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

Eco-profiles and Environmental Declarations

PlasticsEurope

Version 2.0 (April 2011)

PlasticsEurope
Association of Plastics Manufacturers

Life Cycle Inventory (LCI) Methodology and Product Category Rules (PCR) for Uncompounded Polymer Resins and Reactive Polymer Precursors

Version 2.0 (April 2011)

This updated version of the PlasticsEurope Eco-profile and EPD methodology document is the successor of version 1.2. It includes the following improvements:

- additional guidance on unit and aggregated process inventories, review and database management in response to the UNEP/SETAC workshop on LCA;
- clarifications on energy nomenclature (specifically the concept of feedstock energy);
- clarifications on waste reporting in compliance with the ILCD requirements;
- more detailed procedures on review in compliance with the ILCD requirements;
- guidance on fully integrated electronic deliverables consisting of EPD, Eco-profile report and life cycle inventory datasets in the three most common formats (Excel, ELCD, and Ecospold).

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Plastics
The Material for the 21st Century

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1. Introduction

1.1. Development of Eco-Profiles

PlasticsEurope, the association of European plastics manufacturers, was the first industry organisation to assemble detailed environmental data on the processes operated by its member companies with the firm intention of making this information available for public use.

The first PlasticsEurope Eco-profile reports were published in 1993. Since then, further reports have been added and continuously updated so that there are now more than 70 Eco-profile reports freely available from the PlasticsEurope website. In 2006, an Environmental Product Declaration programme was commenced to complement the Eco-profile reports.

Eco-profile reports cover the high volume, bulk polymers, some of the more widely used engineering plastics and some of the standard plastics conversion processes. Eco-profiles are widely acknowledged among life cycle practitioners and other stakeholders worldwide as representative datasets. They have been included in various commercial life cycle databases as well as in the publicly available European Life Cycle Database (ELCD) operated by the European Commission's Joint Research Centre.

1.1.1. Objectives of Eco-profiles

PlasticsEurope had very clear objectives in view when originally compiling the Eco-profile reports:

- compile average industry data which could be used for internal company benchmarking allowing individual process improvement:
    - leading to elimination of poor sections of processes;
    - improvements by addition of waste treatment sections.
- include sufficient data which could be used by customers for product development against environmental criteria to:
    - allow evaluation of the plastics contribution relative to the overall product;
    - enable collaboration with recovery procedures to reduce collective impacts;
    - draw attention to poor environmental links in user chains, which can lead to subsequent improvement.
- target generic data which could be used to optimise the management of plastics waste:
    - facilitates choosing among options such as mechanical recycling, reuse as a petrochemical raw material and use as a substitute fuel;
    - provides sufficient data to investigate alternative solutions for regulatory compliance, e.g. with the EU Packaging and Packaging Waste Directive.

It was also important to provide neutral, objective, quantitative information with no attempt at interpretation, so that only explanations on how the data were generated need be given.

1.1.2. Future of Eco-profiles

In the years since the first Eco-profile reports were published, Life Cycle Assessment methodology and practice has undergone substantial changes, not least due to the ISO standardisation work which in turn was influenced by industry experiences. New concepts, such as Environmental Product Declarations (EPD) and Carbon Footprint have emerged. Downstream industries like building and construction adopt sectoral sustainability strategies and in turn advance standardisation.

Throughout all these developments, Eco-profiles have proved to be a robust, versatile and useful database. At the same time, it was clear that Eco-profiles need to change in order to reflect best practices in Life Cycle Assessment and to respond to changing stakeholder needs. During the years, PlasticsEurope has periodically sought stakeholder input on the Eco-profile methodology. Furthermore, globalisation demands that such efforts be increasingly harmonised and results be comparable.

Hence, PlasticsEurope welcomes and actively invites the liaison with regional federations, notably the *American Chemistry Council's Plastics Division ACC PD* in the US, the *Plastics and Chemicals Industries Association PACIA* in Australia, and the *Plastics Waste Management Institute PWMI* in Japan –

- to further enhance the market acceptance of the Eco-profile methodology,
- to work towards a globally harmonised methodology for the plastics industry world-wide, and
- to advance the compatibility of this methodology with other material- or sector-specific methodologies based on shared best practices.

1.2. General Programme Information

The PlasticsEurope Eco-profile and EPD programme will support the development and publication of Life Cycle Inventory (LCI) datasets as well as Type III Environmental Product Declarations (EPDs) for uncompounded polymer resins, or reactive polymer precursors.

The programme is open to any party who wishes to develop an LCI or EPD under the rules of the PlasticsEurope Eco-profile and EPD programme. To foster the uptake of best practices and the continued success of this programme, PlasticsEurope aims to –

- Encourage and enhance industry participation in data collection for Eco-profiles and their continuous update and refinement. This concerns PlasticsEurope's own member companies, but also downstream users (such as converters), related federations, and other interested parties. In particular, PlasticsEurope offers collaboration with the Europe*an Plastics Converters EuPC* and the Europe*an Plastics Recyclers EuPR* in order to encourage and promote the preparation of Eco-profiles for conversion and recovery processes.
- Enhance outreach to the target audience for the purposes of improving dissemination and acceptance of this framework. It will be essential that the users of Eco-profiles and EPDs makes responsible use of these datasets. As a primary requirement of user responsibility, PlasticsEurope would like to ensure an awareness and understanding of this document.

1.3. Roles and Responsibilities in Eco-profile Projects

1.3.1. Data Owner

Regularly, the respective Product Committee within PlasticsEurope is the data owner; but another industry association participating in the PlasticsEurope Eco-profile programme may also adopt this role. The identity and contact details of the data owner shall be stated. The data owner approves the Eco-profile Project Team (EPT, see 1.4.3) and may have a delegate in the EPT.

It should be carefully noted that the data ownership and the associated responsibility for the accuracy and integrity of the dataset remains with the original data owner, even if the dataset is included in a third-party database or otherwise reproduced, in particular through electronic media. However, the data ownership and the associated responsibility cease where ownership is formally transferred (by contract), or where a third part modifies the dataset in any way, in particular altering the life cycle inventory (LCI) entries.

1.3.2. LCA Practitioner and Dataset Developer

The LCA practitioner and dataset developer (see 1.4.3) is a qualified expert and will usually be an LCA consultant or similar service provider. Subject to a pre-qualification procedure (see 5.1.2), the service provider must have demonstrated expertise and experience in LCA. The LCA practitioner carries out the data collection and calculation. The dataset developer is responsible for the preparation of the dataset and all deliverables (Eco-profile, EPD, electronic datasets). The identity and contact details of LCA practitioner and dataset developer shall be stated.

1.3.3. Programme Owner

The programme owner of the PlasticsEurope Eco-profile and EPD programme is:

PlasticsEurope

Av. E. Van Nieuwenhuyse 4/3 ◆ B–1160 Brussels, BELGIUM

Tel.: +32 (2) 6753297 ◆ Fax: +32 (2) 6753935

Web: http://www.plasticseurope.org ◆ e-mail: info@plasticseurope.org

1.3.4. Programme Manager, Reviewer and Database Manager

The programme manager (see 1.4.3) of the PlasticsEurope Eco-profile and EPD programme is:

DEKRA Industrial GmbH

Handwerkstraße 15 ◆ D–70565 Stuttgart, GERMANY

Tel.: +49 (711) 7861–3553 ◆ Fax: +49 (711) 7861–3588

Web: http://www.dekra.com/

The programme manager also has the following responsibilities:

- Reviewer – The programme manager will monitor the proceedings of the Eco-profile project for adherence with the rules of this methodology document, and review submitted Eco-profile and EPD reports. The review confirms quality and compliance of the Eco-profile and EPD calculations and reports with the rules of this methodology document.
- Database Manager – The programme manager will validate electronic datasets before inclusion in the PlasticsEurope Eco-profile and EPD database, and publish the validated datasets. The validation confirms compliance of the electronic Eco-profile and EPD datasets with the rules of this methodology document.

1.4. Purpose of this Document

This framework document has three distinct functions: Eco-profiles Methodology, Product Category Rules (PCR), and Protocol.

1.4.1. Eco-profiles Methodology

The Eco-profiles methodology establishes the instructions for the calculation of Life Cycle Inventory (LCI) datasets in accordance with the ISO 14040–44 series of standards, »Environmental management — Life Cycle Assessment«.

1.4.2. Product Category Rules (PCR)

As Product Category Rules (PCR), this document establishes the instructions for the development of Type III Environmental Product Declarations (EPDs) for the product category of uncompounded polymer resins, including reactive polymer precursors in accordance with the ISO EN 14025, »Environmental labelling and declarations – Type III environmental declarations – Principles and procedures« and the provisions in the ISO 14040–44 series of standards, »Environmental management — Life Cycle Assessment«.

The main goal of EPDs is the business-to-business communication of the key environmental aspects of polymers, and to facilitate their interpretation. The target audience for EPDs is primarily downstream users of polymers, such as compounders, converters, and manufacturers, as well as other interested parties, such as OEMs, specifiers and retailers.

The EPDs developed under this programme are based on the Eco-profiles described above. Hence, in addition to the rules for developing the Life Cycle Inventory (LCI), this document specifies which life cycle indicators shall be declared in the EPD and how they are calculated. This document also provides guidance on communicating additional information – mandatory or optional – which is relevant to the environmental performance of products within this product category.

1.4.3. Protocol

As a protocol, this document is also meant to provide procedural guidance for the organisation, management, and workflow of Eco-profile and EPD projects. Figure 1 provides an overview of the workflow.

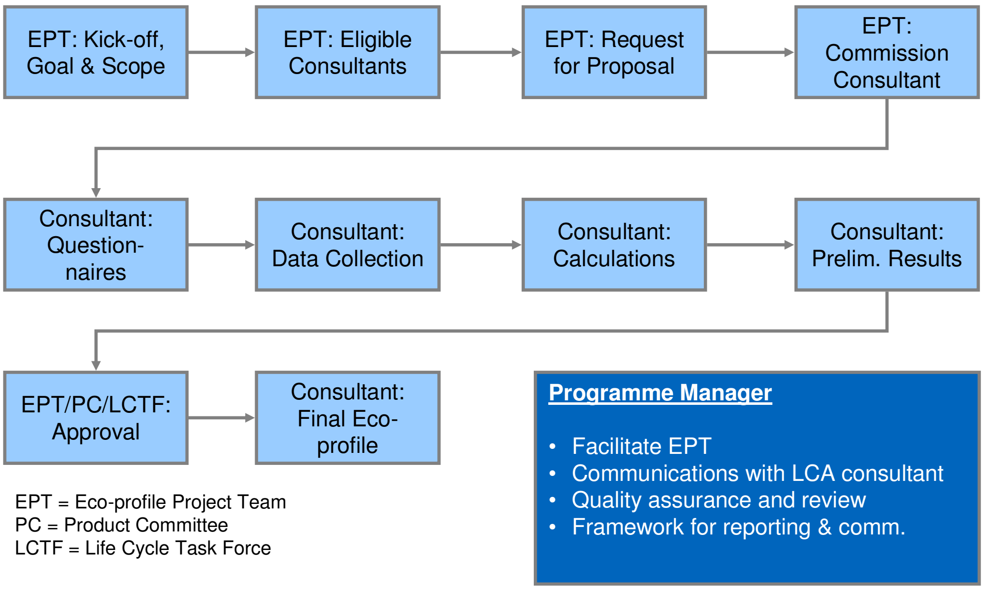

Figure 1: Workflow of Eco-profile and EPD projects

In more detail, the following steps are foreseen when managing Eco-profile and EPD projects:

1. Progr Mgr conducts **pre-qualification** of eligible consultants.
2. Progr Mgr checks list of Eco-profiles and notifies LCTF and Product Committee & HSE Group of **necessary updates**, based on any or all of the following criteria:
   - Age of dataset,
   - Quality of data (e.g. known inconsistencies or errors),
   - Request for update by Product Committee.
3. LCTF issues **request for proposal**
   - Directly to eligible consultant, or

- Open tender process,

as per co-decision with Product Committee.

4. Progr Mgr & LCTF convene **Eco-profile Project Team (EPT)**:
   - LCTF
   - Product Committee & HSE Group
   - Consultant
   - Progr Mgr

➔ specify how to implement ③ (if necessary).

5. Consultant distributes **questionnaires** on behalf of the EPT.
6. Consultant (under bilateral confidentiality agreement) conducts **data collection** with each member company (iterative process).
7. Consultant conducts **calculations** according to this methodology document.
8. Consultant submits **preliminary report** (format according to this methodology document) to the EPT ➔ forward to Product Committee & LCTF.
9. ProgrMgr **reviews** preliminary report for compliance with this methodology document.
10. Product Committee & LCTF **review and approve** results.
11. Consultant submits **final Eco-profile** to the EPT ➔ forward to LCTF.
12. ProgrMgr **publishes** results on behalf of Product Committee.

1.5. Revisions of this Document

The Eco-profile methodology and PCR document were developed in the course of an international bottom-up process with stakeholder participation and independent third-party review and went through the following stages of discussion:

- 1993 — Publication of first Eco-profiles with intermittent updates since then;
- 2005 — Publication of Eco-profile methodology as a stand-alone report;
- June 2005 — Stakeholder workshop on EPD programme and PCR;
- June 2006 — Third-party review and publication of PCR;
- January 2007–December 2008 — Publication of first ten EPDs;
- September 2008 — Expert workshop on consolidated Eco-profile methodology and PCR document;
- March 2009 — Publication of consolidated Eco-profile and EPD methodology.
- May 2009 — Release of version 1.1.
- June 2010 — Release of version 1.2.

This Eco-profile methodology and PCR is a living document. PlasticsEurope as the programme operator will ensure ongoing monitoring of the applicability and appropriateness of this document supported by practical experience. If relevant changes in LCA methodology or in production technology for the product category occur, the document will be revised. In any case, the validity of the document will be reviewed, at the latest, after three years from the date of issue and will be revised as necessary. Changes will be published on PlasticsEurope's website and may also be submitted to applicable international fora, such as *GEDnet*®.

1.6. Applicable Standards

This framework document refers to the following underlying standards, listed in hierarchical order:

- ISO 14040–14044: Life Cycle Assessment;
- ISO EN 14025: Type III Environmental Declarations;
- European Commission: International Reference Life Cycle Data System (ILCD): technical guidance document on good practice in life cycle assessment;
- prEN 15804: product category rules, environmental product declarations, and impact assessment models specifically for building and construction products;
- ISO 21930 and new standards prepared by CEN TC 350: use of environmental product declarations specifically for building and construction products.

Where appropriate, generic rules are adopted from these standards. This document refines these rules according to the specific conditions and requirements of the plastics industry sector and sets out the appropriate implementation of these rules.

1.7. Terminology

PlasticsEurope defines the term Eco-profile as a cradle-to-gate Life Cycle Inventory (LCI) dataset. This document uses the terms Eco-profile and LCI interchangeably.

Technical terms and concepts around life cycle assessment are defined in accordance with the ILCD handbook, which in turn uses ISO definitions where possible. For an explanation of the commonly used terms and abbreviations used throughout this document, please refer to the glossary in the annex 6.1.

2. Goal & Scope

2.1. 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 in view of a defined functional unit.

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 or within larger industrial networks. Therefore, PlasticsEurope considers disaggregated gate-to-gate unit processes to be inappropriate to represent industrial reality of polymer production. Note that gate-to-gate Eco-profiles may still be provided for conversion processes.

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 functional units 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.

2.2. Product Category and Declared Unit

2.2.1. 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).

Additionally, this programme is open towards associated organisations of downstream users and related industries, and PlasticsEurope offers collaboration to also include the following neighbouring product categories in this programme:

- feedstock, precursors and polymers from renewable resources (»biopolymers«), including the agricultural preproduction;
- **semi-finished plastics products**, including compounding and conversion processes;
- **recycled polymer granules**, including collection and sorting as well as conversion to secondary plastics.

2.2.2. Reference Flow, Declared Unit and Functional Unit

The default reference flow and declared unit of PlasticsEurope Eco-profiles and EPDs are (unless otherwise specified[1]):

1 kg of polymer resin (or, reactive precursor) »at gate« (production site output) representing a European industry production average.

This implies that the default declared unit does not include compounding. However, the inclusion of the related product categories given above – semi-finished products and recycled granules – may require variant declared units which are then explicitly defined and emphasised.

It should be noted that, for the purposes of the cradle-to-gate LCI modelling described herein, the above declared unit is identical with the concept of the Functional Unit. However, the careful distinction is made because

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

the reference flow (polymer resin or reactive precursor) is not a finished product or application and hence cannot be defined in terms of function. This is why the whole life cycle needs to be considered, using the PlasticsEurope Eco-profile as an LCI building block, thus defining a proper Functional Unit (application, product, service) before assessing the environmental impacts.

2.3. Product and Producer Description

2.3.1. Product Description

The product to be declared shall be clearly stated, e.g. by polymer name and family if applicable, also indicating the ISO code for polymers, IUPAC name and GHS and/or CAS number, where applicable. The main production steps shall be visualised in a flow diagram. The main applications of the product shall be described. Where relevant, product standards shall be referred to.

2.3.2. 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. As a general rule, Eco-profiles should represent a minimum of three (3) producers.

Sector groups within PlasticsEurope (e.g. *ECVM*) or associated federations (e.g. *BING, EPPA, EuPC, EuPR, Euro-Chlor, EXIBA*) can issue Eco-profiles and EPDs under the PlasticsEurope programme.

It is conceivable that individual companies would like to prepare Eco-profiles or EPDs referring to their own primary data about the production processes under their operational control. Also, for instance, there may only be a single producer of a given polymer, or a converter may wish to report a specific plastics application. While PlasticsEurope cannot endorse such studies and will not publish them as Eco-profiles or EPDs under the PlasticsEurope programme, this certainly does not prevent third parties from adopting this methodology for their own LCI or EPD programmes.

In any case, Eco-profiles and EPD prepared in accordance with this PCR shall always provide the name, address and web link of the organisation (federation, sector group, or consortium of companies) producing the declared product; plus, the name and contact details of the person who can provide further information about the EPD.

3. Life Cycle Inventory and Eco-profile

3.1. System Boundaries

3.1.1. General Considerations

As a general rule, the selection of LCI system boundaries shall reflect the goal of the production process. This may require careful deliberation because usually polymers and precursors are manufactured in integrated production sites along with a wide variety of other products and co-products. The interdependence of processes and the interchange of substance flows implies a certain complexity (cf. Figure 3).

Two basic cases of system boundaries can occur:

- By default, PlasticsEurope Eco-profiles and EPDs refer to the **production of polymers or precursors** and are based on a **cradle-to-gate system** (Figure 2). The production stage covers all life cycle processes from extraction of natural resources, up to the point where the product is ready for transportation to the customer. Packaging of the material is not included. The use phase and end-of-life management are not included in the cradle-to-gate information module.

- **Conversion** processes, however, shall be reported as **gate-to-gate** Eco-profiles, i.e. as a module with inputs of polymer and process energy, among others. The same goes for **recovery** processes producing recycled polymer granules.

The types of unit processes include (Figure 2) –

- Raw materials and energy: usually background datasets from third-party databases;
- Polymer (or, precursor) production: key foreground processes included in data collection;
- Conversion (or. semi-finished product manufacture) and specific recovery processes can be included on a case-by-case basis and need to be reflected in the definition of declared unit and system boundaries (see above);
- Installation, use, and general end-of-life management are excluded for the purposes of creating cradle-to-gate LCI datasets.

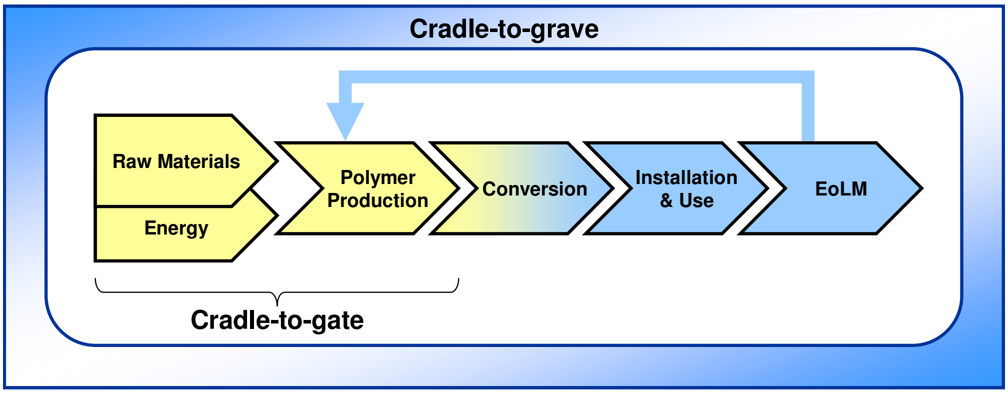

Figure 2: Cradle-to-gate system boundaries (EoLM – end-of-life management)

Optionally, an EPD may provide environmentally relevant information pertaining to the use phase and to end-of-life management as additional information.

3.1.2. Cradle-to-Gate System Boundaries for Production

The following processes shall be included in the cradle-to-gate LCI system boundaries (Figure 3):

- Extraction of non-renewable resources (e.g. operation of oil platforms and pipelines);
- Growing and harvesting of renewable resources (e.g. agricultural planting);
- Beneficiation or refining, transfer and storage of extracted or harvested resources into feedstock for production;
- Recycling of waste or secondary materials for use in production;
- Refining of non-renewable or renewable resources into energyware;[2]
- Production processes;
- All relevant transportation processes (transport of materials, fuels and products at all stages);
- Management of relevant waste streams or pollution generated by processes within the system boundaries.

[2] Energyware: Tradable commodity used mainly to produce mechanical work or heat, or to operate chemical or physical processes, and which is listed in Annex A of ISO 13600 (1999).

Further processes may need to be included if relevant to the goal of the production process:

- If a process is aimed at polymer resin production, then it is included as a whole;
- If a process includes production of polymer resins as a by-product, all activities that are connected to resin production shall be included and the system boundaries shall allow for an appropriate allocation.

The system boundaries and included processes shall be transparently documented, for example, as displayed in the sample flowchart (Figure 3).

Note that capital, i.e. the construction of plant and equipment as well as the maintenance of plants, vehicles and machinery is outside the LCI system boundaries of Eco-profiles. This is not least because impacts associated with these aspects are usually insignificant.

The end-of-life management of plastics is outside the LCI system boundaries of Eco-profiles for the production of polymers and precursors. However, Eco-profiles for recycled polymer granules will specifically address recovery processes. In addition, EPDs may provide recommendations for recovery and methodological guidance on modelling recovery as additional information.

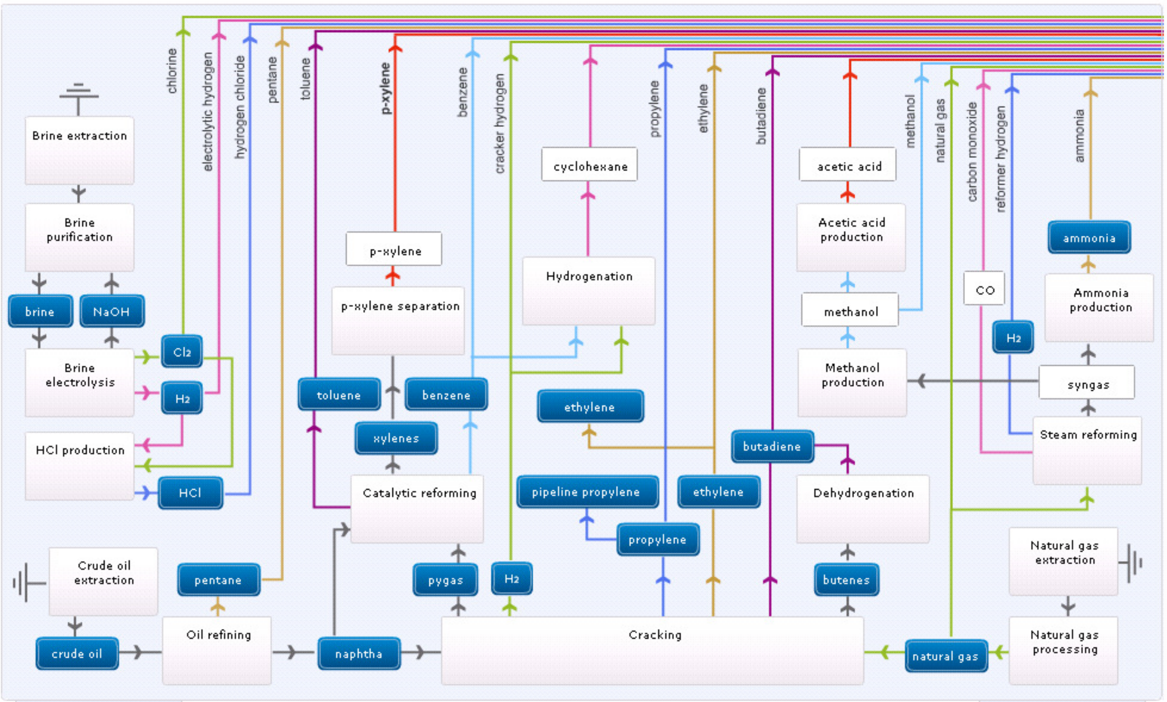

Figure 3: Sample illustration of system boundaries and interconnected processes in the chemical and plastics industry (source: PlasticsEurope website)

3.1.3. Sub-systems and Unit Processes

The data describing the overall effect of any extended industrial system must be derived from a number of different operators, each of whom will be taking the output from an upstream operation, processing it and passing it on to the next operation downstream. As a result, large systems must be sub-divided into a set of sub-systems such that each sub-system encompasses the activities of a single operator. After this first sub-division, it frequently happens that the activities of a single operator are themselves complex and so the sub-system describing this operator must be further sub-divided.

In general, the ultimate choice of sub-systems is usually determined by the availability of data and the overall system is analysed only to such a level of detail that the component sub-systems correspond to operations for which data are available. Analysing to a greater level of detail is point less since performance data will not be available. In naphtha cracking, for example, it is seldom possible to separate the performance of furnace, quench tower and separation stages, since the only data that are readily available describe to whole of the cracking plant.

It is also important to remember that all sub-systems possess the same characteristics as a system. That is their function must be specified and, because they too are physical systems, they must also obey the standard scientific laws. For materials processing systems and sub-systems, the function can usually be described in terms of the conversion of specified set of inputs to a specified set of outputs.

3.1.4. Modular Eco-profiles

While the definition of unit processes and sub-systems (see 3.1.3) concerns the modelling and calculation of Eco-profiles, there is also a need to decide appropriate modules for reporting (see 5.2). Eco-profiles, like any other LCI dataset comprising multiple processes, are »monolithic« in that they do not allow for identifying the inputs and outputs of the underlying unit processes. For reasons of realistic system representation and commercial confidence, this is intentional (see 2.1). However, some options exist to anticipate questions and issues arising from this:

- **Input** — Preparing a separate Eco-profile is justified, where feedstocks or precursors are outside the scope of PlasticsEurope and not under operational control of the member company, e.g. petrochemical feedstocks from the supply chain. These are effectively background datasets (see 3.5).
- **Process** — Where a **dominance analysis** shows that a unit process or sub-system contributes more than 30% to an indicator result (inventory or impact level), preparing a separate Eco-profile of this sub-system shall be considered. This will often be the case for the main feedstocks or precursors, as is demonstrated by the hierarchical flowchart of interdependent Eco-profiles (Figure 3).
- **Output** — Preparing a separate Eco-profile is also justified, where an intermediate is used for a variety of other processes other than the product under consideration. This is commonly the case with monomers and other basic building blocks. Provided that the resulting »building block« Eco-profiles are applicable to and representative of other production systems as well, they can thus be used for different downstream uses.

This approach effectively results in modular Eco-profiles (Figure 4): while not broken down to a unit process level (which could render misleading results), building blocks of realistic sub-systems can thus be recombined.

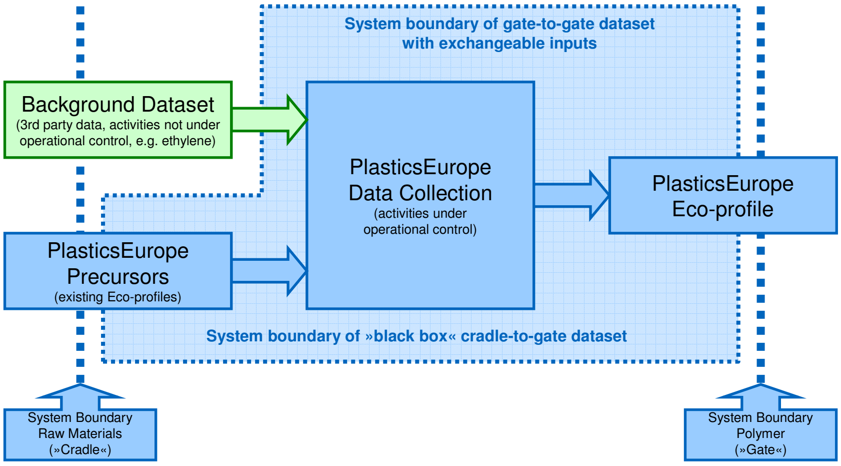

Figure 4: Modular Eco-profiles

3.1.5. Technological Reference and Coverage

The technological reference is defined as follows:

- **Available technology:** The LCI data shall represent technology in use, i.e. technology applied in the defined production region (see below) and employed by the participating producers. The coverage (percentage of total production volume) shall be stated.
- Boundaries towards other product systems: Eco-profiles shall differentiate –
  - primary data from foreground processes, i.e. those that are under operational control, and
  - secondary data from background processes, i.e. those operated by third parties where only indirect management control or no control exists.
- **Inputs of secondary materials (recyclate) and outputs of wastes for recovery or disposal** shall be noted as crossing the system boundaries. Whether these are analysed further (for instance, by system expansion or by credits) or not, the LCA practitioner shall record the chosen method, its rationale, and sufficient detail to facilitate reviews and verification.

3.1.6. Time-related Reference and Coverage

The Eco-profile and EPD shall state –

- the time period for which the LCI data was collected,
- the reference period, i.e. usually the reference year, and
- the expected temporal validity of the dataset during which the data is considered to be sufficiently valid, i.e. an expiry date after which a revision of the Eco-profile is foreseen.

All LCI data should be collected as 12 month averages; exceptions shall be justified.

3.1.7. Geographical Reference and Coverage

Eco-profiles and EPDs usually refer to a European average, as defined by PlasticsEurope's statutes and membership, and the respective locations of sites participating in the LCI data collection. In any other case, the geographic location of the production sites included in the calculation of LCI data shall be recorded and justified.

LCI data describing the direct inputs and outputs of foreground processes (resin production) shall be representative of the defined production region.

3.2. Cut-off Rules

The LCI data collection for Eco-profiles shall aim for completeness – a closed mass and energy balance – and avoid cut-offs altogether. Where quantitative data are available, they shall be included.

However, no undue effort should be spent on developing data of negligible significance concerning environmental effects. Where elementary flows are unknown or no quantitative data are available, the following minimum criteria shall guide Eco-profile data collection:

- Include all material inputs that have a cumulative total of at least 98% of the total **mass** inputs to the unit process;
- Include all material inputs that have a cumulative total of at least 98% of total **energy** inputs to the unit process; and
- Include any material, no matter how small its mass or energy contribution, that has significant effects in its extraction, manufacture, use or disposal, is highly toxic, or is classified as hazardous waste (**environmental significance**).

Cut-offs may become necessary in cases where no data are available, where elementary flows are very small (below quantification limit, see 3.3.5), or where the level of effort required to close data gaps and to achieve an acceptable result becomes prohibitive.

Flows that are cut off, estimated, or substituted shall be recorded in qualitative and quantitative terms, and the omission shall be examined and justified, if applicable, by a sensitivity analysis (see 3.3.2) considering –

- **Mass**: percentage of total input or output mass flows, respectively;
- **Energy**: percentage of total input or output energy flows, respectively;
- **Cost**: percentage of market value;
- **Environmental significance**: percentage contribution to relevant impact indicators.

3.3. Data Quality Requirements

By default, the LCI data for Eco-profiles are collected with an **attributional** (accounting, descriptive) approach, i.e. describing the environmentally relevant physical flows to and from unit processes (subsystems of the life cycle). To this aim, the attributional approach specifies a product property (typically economic value) by which outputs from a market are allocated to the inputs of a market. This allows for a description of the environmental performance of production sites at a point in time (typically in the recent past).

By contrast, the **consequential** (change-orientated) approach specifies how the output from the market increases the marginal input to the market, as determined by production costs and long-term market trends. This allows for a description of how the environmentally relevant physical flows to and from the technological system will change in response to possible changes in the life cycle, i.e. the consequences of actions.

Life cycle inventory data are collected from the participating companies and their respective plants. Most of the information can be derived from existing records. Few companies have the resources available to carry out new measurements on their plants, but usually the monitoring of plants is sufficiently detailed. There may yet be cases where data are from different sources (e.g. calculated as opposed to measured) or data gaps need to be closed by estimates. For the sake of comparability, the following requirements about data quality shall be followed, and data quality shall be reported.

3.3.1. Data Sources and Types of Data

Individual plants at each step of the production chain may be sourced with varying feedstocks, depending on production circumstances, geography, etc. Consequently, outputs are often not traceable to single inputs, and material specification typically occurs in general terms and is not supplier specific.

Eco-profile and EPDs developed by PlasticsEurope shall use average data representative of the respective foreground process (usually a polymer resin production), both in terms of technology and market share. The primary data shall be derived from site specific information for processes under operational control supplied by the participating member companies of PlasticsEurope (see 3.4). Secondary data may be derived from generic datasets (see 3.5) for background processes, or to close data gaps (see 3.3.6).

In the course of the data collection and research, the type of data (by source) shall be noted as follows:

- Primary data –
  - Measured (e.g. accounting or analytical data);
  - Calculated (e.g. using stoichiometric relations or emission factors);
  - Estimated (e.g. expert judgment);
- Secondary data (e.g. literature, third-party database).

3.3.2. Data Quality Indicators

Data quality should be assessed considering the following requirements (Table 1):

- Technological, temporal, and geographical coverage (with regard to goal and scope, see 3.1);
- Relevance, representativeness and consistency (with regard to goal and scope);
- Completeness (e.g. by noting omitted or substituted flows);
- Precision and accuracy (e.g. by providing a confidence range);
- Data sources, reliability and uncertainty (e.g. ranging from verified measurement to non-qualified estimate).

In order to assess accuracy, specifically where estimates or substitutes are used, a **sensitivity analysis** should be conducted as follows: each data item is doubled and halved, then checking whether the final impact assessment for the product system being modelled varies by less than 5%, in which case the approximate values can be used – where the variation is greater than 5% further investigation of this parameter shall be undertaken.

The LCA practitioner shall address each of the requirements as per Table 1 in the Eco-profile report. The electronic ELCD format (see 5.2.4) also requires that these criteria be reported.

These data quality criteria shall then be checked and confirmed in the external review of the Eco-profile report and dataset (see 5.1.4). Based on the outcome, the reviewer can assign data quality indicators (DQI) to the dataset.

Table 1: Requirements for data quality (source: UNEP/SETAC LCA Guidance 2011, in publication)

Requirement	**Description (as per ISO 14040–44 as far as applicable)**
Technological coverage	Specific technology or technology mix for which data was collected (see 3.1.5).
Time-related coverage	Age of data and the minimum length of time over which data was collected; additionally the expected temporal validity of the dataset (see 3.1.6).
Geographical coverage	Geographical area from which data for unit processes was collected (see 3.1.7).
Relevance and representativeness	Qualitative assessment of the degree to which the data set reflects the true population of interest (i.e., geographical coverage, temporal and technology coverage).
Consistency	Qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis.
Reproducibility	Qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study.
Precision and accuracy	Measure of the variability of the data values for each data expressed (e.g., variance).
Completeness	Percentage of flows measured or estimated.
Data sources	Documentation of the data origins (see 3.3.1).
Reliability and uncertainty	Uncertainty of the information (e.g. data, models and assumptions).

3.3.3. Nomenclature of Elementary Flows

In order to support Life Cycle Impact Assessment (LCIA), the LCI entries shall follow a rigorous nomenclature:

- **Substance flow names** (for purposes of data collection and reporting) shall be in accordance with the *Pollutant Release and Transfer Register* (*PRTR*, former *EPER*) and *ILCD*;
- **Organic compounds** shall be reported as the exact form (with CAS or IUPAC number), but see 3.3.4 for the handling of substance groups;

- **Metals** shall be reported as single species, and should also mention the particle sizes of metals because it controls dissolution rates and fate.

Note that within the European Union (EU), there are definitive lists of air and waste emissions that must be reported by facilities above a certain size. The relevant Directive is 96/61/EC with a subsequent Commission Decision 2000/479/EC published in the Official Journal L192/36 on 28/07/2000. The official list of air and wastewater emissions contains 37 and 26 pollutants, respectively.

For further guidance on nomenclature of elementary flows, please refer to the *ILCD* handbook.

3.3.4. Substance Groups

Wherever feasible, an attempt shall be made to report single species for elementary flows. Substance groups, such as »metals (unspecified)«, shall be avoided where possible.

Some chemicals, however, such as polycyclic aromatic hydrocarbons (PAH) and chlorinated fluorinated carbons (CFC), are recorded in the LCI data collection as group parameters. Since characterisation factors are only available for individual chemical species, such as anthracene and chrysene, or CFC-11 and CFC-12, this causes problems in the LCIA phase. Similar problems arise for Volatile Organic Compounds (VOC), sulphur compounds, absorbable organic halogens (AOX) and hydrocarbons (CxHy).

These group parameters should preferably be broken down into their individual chemical constituents and specified as such. If unavoidable due to limited availability of detailed primary data, substance groups shall be defined as detailed as possible with regard to their environmental relevance, specifically –

- methane and non-methane volatile organic compounds (NMVOC) shall be differentiated;
- halogenated and non-halogenated NMVOC should be differentiated;
- among polycyclic aromatic hydrocarbons (PAH), benzo(a)pyrene shall be recorded separately.

For further guidance on substance groups and single substances, please refer to the *ILCD* handbook and to the *PRTR* substance list.

3.3.5. Detection and Quantification Limits

LCI data sets shall report numerical values where these are above detection or quantification limits. If, however, entries are below detection or quantification limits, no numerical value can be given (not even zero nor any arbitrary estimate between zero and the quantification limit). Note that the detection limit may vary depending on the substance: hence it should be recorded during data collection.

For the purposes of Eco-profile reports, such entries should be reported as »not quantifiable« with a footnote explaining that items are below detection or quantification limit. These cases should then be handled by applying cut-off rules (see 3.2).

3.3.6. Data Gaps and Overseas Production

Gaps in primary datasets may occur, for instance, because of –

- Lack of emission data for a given unit process;
- Use of imported materials (overseas production);
- Use of third-party waste management or wastewater treatment processes, or;
- Products or processes otherwise outside the operational control of the data provider.

In such cases, the data gap should be addressed by substituting an industry average. The use of generic datasets for secondary or background data is discussed in section 3.5. This substitution shall be recorded and commented upon.

In cases where region-appropriate LCI data for imported materials and non-domestic processes (overseas production) are unavailable from both primary and secondary sources, the supply chain should be modelled using process data typical of European production technologies. These data will then be adapted where possible to make the data mimic the infrastructure and operations of the origin countries, for example, adjusting transportation distances and modes, and electricity generation fuel mix, calorific value and emission profile of solid fuel resources etc. Where such adaptations are undertaken it shall be clearly recorded that the inventories are based on European production data and are not actual inventories for imported production.

3.4. Collection of Primary or Foreground Data

Primary or foreground data comprises all data concerning processes under operational control of the respective producer.

3.4.1. Data Collection Conventions

The following conventions apply to data collection:

- **Units** — SI units are used throughout the Eco-profiles and EPD (or any report submitted to the verifier). Hence, data should be collected in SI units if at all possible, keeping unit conversions and the associated error potentials to a minimum.
- **Calorific values** — Gaseous fuels are commonly recorded in terms of their energy content – indeed natural gas fuel is sold by energy content rather than mass. Similarly exchanges of fuels internally are often recorded by energy content (see 3.8.3). Eco-profiles should record gross calorific values (upper heating value); alternatively, the net calorific value (lower heating value) of the water-free resource could be specified. In any case, the reference shall be clearly stated because the difference between gross and net calorific value can cause substantial errors in calculation. Additionally, the mass flow should be provided as well, if at all possible.

3.4.2. Data Collection for Waste Streams

It should be noted that, in accordance with the rules in the *ILCD* handbook, the final LCI dataset must not include any waste streams for treatment (economic flows, see Figure 7), but only final deposits released into the environment (see 3.8.1). Therefore, for all waste streams recorded during data collection the intended waste treatment shall be mentioned. In the course of the LCI modelling, all waste streams shall be assigned to the applicable waste treatment systems accordingly.

During data collection, waste streams should be specified as precisely as possible, noting European Waste Catalogue (EWC) numbers where applicable and specifying the foreseen treatment of the waste. At minimum, solid waste shall be differentiated into simplified categories of **non-hazardous** and **hazardous** with an explicit mention of the treatment or disposal option:

- for energy recovery,
- for landfill disposal,
- for waste incineration etc.

Additionally, solid wastes could be differentiated according to the following two different formats. These results can be provided as an optional informative documentation:

- **European Union system (EWC codes)** — categorises solid waste by origin and is concerned with the collection and handling of the waste. The principles governing solid waste management in the European Union are laid down in Directive 2008/98/EC. The European Waste Catalogue (EWC) List of Waste should be used to identify the different components of solid waste as per the groups shown in Table 2. In the LCI results tables, entries shall be marked with an asterisk (*) if the waste is categorised as hazardous as defined by EU Directive 91/689/EEC.

Table 2: European Waste Catalogue (EWC) List of Waste

EU Group	Waste Origin
01	Mining and mineral processing
02	Agriculture, horticulture, forestry, food preparation
03	Wood processing, pulp and paper industries
04	Leather, fur and textile industries
05	Oil, gas and coal processing
06	Inorganic chemical industries
07	Organic chemical industries
08	Paints, varnishes, enamels, adhesives, sealants & printing ink
09	Photographic industry
10	Thermal processes (Power stations, metals, glass, ceramics)
11	Chemical surface treatments & hydrometallurgy
12	Shaping & non-chemical surface treatments of metals & plastics
13	Oil wastes (except edible oils)
14	Organic solvents, refrigerants & propellants
15	Waste packaging, absorbants, filter mat'ls & protective clothing
16	Wastes not otherwise specified
17	Construction & demolition wastes
18	Human and animal health care
19	Waste management facilities & water treatment plants
20	Municipal wastes

- **Empirical system** — categorises solid waste into municipal (domestic) or industrial waste by identifying the type of disposal that has to be applied or the use, if any, to which the waste can be put after appropriate processing:
    - **Municipal solid waste** (MSW, domestic waste) can be regarded as that typically generated by domestic households and usually collected for disposal by the local municipal authority. Some forms of this type of waste are also generated by commercial premises such as shops and offices and will also form part of the total waste generated by industrial sites as a result of operating offices and canteens. Some components of municipal waste are easily categorised as for example pack-

aging wastes such as glass containers, tinplate cans, etc. and waste food products (putrescibles). Nevertheless, there are instances when the composition of this type of waste is not known and then it must be characterised as municipal solid waste.

- **Industrial waste** is further broken down into –
- **Mineral waste** refers to waste earth and rock generated in mining operations. The principal source of mineral waste relevant in the context of Eco-profiles is often coal production. Frequently, mineral waste is returned to a mine working once the valuable minerals have been removed and so represents a measure of the rock moved rather than the generation of permanent waste. Where the waste is known to be returned to the mine, it is recorded separately as waste returned to mine.
- **Mine tailings** represent the residue left after mineral processing and may be inert or contain processing chemicals. In remote mines, tailings will usually be disposed of locally.
- **Slags and ashes** refer to the solid waste produced by industrial boilers and furnaces. This is usually inert and because it contains no organic matter that can decay with time, it is frequently used in civil engineering operations such as road building. When slags and ashes are used in civil engineering projects they are products from the process producing them and so carry with them a proportion of the burdens of the processes.
- **Inert waste from chemical processes** could, in principle, be sent to landfill sites without further treatment.
- **Regulated waste from chemical processes** represents the category of chemical waste that has to be sent to special storage sites because it is corrosive or toxic.
- **Construction waste** is usually generated in building and plant construction operations.
- **Waste to incinerator** is sent off-site for incineration. Usually, no information is available for these external incinerators and any such waste is recorded separately.
- **Waste to recycling** is collected by external operators and recycled. Usually no information is available about the way in which these materials are handled once outside of the plant.
- **Mixed industrial waste** is a catch-all classification so that if the waste does not fit into any of the other categories it will normally appear here. Usually this consists of wastes such as discarded industrial packaging and general housekeeping waste and is similar to domestic refuse that would usually be handled by municipal authorities.

3.4.3. Practical Hints on Data Collection

In preparation of the LCI data collection, the Eco-profile Project Team (EPT) will hold a meeting including a knowledge-building session in order to raise awareness about the procedures and success factors of the exercise.

The LCA practitioner will usually employ an *Excel*-based questionnaire which is distributed to the participating member companies. To this aim, a generic questionnaire template could be developed which should contain default substance flow names as per the ILCD handbook, accommodate data entry in varying units (drop-down to select unit), offer automatic conversion to metric standard units (e.g. tonnes to kg), and ensure a base-level plausibility by restricting numerical entries to reasonable ranges.

The following requirements for data quality should guide the data collection:

- Direct measured data should be preferred over inferred or estimated data;
- Locally appropriate data should be preferred over data from remote sources;
- Data for identical processes should be preferred over data from analogous processes;
- Recent data should be preferred over older data;

- At last resort estimated data should be used until the mass and energy balance for the process is complete.

3.5. Use of Secondary or Background Data

Secondary or background data concerns processes either outside the operational control of the respective producer, or for which primary data are not available at a feasible effort. Such generic datasets can be derived from publicly available or commercial LCI databases.

Examples of generic datasets include:

- raw material deliveries (third party production, see 3.1.4),
- transport,
- grid electricity mix,
- desalinated water,
- nitrogen,
- compressed air,
- on-site wastewater treatment.

Generic background datasets should comply with quality requirements set out in the *ILCD* handbook. Such datasets can be obtained from, for instance, the *ELCD* database, the *ecoinvent* database, or equivalent databases. As a minimum requirement, generic datasets should to comprise meta information (documentation, see 5.2) and should have undergone external review.

In any case, the selected generic dataset needs to be recorded and reported in the list of unit processes. The LCA practitioner shall examine the consistency of different background datasets and compare the selected datasets against benchmarks, as far as available.

3.5.1. Modelling Intermediates and Ancillary Polymer Production Processes

Data for intermediates and ancillary polymer production processes should be taken from the PlasticsEurope Eco-profile database, where available.

Note that the use of generic datasets is an option, not an obligation: indeed there may be reasons to use proprietary datasets, for example, for intermediates like syn-gas or chlorine which are specific to a production site. As above, where possible, a comparison with the respective benchmarks should be conducted.

3.5.2. Modelling Energy Supply

The energy supply shall be modelled on a site-specific basis. If direct energy supply is derived from one source, then this should be used, and where energy is taken from a national or regional grid, then this shall be modelled specifically for the specified geographic region.

Generic data for energy can be obtained from the database of the *International Energy Agency IEA*[3].

When accounting for renewable energy or carbon offsets, appropriate quality standards shall be taken into consideration. In any case, credits must be reported as distinct line items, and off-set emissions must not be included in the LCI dataset (see 4.3.2). Mechanisms for compensating for the environmental impacts of products (e.g. prevention of the release of, reduction in, or removal of greenhouse gas emissions) are outside the boundary of the product system (see draft standard ISO 14067, clause 3.9.4). It is generally not recommended to in-

[3] IEA Website: www.iea.org (energy information centre).

clude renewable energy certificates (RECs) or carbon offsets at all, but where they are (as per decision of the EPT), this needs to be transparently recorded and the flows shall be kept separate. If it is an elementary flow, it shall be reported as a distinct flow; if it is an intermediate flow, it shall be non-terminated.

3.6. Unit Process Inventory Datasets

Once the required process data have been collected, they will be recorded in unit process inventory (UPI) datasets. These are the building blocks of the cradle-to-gate LCI. It must be clearly noted here that UPI datasets are **strictly confidential information** and hence subject to the non-disclosure agreement between the data provider (member company) and the dataset developer.

The dataset developer is required to keep these records for a minimum of ten (10) years . Upon request, the dataset developer shall make the anonymised records available to the reviewer (see 5.1.3).

3.7. Calculation Rules

3.7.1. Vertical Averaging

When modelling and calculating average Eco-profiles from the collected individual LCI datasets, vertical averages shall be calculated (Figure 5). Vertical averaging involves combining a sequence of unit process inventories (UPI, see 3.6), or sometimes aggregated processes, which are linked by a reference flows, e.g. precursors or intermediates. Vertical aggregation also means that data are first calculated separately for each production chain, and only then an average is calculated, weighted by the production tonnage of each chain.

By contrast, horizontal averaging (Figure 6) implies aggregating multiple UPI or aggregated processes each supplying the same reference flow. Horizontal averages may in some cases be useful to handle data gaps or for benchmarking purposes. However, utmost care needs to be taken that the operations thus included in the average are indeed consistent; further, the horizontally averaged performance may not represent a viable system due to interdependencies between operations.

The sub-system boundaries for the production chains to be vertically averaged should be set in such way as to avoid allocation as far as possible. They shall take into account a sufficient number of representative site-specific production routes. The datasets obtained by vertical averaging are deemed to be the most appropriate representation of industrial reality, reflecting the high level of integration within production sites and industrial networks.

For reasons of confidentiality and in order to avoid revealing commercially sensitive information, averages should be calculated from at least three (3) distinct individual datasets. Note that this may pose problems in some cases where too few producers exist for a given product – such cases will need to be resolved by the EPT.

In practice, Eco-profiles will often use a hybrid of vertical and horizontal averages in that intermediates may constitute a reasonable sub-system boundary. Therefore, wherever possible and useful, meaningful intermediates can also be reported as »partial-chain«, or modular, Eco-profiles (see 3.1.4).

Additionally, academic researchers and practitioners from other regions can contact PlasticsEurope about a re-calculation of the industry average model with, for instance, energy supply pre-chains exchanged for regional specifics, as far as reasonably possible.

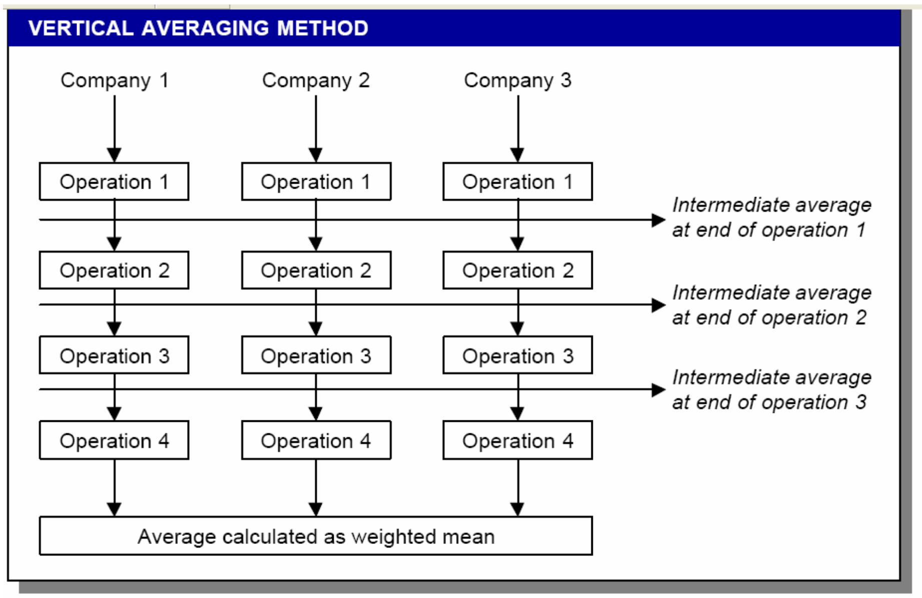

Figure 5: *Vertical Averaging (Source: Eco-profile of high volume commodity phthalate esters, ECPI European Council for Plasticisers and Intermediates, 2001)*

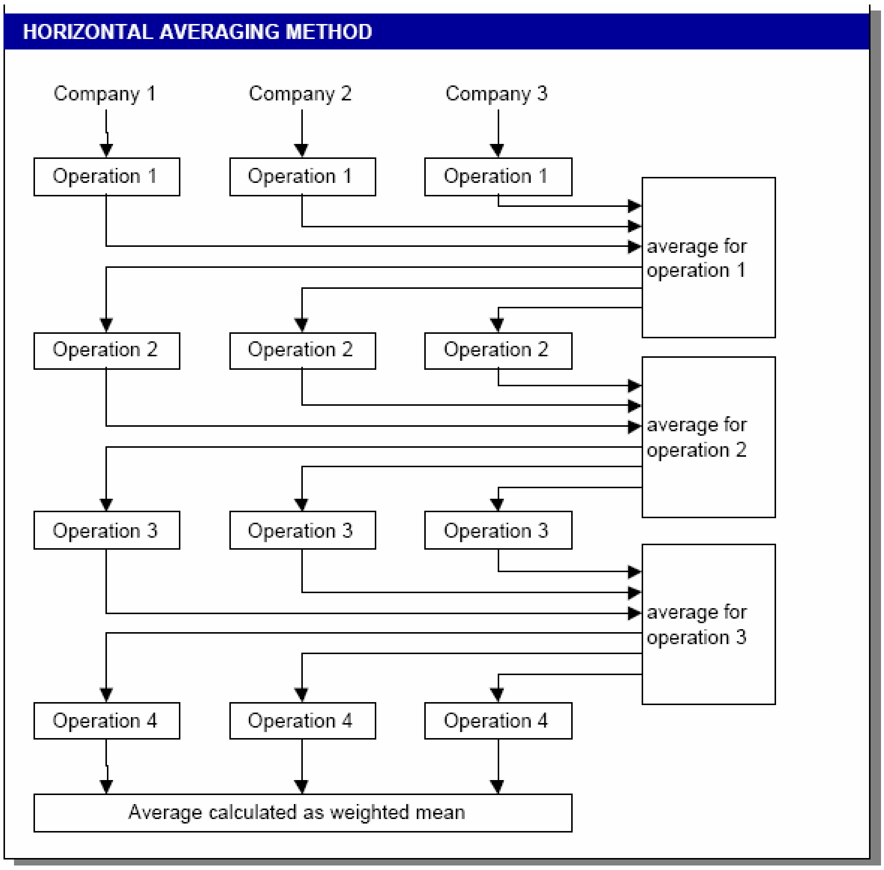

Figure 6: *Horizontal Averaging (Source: Eco-profile of high volume commodity phthalate esters, ECPI European Council for Plasticisers and Intermediates, 2001)*

3.7.2. 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. To this aim, a generic process with the same function (product) can be introduced, and the examined system receives credits for the associated burdens avoided elsewhere (»avoidance allocation«, avoided burden). System expansion should only be used where there is a dominant, identifiable displaced product, and if there is a dominant, identifiable production path for the displaced product

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 subsystem under consideration.

Since production systems are controlled by different strategies and allocation is always a value judgment, PlasticsEurope's stipulates the following »allocation philosophy«: from the following allocation methods the practitioner shall select the one most appropriate to the goal of the production system and transparently record the justification of this choice; the chosen allocation method shall also be noted in the meta-data (see 5.2.1).

The following allocation methods are eligible options:

- **Mass or energy allocation** aims at a close representation of physical causality, i.e. the causal relationships between the inputs and outputs. The choice of partitioning parameter is meant to reflect the physical behaviour of the system as shown by mass or energy flows.
- **Stoichiometric allocation** aims at a close representation of physical causality in case of chemical transformation processes, i.e. as shown by molecular flows.

For example, in order to produce 1 kg of chlorine from an electrolytic cell, a total of 1.648 kg of rock salt (NaCl) must be fed into the cell, assuming stoichiometric performance. However, there would also be a co-product of sodium hydroxide (NaOH). Thus of the 1.648 kg of NaCl, 1.000 kg is chloride (Cl^-) which goes to produce the chlorine and 0.648 kg of sodium (Na^+) which goes to produce NaOH. Therefore the quantity of NaCl that is attributable to the chlorine product is 1 kg and not 1.648 kg.

- **Economic allocation** aims at a close representation of the economic purpose of production systems, i.e. as indicated by prices or costs.

In particular, stoichiometric and economic allocation should be considered in order to avoid inappropriate results where these are an upshot of mass allocation. In case of substantial deviation, i.e. more than 20%, between the resulting LCI or impact indicator from mass allocation and an alternative method, the influence of the choice of allocation method shall be addressed by a sensitivity analysis.

In principle, allocation rules should reflect the goal of the production process. Furthermore, it should be noted that allocation not only affects calculated results, but also the primary data collection in that certain elementary flows might be dropped from the outset. The same allocation method shall be applied consistently throughout all datasets contributing to an average (see 3.7.1).

The chosen allocation method and its rationale shall be recorded in the Eco-profile report. Where possible, a sensitivity analysis (see 3.3.2) should be carried out to illustrate the variability in results for alternative allocation methods.

3.7.3. Interchange of Hydrocarbon Fuels

Frequently waste hydrocarbon products from one process are exported for use as fuels to another, but totally unrelated, process elsewhere on the site. Often, the chemical composition of these fuels is unknown, as is their calorific value, which may, in any case, vary with time depending on the types of waste produced. In such cases, the following procedure shall be used:

- During their production, the total materials and energy consumption and the emissions generated are partitioned over all products with the by-product fuel being regarded as a useful product. When this by-product is consumed by another process, it carries with it a proportion of the inputs and outputs of the producing operation so that these are »charged« to the receiving operation.

- When the precise calorific value of the »unknown« hydrocarbon is not known, it is assigned an arbitrary value of 40 MJ/kg. It is therefore necessary to examine the sensitivity of the final result to this value. If the value is set too high, any process that produces a significant quantity of by-product will effectively be exporting energy and emissions that should more properly be attributed to the main product. Conversely, if the value is set too low, the main product is being charged with more resources and emissions than is correct. In practice it has been found that the quantities of fuels exported in this way tends to be relatively small and whenever sensitivity analysis have been performed, it is found that a change of 20% in the calorific value of the by-product fuel (i.e. 32 MJ/kg to 48 MJ/kg) usually results in variations in the final answer of less than 2%.

- When such by-product fuels are subsequently burned, the combustion emissions are assumed as for heavy fuel oil combustion.

3.7.4. Allocation Rules for End-of-life Management

In case of material or energy recycling, the **recycling potential** approach shall be employed. For detailed guidance, please refer to the *ILCD*.

The following specific cases are noteworthy:

- Plastics waste for recycling leave the system without any burdens.

- Secondary raw materials enter the system with burdens due to collection, sorting and conversion of pre- and post-consumer plastic wastes.

In case of open-loop recycling, when assigning burdens to primary and secondary life cycles, the 50:50 rule should be adopted as a default. If this rule is employed, it shall be transparently recorded and the ramifications should be examined by sensitivity analysis (see 3.3.2).

3.8. LCI Results

3.8.1. Structure of LCI Datasets

The core of the Eco-profile report is the Life Cycle Inventory (LCI) table, representing inputs and outputs of the product system under consideration (Figure 7).

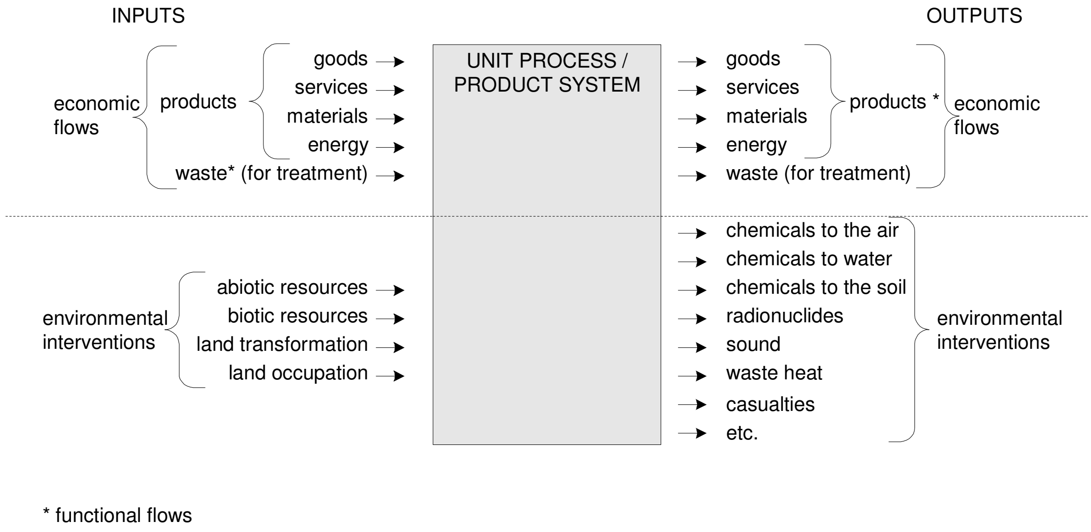

Figure 7: Basic structure of a unit process or product system in terms of its inputs and outputs

As a cradle-to-gate LCI, the aggregated dataset is composed of a number of unit processes inventories. The single product reference flow (see 2.2.2) is thus related to a number of input and output flows from and to the environment.

In general, input and output flows can be differentiated into:

- **Economic flows** supplied by or delivered to other unit processes or sub-systems (in particular, this includes the product reference flow);
- **Environmental interventions** taken from or released to the environment.

In the final cradle-to-gate LCI, the only remaining economic flow will hence be the product reference flow. Other economic flows recorded in the unit process inventories will have to be traced back to the environment by including the necessary upstream or downstream unit process inventories and/or by allocation in case of multi-output systems (see 3.7.2).

In some cases, environmental flows may have to be denoted as cut off (see 3.2) in cases where they were not tracked to the system boundary or if they cannot be quantified.

The LCI results are presented as a set of input and output tables each describing some aspect of the behaviour of the systems examined. In all cases, the tables refer to the gross or cumulative totals when all operations are traced back to the extraction of raw materials from the earth.

The list of elementary flows in the results tables shall use the structure and nomenclature of the *ILCD*. The CAS numbers of all elementary flows should be included in the results tables for ease of substance identification. This becomes especially important when assigning substances to impact assessment models or when transferring data between databases.

3.8.2. Data Categories by Type of Operation

It may often be useful to differentiate the results of Eco-profile further into a number of categories, identifying the type of operation that gives rise to them. Although identifying these categories is relatively straightforward, assigning individual data to them may involve some deliberation. Primarily, process- and transport-related entries shall be identified separately by default:

- **Process** — This category represents the production processes (key foreground process level) under considerations and shall exclude the operations differentiated below.
- **Transport** — This category is easily identified, and so the direct energy consumption of transport and its associated emissions are always separated, for example, the delivery of coal to a power station. Transport shall include the associated fuel pre-chains.

Beyond these default data categories, the following categories should be separately reported as necessary or appropriate to the Eco-profile at hand:

- **Fossil fuel production and use** — This category comprises all fossil fuel-related operations. First, fuel production processes are defined as resulting in the delivery of fuel, or energy, to a final consumer whether domestic or industrial. For such operations all inputs, with the sole exception of transport, are included as part of the fuel production function. For example, the burdens associated with the production of the coal used in a power station would be assigned to fuel production. Second, fuel use is defined as the use of energy delivered by the fuel producing industries. Thus fuel used to generate steam at a production plant and electricity used in electrolysis would be treated as fuel use operations. Again, only the fuel used in transport is kept separate.
- **Biomass production and use** — This category refers to the inputs and outputs associated with the use of biogenic materials such as wood. The reason for isolating this as a separate category is that such materials absorb carbon dioxide while growing (carbon sequestration). Thus biogenic CO_2, whether as a negative quantity during tree or plant growth or as a positive quantity, if the wood products are eventually burned, is always identified as such. Similarly, biomass fuels are kept as a category separate from other fuels.

Where biogenic carbon dioxide or biogenic methane are relevant, or where biodegradable or recycled materials are used, the *ILCD* handbook should be consulted for further guidance on modelling and impact assessment.

Note that most products leaving an oil refinery could be used as fuels or feedstocks. Refineries, therefore, could be classified as either fuel producing operations or materials processing operations. In either case, care should be taken when assigning inputs and outputs to the refinery process to allow for appropriate allocation (see 3.7.2) of energy use and emissions to the respective fuel or feedstock reference flows. By adopting this procedure, it is easier to identify the process data in downstream operations.

3.8.3. Energy Data

The Eco-profile shall report the cumulative requirement of primary energy resources at the system boundary of extraction from the earth (Table 3). By default, the upper heating value (UHV) shall be used in Eco-profile reports. For the purposes of LCI datasets and EPDs, however, the lower heating value (LHV) should also be included where applicable (see 4.1.1). Note that these results usually depend critically on allocation (see 3.7.2). The basis of these inventory indicators is a combined energy and carbon flow balance (Figure 8).

- As a key indicator on the inventory level (see 4.1.1), the **primary energy demand** (system input) shall indicate 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 the primary energy incorporated in the product, the **energy content in polymer** (system output) shall indicate the energy recovery potential, quantified as the gross calorific value (upper heating value, UHV). Since the functional unit is 1 kg of the declared polymer (reference flow, see 2.2.2), the potentially recoverable energy content in polymer [MJ] is numerically identical with the gross calorific value [MJ/kg]. This depends upon the chemical composition of the output (free enthalpy).

- 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 will be removed during allocation (see 3.7.2).

Table 3: Primary energy demand (system boundary level)

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

A figure should be used to better illustrate the energy flow through the product system, including the relevant primary resources (system input), fuels/feedstock energy, types of useful energy (key processes), and energy content in the polymer (energy recovery potential, system output), see Figure 8.

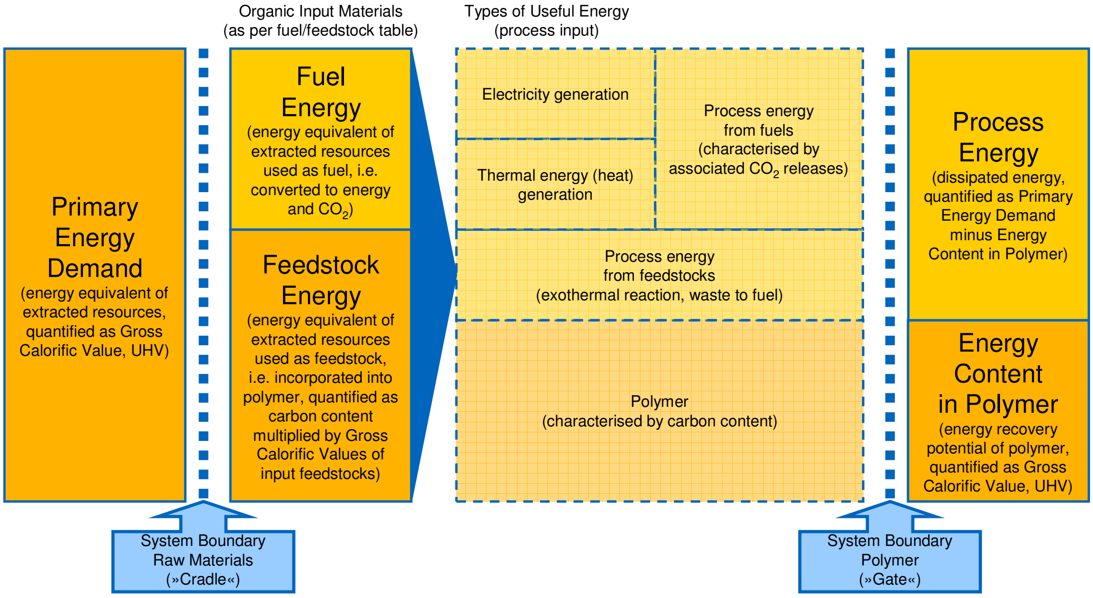

Figure 8: Energy flow diagram showing how primary energy demand (system input) is disproportioned into fuel and feedstock energy (within system), and process energy and energy content in polymer (system output)

In addition, and to facilitate interpretation and identification of optimisation potentials, the results for energy requirements shall also be analysed as follows:

- **Analysis by primary energy resources** — Primary energy resources extracted from the earth should be provided as per Table 4, in energy and mass equivalents where applicable. While energy and mass equivalents are related, the relationship is not a simple one, because within each of the fuel groups there will be a mix of calorific values. The precise nature of this mix will vary from one system to another. Therefore a single mass-to-energy conversion factor cannot be defined which will hold true in all systems. Further, the entries for nuclear energy (see footnote 5) and hydro-power as well as hydrogen, sulphur and recovered energy are not primary energy resources in the conventional sense of fuels extracted from the earth, but they should be included to obtain an energy balance and to show their relative importance; in some systems they may be replaced by other fuels. Recovered energy from steam and condensate recovery processes should be entered into these tables as a separate entry. Similarly, any energy recovered from hydrogen and sulphur combustion should also be entered. The primary fuels shall be kept separate from the feedstocks (see below).

- Further, the **feedstock energy** shall be quantified as the share of the primary energy demand which is incorporated into the polymer (Table 4), as opposed to being used as a fuel for process energy. Hence, the feedstock energy is a measure of the stoichiometric contributions to the polymer, quantified as energy resource equivalents on the input level:
    - In view of resource depletion, primarily fossil hydrocarbon feedstocks (such as oil and gas) shall be considered here because they are depletable resources. To this aim, the stoichiometric carbon (C) and hydrogen (H) contents of the reference flow (usually a polymer) are multiplied by the gross calorific values of the respective input feedstocks (oil, gas, or hydrogen fuels; shown as a carbon balance in Figure 9). Due to the predominance of hydrocarbon backbones in polymers, this will usually represent >95% of the feedstock energy. Biogenic hydrocarbon feedstocks shall be recorded separately.
    - The same method should be applied to other elements (where relevant) which are considered depletable resources, such as minerals and metals: primary energy demand equivalents based on gross calorific values can be assigned to these as well (representing the free enthalpy released in an oxidation reaction). Some of these (such as silicone, Si) may be relevant in certain plastics.
    - In a problem-orientated simplification, some elements considered to be abundant resources, such as nitrogen (N), sulphur (S), and chlorine (Cl), and hence may be excluded from this calculation. Exclusions need to be justified based on a sensitivity analysis (i.e. how omissions affect the feedstock energy results).
- The remainder (primary energy demand minus feedstock energy) is denoted as **fuel energy** (in case of hydrocarbons corresponding with CO_2 or H_2O emissions in the output).
- Note that the difference between the feedstock energy and the energy content in polymer (see above), after allowing for materials losses during manufacture, is a measure of the energy that has been incorporated into or liberated from the materials during processing. Feedstock energy must therefore <u>not</u> be interpreted as the calorific value of the output from a system; rather it is the calorific value of the <u>inputs</u>.

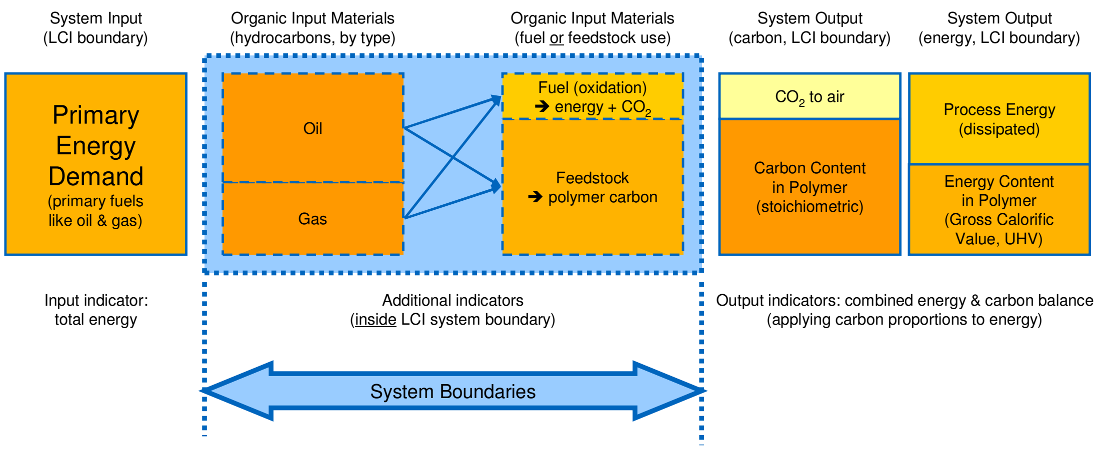

Figure 9: *Combined energy and carbon flow balance to analyse how hydrocarbons feedstocks is disproportionated into the polymer carbon backbone and CO_2 air emissions; the same type of balance needs to be analysed for hydrogen and H_2O.*

Table 4: Analysis by primary energy resources (system boundary level), expressed as energy and/or mass (as applicable)

Primary energy resource input	Total Energy Input [MJ]	Total Mass Input [kg]	Feedstock Energy Input [MJ]	Fuel Energy Input [MJ]
Coal				
Crude oil				
Gas/condensate				
Hydro				
Nuclear				
Lignite				
Wood				
Biomass				
Peat				
Sulphur				
Hydrogen				
Recovered				
Sub-total Renewable				
Sub-total Non-renewable				
Total				

- **Analysis by type of useful energy** — For selected key processes of the foreground system (usually a key precursor and the polymerisation step), this analysis should differentiate the process energy requirements by useful energy (electricity, heat/thermal energy) (Table 5). This analysis facilitates the process optimisation on an input level; further, it allows for exchanging default and customised upstream modules (pre-chains, background processes) as part of scenario analysis. In order to avoid double-counting, a careful distinction between useful energy and fuel type is important. Note that feedstocks and other fuel-bearing materials may contribute a certain share of the process energy requirements; for instance, a cracker will use natural gas both for process heat and to generate ethylene as a feedstock for polymerisation. This fuel/feedstock share is addressed by the following analysis.

Table 5: Analysis by type of useful energy (key foreground process level)

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

- **Analysis by input fuel/feedstock energy** — For selected key processes of the foreground system (usually a key precursor and the polymerisation step), this breakdown represents the energy of fuel-bearing materials that are fed into the system but may be used as materials rather than fuels (Table 6). Chemical processes often make use of the energy embodied in the input materials, e.g. in the course of an exothermal oxidising reaction. The quantities of hydrocarbon feedstocks that are taken into the system are represented in terms of their gross calorific value because frequently, in the course of processing, some, if not all, of this feedstock may be converted into a fuel. It is a simple matter to convert from feedstock energy to mass if the calorific value is known (feedstock energy = calorific value × mass, see Table 8).

Table 6: Analysis by type of fuel or feedstock (key foreground process level)

Type of fuel/feedstock in process input	Value [MJ]
Oil	
Gas	
Other fuels/feedstocks (relevant contributions to be specified)	
Total (for selected key process)	

- **Contribution analysis by type of process** — For the whole system, the contribution of the various types of processes to the primary energy demand should be examined in order to identify dominant influences (Table 7). In particular, background processes (e.g. hydrocarbon feedstock production, electricity generation) should be distinguished from key foreground processes (e.g. precursor or intermediate production, polymerisation). Where relevant, the contribution of transport processes should be recorded. It should be noted that where chemical processes include fuel/feedstock inputs (as analysed above), this breakdown will not stringently reflect process energy requirements.

Table 7: Contribution analysis by type of process

Process	Value [%]
Background processes (e.g. hydrocarbon feedstock production, electricity generation; relevant contributions to be specified)	
Key foreground processes (e.g. precursor or intermediate production, polymerisation; relevant contributions to be specified)	
Transport processes	
Total	**100%**

Typical values of **calorific values** are shown in Table 8. However, in the calculations actual values for specific feedstocks shall be used and, for some materials, there can be a large spread of values. Note that feedstock energy is not equal to the calorific value of the output products because of materials losses and changes in chemical composition during processing.

Table 8: Typical calorific values for various fuels or feedstocks. In practice, values for naturally occurring fuels can vary widely, depending on composition. The values shown here should be used as a guide only.

Feedstock	Unit	Calorific value [MJ per unit]
Natural gas	m^3	38.8
Natural gas	kg	54.1
Crude oil	kg	45.0
Coal	kg	28.0
Lignite	kg	15.0
Sulphur	kg	9.3

The importance of the breakdown by type of useful energy and fuel/feedstock is that energy content of delivered fuel and feedstock energy are dependent on the technology used by the process operators. In contrast, the fuel production and delivery energy depends upon the country in which the processes are carried out. The production and delivery of one unit of electrical energy requires a different number of units of primary energy because of the different generating methods and mix of primary fuels. If the aim is to compare technologies or plants that are using the same technology, then the country-dependent data could be stripped out of the results by omitting fuel production and delivery processes.

When comparing technologies, it is important to remember that many processes, especially in the chemical industry, employ on-site steam and power generation that often reflects the need to achieve site optimisation rather than process-specific optimisation. Furthermore, when on-site power generation is practised, it is important to remember that the total fuel input to the generation process will be included in the energy content of delivered fuel. Since the total energy input includes the inevitable conversion losses from thermal to electrical energy, such a process may appear less efficient than one that draws its electricity from the public supply. If account is not taken of this effect, it is possible to draw erroneous conclusions from any comparisons of technologies.

3.8.4. Raw Materials Inputs

Raw materials inputs shall be reported as all materials that are extracted from the earth. Fuels and water consumption, however, are reported elsewhere (see 3.8.3 and 3.8.5, respectively).

Note that sulphuric acid is manufactured from both elemental sulphur and from sulphur dioxide recovered from oil refining and metallurgical processes. If feasible, these different sources of sulphur should be entered separately in the raw materials table as either elemental or bonded sulphur.

Further, the entries for air, nitrogen and oxygen refer to compressed air, liquid or gaseous nitrogen and liquid or gaseous oxygen, respectively, that are taken into the processes for use as process materials or services. Air or oxygen – as a resource – used in fuel burning is not recorded.

Note that these results usually include an allocation step (see 3.7.2).

3.8.5. Water Consumption

Almost all industrial processes use water either as cooling water or process water. In the calculation of Eco-profiles, cooling water shall be specifically identified. Further, irrigation water shall be recorded separately, e.g in case of agricultural pre-chains. All other water shall be treated as process water. The source of water supply shall be reported as per Table 9.

Table 9: Gross water resources and uses [kg water per kg]

Source	Process water	Cooling water	Irrigation water	Total
Public supply				
River/canal				
Sea				
Unspecified				
Well				
Totals				

Note that if a plant is close to a river or to the sea, then cooling water may be extracted from these sources and returned after passing once through the system. However, for many inland plants this is not possible and cooling is usually achieved using a recirculating system. The cooling water taken into such plants from external sources is usually only that needed to top up the system, i.e. to replace that which has evaporated. Consequently, some care is needed when comparing the demand for cooling water for different plants because those using once-through systems show a much higher consumption than those using recirculating systems.

3.8.6. Air Emission Data

Air emission data shall be reported as cumulative totals arising when all operations are traced back to the extraction of raw materials from the earth.

Note that the recorded emissions refer to those remaining after any on-site treatment: and so do not necessarily reflect the output of the production sequence to the on-site air treatment facility.

As a general rule, the air emission data in LCI shall be adequate to calculate relevant impact categories in LCIA. This requirement is fulfilled when using the default list (see 3.3.3 and 3.3.4).

Note that emissions reported by sites and facilities in compliance with EU regulations relate to single site emissions. Eco-profile results usually refer to data aggregated from a number of sites often in different geographical locations. Great care is therefore needed in any interpretation of LCI data since the reported, aggregated emissions do not refer to a point source.

Where they are known, fugitive emissions should be recorded separately. Such emissions refer to losses from the system other than reaction losses. They will therefore include storage tank losses, losses in the delivery systems and leakage from pipe flanges and valves.

Air emissions should be grouped into categories as described earlier (3.8.2).

In case the product system includes renewable materials or biomass as fuel, special care needs to be dedicated to handling »negative emissions«, i.e. CO_2 uptake during the agricultural or forestry pre-chain (see 4.2.2).

3.8.7. Wastewater Emission Data

Wastewater emission data shall be reported as cumulative totals arising when all operations are traced back to the extraction of raw materials from the earth.

Note that the recorded emissions refer to those remaining after any on-site treatment: and so do not necessarily reflect the output of the production sequence to the on-site wastewater treatment facility.

It is important to recognise that some parameters will inevitably involve an element of double counting. In particular, both BOD and COD, which are the result of a specific monitoring test, will give rise to this because of the presence of some emissions, which are separately identified elsewhere. These parameters can, however, be used for plausibility checks and are therefore retained in spite of the double counting.

As a general rule, the wastewater emission data in LCI shall be adequate to calculate relevant impact categories in LCIA. This requirement is fulfilled when using the default list (see 3.3.3 and 3.3.4).

Note that emissions reported by sites and facilities in compliance with EU regulations relate to single site emissions. Eco-profile results usually refer to data aggregated from a number of sites often in different geographical locations. Great care is therefore needed in any interpretation of LCI data since the reported, aggregated emissions do not refer to a point source.

Water emissions should be grouped into categories as described earlier (see 3.8.2).

3.8.8. Solid Waste

Waste management operations shall be within the system boundaries (see 3.1.2 and 3.8.8, Figure 10). Such operations may include landfill (inert waste, municipal waste), underground storage (hazardous waste, nuclear waste), waste incineration, waste water treatment, carbon capture and storage, etc. These are technical processes and thus should be part of the product system. Hence, in terminated datasets, wastes shall not be treated as elementary flows. Any flows of waste for treatment must have been traced to the applicable waste treatment facilities and modelled accordingly. In accordance with 3.4.2, only final deposits released into the environment shall be recorded in the LCI tables.

In addition, however, to facilitate interpretation by producers, the waste arising on the selected foreground process level (usually the polymerisation step) should be reported as well (see 4.1.5).

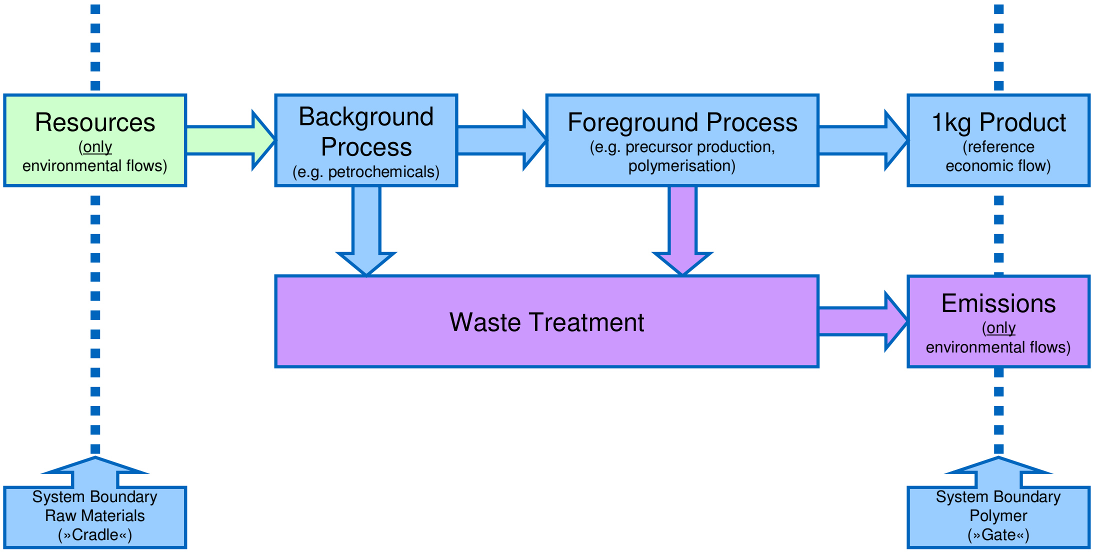

Figure 10: Solid waste recorded as (a) waste generation at key foreground process level (before treatment) and (b) final deposit at system boundary (after treatment).

4. Life Cycle Impact Assessment and EPDs

It should be carefully noted that Eco-profile projects comprise the calculation of the Life Cycle Impact Assessment (LCIA) as an mandatory step so as to prepare a default set of impact categories as environmental key performance indicators. These may be reported in either of the following ways:

- As an optional annex of the Eco-profile report, or
- As an optional Environmental Product Declarations (EPDs).

The rules for calculation and presentation in both formats are identical except where otherwise noted below.

4.1. Key Performance Indicators – Mandatory Parameters

As key performance indicators (KPI), the results of the Life Cycle Impact Assessment (LCIA) are reported in EPDs in a minimum set of mandatory inventory and impact category parameters. For the selection of impact categories the primary reference is the *CML* Guide to LCA (2002). Additionally, reference is made to the *ILCD* handbook in order to capture the emerging best practices. For calculation methods of the individual parameters, refer to section 4.2.

4.1.1. Inventory Level – Input Parameter: Primary Energy Resources

The use of primary energy resources shall be reported and differentiated into renewable and non-renewable resources:

- Primary energy demand (cumulative energy demand, CED or gross energy requirements, GER[4]), measured as upper heating value (UHV) in MJ, differentiated into –
- **Non-renewable primary energy resources**[5], measured as upper heating value (UHV) in MJ, and

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[4] Note that the primary energy demand (synonymously, cumulative or gross energy demand) is, strictly speaking, not an impact indicator, but a technical indicator of the total energy input into the system. From an environmental impact perspective, the depletion of non-renewable resources is measured as ADP (see 4.1.3).

[5] For fissible uranium, use energy extractable in light water reactor.

- **Renewable primary energy resources**, measured as harvested energy in MJ.

Since it is common practice to use the lower heating value (LHV) in many LCA studies, these indicators should also be reported as lower heating values where applicable (see 3.4.1).

In addition, as the **embodied energy**, quantified as gross calorific value of polymer, shall be reported to indicate the energy recovery potential (see section 3.8.3).

4.1.2. Inventory Level – Input Parameter: Water

The use of water shall be given as follows (if possible, specifying the source, e.g. groundwater):

- Process water in kg,
- Cooling water in kg.

If other water uses (e.g. irrigation in agricultural pre-chains) are found to be relevant, these should be commented upon.

4.1.3. Impact Level – Input Parameters: Natural Resources

The depletion of material and energy resources and the use of water shall be given as follows:

- **Abiotic Depletion Potential (ADP), Elements**: all mineral resources, excluding fuels, measured as kg antimony (Sb) equivalents,
- Abiotic Depletion Potential (ADP), Fossil Fuels: all abiotic fuels, measured as MJ (LHV).

4.1.4. Inventory Level – Output Parameters: Key Air Emissions

As a minimum, the following air emission data shall be reported as kg:

- Total carbon dioxide (CO_2),
- Total carbon monoxide (CO),
- Total methane (CH_4),
- Total sulphur dioxide (SO_2),
- Total nitrous oxides (NO_x).

4.1.5. Inventory Level – Output Parameter: Waste

As per 3.8.8, waste shall be reported as follows:

- At the system boundary (after treatment): final deposits (life cycle inventory output item);
- At the key foreground process level (before treatment): waste generation (arising from the selected foreground process, i.e. usually the polymerisation).

4.1.6. Impact Level – Output Parameters: Impact Categories

The following set of environmental impact categories shall be included in the EPD:

- **Global Warming Potential (GWP)**: greenhouse gas contributions in kg carbon dioxide (CO_2) equivalents (time horizon 100 years),
- **Acidification Potential (AP)**: acidifying contributions in g sulphur dioxide (SO_2) equivalents,

- **Eutrophication Potential (EP)**[6]: nutrifying contributions (aquatic and terrestrial eutrophication) in g phosphate (PO_4^{3-}) equivalents,
- **Ozone Depletion Potential (ODP)**: ozone depleting contributions in g CFC-11 equivalents,
- **Photochemical Ozone Creation Potential (POCP)**: summer smog contributions in g ethene (ethylene) equivalents,
- Dust and particulate matter in g[7].

4.2. Calculation of Impact Categories

The selection of impact calculation methods is not arbitrary because results can differ substantially and will thus make reliable business decision impossible. Hence, the calculation of impact categories shall follow the guidelines set out in the *CML* Guide to LCA (2002) including the respective regular updates of characterisation factors published on the *CML* website. In addition to this default guideline, the following documents could be considered for further information:

- the *ILCD* handbook;
- the *ReCiPe* project;
- pre-EN 15804.

It should be carefully noted that all these guides constitute secondary literature: the LCA practitioner shall take care that the most recent update of the characterisation models from primary sources is used to calculate the selected impact categories.

In any case, the impact assessment shall be conducted using global (or, European) impact models, rather than regionalised approaches. A sensitivity analysis may be conducted to demonstrate regional differences in case this is useful and feasible.

4.2.1. Abiotic Depletion Potential (ADP)

The Abiotic Depletion Potential (ADP) measures the extraction of natural resources such as iron ore, scarce minerals, and fossil fuels such as crude oil. This indicator should be characterised based on ultimate reserves and extraction rates using Antimony (Sb) as a reference. Alternative methods (based on economic reserves or exergy) and references (silver, iron) should be considered as the scientific debate is on-going.

A further differentiation of ADP into elements (mineral resources) and fossil fuels (abiotic fuels) should be done as set out in 4.1.3.

4.2.2. Global Warming Potential (GWP)

The Global Warming Potential (GWP) characterisation factor referring to the time horizon of 100 years shall be used. The primary source of GWP characterisation factors is the *Intergovernmental Panel of Climate Change (IPCC)*, the most recent update being the Third Assessment Report (TAR) of 2007.

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[6] Previously, Nutrification Potential (NP), was used synonymously. This was changed to Eutrophication Potential as the more widely used and generic term. Where, in older EPDs, NP is reported, this is to be read as synonymous with EP.

[7] If PM-specified data are available, this indicator should be reported in g PM10. An explanatory statement may designate the origins, e. g. mining and furnaces.

With regard to the concept of **Carbon Footprint**, defined as a life cycle assessment with the analysis limited to emissions that have an effect on climate change, it is essential that such an analysis shall be conducted in accordance with LCA and GHG reporting standards (ISO 14040–14044, 14064), including a Critical Review where LCA results are used for public communication.

PlasticsEurope Eco-profiles and EPDs are comprehensive datasets on GHG emissions from cradle to gate, including all the ancillary raw materials used and peripheral processes and may therefore be used as building blocks of a Carbon Footprint exercise. But the practitioner must be aware of the potential heterogeneity of the background data and the need to carefully analyse the consistency of all datasets underpinning the final result of the calculation. This requirement becomes critical where Carbon Footprint (CF) is used to support business decision making.

For the purposes of EPDs, a footnote should be added that the indicator Global Warming Potential (GWP)[8] corresponds to the Carbon Footprint (CF), but refers to the production of polymers (cradle-to-gate system) only.

If for a given polymer there is no EPD (yet), the Eco-profile report should include a table of GWP results as an annex. If an EPD is prepared, the table of GWP results should be omitted from the Eco-profile report. This is meant to ensure that questions around the topic of GWP and Carbon Footprint can be answered irrespective of the existence of an EPD.

Where biogenic carbon dioxide or biogenic methane are relevant, or where biodegradable or recycled materials are used, the *ILCD* handbook should be consulted for further guidance on modelling and impact assessment. In particular, any potential credits arising from the use of biogenic carbon must be recorded separately and not rolled into the total GWP indicator, because some method award credits to the production, and some to the end-of-life management.

4.2.3. Acidification Potential (AP)

The Acidification Potential (AP) is quantified according to second option in *CML* 2002 [Heijungs 1992, Hauschild & Wenzel 1998] and includes 12 acidifying components.

4.2.4. Eutrophication Potential (EP)

The Eutrophication Potential (EP) – or, Nutrification Potential (NP), see footnote 6 – as per *CML* 2002 does not differentiate between emissions to air and emissions to water.

4.2.5. Ozone Depletion Potential (ODP)

The Ozone Depletion Potential (ODP) as per *CML* 2002 may often be »not quantifiable«, since the respective LCI items are below quantification limits.

4.2.6. Photochemical Ozone Creation Potential (POCP)

The Photochemical Ozone Creation Potential (POCP) as per *CML* 2002 requires a careful differentiation in the LCI:

- nitrous oxides (NO_x) shall be differentiated into nitrous monoxide (NO) and nitrous dioxide (NO_2) – and differentiated from dinitrous oxide or laughing gas (N_2O), for that matter – and
- hydrocarbons or NMVOC shall be differentiated into ethylene, propylene, and further single species (which may or may not have a POCP characterisation factor).

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[8] It should be noted that GWP is an LCIA characterisation factor, but is used here to denote the characterisation result as well (as an impact indicator).

4.2.7. Dust and Particulate Matter

Dust and particulate matter shall be reported as PM 10. If possible, the following fractions should be provided:

- PM 2.5 (particulate matter ≤ 2.5 µm), and
- PM 2.5–10.

Where possible, particulate matter above PM 10 – secondary particles which are formed from gaseous emissions like nitrous oxides, sulphur dioxide, ammonia, etc. – should also be reported separately as PM ›10.

4.2.8. Land Use

PlasticsEurope monitors the methodology development concerning land use. For the time being, land use is not reported.

4.3. Additional Information – Optional for EPDs

There is an emerging scientific consensus that risks concerning health or environment cannot be assessed by means of LCIA, in particular, if the results are meant to support business decisions.

However, there may be further relevant information about the environmental performance of the product system under study. According to ISO CD 14025, sections 7.2.3.and 7.2.4, such information may be included in an EPD under »additional information«.

4.3.1. Additional Environmental and Health Information

OPTIONAL — Additional information related to environment and health issues other than derived from LCA can be provided as one or several optional sections:

- **Material Safety Data Sheet (MSDS)** information may be used as a basis for risk communication.
- With regard to **human and eco-toxicity**, this is outside the scope of EPDs due to the recognised lack of scientific consensus for the existing models. But it is important to note that the LCI datasets provided as Eco-profiles are sufficiently complete and comprehensive to meet the information needs of stakeholders interested in conducting LCIA to this aim. While PlasticsEurope does not endorse the toxicity impact assessment, this step is within the responsibilities of the users of Eco-profiles.

Note that any assessment of accidents or associated risks is outside the scope of Eco-profiles and EPDs.

Further, it should be noted that that impacts on indoor air quality or on soil and groundwater (as required by ISO 21930 and CEN TC 350 for EPDs on building and construction products) can only be determined at the application level.

4.3.2. Additional Technical Information and Eco-efficiency

MANDATORY — The embodied energy (gross calorific value, UHV) of the polymer as a measure of energy recovery potential shall be reported as an additional technical information.

OPTIONAL — The inclusion of additional technical information in the EPD, such as specifications or technical properties of the polymer resin that are potentially relevant for environmental performance during its use phase, is optional. Such information can be important to the supply chain in that it addresses success factors of the applications. The following are examples of applications and their success factors:

- Thermal conductivity for building applications and window frames,
- acoustic performance for building applications,

- light weight design options for vehicles, transport or packaging applications,
- gas barrier properties for building or packaging applications.

Furthermore, eco-efficiency considerations may be included in the EPD. As per *WBCSD*, Eco-efficiency is defined as a ratio of benefit (utility, value creation, societal benefit) and burden (environmental load). This will need to be defined on a case-by-case basis for specific sample applications.

In this context, offsetting and other forms of monetising can play a role. The term offsetting is defined as financing activities which compensate the climate effect (and often at the same time also the use of non-renewable resources) resulting from the production. Whenever arguments around offsetting are included, clear reference to defined applications shall be made. Any offsets or credits need to be reported transparently as a distinct line item, as opposed to a rolled up net balance with hidden externalities. Note that off-set emissions must not be included in the LCI dataset (see 3.5.2).

5. Quality Assurance and Communication Formats

5.1. Quality Assurance of Eco-profiles

5.1.1. Critical Review of this Methodology

The preceding version of this PCR was submitted to a review by a third-party panel (see 6.3). For this updated version of the LCI methodology and PCR document, the review panel's comments were addressed and the document was again subject to a stakeholder consultation of independent experts (see 1.5).

5.1.2. Pre-qualification of LCA Practitioner

In order to be recognised as an eligible LCA practitioner and dataset developer – invited to tender for Eco-profile and EPD projects – LCA consultants and similar service providers need to have demonstrated expertise and experience in LCA. Their qualification should be confirmed by means of a round robin test or »shadow Eco-profile« calculation, i.e. a re-calculation based on a sample dataset, with results to be compared with an existing benchmark. This is meant to ensure the accuracy of calculation procedures.

5.1.3. Internal Review and Plausibility Checks

First, before submitting the preliminary Eco-profile report and calculations to the EPT, the LCA practitioner and dataset developer shall conduct an internal review. This can be included in on-going quality assurance procedures. In particular, the LCA practitioner shall conduct plausibility checks as per ISO 14040–44, e.g. checks on units and dimensions, completeness, consistency, and sensitivity analysis etc. For further details about such checks, reference is made to the *ILCD* handbook.

Second, after submitting the preliminary Eco-profile report and calculations to the EPT, the results of the calculations (i.e. the respective industry averages) will be discussed in the EPT for further cross-checking. These measures are meant to eliminate errors of the primary data and data collection procedures.

Third, the LCA practitioner shall compare the final results with the previous version of the Eco-profile, if available, and comment on any significant changes (see 5.2.2). Interpretations and explanations shall be included in the Eco-profile report. This will be part of a benchmarking approach and will also provide invaluable feedback to the member companies. The LCA practitioner should mention any known reason for significant changes between updates in order to facilitate plausibility checks and interpretation.

5.1.4. ISO Compliance, External Review and Critical Review

All procedures, methods and assumptions shall comply with the requirements set forth in ISO 14040–44 (see 1.6). In particular, the Eco-profile reports (LCI data collection and calculations) shall be prepared in an auditable way.

Before approval of the Eco-profile or EPD reports and before inclusion of the dataset in the PlasticsEurope database, the programme manager (see 1.3.4) shall conduct an external review. In particular, the reviewer should check and confirm whether the data quality requirements are met and, optionally, assign data quality indicators accordingly (see 3.3.2).

While not mandatory as per ISO 14040–44 for non-comparative cradle-to-gate LCI datasets, the external review enhances the acceptance of PlasticsEurope Eco-profiles as best-quality datasets, may be a precondition for inclusion into third-party databases (such as the *ILCD* network), and facilitates a Critical Review in the course of comparative Life Cycle Assessment (LCA) studies. Where Eco-profile datasets are used as a building blocks in third-party comparative LCA studies, the Eco-profile report can hence be submitted to an independent Critical Review panel. This step is mandatory if comparative assertions are derived from the LCA and disclosed to the public. Further guidance on the procedures and the necessary qualification of reviewers can be found in the *ILCD* handbook.

5.2. Format of Eco-profiles and EPDs

This section provides guidance on data formats, report templates, and electronic data exchange. For requirements concerning the reported content matter (scope, modular Eco-profiles), please refer to sections 3.1.3 and 3.1.4.

5.2.1. Meta-data

So-called meta-data, i.e. a description of the LCI dataset and the underlying methodology shall be prepared including –

- General information about the data owner, dataset developer, programme owner, and programme manager (see 1.3),
- number of plants participating in the LCI data collection,
- representativeness or coverage in terms of production volume or tonnage (i.e. percentage of total production represented by the sampled plants),
- year of data collection,
- year of reference,
- expected temporal validity (see 3.1.6),
- noteworthy cut-offs (see 3.2),
- an overall evaluation of data quality (see 3.3.2), and
- the chosen allocation method (see 3.6).

The Eco-profile report shall include a summary of the external review (see 5.1.4) in a distinct section. Accordingly, the electronic dataset shall include the review report in accordance with the template in Table 10. For further guidance, please refer to the *ILCD* handbook. The meta-data shall be included in all electronic datasets (see 5.2.4).

Table 10: Template of review report (source: UNEP/SETAC LCA Guidance 2011, in publication)

Type of review	Possible entries (drop-down selection): Internal, External, …	
Elements of review	Goal and scope definition	Possible entries (drop-down selection): Compliance with ISO 14040–44; Cross-check with other dataset or source; Energy balance; Expert judgment; Mass balance; Documentation; … [source: ILCD data format definition]
	Raw data	
	Unit process(es), single operation (UPI)	
	Aggregated process inventory (API)	
	LCI results or Partly terminated system	
	LCIA methods that are applicable	
	Dataset Documentation	
	Check of the quality indicators (DQI)	
	Life cycle inventory methods	
Conclusions	Confirmation that all performed checks have been passed	yes/no
Reviewer name and institution	*This is a free-text field to provide name, affiliation, and roles/assignments of the reviewer(s).*	
Review details	*This is a free-text field which can provide procedural details of the review process.*	
Review Summary	*This is a free-text field to provide the overall review statement.*	

5.2.2. Format of Eco-profile Report

The Eco-profile report shall comprise:

- a standardised executive summary, which is identical with the EPD (see 5.2.3)
- a project-specific detailed report with supplementary data and analyses (see 3.8),
- comments upon changes compared with the previous version of the Eco-profile as far as applicable (see 5.1.3),
- where necessary, any specific references (see 6.2),
- a glossary of terms (see 6.1).

5.2.3. Format of EPDs

The EPD shall comprise:

- The meta-data (see 5.2.1),
- a description of the product and the production process (see 2.3),
- optional: comments and recommendations on the use phase and end-of-life management of sample applications deemed illustrative or representative,
- the declaration of environmental performance, i.e. the key performance indicators – mandatory parameters (see 4.1) as rounded figures for ease of reading,
- mandatory and optional additional information (see 4.3).

Where the EPD is used separately, the reference to the full Eco-profile report must be included, and a glossary of terms may be advisable.

5.2.4. Dataset Formats for Electronic Exchange of LCI Data

PlasticsEurope will provide Eco-profiles in the following electronic formats:

- Eco-profile report as text (*PDF*) document (see 5.2.2),
- EPD as text (*PDF*) document (see 5.2.3),
- Complete LCI dataset as spreadsheet (*Excel*) format, containing unrounded figures for purposes of manual or spreadsheet life cycle calculations;
- Complete LCI dataset in *ELCD* and *EcoSpold* formats, so as to facilitate the electronic exchange of life cycle data and life cycle software calculations.

The LCI datasets (*Excel, ELCD* and *EcoSpold* formats) shall comprise the meta-data (see 5.2.1) and a reference to the full Eco-profile report (see 5.2.2).

5.2.5. Interpretation and Expected Uses of Eco-profiles

As stated section in 2.1, Eco-profiles (LCI datasets) and EPDs from this programme are intended to be used as follows:

- Benchmarking within PlasticsEurope's member companies to support product-orientated environmental management and continuous improvement of production processes;
- Modular »cradle-to-gate« building blocks of life cycle assessment (LCA) studies by downstream users of plastics and other interested parties;
- Comparisons only if functional equivalence is established, i.e. when the whole life cycle of defined applications or products is considered, but not on the level of Eco-profiles or EPDs because 1 kg each of different polymers are not functionally equivalent;
- Calculation of toxicity-related impact categories in LCIA, while possible on the basis of Eco-profiles (LCI datasets), is not endorsed by PlasticsEurope since the on-going methodology development is deemed insufficiently mature to support business decisions, and would remain within the responsibilities of the users of Eco-profiles.

5.2.6. Environmental Claims

Environmental claims shall be compliant with ISO 14021. Where possible, environmental claims should refer to the product life cycle and in such cases be based on Eco-profiles and/or EPDs, in order to ensure a transparent and scientifically sound basis. It is recommended to also refer to the underlying business processes, e.g. a product-orientated environmental management system.

5.3. Eco-profiles and EPD Database Management

PlasticsEurope operates a publicly available web-based database of their Eco-profiles and EPDs. The programme manager (see 1.3.4) also manages the database, as shown in Figure 11. This ensures that –

- Eco-profile and EPD reports are reviewed;
- Electronic datasets are validated;
- Users of the database can ask questions and give feedback.

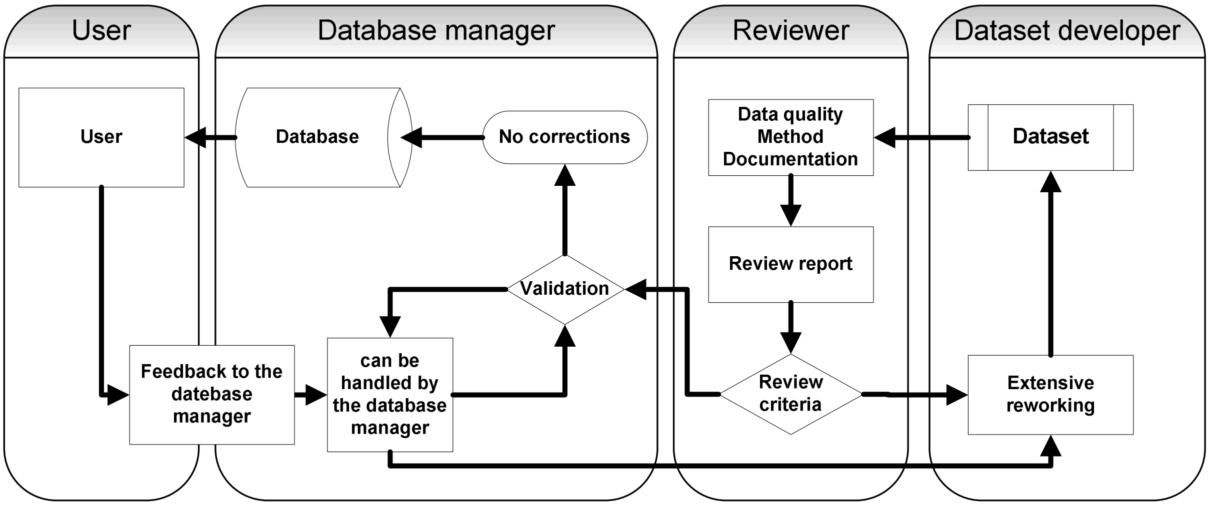

Figure 11: Database management (source: UNEP/SETAC LCA Guidance 2011, in publication)

6. Annex

6.1. Glossary

- **Abiotic depletion potential, ADP** — An environmental impact category, measuring the extraction of primary resources, such as minerals, metals, and fossil fuels.

- **Acidification potential, AP** — An environmental impact category (»acid rain«). Emissions (e.g. sulphur oxides, nitrous oxides, ammonia) from transport, energy generation, combustion processes, and agriculture cause acidity of rainwater and thus damage to woodlands, lakes and buildings. Reference substance: sulphur dioxide.

- **Eco-profile** — Another term for ➔ **Life Cycle Inventory**, used synonymously by PlasticsEurope, usually cradle-to-gate, but in case of conversion processes it may also be gate-to-gate.

- **Eco-profile Project Team, EPT** — A dedicated temporary task force formed for the purposes of overseeing Eco-profile work for a specific polymer. The team consists of members of PlasticsEurope's respective Product Committee, HSE group, Life Cycle Task Force (LCTF), plus the LCA practitioner and the programme manager.

- **Environmental Product Declaration, EPD** — A standardised method (ISO 14025) of communicating the environmental performance of a product or service based on LCA data.

- **Eutrophication potential, EP** — An environmental impact category (also in some cases, nutrification potential). Emissions such as phosphate, nitrate, nitrous oxides, and ammonia from transport, energy generation, agriculture (fertilisers) and wastewater increase the growth of aquatic plants and can produce algae blooms that consume the oxygen in water and thus smother other aquatic life. This is called eutrophication and causes damages to rivers, lakes, plants, and fish. Reference substance: phosphate.

- **Feedstock energy** — Definition in accordance with ISO 14040 »combustion heat of raw material input that is not used as an energy source, to a product system, expressed in terms of higher heating value or lower heating value. NOTE: Care should be taken to ensure that double counting of raw material energy content is not done« [ISO 14040, 3.17]

- **Global warming potential, GWP** — An environmental impact category (»greenhouse effect«). Energy from the sun drives the earth's weather and climate, and heats the earth's surface. In turn, the earth radiates energy back into space. Atmospheric greenhouse gases (water vapour, carbon dioxide, and other gases) are influencing the energy balance in a way that leads to an increased average temperature on earth's surface. Problems arise when the atmospheric concentration of greenhouse gases increases due to the »man-made« (or anthropogenic) greenhouse effect: this additional greenhouse effect caused by human activities may further increase the average global temperature. The index GWP is calculated as a multiple equivalent of the absorption due to the substance in question in relation to the emission of 1 kg of carbon dioxide, the reference substance, over 100 years. The term carbon footprint is considered to be synonymous with the GWP of a product.
- **Life Cycle Impact Assessment, LCIA** — evaluation of the environmental relevance of material and energy flows (e.g. with regard to resource depletion or global warming potential).
- **Life Cycle Inventory, LCI** — an input/output analysis of material and energy flows from operations along product system; PlasticsEurope also uses the term ➔ **Eco-profile**.
- **Life Cycle Assessment, LCA** — A standardised management tool (ISO 14040–44) for appraising and quantifying the total environment impact of products or activities over their entire life cycle of particular materials, processes, products, technologies, services or activities.
- **Offsetting** — Financing activities which compensate the climate effect (and often at the same time also the use of non-renewable resources) resulting from the production.
- **Ozone depletion potential, ODP** — An environmental impact category (»ozone hole«). The index ODP is calculated as the contribution to the breakdown of the ozone layer that would result from the emission of 1 kg of the substance in question in relation to the emission of 1 kg of CFC-11 as a reference substance.
- **Photochemical ozone creation potential, POCP** — An environmental impact category (photooxidants, »summer smog«). The index used to translate the level of emissions of various gases into a common measure to compare their contributions to the change of ground-level ozone concentration. The index POCP is calculated as the contribution to ozone formation close to the ground due the substance in question in relation to the emission of 1 kg of ethene as a reference substance.
- **Product Category Rules, PCR** — A set of rules for the preparation of LCA and EPD within a functionally defined class of products. A PCR document is a necessary component of any Type III Environmental Declaration programme (ISO 14025).

6.2. References

- AusLCI & ALCAS: Guidelines for Data Development for an Australian Life Cycle Inventory Database. Committee Draft of 8 July 2008.
- CML Guide: Guinée, Jeroen B. (Ed.): handbook on Life Cycle Assessment – Operational Guide to the ISO Standards. Springer, 2002.
- EU landfill directive - Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste – Official Journal L 182, 16/07/1999 pp. 0001–0019.
- EU Waste list – 2000/532/EC: Commission Decision of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC

on hazardous waste (notified under document number C(2000) 1147) – Official Journal L 226, 06/09/2000 pp. 0003–0024.

- Guinée, Jeroen B., Reinout Heijungs, Ester van der Voet & Gjalt Huppes, 2007. LCA-based greenhouse gas indicator for bio-based energy: some theoretical issues. Extended Abstracts Proceedings of the SETAC Europe 14th LCA Case Studies Symposium, 3-4 December 2007, Göteborg, Sweden.

- ILCD: European Commission International Reference Life Cycle Data System (ILCD).
  ➔ http://lca.jrc.ec.europa.eu

- ISO 13600.1997: Technical energy systems – Basic concepts. ISO, Geneva, 1997.

- ISO 14025: Environmental labels and declarations – Type III environmental declarations. ISO, Geneva, 2006 (in publ.).

- ISO 14040 – 14044: Life Cycle Assessment. ISO, Geneva, 1997 – 2006.

- ISO 15686: Buildings and constructed assets – Service life planning. ISO, Geneva, 2001.

- ISO 11469: Plastics – Generic identification and marking of plastics products.

- ISO 1043-1: Plastics – Symbols and abbreviated terms – Part 1: Basic polymers and their special characteristics.

- IUPAC International Union of Pure and Applied Chemistry: Name Code – Nomenclature of Organic Chemistry, Sections A, B, C, D, E, F, and H, Pergamon Press, 1979. Edited by J Rigaudy and S P Klesney.

- NREL U.S. LCI Database Project Development Guidelines. Final Draft, 2004.
  ➔ http://www.nrel.gov/lci/database/default.asp

6.3. General Programme Instructions and Previous Version of PCR

The General Programme Instructions and the previous version of the PCR (including the report of the review panel) were published in June 2006. These documents and further information on PlasticsEurope's Eco-profile and EPD programme can be found in the archives of PlasticsEurope's website.

➔ http://www.plasticseurope.org

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