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Basic principles and recommendations for describing the dismantling, post-use, and disposal stage of construction products

A guidance document for the construction product industry and standardization bodies for the design of modules C and D in EPD and PCR

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Basic principles and recommendations for describing the dismantling, post-use, and disposal stage of construction products

A guidance document for the construction product industry and standardization bodies for the design of modules C and D in EPD and PCR

Final Report

by

Dr. Wolfram Trinius, Julia Sievert
Ingenieurbüro Trinius GmbH, Hamburg

Dr. Eva Schmincke
Tübingen

Frank Grootens, Nora Pankow, Andrea Untergutsch
Institut Bauen und Umwelt e.V., Berlin

Julia Görke
thinkstep GmbH, Leinfelden-Echterdingen

Dr. Frank Werner
Frank Werner Umwelt und Entwicklung, Zürich, Schweiz

Prof. Dr. Thomas Lützkendorf
Bau-, Energie- und Umweltberatung Weimar, Weimar

Prof. Dr. Alexander Passer
TU-Graz, Graz

Susanne Bergius
Berlin

On behalf of the German Environment Agency

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Umweltbundesamt
Wörlitzer Platz 1
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Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

Study performed by:
Ingenieurbüro Trinius GmbH
Barmbeker Str. 9a
22303 Hamburg

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Til Bolland

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Abstract

A lot of data is needed for life cycle assessments of buildings. Environmental Product Declarations (EPDs) according to EN 15804 can be used as a data basis – at least for the construction products used and the technical systems installed and for the transports, processes on the construction site, supply and disposal processes. EPD record the energy and material flows and describe the associated effects on the global environment. In the past, EPDs generally covered the production phase, including preliminary stages, with the system limit "cradle to gate" (module A in the logic of EN 15804). However, this is not enough to meet today's ecological challenges and new regulatory requirements. EPDs covering the entire product life cycle "from cradle to grave" (or modules A to D) are required. On the one hand, this guideline contains a system for the preparation of so-called End-of-Life Declarations, i.e. only for modules C and D, by actors responsible for these processes. On the other hand it describes how this information can be integrated into EPDs of construction product manufacturers. The aim is to provide realistic and comparable LCA data for the end of product life and building balance sheets.

Kurzbeschreibung

Für Ökobilanzen von Gebäuden werden viele Daten benötigt. Zu den eingesetzten Bauprodukten, haustechnischen Systemen und zu den Transport-, Baustellen-, Ver- und Entsorgungsprozessen können als Datengrundlage Umweltproduktdeklarationen nach EN 15804 herangezogen werden (Environmental Product Declarations, EPDs). Sie erfassen die Energie- und Stoffströme und beschreiben die damit verknüpften Wirkungen auf die globale Umwelt. In der Vergangenheit deckten EPDs in der Regel die Phase der Herstellung inkl. Vorstufen mit der Systemgrenze „cradle to gate – frei Werktor“ ab (Modul A in der Logik der EN 15804). Dies reicht jedoch nicht aus, um den heutigen ökologischen Herausforderungen und neuen regulatorischen Vorgaben gerecht zu werden. Es werden EPDs, die den gesamten Produktlebenszyklus „von der Wiege bis zur Bahre“ (respektive Module A bis D) abdecken, benötigt. Dieser Leitfaden enthält zum einen eine Systematik für die Erstellung von sogenannten End-of-Life Deklarationen, also nur für die Module C und D, durch Akteure, die diese Prozesse verantworten. Zum anderen beschreibt er, wie diese Informationen in EPDs der Bauprodukthersteller integriert werden können. Ziel ist es, dadurch realistische und vergleichbare Ökobilanzdaten für das Produktlebensende und die Gebäudebilanzierung zur Verfügung zu stellen.

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List of Abbreviations

BNB	Bewertungssystem Nachhaltiges Bauen
BREEAM	Building Research Establishment Environmental Assessment Method
c-PCR	Complementary product category rules
CEN	European Committee for Standardization
C&D	Construction and demolition
CRP	Construction Products Regulation
DGNB	German Sustainable Building Council
EoL	End-of-life
EoLD	End-of-Life Declaration
EPD	Environmental Product Declaration
ETICS	External Thermal Insulation Composite System
EU	European Union
EWC	European Waste Catalogue
ISO	International Standards Organization
LCA	Life-cycle assessment
product TC	Product technical committee
SM	Source materials
SR BTP	le Syndicat des Recycleurs du Bâtiment et Travaux Publics. Since 2018: le Syndicat des Enterprises du Deconstruction, Depollution et Recyclage (SEDDRe)

Summary

Implementing principles of sustainable development in the construction and real estate industries includes the key tasks of conserving resources, avoiding negative impacts on the global and local environment, and protecting the health of processors, users, residents, and visitors.

For this reason, when planning new construction, modernization, conversion, and demolition activities, the possible impacts on human health and the environment must be taken into account.

Life-cycle assessment is used to account for these impacts. Life cycle assessment is a technique used to record, evaluate, and target the environmental performance of construction works with the aim of conserving resources and protecting the environment, the climate, and human health. With the help of a suitable model, life-cycle assessment describes a construction works over the course of its planned or expected life cycle.

In practice, these models are created in the planning stage, i.e. before the building is constructed, and are therefore inevitably based on assumptions, forecasts, and scenarios, in particular to describe the stages that follow the initial construction stage: the use, maintenance, replacement, dismantling, and disposal stages. This presents an ongoing challenge, both with regard to modeling as well as the lack of sufficient data and methods.

This guidance document describes how standardization bodies and the construction products industry can deal with these challenges and identify appropriate solutions. This improves on the foundations required to analyze holistically the whole building life cycle.

Today, the data used to perform life-cycle assessments are based on environmental product declarations (EPD) for construction products, building systems, transport, construction site supply, and disposal processes. EPDs capture the energy and material flows and describe their associated impacts on the global environment.

Modeling the life cycle of construction works requires that corresponding life cycle stage information be available for the construction products used and that these correspond to the concrete building type and its planned use. It is important to note: the product lifetime may differ from the life cycle of a construction works – the actual product lifetime can be shorter or longer.

In the past, EPDs usually included information on the product stage, limiting the system boundaries to “cradle-to-gate” (Modules A). However, this is not sufficient to achieve the level of environmental performance expected today, meet new regulatory requirements, or carry out a life cycle assessment from cradle to grave (Modules A to D respectively).

A political goal to strengthen the circular economy in the interest of conserving resources. This is also reflected in the normative requirements of EN 15804, which requires that information about the end of a product’s life be included in EPDs. In addition, there is an increasing willingness on the part of industry to accept extended product responsibility.

These recent developments lead to a need for basic principles and recommendations for the creation of more complete EPDS and the scenarios described therein, which can then be used accordingly for the life cycle assessment at the building level. In principle, this is already possible for the use stage, since manufacturers develop and optimize their products for a specific application. If a variety of uses apply for a certain product, manufacturers should provide information on use in such a way that the appropriate scenario can be selected for the building evaluation, e.g. by specifying different use scenarios in the EPD.

Manufacturers of construction products, or life-cycle assessors commissioned by them, are confronted with the task of declaring data for EPD modules C (keywords: dismantling, reuse, recover, disposal) and D (recycling potential) for processes over which they have no direct control. For this

reason, they therefore currently often rely on using generic data for common disposal and recovery processes. Since there are no specifications for the selection of scenarios at the end of life, the assumptions made for the products within the same product groups can be quite different and thus not comparable.

This leads to uncertainty and gaps in the data that need to be overcome.

This guidance document presents a system for creating end-of-life declarations for Modules C and D, to be carried out by actors who initiate these processes, as well as how this information can be integrated into EPDs belonging to construction product manufacturers. The aim is to provide realistic and comparable life cycle assessment data for the end of the product life and for building life-cycle assessment.

In addition to LCA results, the EoLD format also contains acceptance and exclusion criteria, e.g. with regard to impurities and pollutants. Thus, the EoLD also results in an environmental benefit for the manufacturers of construction products, since they find out information in the EoLD which helps them avoid or substitute problematic substances included in the product design.

Specifically, the creation of the EoLD provides for the following steps and actors: recycling and disposal companies create the EoLDs and thus provide the life cycle assessment results for the EoL processes. In order for a product manufacturer to be able to choose the process that can be used for this product, the recyclers and disposers must also describe the prerequisites or conditions for the acceptance of residual materials, such as the type and extent of harmful and/or problematic impurities in their products.

Each EoLD must also describe when the end of waste state has been reached. This is important from a methodological point of view so that the allocation of potential loads and benefits for the declared product system or for the subsequent product system can be distributed consistently and fairly over different life cycles.

Zusammenfassung

Um die Prinzipien einer nachhaltigen Entwicklung in der Bau- und Immobilienwirtschaft umzusetzen, ist es zentrale Aufgabe, natürliche Ressourcen zu schonen sowie negative Wirkungen auf die globale und lokale Umwelt und die Gesundheit der Verarbeiter, Nutzer, Bewohner, Anwohner und Besucher zu vermeiden oder zumindest zu verringern.

Darum müssen bei der Vorbereitung von Neubau-, Modernisierungs-, Umbau- und Rückbaumaß-nahmen mögliche Auswirkungen von Entscheidungen auf Mensch und Umwelt berücksichtigt und einbezogen werden.

Dazu dienen Lebenszyklusanalysen, auf Basis derer die Umweltqualität von Bauwerken ermittelt, bewertet und gezielt in Richtung Ressourcenschonung, Klimaschutz, Umweltschutz sowie Gesundheitsverträglichkeit beeinflusst werden kann. Die Lebenszyklusanalyse erfasst mit Hilfe eines geeigneten Modells ein Bauwerk vollständig entlang seines geplanten/erwarteten Lebensweges.

In der Praxis werden diese Modelle in der Planungsphase, also vor der Errichtung des Gebäudes erstellt und basierend daher insbesondere für die Zeit nach Inbetriebnahme des Gebäudes zwangsläufig auf Annahmen, Prognosen und Szenarien u.a. zur Nutzung, Instandsetzung sowie zu Ersatzinvestitionen, Rückbau und Entsorgung. Das war und ist eine Herausforderung, sowohl mit Blick auf die Modellbildung als auch bezogen auf mangelnde Daten und Methoden.

Dieser Leitfaden beschreibt, wie Normungsgremien und die Bauproduktindustrie mit diesen Herausforderungen umgehen können und zeigt entsprechende Lösungsansätze auf. Damit werden die Grundlagen, der für eine ganzheitliche Betrachtung erforderlichen Analysen über den gesamten Gebäudelebenszyklus, verbessert.

Datengrundlage von Lebenszyklusanalysen sind heute Umweltproduktdeklarationen (Environmental Product Declarations, EPDs) zu eingesetzten Bauprodukten, haustechnischen Systemen und Informationen zu Transport-, Baustellen-, Ver- und Entsorgungsprozessen. EPDs erfassen die Energie- und Stoffströme und beschreiben die damit verknüpften Wirkungen auf die globale Umwelt.

Eine Modellierung des Lebenszyklus von Bauwerken setzt voraus, dass für die Bauprodukte entsprechende Informationen für einzelne Lebenszyklusphasen vorliegen, die zu dem konkreten Gebäudetyp und dessen geplanter Nutzung passen. Dabei ist zu beachten: Die Lebensdauer eines Produktes kann sich vom Lebenszyklus eines Bauwerks unterscheiden – sie kann kürzer oder länger sein.

In der Vergangenheit deckten EPDs i.d.R. die Phase der Herstellung inkl. Vorstufen mit der Systemgrenze „cradle to gate – frei Werktor“ ab (Module A). Dies reicht jedoch nicht aus, um den heutigen ökologischen Herausforderungen und neuen regulatorischen Vorgaben gerecht zu werden und Lebenszyklusanalysen von der Wiege bis zur Bahre (respektive A bis D) zu realisieren.

Ein politisches Ziel zur Schonung von Ressourcen ist es, die Kreislaufwirtschaft zu stärken. Das spiegelt sich auch in den normativen Anforderungen der EN 15804 wider, die Angaben zum Produktlebensende als verpflichtende Angabe in EPDs fordern. Außerdem ist eine steigende Bereitschaft der Industrie zur Wahrnehmung einer erweiterten Produktverantwortung erkennbar.

Diese aktuellen Entwicklungen führen zu einem Bedarf an Grundlagen und Empfehlungen für die Erarbeitung von EPDs und den darin beschriebenen Szenarien, die dann für Lebenszyklusanalysen auf Gebäudeebene entsprechend verwendet werden können. Dies gelingt prinzipiell bereits für die Nutzung, da die Hersteller ihre Produkte auf eine bestimmte Verwendung hin entwickeln und optimieren. Besteht eine große Nutzungsvielfalt, so sollten die Hersteller Angaben zur Verwendung so machen, dass bei der Gebäudebewertung das passende Szenario ausgewählt werden kann, z.B. durch Angabe verschiedener Nutzungsszenarien in der EPD.

Hersteller von Bauprodukten bzw. von ihnen beauftragte Ökobilanzierer sehen sich bisher mit der Aufgabe konfrontiert, Daten für die EPD-Module C (Stichworte: Rückbau, Nachnutzung, Verwertung, Entsorgung) und D (Recyclingpotenzial) zu deklarieren, für Prozesse, über die sie keine direkte Kontrolle haben und die daher meist mit generischen Daten für gängige Entsorgungs- und Verwertungsverfahren abbilden werden. Da es bei der Auswahl der Szenarien am Lebens-ende keine Vorgaben gibt, können somit die gemachten Annahmen für gleiche Produktgruppen ganz unterschiedlich und damit nicht vergleichbar sein.

Dies führt zu einer Verunsicherung und zu Datenlücken, die es zu überwinden gilt.

In diesem Leitfaden wird nun eine Systematik vorgestellt, wie zum einen die Erstellung von so-genannten End-of-Life Deklarationen für die Module C und D durch Akteure, die diese Prozesse verantworten, erfolgen kann und zum anderen wie diese Informationen in die EPDs der Bauprodukteherstel-ler integriert werden können. Ziel ist es dadurch realistische und vergleichbare Ökobilanzdaten für das Produktlebensende und die Gebäudebilanzierung zur Verfügung zu stellen.

Das Format der EoLD enthält neben den Ökobilanzergebnissen auch Annahme und Ausschlusskriterien z.B. in Hinblick auf Verunreinigungen oder Schadstoffe. Damit trägt die EoLD auch zu einem umweltlichen Nutzen für die Bauprodukthersteller bei, da sie in der EoLD Informationen finden, die ihnen helfen bereits im Produktdesign problematische Stoffe zu vermeiden oder zu substituieren.

Konkret sieht die Erstellung der EoLD folgende Schritte und Akteure vor: Recycling- und Entsorgerunternehmen erstellen die EoLDs und liefern damit die Ökobilanzergebnisse für die EoL-Prozesse. Damit ein Produkthersteller das für seine Produkt verwendbare Verfahren wählen kann, müssen die Recycler bzw. Entsorger auch die Voraussetzungen/Bedingungen für die Annahme von Reststoffen beschreiben, wie z.B. Art und Umfang enthaltener Schad- und/oder problematischer Störstoffe.

In jeder EoLD muss außerdem beschrieben werden, wann das Ende der Abfalleigenschaften erreicht ist. Dies ist aus methodischer Sicht wichtig, damit die Zuordnung der potentiellen Lasten oder Gutschriften für das deklarierte Produktsystem bzw. für das darauffolgende Produktsystem konsistent und fair über verschiedenen Lebenszyklen aufgeteilt werden kann.

1 Introduction

The conservation of natural resources is a core objective of sustainable management. In the construction and real estate sector, the consumption of energy from fossil fuels during the use stage of buildings – above all because of the associated use of non-renewable resources and resulting harmful emissions – was given priority in the past.

Current sustainability goals and strategies of the UN, the EU, and Germany's Federal Government are, however, also focusing much more on reducing the consumption of primary raw materials required for the construction and maintenance of buildings.

It is clear that the extraction of primary raw materials and the manufacture of construction products have a considerable overall environmental impact. Introducing high-quality material flow management can reduce these negative impacts. This reduces the need for primary raw materials, thereby potentially reducing energy consumption and avoiding landfill waste.

In EU member states, there is still considerable potential for conserving natural resources through improvements in the construction product industry as well as the construction and real estate sectors. It is therefore a declared goal of the EU and the German Federal Government to improve resource efficiency in the construction sector. The complementary goal of establishing an EU-wide circular economy and thereby advancing the use of secondary raw materials is also of key importance. Ideally, resource conservation and climate protection can be combined.

In addition, within the scope of the working towards "sustainable planning and construction", the scientific community, the construction industry, and the EU have made progress in establishing methods to describe and measure natural resource consumption. By evaluating comparisons of variants, resource consumption and environmental impacts can be targeted in the early planning stages.

The construction sector is therefore in a unique position in which the basic principles and tools are already available for describing and evaluating construction works and their parts in order to support the responsible use of resources and the implementation of circular construction practices. In the CEN/TC 350 series of stnadards on sustainable construction, the most important evaluation criteria required for this have been introduced, both for buildings and constructions products.

For the latter, Environmental Product Declarations (EPDs) according to EN 15804 provide the methodology to quantify the energy and material flows as well as the global, regional, and local environmental impacts over the product life cycle and for each life-cycle stage. EPDs are both a tool and a format for communicating this information.

For a long time, however, as a minimum requirement for EPDs it was only mandatory that the product stage be declared. This was sufficient to comply with the EN 15804 standard. In summer 2019, an amended version of the standard (EN 15804+A2) was adopted. The standard now stipulates that the energy and material flows and environmental impacts for the demolition and disposal stage, as well as additional potential for recycling, must be declared in an EPD.

EPDs must also contain information on the product end of life if they are to be used for, among other things, planning recycling-friendly buildings, e.g. in the context of "design for deconstruction" or sustainability certification (cf. BNB, DGNB, BREEAM, Level(s)). This information must be designed in such a way that designers and decision makers can select products based on end-of-life scenarios at the level of the construction works. These scenarios not only describe the building end of life, but also the processes for replacements and the environmental performance of recycled pre-products or raw materials for future product systems.

Manufacturers assume responsibility for the production stage and guarantee certain qualities of the goods they produce. In a narrower sense, manufacturers are not legally liable for how products are actually treated with during the life cycle, but they assume product responsibility in a broader sense, which society and regulators increasingly expect and account for in their sustainability reporting. Manufacturers demonstrate product responsibility by providing planners, fabricators, and users with relevant information about the performance of the product over its life cycle. When the product becomes “waste,” the manufacturer is no longer legally responsible for it; the owner of the waste is (e.g. the building owner or the construction contractor when the product is replaced, demolition companies when a building is torn down).

Today, some manufacturers already provide information about the end of life of the product in an EPD. Manufacturers influence the recyclability of their products, for example, when deciding the material and technical parameters of their products. Some manufacturers participate in existing take-back systems or they establish their own. They advance the development and use of tailor-made collection systems and recycling techniques. At the same time, manufacturers reduce the use of primary resources by using secondary raw materials, thus creating a market/demand for secondary raw materials. The effects of these measures on resources consumption and other environmental aspects over a product lifetime are reflected quantitatively in an EPD. In the best case, the extent to which a product can be considered more environmentally friendly than comparable products, for example, because it has an above-average proportion of secondary raw materials or recycled content, can be substantiated by facts.

Declaring complete and verified product information in an EPD also means that manufacturers voluntarily assume **a high degree of product responsibility** (in the broader sense), since the responsibility for EoL scenarios and the quality of the data use to create the EPD lies primarily in the hands of the manufacturer.

New normative requirements for EPDs (mandatory description of the complete life cycle and declaration of additional recycling potential) as well as the perception of voluntary product responsibility create a need for basic principles and tools for including the deconstruction, preparation for reuse or recycling, and waste disposal stages of construction products in EPDs. These stages are included in Module C of an EPD, the recycling potential is included in Module D.

This guidance document provides a basis for extending EPDs to include information relevant to a circular economy. This document was created as a part of the research project “Resource-efficient structures – EPDs for construction projects: deconstruction and recycling information (modules C and D) and pollutant data” („Ressourcenschonende Bauwerke – EPD für Bauprodukte: Rückbau- und Recyclinginformationen (Modul C und D) sowie Schadstoffangaben“) funded by the Federal Environment Agency (FKZ 371495309 0).

2 Characterization of the current context

In EPDs created according to EN 15804 + A2[1] and ISO 14025[2] it is already possible to declare all stages of the life cycle in modular form. This includes the product stage, including the upstream supply chain (modules A1-A3), transport (module A4), assembly and installation (module 5), use (module B1), maintenance and repair (module B2-B3), replacement or modernization of essential components (module B4-B5), as well as dismantling (C1), transport (module C2), and recycling/recovery and disposal (module C3-C4). In addition, recycling potential can be included in module D.

The systematic declaration of data for the end-of-life stage of construction products, calculated according to appropriate scenarios, is essential for the most common application of EPDs: as a source of data to measure and assess the environmental performance of buildings.

Without information about the end of life of construction product that is realistic, reliable, and suitable for building-level assessment, replacement costs and the end of life or end of service life of buildings cannot be modeled correctly. This complicates the planning and implementation of environmentally friendly, recyclable construction works – a core objective of sustainable construction and the circular economy in the construction sector.

According to the recently published version of EN 15804+A2, the declaration of the end of life of construction products must be included in EPDs in future. To ensure fair competition, information about the product end of life must be reliable and verifiable. Extending the focus to the end-of-life stage also makes available reliable life cycle assessment data for secondary materials. This should make it easier for manufacturers to make decisions about including recycled materials in their products, a practice that aligns with principles of an environmentally sustainable circular economy.

The greatest challenge – also the reason for the development of this guidance document – is that the life cycle stages that begin after the product leaves the factory gate can usually only be described on the basis of scenarios. The owner of an EPD, usually the construction product manufacturer, are responsible for all of the information included in the EPD. However, how a product is used and disposed of once removed from a structure can only be presumed – with varying levels of certainty. This is because detailed knowledge about, or even exact values for, circumstances and procedures during the use, deconstruction, demolition, and disposal stages, are not usually available to manufacturers.

This information gap exists because a variety of actors are involved at very different points in time, act independently, and as yet are not required to coordinate their actions. Reasons for this include the following:

- deciding how construction products are used and installed, which can greatly influence future reuse or recycling potential, is the responsibility of developers, planners, and construction companies;
- deconstruction and demolition are the responsibility of the building owner/developer, de-construction planners, and demolition companies;
- treatment/preparation and disposal/waste recovery are the responsibility of recycling and waste management companies;
- product manufacturers are also partially responsible for the recyclability of their products.

Additionally, the end of life of the building, and thus the end of life of the construction products, is often far in the future, which makes it difficult to establish end-of-life scenarios.

[1] EN 15804: Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products; German and English version EN 15804:2012+A1:2013/prA2:2018;

[2] ISO 14025: Environmental labels and declarations – Type III environmental declarations – Principles and procedures (ISO 14025:2006); German and English version EN ISO 14025:2011

Modeling possible disposal paths is a major hurdle in the creation of EPDs. Manufacturers are not typically prepared to quantitatively describe the disposal or recycling processes, nor are they typically aware of the processes and resulting requirements for recycling management (e.g. logistics). Furthermore, extensive research is required to understand international markets and the legal context for waste management in different countries.

For these reasons, many manufacturers have **so far** failed to include the disposal processes and recycling potential of their products within, or, as may be the case for recycling, outside of the system boundaries of their EPDs. If the modules C (deconstruction and recycling/disposal) and D (recycling potential) were declared, then **scenarios** that **shared little uniformity** or generic processes like waste incineration and disposal of waste in landfills were generally used.

Since the declaration of the end of life of a product according to EN 15804 will no longer be voluntary, there is an urgent need for actors responsible for the end of life of construction products to make information and LCA data available. In practical terms this means that the manufacturer, as the actor responsible for the entire declaration, should be able to delegate responsibility to the actors who can supply robust data, e.g. recycling companies or databases which draw on the results of LCAs produced by recycling companies.

3 Guidance document objectives and target groups

The purpose of this guidance document is to**:**

a) support the construction products industry in taking into account the entire life cycle of construction products in an EPD, thereby implementing current standardization requirements. In particular, it should enable the declaration of verifiable, quantitative information on environmentally relevant circumstances at the end of life of the product that may be relevant for recovery processes;
b) promote the specification and implementation of standard EN 15804: guidance is provided for interpretation, planning, and implementation.

This guidance document aims, in accordance with a), to enable the exchange of information and data between the building deconstruction and recycling industry and the manufacturers of construction products. To facilitate this information exchange, the guidance document introduces the format of an End-of-Life Declaration (EoLD).

This guidance document includes, in accordance with b), a manual in the Appendix. The aim of the manual is to provide direct support to product technical committees (product TCs) and EPD program operators in the derivation and coordination of end-of-life scenarios for products and product groups. The manual shows how to document the assumptions used for the presentation and calculation of the end-of-life processes according to EN 15804. The manual is also intended to promote greater understanding of the conditions under which the appropriate recycling or disposal processes can take place for a product group. The manual provides a basis for the application, selection and, if necessary, adaptation of end-of-life scenarios.

The manual is also intended to provide support for the coordination of scenarios – industry-wide or cross-industry – for typical disposal processes such as landfilling, thermal recovery, or recycling processes, which are material-specific and not product-specific.

The **guidance document and the manual** are intended to help **manufacturers of construction products** provide realistic, reliable information about the product end of life for EPDs. To this end, communication with actors involved at the product end of life is important, as they provide the LCA data in the form of an EoLD.

The primary intended users of the **guidance document** are therefore product manufacturers and the **recycling and waste management companies**. Since generic data for the end of life has been used in the past, the more direct involvement of actors involved in the end of life of construction products and the EoLD format are new. This benefits **building planners, who**, while evaluating the overall environmental performance of a building, must also assess future disposal and recyclability potential and resource efficiency.

Life cycle assessors and **EPD program operators**, who are responsible for the concrete implementation of the recommendations in this guidance document, are another important target group.

The manual primarily addresses **EPD program operators, Product TCs,** and **product forums**. The manual supports the systematic development of end-of-life scenarios in cooperation with the waste management and recycling industry. In particular, the manual supports the creation of (complementary) product category rules to address the subject of end of life. The product category rules (c-PCR) according to CEN/TR 16970[3], which complement EN 15804, are published by the standardization bodies or, if standardization has not (yet) been achieved, by the EPD program operators.

EPDs that declare the environmental impact of disposal and recycling potential (modules C and D) with the help of this guidance document address various actors in the construction sector,

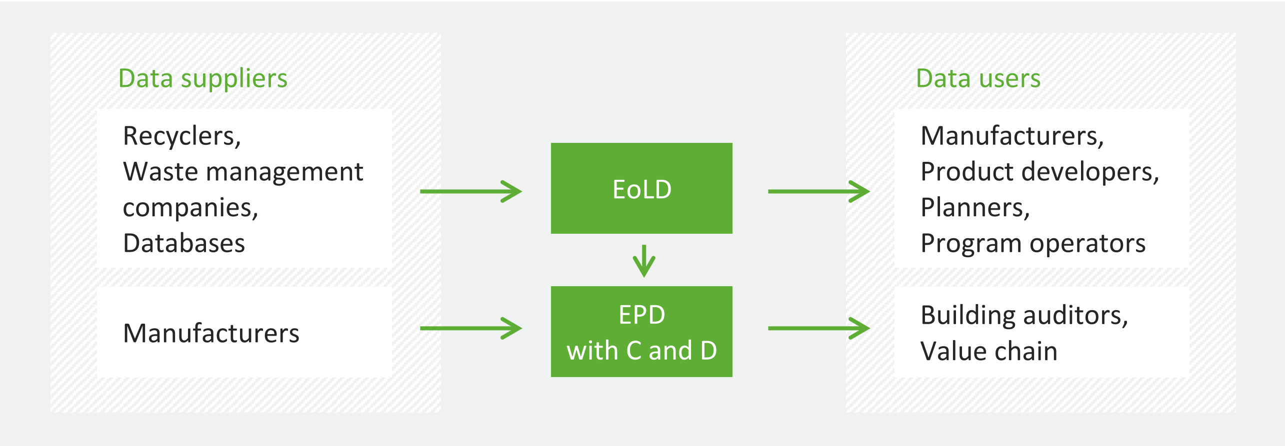
[3] CEN/TR 16970 Sustainability of construction works - Guidance for the implementation of EN 15804

including: building certification systems, planners, construction companies, investors, facility managers, the public sector, database providers, life-cycle assessment service providers, sustainability auditors, and other companies involved throughout the value chain, from the extraction of raw materials to the use stage of buildings.

Optimized and harmonized end-of-life data in EPDs should help give EPDs greater prominence as a data-delivery tool for assessing the contribution of buildings to sustainable development, as mentioned in the Construction Products Regulation (CPR).[4]

Completeness of an EPD may also play an important role in the context of implementing Basic Requirement 7 on the sustainable use of natural resources. EPDs that include reliable data about the end-of-life stage will also help policymakers at the national and European level better understand policy options for action with regard to environmental impacts and materials flows in a circular economy and influence decisions in support of greater resource efficiency.

Figure 1: Suppliers and users of data for EoLDs and EPDs



Source: Authors

[4] Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC

4 Environmental Product Declarations

An EPD describes the environmental impact and resource use of construction materials, products, or components at all stages of their life cycle. The environmental information is quantified in accordance with the stnadards EN 15804[5] and ISO 14040/44[6] and includes the following information.

Table 1: Environmental impact and resource use in an EPD

Environmental impacts with regard to		Required	Voluntary
Climate change	Climate change — total	x	
	Climate change — fossil	x	
	Climate change — biogenic	x	
	Climate change — land use and land-use change	x	
Environmental conserva-tion	Acidification	x	
	Eutrophication — freshwater	x	
	Eutrophication — saltwater	x	
	Water scarcity	x	
	Effects associated with land use / soil quality		x
	Ecotoxicity (freshwater)		x
Protection of human health	Photochemical ozone creation potential (sum-mer smog)	x	
	Ozone depletion	x	
	Particulate matter emissions		x
	Ionizing radiation		x
	Human toxicity, carcinogenic effects		x
	Human toxicity, non-carcinogenic effects		x
Information about use of resources		**Required**	**Voluntary**
Abiotic resource depletion	Minerals and metals	x	
	Fossil fuels	x	
	Water	x	
Total primary energy, renewable	Energy sources	x	
	Material use	x	
Total primary energy, non-renewable	Fossil fuels	x	
	Material use	x	
Use of secondary raw materials as	Secondary materials	if relevant	
	Renewable secondary fuels	if relevant	
	Non-renewable secondary fuels	if relevant	
Net use of freshwater resources			
Output material flows	Reusable components	if relevant	
	Materials for recycling	if relevant	
	Materials for energy recovery	if relevant	

[5] EN 15804+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

[6] ISO 14040/44 :2006 Environmental management — Life cycle assessment — Principles and framework

Energy production	if relevant

The environmental impacts are based on a Life Cycle Assessment (LCA) according to ISO 14040/44[7] and EN 15804[8].

There is a distinction between required and voluntary indicators. Required indicators must be declared in an EPD. Voluntary indicators must be calculated, interpreted, and included in the report, but do not need to be declared in the EPD.

Information about environmental impacts and resource use is included in an EPD for all stages of the product life cycle. The life cycle is subdivided into the modules A1-D, as shown in the following figure.

Figure 2: Life cycle stages and modules according to EN 15804

Product stage			Construction stage		Use stage					End of Life stage				Benefits and loads beyond the system boundary
Raw material supply	Transport	Manufacturing	Transport to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse-, Recovery, Recycling potential
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**C1**	**C2**	**C3**	**C4**	**D**
					B6 Operational energy use									
					B7 Operational water use									
Actual Data			**Scenarios**											

In an EPD, all modules, except for installation and use (A4, A5, and B1-B7), must be specified.

Uncertainty in LCA data increases over the course of the life cycle (A1-C4 and D) of a product, starting when the product leaves the factory gate (A3). Information in modules A1-A3, and in some cases A4 and A5, is generally based on data collected by the manufacturer (foreground data, e.g. energy use, material use, production waste) and background data, which mostly come from LCA databases (e.g. LCA information for the production of 1 kWh electricity mix). These data describe processes that have already taken place and are thus known.

This differs from information about processes that take place in the future, after the product leaves the factory gate. For the later stages, EPDs must rely on scenario-based data, since product manufacturers generally have no influence either on the use, the demolition of a building, or the processes used when construction materials are extracted from buildings (replacement of components, building deconstruction).

[7] ISO 14040/44 :2006 Environmental management — Life cycle assessment — Principles and framework

[8] EN 15804+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products

Module D provides additional information that is outside of the current product system boundary. In this module, benefits and loads from reuse, recovery, or recycling are stated. This information can be applied in the next product system, e.g. in the manufacturing of a new product using recycled materials.

Information about disposal or recycling is based on scenarios typical of processes employed in the present day. This approach results in more robust data, but it also means that the data require additional interpretation when considering future recycling options for products.

An example of an EPD can be found in the Appendix. EPDs are generally published online on the websites of EPD program operators (e.g. Institut Bauen und Umwelt e.V.[9]) and EPD associations (e.g. ECO Platform[10]), and in databases, like the ÖKOBAUDAT[11].

4.1 Declaration of end of life in EPDs

The end of life of a product when a building is demolished or the product has reached the end of its functional life so that it has to be replaced, is described in an EPD in the form of a scenario from the perspective of a product manufacturer. Scenarios must be defined according to life cycle assessment guidelines as described to EN 15804 using real process common in the present day. This is the only way to make verifiable assumptions and calculations of environmental performance and achieve a reasonable level of reliability.

When selecting scenarios, regional differences must be taken into account. This can present challenges. On the one hand, economic processes require sufficient material flows and markets, which usually involves transfer of material flows between countries. On the other hand, EU member states have differing waste legislation that govern the flow of materials, as show in Table 2.

Table 2: Disposal of non-mineral insulation materials in EU Member States

Country	Energy recovery [%]	Landfill [%]
Austria	100	0
Belgium	100	0
Bulgaria	7	93
Croatia	5	95
Cyprus	0	100
Czech Republic	28	72
Denmark	100	0
Estonia	65	35
Finland	77	23
France	54	46
Germany	100	0
Greece	0	100
Hungary	27	73
Ireland	72	28
Italy	45	55

[9] https://ibu-epd.com/veroeffentlichte-EPD/, 2019

[10] https://www.eco-platform.org/list-of-all-eco-epd.html, 2019

[11] https://www.oekobaudat.de, 2019

Latvia	6	94
Lithuania	33	67
Luxembourg	100	0
Malta	0	100
Netherlands	100	0
Poland	25	75
Portugal	41	59
Romania	20	80
Slovakia	36	64
Slovenia	53	47
Spain	24	76
Sweden	100	0
UK	43	57

Source: Adapted from F.Werner, Draft Product Environmental Footprint Category Rules (PEFCRs) for thermal insulation (slide).

The breakdown into thermal recovery and landfilling of non-mineral insulation materials is an example of differences in waste processing practices across Europe: in Greece, 100% of the waste is disposed of in landfills, while in Germany, Belgium, and the Netherlands 100% is used for energy production. This is related to national regulations.

Wood recycling is also regulated differently across EU member states, as shown in the table below from "Screening study on End of Life treatment of wood from doors and windows".[12] In the Czech Republic, for example, 60% of wood from windows and doors is recycled, 40% in Austria, and 10% in German. The different recycling rates are based on different classifications of waste wood.

[12] Intended for EuroWindoor; Final report, October 2018: Screening of EU and national policies, legislation and trends for EoL wooden doors and windows EU Austria, Czech Republic, Denmark, France, Germany, Italy, The Netherlands, Sweden, United Kingdom. Authors: Ramboll Denmark; Document ID 1100032375-266237074-94.

Table 3: Overview of predominant end of life treatment of wooden windows and doors in selected EU member states

Country	Description of End-of-Life Treatment Practice
Austria	Treatment of all waste wood: 40% recycling, 60% incineration with energy recovery. Not clear if this also applies to EoL wooden windows and doors; this has not been investigated/is not monitored in Austria. As of summer 2018, all EoL wooden doors and windows must be sent to incineration with energy recovery.
Czech Republic	*No data specifically on EoL of doors and windows exist.* Currently 60% of recycled wood is used to produce particle board. Industry is planning to increase this share up to 95%. For many years, Czech Republic was a net exporter waste wood, but is now a net importer. Data on EoL waste wood is scarce. According to 2012 data, 1/3 of exported wood is recycled and 2/3 is incinerated. The EoL of wooden waste in general in 2012 resulted in 5% set to landfill, 60% incinerated, and 35% recycled. Since 2012 there has been an increase in demand for recycled wood, thus shares of EoL destinations of wood waste have likely shifted to closer to: 40% recycled, 55% incinerated and 5% landfilled.
Denmark	*No data specifically on EoL doors and windows exist.* For construction waste in general, industry estimates about 2% incineration with energy recovery, 3% landfill, 94% recycling, and 1% reuse. For wood waste from C&D activities, estimates are: 5% reuse, 20% recycling, 75% incineration with energy recovery, and 0% landfill.
France	*No data specifically on EoL doors and windows exist.* From the point of view of SR BTP, even if wood-based panel manufacturers and biomass combustion plants are relatively well distributed across the county, wood waste recovery and recycling routes in France are saturated. Consequently, a proportion of wood waste is exported for recycling or recovery mainly in Italy and Belgium, or it is landfilled. In general, 43% of C&D wood waste is recycled, 34% is incinerated, and 23% is land-filled.
Germany	*No data specifically on EoL wooden doors and windows exist.* It is estimated that more than 90% of wooden waste in general in Germany is sent to incineration with energy recovery, and that the remaining 10% is recycled.
The Netherlands	*No data specifically on EoL wooden doors and windows exist.* In the Netherlands 68% of the A and B wood is incinerated with energy recovery and 32% is recycled. Wood waste from C&D is primarily category B.
Sweden	EoL wooden windows and doors are mostly incinerated for energy recovery. Very limited reuse and repair of wooden doors and windows is carried out by municipalities at, for example, the Eco park Elelyckan in Gothenburg and the Eskiltnas ReTuna facility. There are also a couple of private actors working with to reuse doors and windows, e.g. Kompanjnen, Hus Till Hus and Brattöns Återbruk. Wooden doors and windows are rarely recycled. If recycled, the doors and windows are mainly recycled into particleboard [SE Svensktträ 2003].
United Kingdom	*No data specifically on EoL wooden doors and windows exist.* Wooden windows and doors are classified as mixed wood waste and are generally destined for Chapter IV compliant incinerators for energy recovery or destined for panel board manufacturing. However, non-hazardous wooden windows and doors in good condition, especially those with architectural or ornamental features, are encouraged to be reused for other construction projects; building regulations will apply. In general, 34% of wooden waste in the UK is recycled, 34% incinerated, 26% land-filled, and 6% exported for recycling and incineration.

Source: Adapted from (p. 39) Final report, October 2018: Screening of EU and national policies, legislation and trends for EoL wooden doors and windows EU Austria, Czech Republic, Den-mark, France, Germany, Italy, The Netherlands,

Sweden, United Kingdom. Authors: Ramboll Denmark Intended for EuroWindoor; Document ID 1100032375-266237074-94

A critical factor to consider when declaring life cycle assessment results for end of life is the definition of the end of waste state and the associated benefits and loads for the declared or subsequent product system.

The “polluter pays” principle in EN 15804 means that all loads associated with waste disposal are the responsibility of the manufacturer, i.e. in the case of recycling, this means all loads until the waste reaches end-of-waste status. For many products, this status is specified in the European Waste Framework Directive[13], but is not uniformly regulated in all EU member states. EN 15803 contains the following requirements, which are adopted from the Waste Framework Directive.

During the disposal stage of the product or building all outputs are to be accounted for. This includes the dismantling, deconstruction, or demolition of the building, maintenance, repair, replacement, or renovation and renewal processes, all demolition debris, and all construction products, materials, or building components that leave the building. Output is, however, no longer considered waste if it complies with the following criteria:

- the recovered material, product, or component is commonly used for specific purposes;
- a market or demand exists for the recovered material, product, or component;
- the recovered material, product, or component fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to the products;
- the use of the recovered material, product, or component will not lead to overall ad-verse environmental or human health impacts.

4.2 Data requirements for the calculation of end of life

For robust building life cycle assessments, **life cycle assessors mainly need data from construction product manufacturers and information about their supply chain.** For the product manufacturing modules (A2-A3) and assumptions for the construction stage (A4-A5), **manufacturers** can rely on their own data (A2, A3) or that of their value chain (A5). For the provision of raw materials and energy (A1) (e.g. mining, smelting, refining, energy supply, process heat), generic data from databases are generally used. The same is true for typical transport processes (type of truck or ship). Generic data are also available in databases for certain similar construction or use processes.

Because manufacturers are not typically aware of the processes involved in incineration or landfilling of waste at the end of life stage, LCA results based on generic data are usually used instead. The methods for standard disposal processes often only differ in regional details of execution, efficiency (CHP, landfill gas), and emission variants (household waste, hazardous waste incineration). Sufficiently specific data are available in databases in the form of datasets that have been adapted from generic datasets. For example, generic datasets may be adapted to account for differences in outputs, such as eluates or combustion emissions, depending on material in-puts. Regional and operator-specific differences are often adapted to create a “typical” dataset.

Data for life cycle assessments that model landfilling or incineration are therefore generally available in sufficient quality for the declaration of modules C1-C4 and D. In contrast to “classical” disposal processes such as incineration and landfilling, recycling processes can be very specific. For this reason, generic datasets to describe recycling processes are rarely included in databases and are thus more difficult to manage.

There are generic datasets for select common recycling process (e.g. steel or aluminum recycling). However, less common recycling processes can be very specific to a product group, especially with regard to innovation. Databases do not generally include such corresponding datasets. If a specific recycling process is to be declared in an EPD, appropriate records for the recycling scenario must be

[13] DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives, Article 6, https://eur-lex.europa.eu/

included. Only recycling procedures that actually take place may to be calculated and sufficient proof of these processes must be provided.

5 End of life Declaration (EoLD)

An EoLD is a stand-alone declaration that provides information needed for modules C and D of an EPD. EoLDs are produced by entities involved in recycling and disposal. EoLDs provide the life cycle assessment results of the EoL processes that are carried out and managed by recycling and disposal companies. Manufacturers are generally aware of the potential disposal pathways for their products, but are not usually aware of the respective processes, their substance flows, and their associated environmental impacts.

In order for manufacturers to be able to choose the process relevant for their products, the respective recycling or disposal companies must describe their conditions for accepting products with residues, including the type and extent of pollutants and/or problematic impurities contained in products. This information allows recycling and disposal companies to assign the appropriate process to the respective product. The manufacturer can – depending on what is possible with the product – specify different scenarios as so-called 100% processes, e.g. various recycling processes, incineration, or landfilling. Each procedure is calculated for 100% of the resulting residue or recyclate. In addition, a manufacturer can also specify a representative combination of methods. The building life cycle assessor can then select the most appropriate scenario according to the regional context.

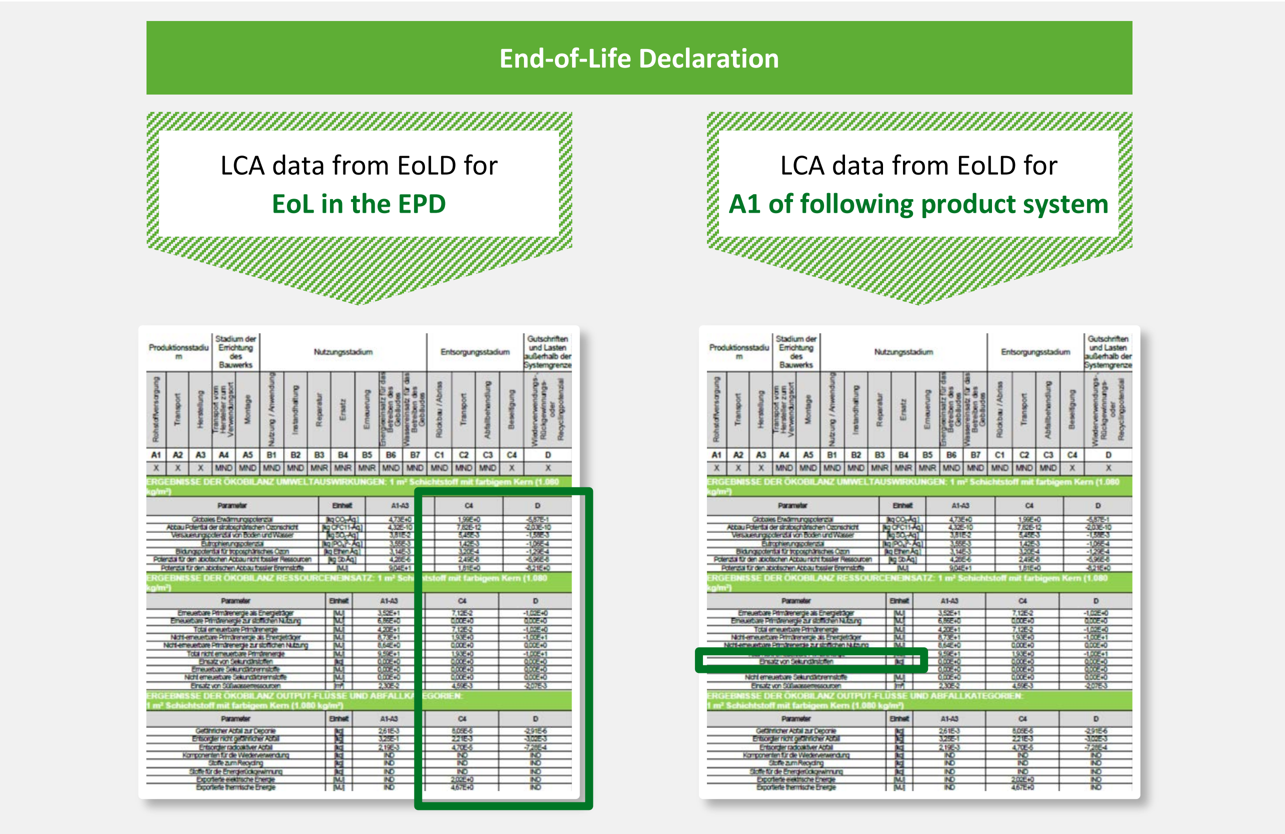
EoLDs help give the product manufacturer a clearer picture of the need for information and third-party conditions at the end of the product life and, in some cases, to account for these requirements in the product design stage, for example, with regard to avoiding pollutants. Building planners and actors responsible for installation, use, and dismantling can also contribute to reducing and preventing the introduction of impurities during the use stage, or during demolition or dismantling, on the basis of information in the EoLD. EoLDs are stand-alone documents and the content therein will be also be accessible in building life cycling assessment databases. By referring to these databases, building planners seeking a sustainable building certificate can select the appropriate dataset based on the region, technology, or installation context to model the end of life stage. If impurities are to be expected, for example, mineral oil contaminated flooring from garages and gas stations, the planner account for this by selecting the correct dataset.

With an EoLD, the recycling and waste management industry can provide specific datasets in a form that allows modules C and D of an EPD to be calculated according to EN 15804. The datasets for recycling, incineration, or landfilling are supplied by the waste management industry directly to the manufacturer or in databases and can then be used by the manufacturer to declare disposal and recycling potential in an EPD.

The advantage of the EoLD for waste management companies and recyclers is that they can make the environmental performance of their processes "readable" for the manufacturer and EPD-compliant. In this way, they also describe the input and waste acceptance criteria for the respective recycling process from a practical perspective – in particular with regard to pollutants and contaminants. Such information is essential for selecting the appropriate scenario at the building level. For example, a manufacturer of precast concrete products could declare two recycling scenarios: (1) recycling concrete from dismantled precast components without sulphate impurities into high quality granules and (2) recycling concrete from C&D waste with sulphate impurities into gravel for road construction.

The dataset for the recycling scenario of an EoLD not only provides a description of the end of life of the product, but also the necessary data for the input of secondary materials into a sub-sequent product system, since the recycling processes and characteristics of the recycled product must be documented and included in the calculation. For example, the recycling processes are described after end-of-waste status is reached, which is necessary both for module D and as an input for secondary materials into a subsequent product system.

Figure 3: Application of the EoLD as a dataset for modules C, D, and A1 of a subsequent product system



Source: Authors

Most disposal and recycling processes depend on the material from which the product is made. An end of life process can be applied to a material that appears in many products, provided that this material is supplied in the appropriate manner. From the perspective of the recycler, knowing the identity of the specific construction product manufacturer (a specific company) is no longer relevant at the end of life stage. It would therefore make sense to find solutions for such groups of construction products and to jointly request from disposal companies the base data as an EoLD. **Manufacturers could act with the support of their associations and request EoLDs for their products.**

However, the separability of the materials in a product can lead to additional processes that are then product specific. For example, glued ETICS cannot be disassembled and are thus not recyclable, rather they are incinerated. Mechanically attached systems, on the other hand, can be dismantled and separated into recyclable materials. The conditions for acceptance of the products and materials for recycling processes are determined by the recycler.

An EoLD must describe a realistic type of waste treatment at the end of a product's life and al-low the comparison of recycling processes with landfilling and incineration on the basis of reliable and specific information. To determine the disposal process of a product, manufacturers must communicate with the disposal side to analyze which treatment processes are economically and technically feasible. On the other hand, when defining an EoL scenario for a product, manufacturers must explain conditions under which the acceptance criteria are met. For example, they must describe the installation scenario (A5), the use scenario (B modules), and the disassembly scenario (C1) accordingly. These scenarios must be coordinated. The data quality used to describe the scenarios must be both high, in accordance with the requirements of EN 15804+A2, and verifiable. This means that the data quality must be described with regard to the criteria “geographical, temporal and technical representativeness”. The procedures must be the actual applied procedures, meaning that they make economic sense. This metadata for the dataset is also part of the EoLD.

With the introduction of EoLDs from the disposal side, the EoL modules in EPDs can be specified with more robust and realistic data. Over time, reliable and robust data on environmental in-formation about the end of life of construction products will also become available in databases.

5.1 Benefits of the EoLD

The provision of life cycle assessment data in EoLD format benefits the waste management industry by providing quantified end of life environmental information for construction products in a similar from to an EPD. The EoLD also contains information on the presence of pollutants.

The purpose of the EoLD is to provide the basis for the description and assessment of the end of life for building products, as well as for buildings and other structures, and to identify those that are generate lower environmental impacts.

Thus, the goal of the EoLD is to ensure:

- the provision of verifiable and consistent data for an EPD based on a life cycle assessment;
- the provision of verifiable and consistent product-related technical data or scenarios for the description and assessment of the environmental performance of buildings at the end of their lives;
- that comparisons between construction products are made in the context of their properties at the end of life of the building;
- the communication of environmental information for construction products between economic partners (B-to-B).

EPDs are a practical tool for the exchange of information between all actors. They show who can improve something in the product life cycle and how: from design and production to installation, dismantling, and waste treatment at the end of a product’s life / end of life of a product.

EoLDs contain important information that enables manufacturers to learn how the recyclability of the product can be improved, e.g. with regard to the separability of materials or the avoidance of interfering substances.

As the installation stage of the products is of great importance for later disposal, manufacturers must provide targeted supporting information for the proper application and installation of products in order to achieve higher recycling rates and cleaner, and thus more recyclable, recycled materials, i.e. better overall economic performance of recycling activities.

For the waste disposal industry, the EoLD approach offers the opportunities to get in touch with the manufacturers and, if necessary, to improve their own processes. This allows recyclers to differentiate themselves in a growing market for recycled raw materials or pre-products. For example, when recycling companies learn more about certain product properties and ingredients from manufacturers, they may be able to improve recycling rates by identifying and targeting specific contaminants and impurities and responding appropriately.

Enhanced communication between recyclers and manufacturers can also benefit building certification systems by making the overall LCA of a building more specific and robust based on the improved data. Since these are still scenarios, an interpretation of the scenario results at the building level must also be included.

EoLDs can also fulfill a role in international harmonization and standardization by including the experience of waste management companies in the formation of standard scenarios (default scenarios) for a product group in their c-PCR. Based on robust EoLD data, such standard scenarios will improve the comparability of EPDs.

The same task should be done by associations in cooperation with EPD program operators, as long as the product TCs have not yet created their own c-PCR with corresponding standard scenarios.

5.2 EoLD Content

The EoLD methodologically follows the requirements of EN 15804. The EoLD contains company-specific, technical, and LCA-relevant information on modules C3 and/or C4 and D. It contains a description of the EoL route and the materials and conditions under which the material is accepted by the disposal companies for the declared route. If the waste treatment process (product level) in C3 or C4 is dependent on C1 (construction and products), namely the type of de-construction (e.g. selective dismantling) and/or type of transport (e.g. mode of transport, means of transport, transport distance) and/or the material composition of the product and/or impurities during the service life, then the appropriate requirements and conditions have to be specified and taken into account in the life cycle assessment. The LCA results are declared using the same approach as in an EPD in order to be able to link both documents.

If, as is often the case for transport processes, standard information modules are already available as an LCA dataset, these can be incorporated into the EoLD. Databases such as Ökobau.dat can also provide information modules, for example for typical construction machinery or demolition processes.

The following general information is required in an EoLD (based on the content of an EPD[14]):

a) Name and address of the waste treatment company or, in the case of an average EoLD, an indication of the region and the companies for which the average EoLD has been prepared.
b) Description of the type of disposal/recycling process, including the reference unit/unit of performance (e.g. t, m^3, m^2, piece). The units must be selected according to the requirements of EN 15804 for a declared unit, including the mass reference, so that the declared results of the EoLD can be joined with an EPD for the preceding modules, even if the remaining EoLD is based on a functional unit.
c) Identification of the disposal/recycling process, indicating the European Waste Catalogue (EWC) code and the characteristics of the waste, materials for recycling, or energy recovery material used as input to the disposal process.
d) Specification of system boundaries according to EN 15804+A2 Chapter 6.3.5.
e) Description of the acceptance criteria or exclusion criteria of the waste used as input to the disposal or recycling process, in particular with regard to contamination and impurities.
f) Description of the nature and characteristics of the end-state of the treated waste that has undergone the waste treatment process, or the product resulting from the recycling process.
g) Information about which C modules are taken into account in the EoLD and under which assumptions they can be included in the EPD.
h) Information about assumptions for deconstruction/demolition (C1) and transport (C2).
i) Information about the region for which the EoLD and the procedure is technically and economically applicable. The waste treatment operator may also indicate that the procedure is applicable not only at their site but for a region/country. At the building level, the auditor must then decide whether these processes are relevant. Recyclers can also join together and declare a German or European average recycling process.
j) If average environmental performance is declared in an EoLD, e.g. an association average, this fact together with a description of the value range and the variation of the impact assessment must be presented in the form of an explanation, as far as this is significant; here, the requirements about

[14] EN 15804

the end-of-waste status. If the end-of-waste status is reached on only after the removal of impurities, the processes for this are part of the product system, i.e. must be declared in C3.

k) The Annexes, companies or groups of companies, or those representing the them for which the EoLD is representative.
l) Description of the environmental impacts, the use of resources, the waste categories ultimately resulting from the disposal process and the output (e.g. ash from incineration) are declared in tabular form in an EoLD in accordance with the requirements of EN 15804, so that this information can be added to an EPD. The EoLD also contains the tables describing the EoL (see 7.3.4. der EN 15804).
m) Information about the end-of-waste state. If this achieved only after the removal of impurities, the processes are part of the product system and are to be declared in C3.

Requirements for verification of the EoLD are identical to the criteria for creating an EPD. In the case of verification, a project report must be prepared, and the following additional information must be included in the EoLD:

n) Name of the program, the address of the program operator, and, where available and relevant, the logo and website;
o) Date of publication and start date of the validity period.

5.3 Sample EoLD

An example of an EoLD is presented in Table 4.

Table 4 Sample EoLD for C&D waste recycling

Content	Description	Example[15]
Material description		**Construction and demolition wastes**
Waste code	Waste code according to 2014/955/EU[16]	17 01 07 mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06
Process name	Type of (recycling) process	Mineral C&D waste recycling
Description of the process	Technical description of the End-of-Life path(s)	"Mineral C&D waste is broken apart and sorted at the waste treatment facility. Efficient sorting machines separate and dispose of foreign and defective substances. The final product, high-quality brick and concrete aggregate, is used in <indicate region D/EU>, particularly in road construction, but also as fill material."
Declared C module (C3 or C4)	Indication of the declared module according to 2008/98/EG[17] ► Reuse, (C3) ► Recycling, (C3) ► Other use, e.g. energy recovery, (C3/C4) ► Disposal (landfilling or incineration) (C4)	C3
Regional applicability	Information about the region for which the EoLD and the method can be applied with regard to the technology applied and the economic context.	"Delivery in: ADDRESS" Applicable in e.g. Germany

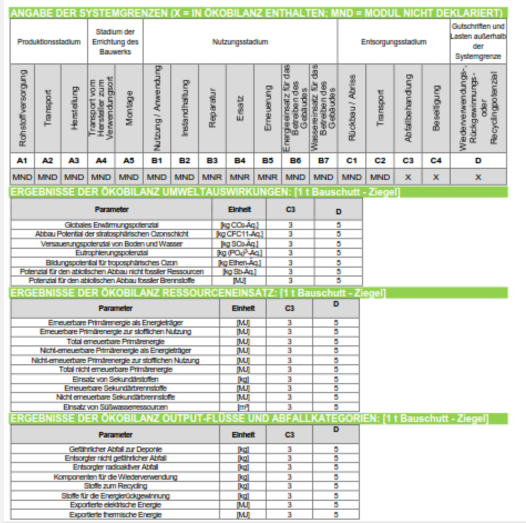
[15] Source: https://www.dachser-beton.de/produkte/bauschutt-recycling/

[16] https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32014D0955&from=DE

[17] https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32008L0098&from=en

Content	Description	Example[15]
Input material	Input to the end-of-life process	Mineral construction and demolition waste according to acceptance criteria
Output material	Technical characteristics of the processed material. Outputs of the end-of-life process.	The end products are RC-Sand 0/5 (recycled sand) und RC-Mix 0/32 (concrete/brick), quality-controlled and certified mineral substitute building material (Certificate: 12-2017/4118-86-503)
Criteria for acceptance	Description of the recycler's acceptance criteria	"Construction materials consisting mainly of natural rocks and minerals are accepted. This includes granite, sand-lime brick, clay brick, roof tiles, composite brick, concrete (also reinforced concrete with and without steel), porcelain"
Criteria for exclusion	Impurities and hazardous substances that affect recyclability	"Construction materials that contain too much foreign matter (over 20%) and substances hazardous to water or chemical contaminants are not accepted. These include: wood, paint residues, paints and coatings, wallpaper, construction chemicals, adhesives and carpet residues, sealants, packaging materials (paper and plastic)"
Deconstruction (C1) details	Requirements for deconstruction based on the acceptance criteria relevant for the EoLD life cycle assessment	Mechanical pre-sorting according to the acceptance criteria is required before delivery.
Logistic, transport (C2) details	Information about the roles of various relevant actors for the comprehensive description and declaration of end-of-life path(s)	Bulk waste is transported by truck.
Reuse, recovery, or recycling potential module (D) details	► References to account for benefits and loads outside the system boundary according to EN15804 ► Identification of replaced materials, products, and processes	A benefit is declared for the substitution of RC-Sand 0/5 (recycling sand) and RC-Mix 0/32 (concrete/brick).

Content	Description	Example[15]
	► Criteria and selection of plausible processes to quantify the potential benefits of substitution	
End of waste criteria	Information about the end of waste criteria.	Delivered, presorted C&D waste according to the acceptance criteria (i.e. the sorting processes are included in C3, recycling processes are included in module D).
LCA data		
Reference flow		1 t C&D waste
System boundary		C3 and D see Figure
Assumptions and estimates	Assumptions and estimates used in the calculation of the LCA must be disclosed, including information about ► Modeling of recycling rates ► Impurities, and if applicable, processes used to remove impurities ► Loses ► Non-recyclable residual materials ► Data sources. If 100% scenarios are described, no recycling rates are required for the calculation. This is adjusted to the building level. However, the recycling rate may be a helpful parameter for the building auditor.	

Content	Description	Example[15]
Results	The results are declared in a form that allows integration with an EPD.	

ANGABE DER SYSTEMGRENZEN (X = IN ÖKOBILANZ ENTHALTEN; MND = MODUL NICHT DEKLARIERT)

Produktionsstadium			Stadium der Errichtung des Bauwerks		Nutzungsstadium							Entsorgungsstadium				Gutschriften und Lasten außerhalb der Systemgrenze
Rohstoffversorgung	Transport	Herstellung	Transport vom Hersteller zum Verwendungsort	Montage	Nutzung / Anwendung	Instandhaltung	Reparatur	Ersatz	Erneuerung	Energieeinsatz für das Betreiben des Gebäudes	Wassereinsatz für das Betreiben des Gebäudes	Rückbau / Abriss	Transport	Abfallbehandlung	Beseitigung	Wiederverwendungs-, Rückgewinnungs- oder Recyclingpotenzial
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
MND	MND	MND	MND	MND	MND	MND	MNR	MNR	MNR	MND	MND	MND	MND	X	X	X

ERGEBNISSE DER ÖKOBILANZ UMWELTAUSWIRKUNGEN: [1 t Bauschutt - Ziegel]

Parameter	Einheit	C3	D
Globales Erwärmungspotenzial	[kg CO_2-Äq.]	3	5
Abbau Potential der stratosphärischen Ozonschicht	[kg CFC11-Äq.]	3	5
Versauerungspotenzial von Boden und Wasser	[kg SO_2-Äq.]	3	5
Eutrophierungspotenzial	[kg $(PO_4)^{3-}$-Äq.]	3	5
Bildungspotential für troposphärisches Ozon	[kg Ethen-Äq.]	3	5
Potenzial für den abiotischen Abbau nicht fossiler Ressourcen	[kg Sb-Äq.]	3	5
Potenzial für den abiotischen Abbau fossiler Brennstoffe	[MJ]	3	5

ERGEBNISSE DER ÖKOBILANZ RESSOURCENEINSATZ: [1 t Bauschutt - Ziegel]

Parameter	Einheit	C3	D
Erneuerbare Primärenergie als Energieträger	[MJ]	3	5
Erneuerbare Primärenergie zur stofflichen Nutzung	[MJ]	3	5
Total erneuerbare Primärenergie	[MJ]	3	5
Nicht-erneuerbare Primärenergie als Energieträger	[MJ]	3	5
Nicht-erneuerbare Primärenergie zur stofflichen Nutzung	[MJ]	3	5
Total nicht erneuerbare Primärenergie	[MJ]	3	5
Einsatz von Sekundärstoffen	[kg]	3	5
Erneuerbare Sekundärbrennstoffe	[MJ]	3	5
Nicht erneuerbare Sekundärbrennstoffe	[MJ]	3	5
Einsatz von Süßwasserressourcen	[m³]	3	5

ERGEBNISSE DER ÖKOBILANZ OUTPUT-FLÜSSE UND ABFALLKATEGORIEN: [1 t Bauschutt - Ziegel]

Parameter	Einheit	C3	D
Gefährlicher Abfall zur Deponie	[kg]	3	5
Entsorgter nicht gefährlicher Abfall	[kg]	3	5
Entsorgter radioaktiver Abfall	[kg]	3	5
Komponenten für die Wiederverwendung	[kg]	3	5
Stoffe zum Recycling	[kg]	3	5
Stoffe für die Energierückgewinnung	[kg]	3	5
Exportierte elektrische Energie	[MJ]	3	5
Exportierte thermische Energie	[MJ]	3	5

6 Outlook

Following the EPD system, the data in the EoLD from product manufacturers would be added to the EPD. However, since data will also be available in databases, e.g. BIM (?) systems, combining the EPD and the EoLD can only carried out concurrent to a building life cycle assessment. In that case, the building location and existing installation context are usually already known. This makes it possible to select appropriate EoL scenarios. The EoLD would then be based on the same methodology as an EPD (data collection for the EoLD carried out by the waste treatment company, update of the EPD after 5 years or in case of significant changes, waste code numbers as basis for possible waste code rules (ACR) comparable to the PCRs) and thereby the building auditors can be provided with much more up-to-date data than is the case today.

The EoLD approach can prompt a change in perspective in the preparation of LCA datasets for building life cycle assessment. Currently, product life cycle assessment is carried out entirely from the perspective of the manufacturer and scenarios are used to describe the life cycle stages after the product leaves the factory gate. If, however, specific data is available that can be used when planning buildings, such as an EoLD for the end of life or specific declarations for the installation and use modules, and all sectors are thus given the opportunities to apply specific data, the LCA can be calculated much more specifically.

7 Handbook/Manual

7.1 Purpose of the Manual

This manual serves as a guide for the technical product committees for standardization in Europe for the declaration of the end-of-life of products in an EPD according to EN 158045.

An EPD contains quantified environmental information for a construction product or service that is harmonized and scientifically grounded. It also provides information on health-related emissions to indoor air, soil, and water during the use stage of the building. The purpose of an EPD in the construction sector is to provide the basis for the description and assessment of buildings and other structures to identify those that have a lower environmental impact.

The c-PCR document (core product category rules) of the respective product group[18] contains specific calculation rules to supplement the corresponding rules from EN 15804.[19]

This applies in particular to the elaboration of the scenarios of assembly (A5), use (B1-B7), disposal (C1-C4), and recycling potential (D).

Table 5: Life cycle stages and modules according to EN 15804

Product stage			Construction stage		Use stage					End of Life stage				Benefits and loads beyond the system boundary
Raw material supply	Transport	Manufacturing	Transport to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse-, Recovery, Recycling potential
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**C1**	**C2**	**C3**	**C4**	**D**
					B6 Operational energy use									
					B7 Operational water use									

The declaration of the processes in A1-A3 (production), C1-C4 (disposal), and D (recycling potential) is mandatory for all manufacturers with the following exceptions for products and materials that:

- are physically connected to other products during installation so that they cannot be separated from during disposal, and
- are no longer identifiable due to physical or chemical conversion processes during disposal.

If modules C1 to C4 and module D are not declared, this decision must be justified.

[18] Z.B. CEN TC 143 Sustainability of construction works - Environmental product declarations - Product category rules for resilient, textile and laminate floor coverings; CEN TC 88 Thermal insulation products - Product category rules (PCR) for factory made and in-situ formed products for preparing environmental product;

[19] Guidance for the development of a c-PCR document is given in CEN TR 16970:2016

The requirement to declare modules C and D presents a challenge for manufacturers in that they are often not in the position to be able to quantify disposal processes, and if they do not recycle the product themselves, they cannot demonstrate a quantitative recycling potential.

Quantifying the typical disposal processes of incineration or landfilling, however, is possible with the help of databases that include datasets for material and energy flows and the associated environmental impacts. Accordingly, it is helpful if the datasets for specific recycling processes are available.

This is what the End-of-Life Declaration (EoLD) achieves. For the disposal companies and recyclers who can provide data describing the disposal and recycling processes, as described in the manual.[20] The product category rules of the product groups that are developed by the product TCs must include the appropriate specifications.

7.2 Specifications in EN 15804+A2 for Disposal

All calculation rules from EN 15804 for the life cycle assessment of the product system of a construction product also apply to the calculation of the environmental impact in the disposal stage. The precautionary principle apples, according to which the environmental impacts of disposal are to be assigned to the product system that produced the waste. Chapters 6.2.6 and 6.3.5.5 provide basic rules for modeling the disposal stage. Environmental impacts arising in the course of disposal, or material or energy flows associated with disposal, which may replace new production in another subsequent product system, are assigned to module D as recycling potentials.

The disposal stage includes the following activities:

- C1 Disassembly, including the deconstruction and demolition of the product from the building, including initial sorting on the site.
- C2 Transport of the discarded product as part of waste treatment, e.g. to a recycling center and the transport of waste for final disposal.
- C3 Waste treatment, e.g. collection of waste fractions from demolition and waste treatment of material flows intended for reuse, recycling, and energy recovery.
- C4 Waste disposal included waste pretreatment and landfilling

EN 15804 requires key data for disposal processes (7.2.4.3, Table 7, 8, 15) and transport (Table 10). The uniform declaration of these data facilitates the application of the disposal scenarios in the assessment of the environmental quality of buildings.

7.3 Step-by-step/gradual development of system boundary conditions for disposal scenarios

Disposal processes and the criteria for waste acceptance are known to waste management companies. In order for this information to be integrated into an EPD for the C1-C4 modules, the disposal companies must provide life cycle assessment data. This data is already available in life cycle assessment databases for classic waste treatment processes, such as waste incineration or landfilling. For specific processes, however, it is necessary for waste management companies/disposal companies to provide the information in the form of an End-of-Life Declaration (EoLD), for example.

The goal of c-PCRs is to establish harmonized requirements and system boundary conditions for EPDs. Since declaring the product end-of-life will no longer be voluntary in future, it is advisable that criteria for the end-of-life for product groups be set by c-PCRs in order to ensure fair and comparable information in EPDs.

[20] Principles and recommendations for describing the end of life of construction products in environmental product declarations (EPD)

The Product TCs should first check the possible waste treatment and disposal processes for representativeness (identify applicable region and product types) and completeness. These processes can be verified based on the information in an EoLD, since the procedures are applicable for manufacturers when products at end-of-life or waste produced in modules A1-B7 meet the acceptance requirements of waste management companies. Communication with the relevant waste management companies is essential.

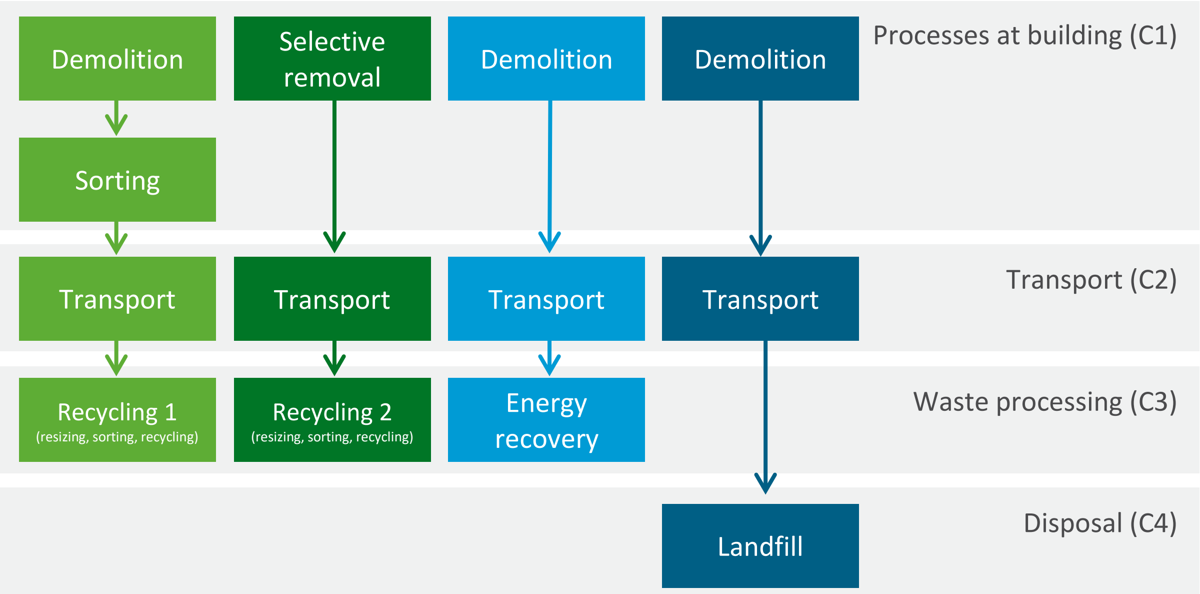
When defining the EoL processes in a c-PCR, a decision tree for the scenario selection can be derived based on the information and acceptance criteria of waste management companies.

7.3.1 Scenario definition

For each product group, or subgroup, the main scenario is to be defined first (e.g. recycling vs. incineration).

For each of these main scenarios, a decision tree is to be generated in which the acceptance criteria must be taken into account for the selected procedure.

Figure 4: Scenario definition



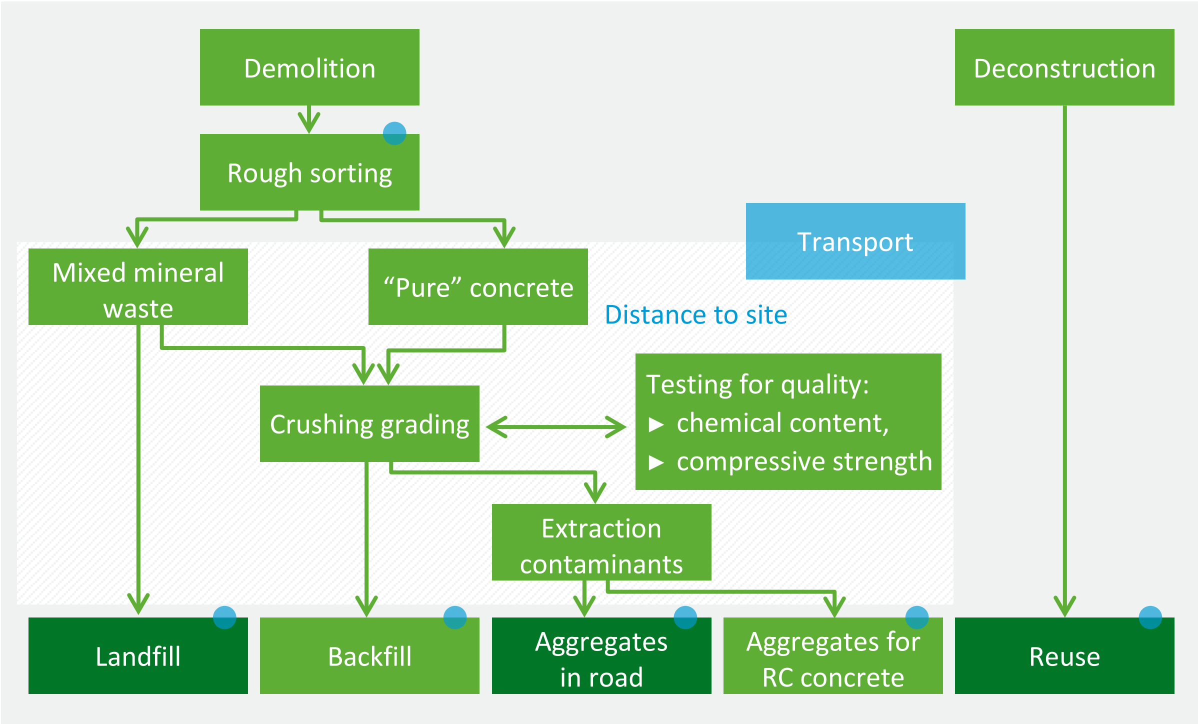
Source: Authors

Decision tree that shows the possible disposal paths.

Example of concrete:

See Figure F for an example of disposal paths for concrete.

Figure 5: Example of disposal paths for concrete – Decision tree for concrete EoL



Source: Authors

The disposal stage of the construction product begins with its replacement, removal, or dismantling from the building or structure when it no longer fulfills a function. This stage can also begin when the demolition or dismantling of the building.

To develop a decision tree, the following questions are to be answered (Example: C&D waste recycling):

Content	Description	Example[21] C&D waste in Germany
Description of the process of removal from the building	a) From demolition b) From dismantling c) Extraction	a) C&D waste b) Concrete aggregate without contamination c) Not relevant
Name of possible processes	Landfill, backfill, incineration, recycling	Landfill, C&D waste recycling
Declared C module (C3 or C4)	Indication of the declared module according to 2008/98/EG[22] ► Reuse, (C3) ► Recycling, (C3) ► Other use, e.g. energy recovery, (C3/C4) ► Disposal (landfilling or incineration), (C4)	a) Disposal b) C&D waste recycling

[21] Source: https://www.dachser-beton.de/produkte/bauschutt-recycling/

[22] https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32008L0098&from=en

Description of the process	Technical description of the End-of-Life path(s)	a) Coarse aggregate b) Fine aggregate, sorting to avoid impurities
Waste code of the end product	Waste code according to 2014/955/EU[23]	17 01 07
Regional applicability	Are the processes available for the region for which the EPD is applicable?	a) Yes, for Germany b) Yes, for Germany
Description of the possibility of landfilling	Technical requirements of the waste product	C&D waste is sorted. Metals and materials with energy content of xxxx MJ/kg are removed.
Description of the possibility of incineration	Technical requirements of the waste product	Not relevant
Description of possible recycled products	Technical requirements of the processed materials	RC-Sand 0/5 (recycled sand) und RC-Mix 0/32 (cement/brick), quality-controlled and certified mineral replacement building material (Certificate: 12-2017/4118-86-503)
Limiting conditions	Acceptance criteria, economic exclusion criteria	► Acceptance criteria for land-filling C&D waste ► Acceptance criteria for recy-cling C&D waste ► Transport distances, which, due to their economic and environ-mental effects, pro-hibit recycling

[23] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014D0955&from=DE

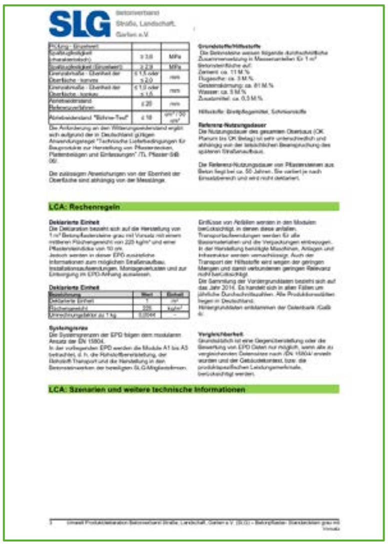
8 Appendix: Example of an Environmental Product Declaration (EPD)[24]


UMWELT-PRODUKTDEKLARATION

nach ISO 14025 und EN 15804

Betonpflasterstein grau mit Vorsatz

Betonverband Straße, Landschaft, Garten e.V. (SLG)


SLG

LCA: Rechenregeln

LCA: Szenarien und weitere technische Informationen


SLG

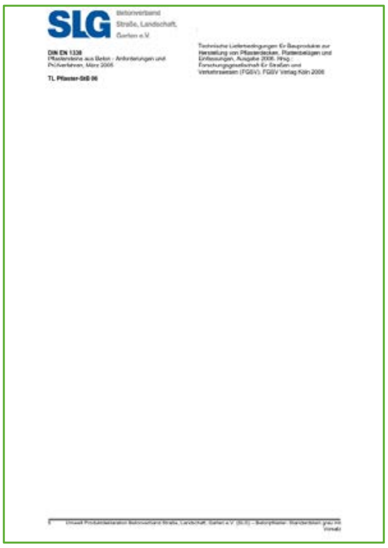
Allgemeine Angaben

Produkt


SLG

LCA: Ergebnisse

Literaturhinweise

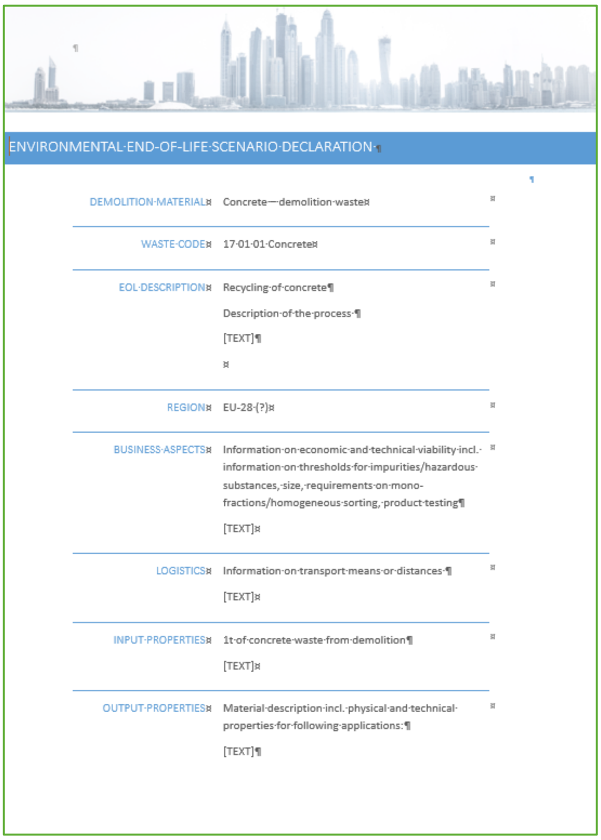

SLG


thinkstep

SLG

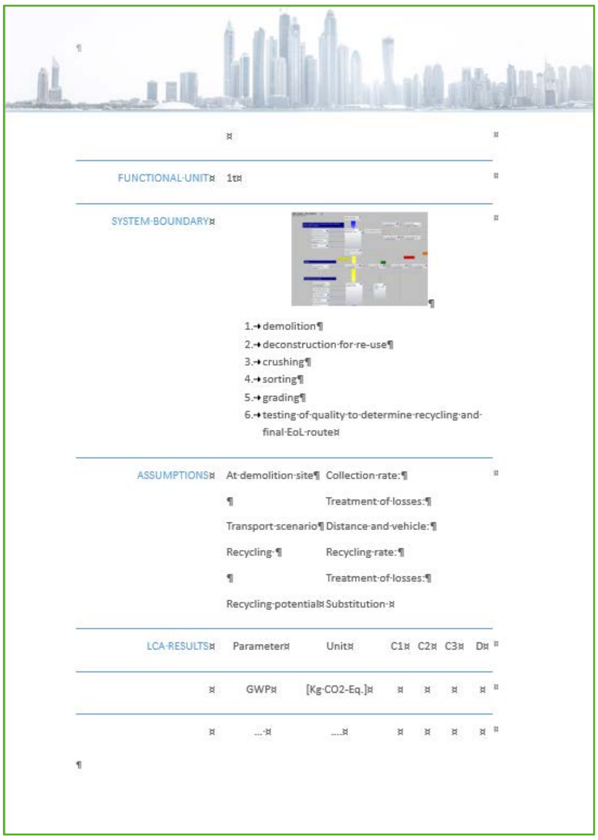
24 https://ibu-epd.com/veroeffentlichte-EPD/, 07/2019

9 Appendix: Example of an End-of-Life Declaration (EoLD)



ENVIRONMENTAL END-OF-LIFE SCENARIO DECLARATION

DEMOLITION MATERIAL	Concrete—demolition waste
WASTE CODE	17 01 01 Concrete
EOL DESCRIPTION	Recycling of concrete Description of the process [TEXT]
REGION	EU-28 (?)
BUSINESS ASPECTS	Information on economic and technical viability incl. information on thresholds for impurities/hazardous substances, size, requirements on mono-fractions/homogeneous sorting, product testing [TEXT]
LOGISTICS	Information on transport means or distances [TEXT]
INPUT PROPERTIES	1t of concrete waste from demolition [TEXT]
OUTPUT PROPERTIES	Material description incl. physical and technical properties for following applications: [TEXT]



FUNCTIONAL UNIT	1t
SYSTEM BOUNDARY	1. demolition 2. deconstruction for re-use 3. crushing 4. sorting 5. grading 6. testing of quality to determine recycling and final EoL route
ASSUMPTIONS	At demolition site: Collection rate:; Treatment of losses: Transport scenario: Distance and vehicle: Recycling: Recycling rate:; Treatment of losses: Recycling potential: Substitution

LCA RESULTS	Parameter	Unit	C1	C2	C3	D
	GWP	[Kg CO2-Eq.]				
	...	....				

10 References

All references are provided as footnotes throughout the document.