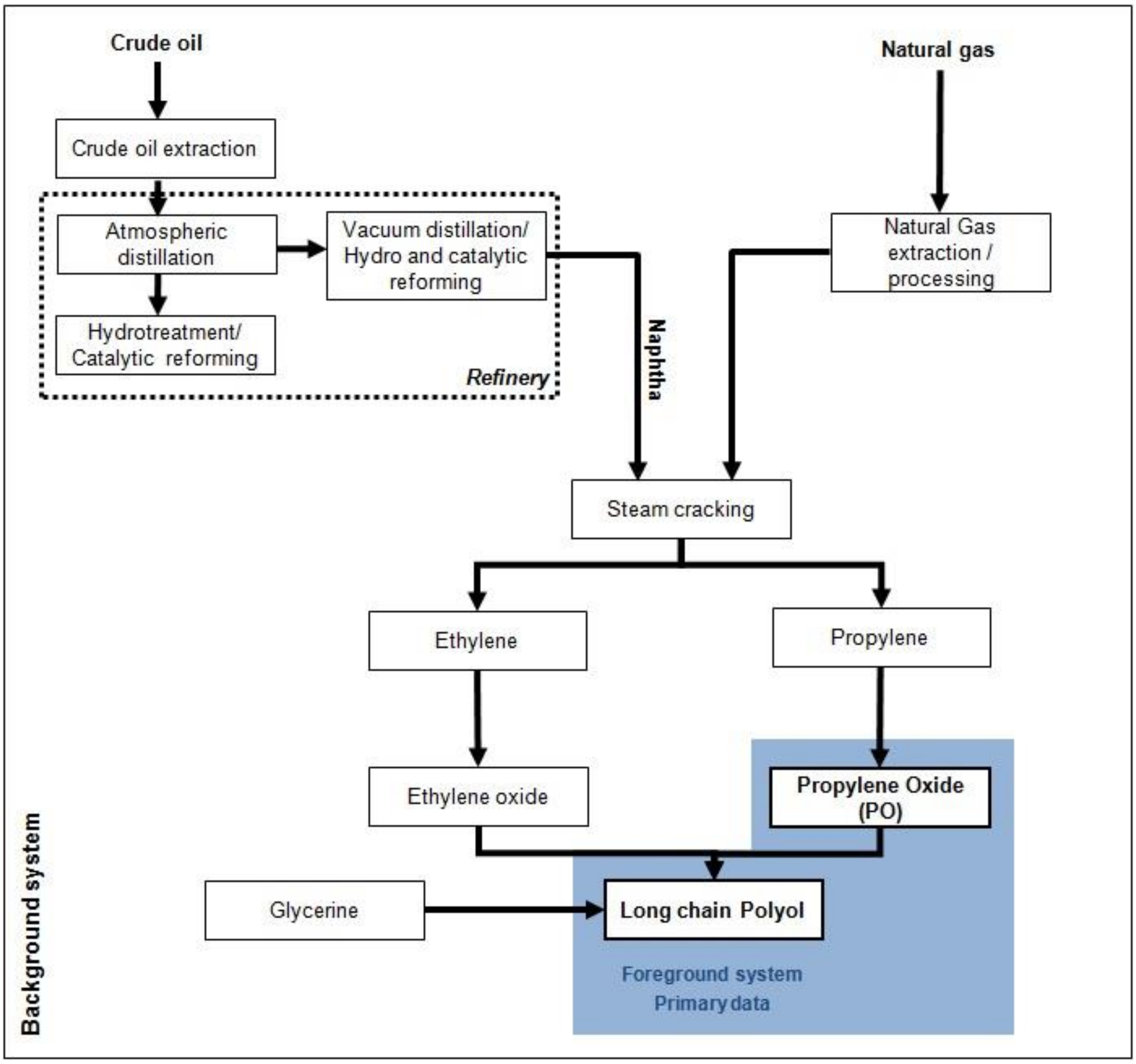

*Figure 2 : Cradle-to-gate system boundaries (long chain polyether polyols)*

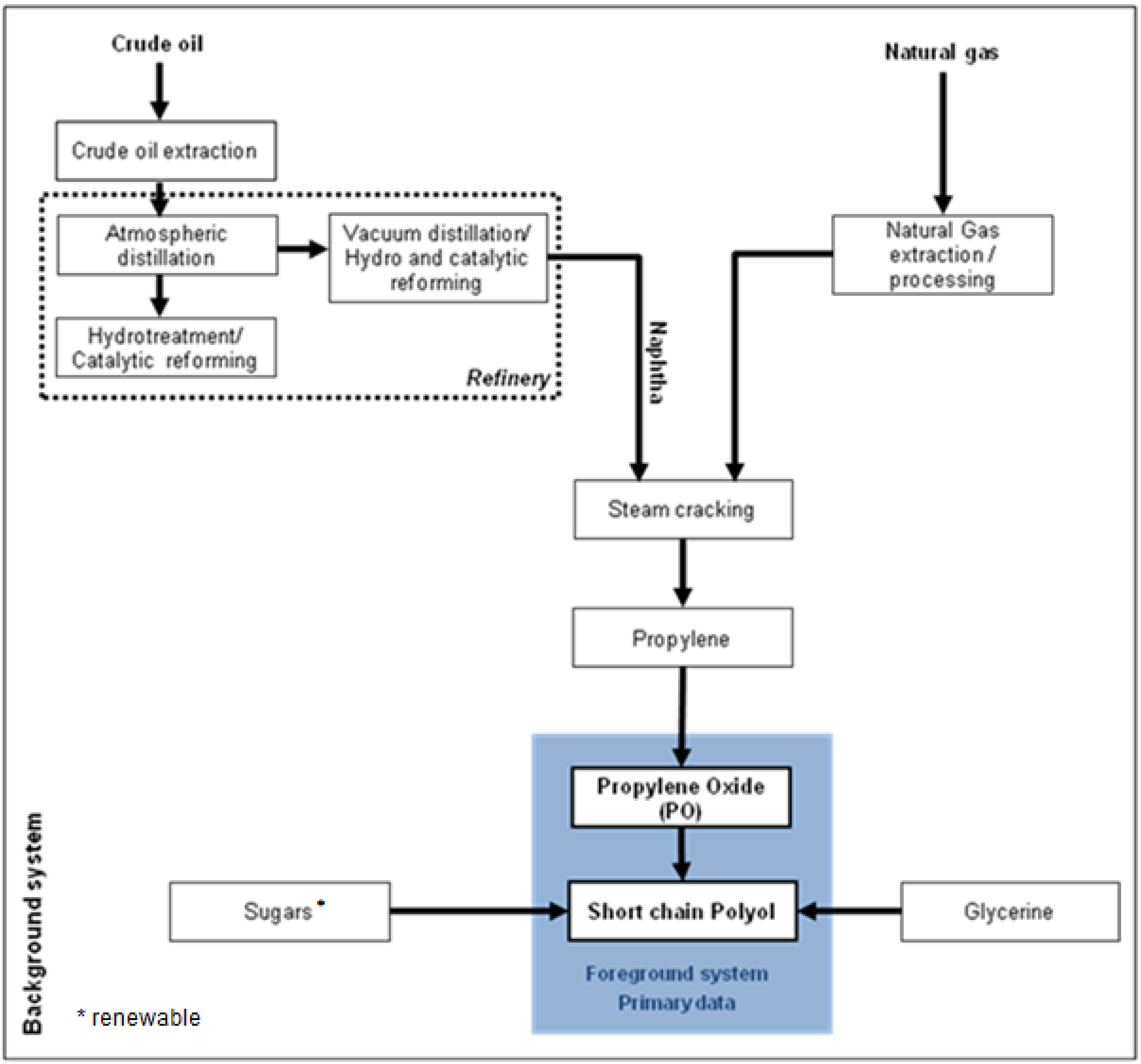

*Figure 3: Cradle-to-gate system boundaries (short chain polyols)*

## 2.6 TECHNOLOGICAL REFERENCE

The production processes were modelled using specific values from primary data collection at site, representing the specific technology for the five companies. The LCI data represent technology in use in the defined production region employed by participating producers. The considered participants cover 80% (long chain polyether polyols) and 80% (short chain polyether polyols) of the European production in 2018.

Primary data were used for all foreground processes (under operational control) complemented with secondary data from background processes (under indirect management control).

## 2.7 TEMPORAL REFERENCE

The LCI data for production was collected as 12-month averages representing the year 2018, to compensate for seasonal influence of data.

Background data have reference years from 2019. The dataset is considered to be valid until substantial technological changes in the production chain occur. Having the latest technology development in mind, the companies participating in this Eco-profile define as temporal reference: the overall reference year for this Eco-profile is 2018 with a recommended temporal validity until 2026.

## 2.8 GEOGRAPHICAL REFERENCE

Primary production data for flexible polyether polyol production is from five different suppliers in the EU. For rigid polyether polyol, production data is from three suppliers. 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 EU boundaries and in order to be applied in other regions adjustments might be required. Polyether polyol imported into Europe was not considered in this Eco-profile.

## 2.9 CUT-OFF RULES

In the foreground processes all relevant flows were considered, trying to avoid any cut-off of material and energy flows. In single cases additives used in the polyether polyols unit process (<0.1 % m/m of product output) were neglected. In all cases it was assured that no hazardous substances or metals were present in this neglected part.

According to the GaBi 2020 LCI database [SPHERA 2020], used in the background processes, 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 1% on the total is expected. All transports in the pre-chain contribute maximum 0.2% to the overall environmental burden. Including production, the contribution of all transports is expected to be less than 1%.,

## 2.10 DATA QUALITY REQUIREMENTS

### Data Sources

Eco-profiles and EPDs developed by ISOPA 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 ISOPA (see Producer Description). The data for the upstream supply chain are taken from the GaBi 2020 LCI database [SPHERA 2020], of the software system GaBi 10. For the most relevant intermediates to the polyether polyol processes, propylene oxide, primary data was provided.

All relevant background data such as energy and auxiliary material are also taken from the GaBi 2020 LCI database [SPHERA 2020]. Most of the background data used is publicly available and public documentation exists.

### Relevance

Regarding the goal and scope of this Eco-profile, the collected primary data of foreground processes are of high relevance, i.e. data was sourced from the most important polyether polyol producers in Europe in order to generate a European industry average. The environmental contributions of each process to the overall LCI results are included in the Chapter ‘Dominance Analysis’.

### Representativeness

The considered participants cover 80% (long chain polyether polyols) and 80% (short chain polyether polyols) of the European production in 2018.

The selected background data can be regarded as representative for the intended purpose, as it is average data

### Consistency

To ensure consistency only primary data of the same level of detail and background data from the GaBi 2020 LCI database [SPHERA 2020] 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 at several sites or determined by literature data or estimated for some flows, which usually have been reviewed and checked for its quality.

### Completeness

Primary data used for the gate-to-gate production of polyether polyol covers all related flows in accordance with the cut off criteria. In this way 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 sources of the owner of the technology, better precision is not reachable within this goal and scope. All background data is consistently GaBi professional data with related public documentation.

### 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 GaBi 10 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 art´ technology using data from a publicly available and internationally used database. It is worth noting that for external audiences, it may be the case that full reproducibility in any degree of detail will not be available for confidentiality reasons. However, experienced experts would easily be able to recalculate and reproduce suitable parts of the system as well as key indicators in a certain confidence range.

### Data Validation

The data on production collected from the project partners and the data providing companies was validated in an iterative process several times. The collected data was validated using existing data from published sources or expert knowledge.

The background information from the GaBi 2020 LCI database [SPHERA 2020] is updated regularly and validated and benchmarked daily by its various users worldwide.

### Life Cycle Model

The study has been performed with the LCA software GaBi 10. The associated database integrates ISO 14040/44 requirements. Due to confidentiality reasons details on software modelling and methods used cannot be shown here. However, in principle the model can be reviewed in detail if the data owners agree. The calculation follows the vertical calculation methodology, i.e. that the averaging is done after modelling the specific processes.

## 2.11 CALCULATION RULES

### Vertical Averaging

When modelling and calculating average Eco-profiles from the collected individual LCI datasets, vertical averages were calculated (Figure 4).

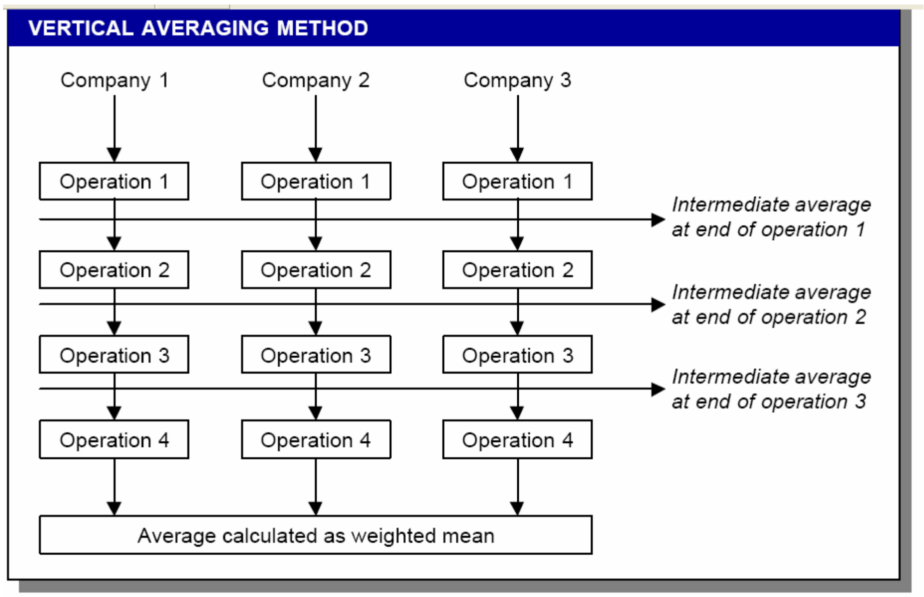

*Figure 4: Vertical Averaging (source: Eco-profile of high-volume commodity phthalate esters, ECPI European Council for Plasticisers and Intermediates, 2001)*

### 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 technical reality, as alternative stand-alone processes are not existing, or alternative technologies show completely different technical performance and product quality output. 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.

For the main precursor propylene oxide price allocation was applied based on feedback from the producers. The sensitivity analysis has shown that even if mass allocation was applied the differences in the results would be 2-3 %.

In the refinery operations, co-production was addressed by applying allocation based on mass and net calorific value [SPHERA 2020]. The chosen allocation in refinery is based on several sensitivity analyses, which was accompanied by petrochemical experts. The relevance and influence of possible other allocation keys in this context is small. In steam cracking, allocation according to net calorific value is applied. Relevance of other allocation rules (mass) is below 2 %.

# 2.12 LIFE CYCLE INVENTORY (LCI) RESULTS

## Delivery and Formats of LCI Dataset

This eco-profile comprises

- a dataset in ILCD format (http://lct.jrc.ec.europa.eu) according to the last version at the date of publication of the eco-profile and including the reviewer (internal and external) input.
- This report in pdf format.

## Energy Demand

The **primary energy demand** (system input) of 91.75 MJ/kg long chain polyether polyols and 91.3  MJ/kg short chain polyether polyols 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).

The **energy content in the polyol** indicates a measure of the share of primary energy incorporated in the product, and hence a recovery potential (system output), quantified as the gross calorific value (UHV), is in a range of 35– 40 MJ/kg.

The difference (Δ) between primary energy input and energy content in the isocyanate 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 treated with cut -off approach (no credits associated to main product system).

*Table 1 Primary energy demand (system boundary level) per 1kg long chain polyether polyols*

| Primary Energy Demand | Value [MJ] |
|---|---|
| Energy content in polymer (energy recovery potential, quantified as gross calorific value of polymer) | 35 – 40 |
| Process energy (quantified as difference between primary energy demand and energy content of polymer) | 51.75 – 56.75 |
| **Total primary energy demand** | **91.75** |

*Table 2 Primary energy demand (system boundary level) per 1kg short chain polyether polyols*

| Primary Energy Demand | Value [MJ] |
|---|---|
| Energy content in polymer (energy recovery potential, quantified as gross calorific value of polymer) | 35 – 40 |
| Process energy (quantified as difference between primary energy demand and energy content of polymer) | 51.3 – 56.3 |
| **Total primary energy demand** | **91.3** |

## Water cradle to gate Use and Consumption

The cradle-to-gate water use is 2099.61 kg for long chain polyether polyol and 2302.02 kg for short chain polyether polyol, respectively. The corresponding water consumption in the same system boundary is 19.28 kg (long chain) and 33.94 kg (short chain)

## Water foreground (gate to gate) Use and Consumption

The following table shows the weighted average values for water use of the long and short chain polyether polyols production processes (gate-to-gate level). For each of the typical water applications the water sources are shown.

*Table 3 Water use and source per 1kg of long chain polyether polyols*

| **Source** | **Process water [kg]** | **Cooling water [kg]** | **Steam Water [kg]** | **Water in Raw Materials [kg]** | **Total [kg]** |
|---|---|---|---|---|---|
| From Tap | 0.01 | 0.03 | 0.00 | 0.00 | **0.04** |
| Deionized / Softened | 0.09 | 0.08 | 0.34 | 0.00 | **0.51** |
| Untreated (from river/lake) | 0.00 | 0.02 | 0.00 | 0.00 | **0.02** |
| Untreated (from sea) | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** |
| Relooped | 0.01 | 2.34 | 0.00 | 0.00 | **2.35** |
| Totals | 0.11 | 2.48 | 0.34 | 0.00 | **2.93** |

*Table 4 Water use and source per 1kg of short chain polyether polyols*

| **Source** | **Process water [kg]** | **Cooling water [kg]** | **Steam Water [kg]** | **Water in Raw Materials [kg]** | **Total [kg]** |
|---|---|---|---|---|---|
| From Tap | 0.02 | 0.02 | 0.00 | 0.00 | **0.04** |
| Deionized / Softened | 0.08 | 0.00 | 0.40 | 0.00 | **0.48** |
| Untreated (from river/lake) | 0.00 | 0.01 | 0.00 | 0.00 | **0.01** |
| Untreated (from sea) | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** |
| Relooped | 0.01 | 8.87 | 0.00 | 0.00 | **8.88** |
| **Totals** | **0.11** | **8.90** | **0.40** | **0.00** | **9.42** |

The following table shows the further handling/processing of the water output of the production process.

*Table 5 Treatment of Water Output per 1kg of long chain polyether polyols*

| Treatment | **Water Output [kg]** |
|---|---|
| To WWTP | 0.20 |
| Untreated (to river/lake) | 0.11 |
| Untreated (to sea) | 0.00 |
| Relooped | 2.54 |
| Water leaving with products | 0.00 |
| Water Vapour | 0.07 |
| Formed in reaction (to WWTP) | 0.00 |
| **Totals** | **2.93** |

*Table 6 Treatment of Water Output per 1kg of short chain polyether polyols*

| Treatment | **Water Output [kg]** |
|---|---|
| To WWTP | 0.14 |
| Untreated (to river/lake) | 0.00 |
| Untreated (to sea) | 0.00 |
| Relooped | 9.10 |
| Water leaving with products | 0.01 |
| Water Vapour | 0.15 |
| Formed in reaction (to WWTP) | 0.01 |
| **Totals** | **9.43** |

Based on the water use and output figures above the **water consumption** can be calculated as:

Consumption = (water vapour + water lost to the sea) – (water generated by using water containing raw materials + water generated by the reaction + seawater used)

- Long chain polyether polyol = 0.07 kg
- Short chain polyether polyol = 0.14 kg

### Dominance Analysis

Table 9 and Table 10 show the main contributions to the results presented above. An average based on the weighted mean from the different technologies of the participating producers is used.

Regarding long chain polyether polyols in all analysed environmental impact categories, intermediates contribute at least 96 % or more of the total impact, with propylene oxide dominating with around 68 % or more.

Regarding short chain polyether polyols in all analysed environmental impact categories, intermediates contribute at least 95 % or more of the total impact, with propylene oxide dominating with around 68 % or more (the only exception is the indicator EP, which is dominated by other, renewable, raw materials (sugars)).

The use of high quality data especially for this case is decisive in the environmental profiles of flexible and short chain polyether polyols. Primary data was therefore collected for the propylene oxide production.

*Table 7 Dominance analysis of impacts per 1kg long chain polyether polyols*

| | **Total Primary Energy** | **ADP elements** | **ADP fossil** | **GWP** | **AP** | **EP** | **POCP** | **ODP** |
|---|---|---|---|---|---|---|---|---|
| Production Process | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Propylene Oxide | 83% | 75% | 84% | 82% | 76% | 68% | 80% | 99% |
| Other Chemicals | 15% | 25% | 14% | 14% | 22% | 30% | 19% | 1% |
| Thermal Energy | 1% | 0% | 1% | 2% | 1% | 1% | 1% | 0% |
| Electricity | 1% | 0% | 1% | 1% | 1% | 1% | 1% | 0% |
| Utilities | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Process Waste Treatment | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% |
| Transports | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Total** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

*Table 8 Dominance analysis of impacts per 1kg short chain polyether polyols*

| | **Total Primary Energy** | **ADP elements** | **ADP fossil** | **GWP** | **AP** | **EP** | **POCP** | **ODP** |
|---|---|---|---|---|---|---|---|---|
| Production Process | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Propylene Oxide | 68% | 83% | 72% | 74% | 66% | 46% | 72% | 99% |
| Other Chemicals | 29% | 17% | 25% | 21% | 31% | 52% | 26% | 1% |
| Thermal Energy | 2% | 0% | 2% | 3% | 1% | 1% | 1% | 0% |
| Electricity | 1% | 0% | 1% | 2% | 1% | 1% | 1% | 0% |
| Utilities | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Process Waste Treatment | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% |
| Transports | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% |
| **Total** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

## Comparison of the present Eco-profile with its previous version

*Table 9 Comparison of the present Eco-profile with its previous version for long chain polyether polyols*

| Environmental Impact Categories | Eco-profile long chain polyether polyols Previous (2012) | Eco-profile long chain polyether polyols New (2021) | Difference (%) |
|---|---|---|---|
| Gross primary energy from resources [MJ] | 89.11 | 91.75 | 3% |
| Abiotic Depletion Potential (ADP), elements [kg Sb eq.] | 7.44E-06 | 1.05E-05 | 41% |
| Abiotic Depletion Potential (ADP), fossil fuels [MJ] | 77.14 | 75.62 | -2% |
| Global Warming Potential (GWP) [kg $CO_2$ eq.] | 2.90 | 2.93 | 1% |
| Acidification Potential (AP) [g $SO_2$ eq.] | 6.19 | 4.34 | -30% |
| Eutrophication Potential (EP) [g $PO_4^{3-}$ eq.] | 0.84 | 0.93 | 11% |
| Ozone Depletion Potential (ODP) [g CFC-11 eq.] | 2.65E-05 | 4.08E-10[1] | -100% |
| Photochemical Ozone Creation Potential [g Ethene eq.] | 1.30 | 0.60 | -54% |

*Table 10 Comparison of the present Eco-profile with its previous version for short chain polyether polyols*

| Environmental Impact Categories | Eco-profile short chain polyether polyols Previous (2012) | Eco-profile short chain polyether polyols New (2021) | Difference (%) |
|---|---|---|---|
| Gross primary energy from resources [MJ] | 83.95 | 91.3 | 9% |
| Abiotic Depletion Potential (ADP). elements [kg Sb eq.] | 5.20E-06 | 1.00E-05 | 92% |
| Abiotic Depletion Potential (ADP). fossil fuels [MJ] | 65.9 | 70.30 | 7% |
| Global Warming Potential (GWP) [kg $CO_2$ eq.] | 2.20 | 2.82 | 28% |
| Acidification Potential (AP) [g $SO_2$ eq.] | 5.89 | 4.23 | -28% |
| Eutrophication Potential (EP) [g $PO_4^{3-}$ eq.] | 1.19 | 1.24 | 4% |
| Ozone Depletion Potential (ODP) [g CFC-11 eq.] | 3.25E-05 | 4.36E-10[1] | -100% |
| Photochemical Ozone Creation Potential [g Ethene eq.] | 0.70 | 0.52 | -26% |

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[1] Since the use of certain halogenated substances has been banned following the implementation of the Montreal Protocol, the following emissions are not present anymore in the updated Sphera datasets: Halon (1301), R 11 (trichlorofluoromethane), R 114 (dichlorotetrafluoroethane) and R 12 (dichlorodifluoromethane) and R22 (chlorodifluoromethane). Particularly R22, which has been removed, has the profound effect of reducing the remaining, already greatly reduced ODP impacts by several orders of magnitude for most datasets. This consequently further reduces the impact results for ODP for many datasets in the database.

For both polyols a direct comparison of the updated results with the previous ones should still refrain from drawing conclusions on the development of process efficiencies due to the following reasons:

- Changes in producers mix (one company not participating anymore)
- Different sites of involved companies covered
- Substantial changes in recipes of Propylene Oxide production (being the main raw material for the polyols)

# 3 REVIEW

## 3.1 EXTERNAL INDEPENDENT REVIEW SUMMARY

The present Eco-Profile is an update of an Eco-Profile published in 2012 for the long/short chain Polyols.

The actual review is based on the final Eco-profile document accompanied by a webmeeting for clarifying open questions and comments of the reviewer, including spot checks of the software model applied and explanations on the primary data collection.

The Eco-profile document was sent and reviewed in March/April 2021.
The compliance of the documents was reviewed according to the current requirements of the Eco-profiles program and methodology, version 3.0 (Oct 2019) of PlasticsEurope and the accompanying template for Eco-profile reports.

The representativeness of the resulting inventory data is estimated according to the expert judgement of ISOPA in respect to the production volumes in Europe. As all main producers have taken part in this study, the technology displays the state-of-the art status.

For the update of the Eco-profile new and complete foreground data were delivered by the participants of the study complemented with upstream process inventories from the current available GaBi database.

The high number of possible products and variability of the product family of polyols is challenging. The declaration of this summary of different products can only result in average values including a relatively high variance. As publication of an industry average, still this is a pragmatic and acceptable way for the communication of life cycle data. The summary of this large group of products limits the specific application in terms of information on fossil and biogenic feedstock content in respect to the requirements of e.g. ISO 14067 in case of studies using this Eco-profile as upstream data for follow-up products.

The collected data are thoroughly processed; the transfer into a systematically built software model shows a sound quality. The methodological approaches follow the PCR requirements. The recommendations of the reviewer have been followed to clarify certain aspects.

The structure and description of the Eco-profile is clear and transparent, thus displaying a reliable source of information.

So far the PCR does not require specific indicators for the impact assessment. While preparing the life cycle inventory / software model necessary requirements for the assessment of further impact categories, e.g. required by the Product Environmental Footprint were partly integrated, i.e. regionalisation of water flows. Applying the LCI for the assessment of further indicators, not assessed within this Eco-profile, the documentation needs to be checked, if respective data are included in the inventory.

## 3.2 REVIEWER CONTACT DETAILS

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# 4 REFERENCES

| | |
|---|---|
| BOUSTEAD 2005 | Boustead. I. Eco-profiles of the European Plastics Industry: Diphenylmethane diisocyanate (MDI) and Eco-profiles of the European Plastics Industry: Tolylene diisocyanate (TDI). Plastics Europe. March 2005 |
| EYERER 1996 | Ganzheitliche Bilanzierung – Werkzeug zum Planen und Wirtschaften in Kreisläufen. 1996 |
| GUINÈE ET AL. 2001 | Guinée. J. et. al. Handbook on Life Cycle Assessment - Operational Guide to the ISO Standards. Centre of Environmental Science. Leiden University (CML); The Netherlands. 2001. |
| GUINÉE ET AL. 2002 | Handbook on Life Cycle Assessment: An operational Guide to the ISO Standards; Dordrecht: Kluwer Academic Publishers. 2002. |
| HEIJUNGS 1992 | Heijungs. R.. J. Guinée. G. Huppes. R.M. Lankreijer. H.A. Udo de Haes. A. Wegener Sleeswijk. A.M.M. Ansems. P.G. Eggels. R. van Duin. H.P. de Goede. 1992: Environmental Life Cycle Assessment of products. Guide and Backgrounds. Centre of Environmental Science (CML). Leiden University. Leiden. |
| HUIJBREGTS 1999 | Huijbregts. M.. 1999b: Life cycle impact assessment of acidifying and eutrophying air pollutants. Calculation of equivalency factors with RAINS-LCA. Interfaculty Department of Environmental Science. Faculty of Environmental Science. University of Amsterdam. The Netherlands. Forthcoming. |
| HUIJBREGTS 2000 | Huijbregts. M.A.J.. 2000. Priority Assessment of Toxic Substances in the frame of LCA. Time horizon dependency of toxicity potentials calculated with the multi-media fate. exposure and effects model USES-LCA. Institute for Biodiversity and Ecosystem Dynamics. University of Amsterdam. Amsterdam. The Netherlands. (http://www.leidenuniv.nl/interfac/cml/lca2/). |
| IPCC 2007 | IPCC. 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change. [Solomon. S.. D. Qin. M. Manning. Z. Chen. M. Marquis. K.B. Averyt. M. Tignor and H.L. Miller (eds.)]. Cambridge University Press. Cambridge. United Kingdom and New York. NY. USA. 996 pp. |
| ISO 14040: 2006 | ISO 14040 Environmental Management – Life Cycle Assessment – Principles and Framework. Geneva. 2006 |
| 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 |

| | |
|---|---|
| PlasticsEurope 2019 | Eco-profiles program and methodology PlasticsEurope. Version 3.0, October 2019. |
| SPHERA 2020 | GaBi LCA Database Documentation. GaBi Solutions. 2020 (https://www.gabi-software.com/databases/gabi-databases/) |
| Ullmann 2010 | Ullmann's Encyclopedia of Industrial Chemistry. John Wiley & Sons. Inc. . Hoboken / USA. 2010 |
| WMO 2003 | WMO (World Meteorological Organisation). 2003: Scientific assessment of ozone depletion: 2002. Global Ozone Research and Monitoring Project - Report no. 47. Geneva. |
| SCIEN 2001 | Scienzechimische.unipr.it; Trends in industrial catalysis in the polyurethane industry; Gerhard Wegener, Matthias Brandt |