Environmental profile of building elements [update 2017]

WE MAKE TOMORROW BEAUTIFUL

OVAM

Flanders
State of the Art

WWW.OVAM.BE

1. Publication title
Environmental profile of building elements

2. Published by:
OVAM, Stationsstraat 110, 2800 Mechelen

3. Legal deposit
D/2018/5024/06

4. Number of pages
46

5. Number of tables and figures
45 tables and 45 figures

6 Price /*

7. Date of publication
Jan. 2018

8. Keywords
building materials; building elements; environmental impact; assessment framework

9. Summary
Building professionals currently have to resort to foreign environmental classification systems to acquire an insight into the Environmental Performance of Materials used in Buildings and Building Elements (in Dutch: MMG: Milieugerelateerde Materiaalprestatie van Gebouw(element)en). However, often the tools and information involved are not transparent and/or not specifically related to the Belgian building context. This publication offers an open and transparent presentation of the MMG assessment framework for the Belgian building context and is an updated version of the publication dd. May 2013. This methodology is the basis for the calculation of the environmental profiles in the first version of the (on-line) tool that was launched by the 3 regional authorities in February 2018. Although the resulting building materials methodology is far from final, it is a dynamic model (including an assessment framework) that will be fine-tuned and expanded in the future. In that context, this publication should be perceived as a communication tool to facilitate the dialogue with stakeholders (architects, material producers, proprietors) in the future.

10. Guidance group and/or author
Authors: Karen Allacker (KU Leuven), Wim Debacker (VITO), Laetitia Delem (BBRI), Leo De Nocker (VITO), Frank De Troyer (KU Leuven), An Janssen (BBRI), Karolien Peeters (VITO), Johan Van Dessel (BBRI), Roos Servaes (OVAM) Evi Rossi (OVAM), Magali Deproost (SPW), Sophie Bronchart (BE) [KU Leuven: Catholic University of Leuven; VITO: Flemish Institute for Technological Research; BBRI: Belgian Building Research Institute; OVAM: Public Waste Agency Flanders, BE: Brussels Environment, SPW: Service Public de Wallonie]

11. Contact person(s)
OVAM – Roos Servaes, Evi Rossi
SPW – Magali Deproost
BE – Sophie Bronchart
VITO – Wim Debacker, Wai Chung Lam
KU Leuven – Frank De Troyer, Karen Allacker
BBRI – Lisa Wastiels, Johan Van Dessel

12. Other titles on this subject
Milieugerelateerde Materiaalprestatie van Gebouwelementen (MMG report) (www.ovam.be/materiaalprestatie-gebouwen)
Annex: Monetarisation of the MMG method (update 2017)

Table of Contents

This publication was developed in close cooperation with:

PREFACE

Buildings have a huge impact on the environment. Today's focus is - justifiably - on energy-efficient construction methods, the keywords being better insulation, energy-efficient heating and use of renewable energy. However, much of the impact can be attributed to the materials used in buildings, as these have an environmental effect during production and transport, during the construction of the building and also during demolition, further processing and any new usage in a next life. The way in which building materials are being used in a building element also determines the eco- friendliness of that building in the scope of its entire life span. Today, these and other factors relating to materials usage are largely underexposed in the available knowledge and in knowledge distribution on eco-friendly building methods. This publication is a start towards filling that knowledge gap.

Since 2010, OVAM has been developing a transparent methodological framework for unequivocal calculation and communication of Environmental Performance of Materials used in Building Elements (MMG) for the Flemish construction industry. In 2014, Brussels Environment and SPW joint the MMG team to work towards a Belgian framework and the development of a user-friendly Belgian tool. The current proposal of methodology is not a final result, but should be considered a dynamic concept that, based on new insights and new scientifically founded data, will be fine-tuned and expanded in the future.

The MMG assessment framework was developed within a process of broad consultation. Numerous experts from the construction industry and from Flemish, Brussels, Walloon and federal government authorities were invited at several public consultation meetings to share their opinion and give advice.
Various materials manufacturers provided producer- and industry specific data input. This enabled the MMG research team to compare the available generic data to producer-specific data and also provided the cooperating manufacturers and industrial organisations a better insight into the environmental impact of their product(s). OVAM is grateful for this proactive involvement, both to the implementing bodies VITO,
KU Leuven and BBRI, to several government authorities, and not in the least to the construction industry itself.

The close collaboration between the 3 regional authorities and the launch of a common tool in February 2018 is a new significant step towards sustainable materials management within the Belgian construction industry, i.e. the supply of transparent and objective environmental information. Our goal is to reach a broad audience with limited or advanced knowledge about sustainable building.

We are certain that this will form the basis of small and larger construction experiments, which, together with a solid and broadly supported vision on sustainability, in the longer term will lead to increased usage of sustainable building materials.

Henny De Baets
Administrator-General of OVAM

1 BUILDING MATERIALS METHODOLOGY

1.1. Why do we need a methodology for building materials?

Building materials generate environmental effects at various life cycle stages: during the manufacture of the materials (extraction, transport, processing); during the construction phase (processing and residual waste); during use and maintenance of the building (emissions, waste); and during the disposal or demolition phase. These environmental effects can take many different shapes. A typology study of the construction of Belgian houses showed that in the entire lifespan of a typical Belgian house built before 2001, building materials represent about ten to thirty percent of the external environmental costs (Allacker et al 2011, Allacker 2010). This relative share is expected to rise over the next decades as a result of the sharp decrease of energy-related external costs that will accompany the construction and renovation of buildings as low-energy, passive, zero-energy and active structures. For this reason, it is essential to acquire a clear insight into the Environmental Performance of Materials used in Building Elements (**M**ilieugerelateerde **M**ateriaalimpact van **G**ebouwelementen, MMG).

Decision-makers, i.e. architects, engineering agencies, contractors, proprietors, project developers and government bodies, often lack the environmental information that is required for objective and transparent creation, selection or support of eco-friendly materials solutions. In addition, some manufacturers and distributors are unaware of the potential environmental impact that building materials have during their life cycle. A quantitative assessment therefore is essential in order to identify and avoid this potential environmental impact as early as the design stage. In an ideal world, next to the technical performance, costs and quality of building materials, design teams would in the design phase of a building element – a floor, an exterior and/or interior wall, a flat and/or pitched roof – consider their lifetime environmental performance. Currently, however, building professionals and the government are forced to use foreign environmental classification systems including the British "Green Guide to Specification" (BRE 2011) and the Dutch "NIBE's Basiswerk Milieuclassificaties Bouwproducten" (NIBE 2011a, 2011b, 2011c), or foreign life cycle inventory databases (LCIs) such as the Swiss "Ecoinvent" (v3.3, 2016), or publicly available labels, self-declaration or Environmental Product Declarations (EPDs). The downside of these tools and information is that they are often not transparent and/or not specifically related to the Belgian building methods and scenarios.

For these reasons, the Public Waste Agency of Flanders, OVAM, together with Service Public Wallonie and Brussel Environment took in 2014 the initiative to work towards the development of a methodology designed for the Belgian construction industry and the launch of a user-friendly tool in February 2018.

back to content

1.2. What does the building materials methodology entail?

In the period covering February 2011 through August 2012, by order of the OVAM the project team comprising VITO, KU Leuven (ASRO) and BBRI developed an expert calculation model (including assessment framework) for the quantification of environmental performance of building elements. The model served as the basis for a limited database of 115 building element variants that is representative of the Belgian construction industry (Servaes, 2012). The expert calculation model has been further developed since 2013. The methodology has been updated to follow amendments within European standardisation and the developments regarding the European Product Environmental Footprint (PEF). Furthermore, the database has been extended to almost 500 building element variants. The extension was also done as data input for the online tool (hereinafter called 'tool') based on MMG that was made publically available in 2018. With the tool, decision-makers will have a user-friendly calculation tool in which they can calculate the environmental impact of their building choices.

1.2.1. MMG ASSESSMENT FRAMEWORK

The parameters of the assessment framework were selected after due consideration. A brief explanation of the choices can be found in this chapter. For a detailed description of the MMG assessment framework we refer to Chapter 2 "Assessment framework".

1.2.1.1. SELECTION OF ENVIRONMENTAL INDICATORS

To stay in line with existing European initiatives in the field of environmental assessment of buildings and building products, from the very start the project took due consideration of the European standardisation, submitted by CEN/TC 350, and of the recommendations of the European "Institute for Environment and Sustainability" (JRC) regarding environmental indicators and impact methods.

In the CEN/TC 350 standards, only seven impact categories are mandatory for an environmental product declaration. Additional impact categories are part of European recommendations, like in the PEF guide (EC, 2013), and of national legislation of some member states (the Netherlands, France, and Belgium). However, in 2016, CEN/TC 350 published a Technical Report (TR) in which the relevance and robustness of additional impact categories, models and indicators are evaluated from a perspective of the possibility of adding those additional impact categories. The TR describes the evaluation of the impact categories human toxicity, ecotoxicity, particulate matter formation, ionizing radiation, land use/ biodiversity, and water scarcity.

The added environmental indicators are reported separately under the name "CEN+ indicators" (see Chapter 2 "Assessment framework").

The following environmental indicators are included in the MMG assessment framework:

- global warming
- ozone depletion
- acidification for soil and water
- eutrophication
- photochemical ozone creation
- depletion of abiotic resources: elements
- depletion of abiotic resources: fossil fuels
- human toxicity (cancer effects and non-cancer effects)
- particulate matter
- ionising radiation: human health effects
- ecotoxicity: freshwater
- water resource depletion
- land use: occupation (soil organic matter and biodiversity)
- land use: transformation (soil organic matter and biodiversity)

1.2.1.2. DATA SELECTION

In order to avail of sufficient generic environmental data, the extensive Swiss LCI database ecoinvent version 3.3 was harmonised as much as possible into the Belgian building context (see section 2.3.1).
In the scope of the MMG research project in the period 2010-2013, a few proactive materials manufacturers and industry organisations offered their own specific environmental data of building products, which provided for interesting comparison with the generic ecoinvent data.

1.2.1.3. THE CHOICE FOR MONETISATION

To allow for a decision-oriented selection of materials solutions, the characterisation values for each individual environmental indicator (both CEN and CEN+ indicators) were optionally aggregated by means of the environmental external cost method (see Chapter 2 "Assessment framework"). For each individual environmental indicator, the characterisation values are multiplied by a monetisation factor (e.g.: X kg CO2 equivalents times Y € /kg CO2 equivalents). This factor indicates the extent of the damage to the environment and/or humans, expressing it in a financial amount for the purpose of avoiding potential damage or settling any damage incurred. These aggregated environmental scores are also reported separately (see below: CEN, CEN+ and the sum of both).
The decision to opt for the environmental external cost method as the weighting method is explained in Chapter 2 "Assessement framework".

1.2.2. HOW IS THE BUILDING MATERIALS METHODOLOGY STRUCTURED?

1.2.2.1. HIERARCHICAL STRUCTURE OF THE EXPERT CALCULATION MODEL

The expert calculation model – for assessment of the environmental performance of buildings and building elements – is built up according to a hierarchical structure and distinguishes four levels of analysis: building, building element, work sections (i.e. building products), and materials (see figure 1) (Allacker 2010, Allacker et al. 2011). Each higher level is based on the previous level. Thus, a building is built up of a number of building elements (such as floors, external walls, internal walls, roof, etc.), which in turn consist of several work sections (e.g. a masonry wall). The work sections are again built up of different building materials (e.g. hollow brick and mortar).

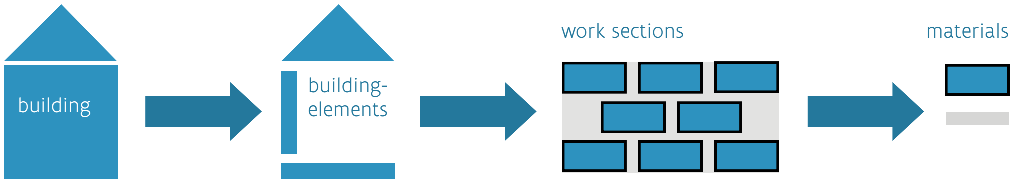

Figure 1: Illustration of the hierarchical structure of the calculation model and its four levels of analysis.

1.2.2.2. THREE DATABASES

In this project, for the three lowest levels of the above-mentioned hierarchical structure – i.e. material, work section and element levels – an extensive spreadsheet was created in three separate steps. The spreadsheet includes several databases containing input and output data that are used for calculating the environmental impact of the selected materials ("Materials Database"), work sections ("Work Sections Database") and elements ("Elements Database") (see figures 2 and 3; Allacker, 2010; Allacker et al. 2011). The element database was made publicly accessible in the tool and users are allowed to change some parameters in these predefined elements (for example: adapt thickness, lambda value or combine other work sections).

A database for buildings was not developed in the scope of this study, but the tool allows evaluation on a 'simple' building level: the total material impact on building level is the sum of all individual building elements. Some 'simple' buildings will be made available within the tool as example.

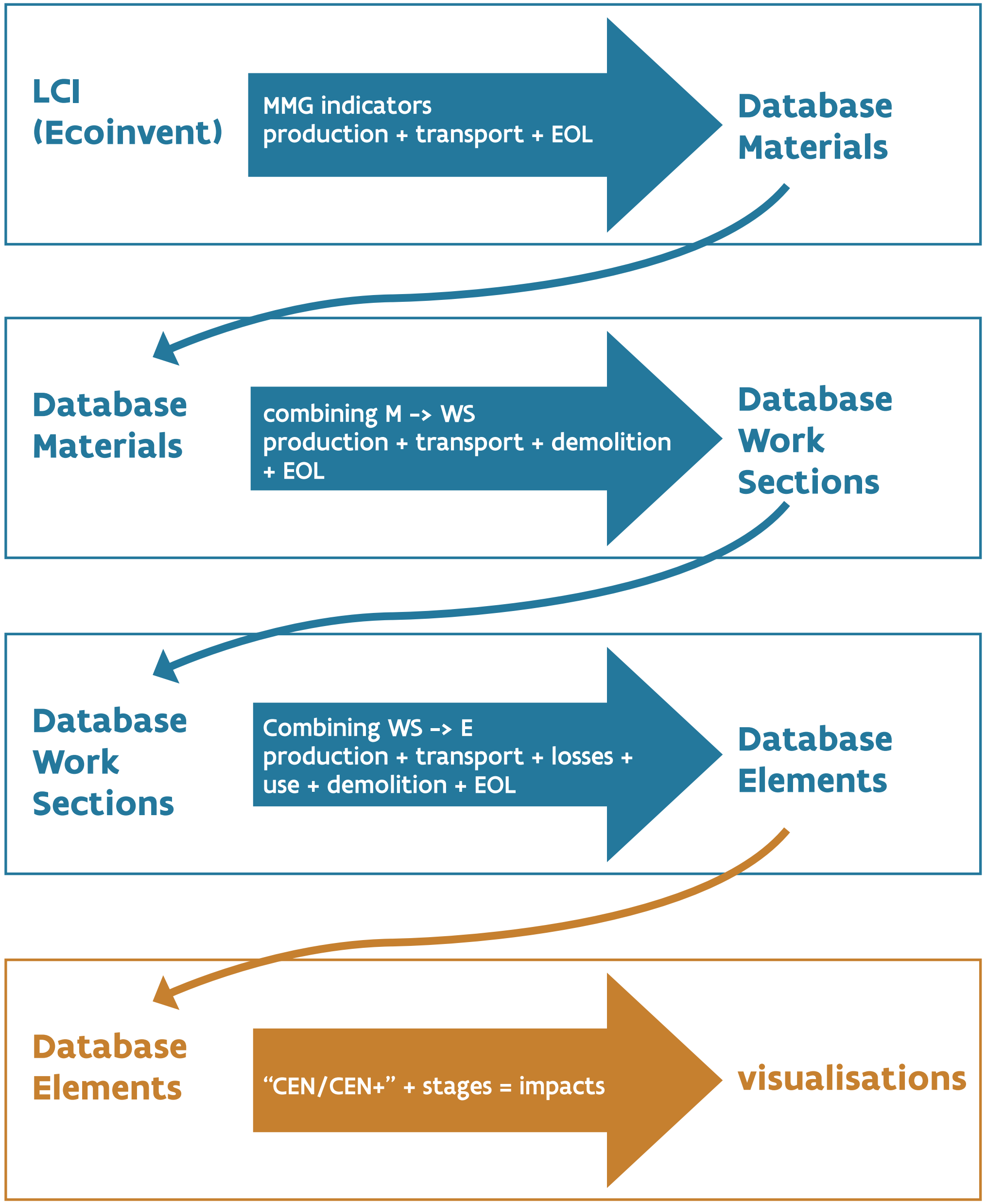

Figure 2: Overview of the three consecutive steps that successively create the databases at a materials, work sections and element level. A visual of the results at each level constitutes a fourth step.

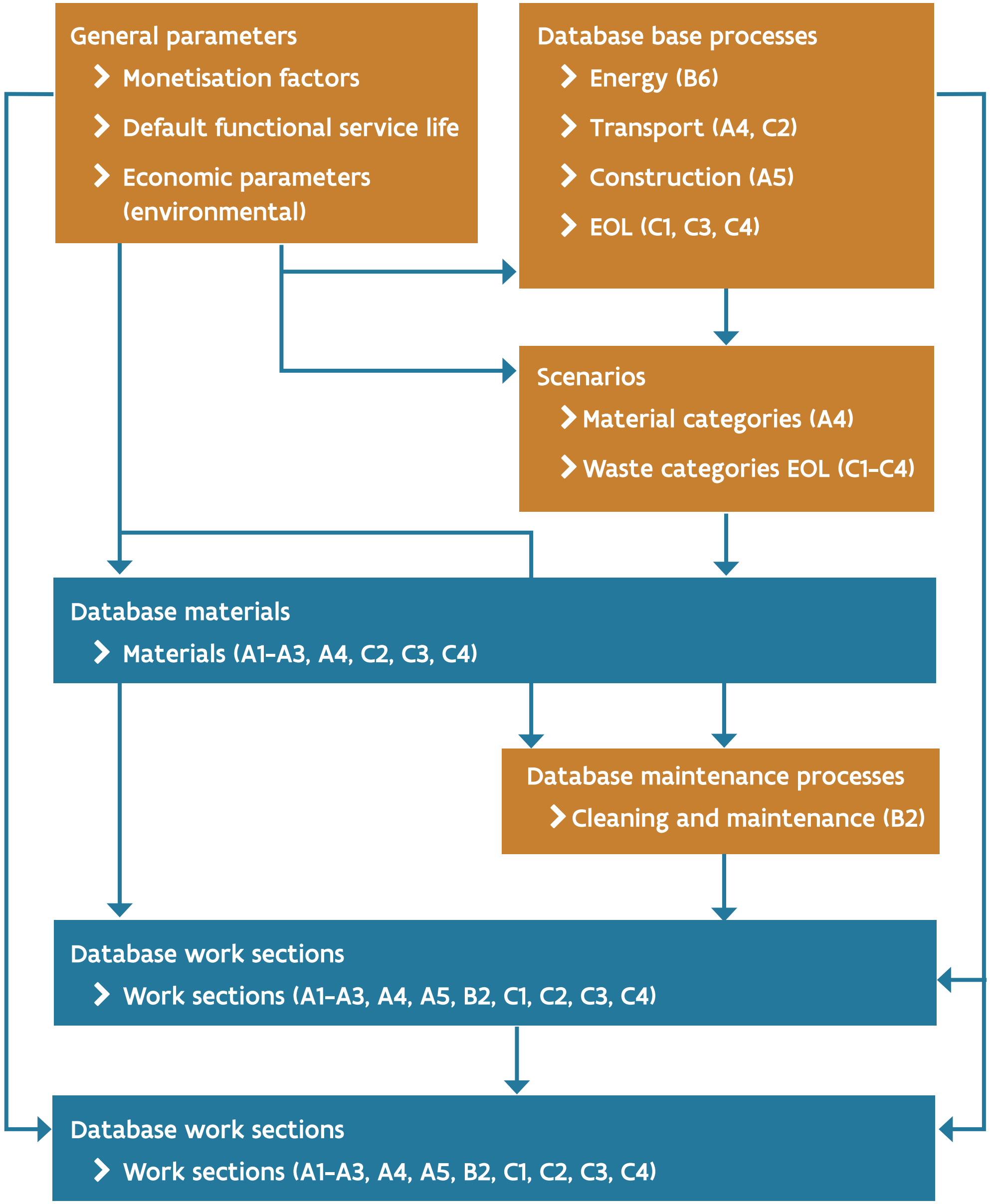

Figure 3: Overview of the structure of the expert calculation model.
The main databases at the three separate levels, i.e. the materials database, work sections database and elements database and accompanying databases are shown in blue; the underlying databases, i.e. general parameters, base processes, scenarios and the maintenance processes, are shown in orange.

back to content

1.2.3. WHAT TYPE OF INFORMATION IS OFFERED BY THE BUILDING MATERIALS METHODOLOGY?

The integrated approach and modular structure of the calculation model as well as the assessment framework generate a large amount of information, which can be used:

- either to obtain a detailed insight into the environmental profile of materials, work sections and building elements, by using seventeen individual environmental scores and taking into account all the separate life cycle stages (the smallest level that can be consulted in the tool is the level of building elements); or
- to compare the environmental profiles of different building element variants (or of different building variants in the tool) – regardless of different (technical) performances – by using seventeen monetised and/or three aggregated environmental scores (CEN, CEN+ and total).

It should be emphasised, however, that in order to provide the required insights, the output of a materials methodology analysing the environmental profile of building elements must always be compared against other building characteristics and requirements, such as technical aspects including thermal and acoustic performance, or financial aspects including initial and periodical investments. Hence the architect or the principal must within the allowed parameters, make due consideration of the materials to be used.

1.2.4. HOW RELIABLE IS THE BUILDING MATERIALS METHODOLOGY?

In the first MMG study of 115 element variants, a sensitivity analyses for 115 element variants has been carried out for the following aspects: building lifespan, transport scenarios, material losses during the construction process stage, end-of-life treatment of demolition and construction waste, and monetisation factors.
Based on the performed sensitivity analyses, a building's lifespan is a very important assessment parameter. Based on Ammar and Longuet (1980) and Allacker (2010), the MMG research project allows for a standard lifespan of sixty years. The standard lifespan of sixty years is a fixed parameter in the first version of the tool. However, in future versions of the tool, it is preferable that this parameter becomes flexible. For comparisons between variants with different life expectancies as regards the building, one must make sure that the results are divided by the estimated life span of the building to avoid faulty comparison.
Furthermore, clear definition of the transport of building materials to – and from – the building site is essential. It is noted that logistics related to the transportation of building materials can play a significant role in the priority sequence of element solutions, especially in the case of heavy and voluminous building materials (e.g. concrete), for which the type of transportation (e.g. a small vs. a large lorry) and the distance between plant/dealer and the building site may have a significant effect on the environmental impact.
Thirdly, it is important to limit any loss of material during transportation to the site and during the actual building works. A variation in loss of material of 0 - 20% (assumption for the MMG study: 5% loss) for all the types of materials however did not produce a significant difference between the aggregated environmental profiles.

back to content

Changing the end-of-life processing scenario has a negligible effect on the aggregated environmental scores of the 115 element variants for the entire life cycle. The sensitivity analysis showed that transportation – either or not through a sorting facility – to the site for final treatment and the handling upon final treatment did not affect the monetised environmental profiles of building elements. By contrast, a change in the end-of-life treatment scenario at a materials and work sections level (monitored from the cradle to the plant entrance) may indeed generate significant changes in the individual and aggregated environmental profiles.

For the sensitivity analysis carried out for the monetisation factors we refer to Chapter 2 'Assessment framework'.

For a more detailed analysis of the robustness and sensitivity of the model, we refer to the MMG final report[1].

1 The MMG final report can be consulted via www.ovam.be/materiaalprestatie-gebouwen (only available in Dutch).

2 ASSESSMENT FRAMEWORK

2.1. Introduction

Calculation and clear communication of the environmental performance of the use of materials in buildings require a transparent methodological framework. In this chapter, we discuss in detail the assessment method underlying the expert calculation model and tool. This method is in line with the European harmonised standards for the assessment of environmental performance of buildings, which have recently been developed in CEN/TC 350[2]:

- EN 15804:2012+A1 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products (CEN 2013)
- EN 15978 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method (CEN 2011a)
- EN 15643-2 Sustainability of construction works - Assessment of buildings - Part 2: Framework for the assessment of environmental performance (CEN 2011b)
- TR 15941 Sustainability of construction works - Environmental product declarations – Methodology for selection and use of generic data (CEN 2010)

Consequently, only the additions to, departures from and clarifications to these standards, as well as adopted values and scenarios that are specific to the model developed here, are discussed in this assessment method.

OVAM, Brussels Environment, SPW, and the other authors of this study warn for any standard changes or recommendations that would be in force after writing the final MMG-report (August 2012) and any other MMG publications.

2 CEN/TC 350: Technical Committee on Sustainability (assessment) of construction works of the European normalisation centre (CEN)

2.2. Objective and scope

The objective of the developed MMG assessment framework, expert calculation model, and tool is to calculate the environmental impact of building elements and buildings both at the level of individual environmental impact categories and at an aggregated level. This permits a better understanding of the environmental performance of materials used in buildings and building elements within a Belgian context, taking into account the entire life cycle of the building or building element.
Aspects of importance to the life cycle assessment are given below.

2.2.1. FUNCTIONAL UNIT[3]

The expert calculation model is intended primarily for assessments at the building element level[4]. The functional unit in the expert calculation model is defined as 1 m^2 of an element (in case of elements that have a geometry of a surface and a thickness, e.g. 1 m^2 of exterior or interior wall or 1 m^2 of floor) as built in practice and that does not score identically for all possible performances. The advantage of this approach is that it allows us to focus on one or more elements without having to design a complete building. A disadvantage of working only at the level of individual elements is that certain choices for one particular element can at times affect other elements (e.g. wider foundation if thicker insulation in the cavity), which can be analysed only at a building level. In addition, depending on the lay-out of the building, the quantity of a particular element per m^2 of floor area can vary (e.g. m^2 of roof for an apartment block or a bungalow).
The 'element method' was introduced as the first step towards the extension to the building level.

3 In line with EN 15978:2011 §7.2 and EN 15804:2013 §6.3.1
4 A building element is a major physical part or system of a building, which consists of several building products (here defined as work sections). Examples are floors, roofs, walls, windows and technical services. Account is taken of the entire life cycle of this element in its particular application in the building.

back to content

The extension to building level has been realised with the tool in which the functional unit is a whole building of which the environmental impact of the sum of the amount of all elements is divided to the m² gross floor area of the building.

The final comparison using functional units must generally also be based on the technical performances of the building (element) and thus must include, among others, the related energy and acoustic performances. The main objective of this assessment method is, however, to compare the material- related environmental impact of various commonly used technical solutions. Consequently, such performances are not included in the definition of the functional unit. In order to be able to compare the building element variants regarding their energy performance on an equivalent basis (and so avoid a situation of less well-insulated variants having a more favourable material- related environmental profile), their influence on heating energy consumption is estimated separately using the equivalent degree-day method (see section 2.3.3).

2.2.2. SERVICE LIFE[5]

Specific requirements for the service life of the building are in most cases defined by the client. In the absence of such requirements, the general assessment method works with a standard assessment period of 60 years for homes, offices, schools and shops[6].
The average life expectancy of buildings is usually longer than 60 years, but it is assumed that after 60 years, the building will most likely be renovated so thoroughly that, apart from the structure, relatively few of the original materials will still be present[7]. Offices and shops are subject to major renovation even faster than dwellings, but the structural elements in principle tend to remain for at least 60 years, which explains why the same evaluation period is chosen.
The fact that offices and shops tend to be renovated more quickly is, however, taken into account by applying a (much) shorter service life for the non- structural elements (e.g. non-load-bearing interior walls) and all finishes (e.g. false ceilings, floor coverings). In the first version of the tool this distinction between different service lives of non-structural elements in relation to specific building functions is not yet taken into account.

5 In line with EN 15978:2011 §7.3

6 Based, among other things, on the service life used in conventional LCA tools.

7 The model assumes that materials are always replaced by the same material. The longer the assessment, the more this assumption and hence the results will differ from reality. The chances are high that materials at the end of their service life will not be replaced by identical materials (owing for example to changes in energy, acoustic or aesthetic requirements and to technical developments).

2.2.3. SYSTEM BOUNDARIES[8]

In the European standards (CEN 2011a, CEN 2013), the life cycle of a building is divided into several stages or modules (see Figure 4), each with clearly defined boundaries. The basic rule here is that an impact is assigned to the stage in which it occurs.

At times, the assessment method departs from these boundaries for practical reasons or else we have given our own interpretation owing to a lack of clarity or to contradictions in the standards. All additions, clarifications and departures with respect to these standards are set out below.

8 In line with EN 15978:2011 §7.4 and EN 15804:2013 §6.3.4

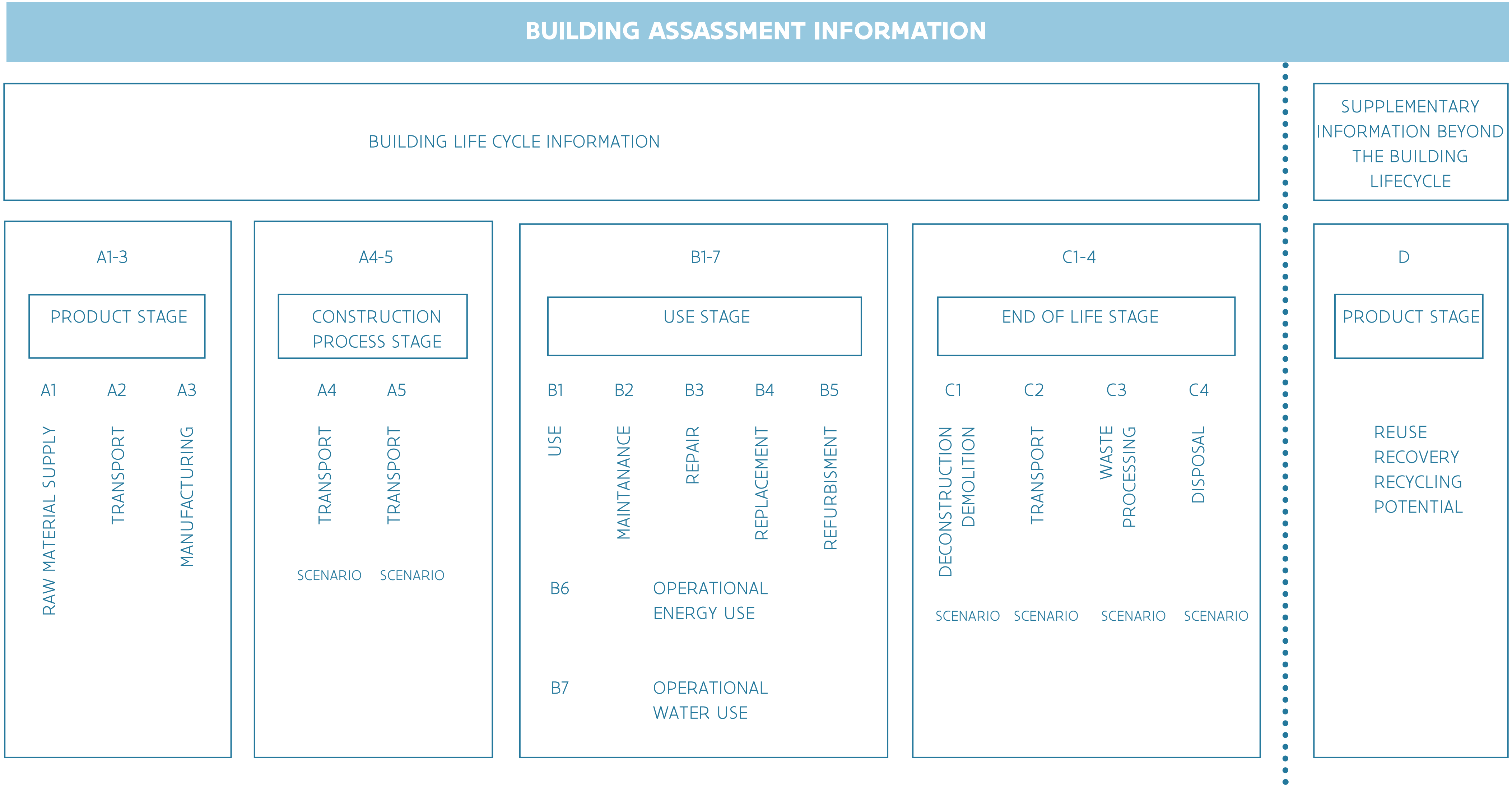

Figure 4: Overview of the life cycle stages and system boundaries within the European standard EN 15978:2011 (CEN 2011a)

2.2.3.1. PRODUCT STAGE (INFORMATION MODULES A1-A3)[9]

In principle, only the impact of the production of the packaging of the finished building product belongs to the product stage, while the disposal of the packaging falls in the construction process stage (where the impact occurs). In the generic LCI database that is used (i.e. ecoinvent v3.3), the disposal of packaging is included, however, in the production stage of the packaging-related material. This thought process was maintained in the construction of the generic LCI data for this project.

For certain raw materials where the import ratio is very significant, specific transportation scenarios have been established for the import of the raw materials to Belgium (see 2.3.1). The impact of the import scenarios is considered as transport to the manufacturer (Module A2) followed by a final manufacturing step (Module A3) and not as transport to the building site (Module A4). This assumption deviates from the Belgian national supplement to the EN 15804 (NBN 2017), hereinafter called 'BE-PCR', in which the conditions are determined for application of the EN 15804 in Belgium.

Reuse of existing building elements in a refurbishment project

Within the tool, it will be possible to indicate whether a work section already exists or is newly built. In case it is an existing work section, only the environmental impact linked with the use stage (Module B) and the end-of-life stage (Module C) will be taken into account for a new service life expectancy of 60 years (in future versions of the tool more complicated calculation options will be introduced including the environmental impact of demolition activities before new built). E.g. in case a work section is originally built in 1988 and the work section is being reused after a building refurbishment realised in 2018, only the environmental impact of the existing work section over a period of 60 years for cleaning, replacement and end-of-life activities is considered. The impacts due to production (Module A) will be zero for this specific work section.

9 According to EN 15804:2013 §6.2.2, the product stage includes raw material extraction and processing, processing of secondary material input (e.g. recycling processes), transport to the manufacturer and manufacturing, including provision of all materials, products and energy, as well as waste processing up to end-of-waste status or disposal of final residues during the product stage.

2.2.3.2. CONSTRUCTION PROCESS STAGE (INFORMATION MODULES A4-A5)[10]

The European standard EN 15978 § 7.4.3.1 states that the production-related impacts of capital goods (e.g. trucks) should be left out of consideration for the construction process stage (CEN 2011a). This provision is not reflected, however, in the standard at product level (EN 15804 § 6.3.4.3). Moreover, the latter explicitly states that all input and output processes for which data is available should be considered (see § 6.3.5) (CEN 2013). Consequently, the impact of capital goods are taken into account in this particular stage[11].

Transportation of building materials (A4)

While a certain proportion of material is lost during transport from the factory to the building site (Module A4), for practical reasons all material losses are imputed in their entirety to the construction stage (Module A5, in total 5% see also section 1.2.4). In the absence of data, the transportation of the construction equipment (cranes, concrete mixers, etc.) to the building site is left out of account.
In case of an existing work section that is being reused, no environmental impact will be considered for the transportation of the reused work section.

Building activities (A5)

In Module A5 it is mainly the waste at the building site itself that is taken into account (e.g. production, transportation and disposal of waste materials in the form of surpluses, trimmings, breakage, etc.) and only to a limited extent (if relevant) the impact of the construction activities as well (e.g. excavation and electricity consumed for cellulose blowing).
As mentioned earlier, for practical reasons the impact of the processing of materials packaging waste is not considered as part of the construction activities, but of the product stage.

10 According to EN 15804:2013 §6.2.3, the construction process stage includes transport of the building products to the building site and installation into the building, including provision of all materials, products and energy, as well as processing up to the end-of-waste state or disposal of residues during the construction process stage.

11 For the other stages, the standards do not explicity state whether the impact of the capital goods should or should not be considered. For this reason, the impact of capital goods is always included in the model als developed.

back to content

2.2.3.3. USE STAGE (INFORMATION MODULES B1-B7)[12]

Cleaning and planned servicing related to preventative and regular maintenance are included in Model B2. Corrective, responsive or reactive maintenance actions that should be considered in Module B3 are excluded, as these are related to user specific scenarios for which no general data are available.
Refurbishment activities (Module B5) are not included yet in the tool, but will be in future versions. In the expert calculation model module B5 is also excluded, given that the analysis in the expert calculation model is carried out for elements and that refurbishment activities by definition[13] relate to a significant portion of the building.
With regard to the modules concerning the normal operational activities of the building (B6-B7: operational energy and water use), for the analysis at element level only the heating energy consumption is considered to a limited extent (see section 2.3.3) and is indicated separately.

2.2.3.4. END-OF-LIFE STAGE (INFORMATION MODULES C1-C4)[14]

In the case of waste incineration with utilisation of energy, there are two possibilities:

A. The waste incineration does not fulfil the criteria for energy valorisation[15] (EU 2008): in this case the impact of the incineration process (including the processing and transport of waste to the incinerator) is assigned in full to the building (element) or work section considered in the analysis (module C). The energy produced by the waste incinerators is thus free in terms of environmental impacts and is not included in the calculation (because all impacts are borne by the building).

B. The waste incineration fulfils the criteria for energy valorisation[16] (EU 2008): in this case the impact of the incineration process falls outside the system boundaries. In other words, the impact is assigned to the energy produced and is therefore included in the energy mix.

In both cases, all the benefits of energy utilisation (i.e. the avoided impacts of e.g. the Belgian electricity mix or the production of heat from gas) are estimated in Module D. However, because of its voluntary nature, the still ongoing methodological discussion and developments regarding the formula within CEN, and the fact that it falls outside the system boundaries of the building, Module D has not yet been taken into account in MMG (CEN 2013, 2011a).

12 According to EN 15804:2013 §6.2.4, the use stage, related to the building fabric, includes the use or application of the installed product, its maintenance, repairs, replacement and refurbishment, including provision and transport of all materials, products and related energy and water use, as well as waste processing up to the end-of-waste state or disposal of final residues during this part of the use stage. Also all impacts and aspects related to losses during this part of the use stage are included. On the other hand, the use stage, related to the operation of the building, includes operational energy use (due to heating and other technical installations) and operational water use (sanitary warm water), including provision and transport of all materials, products, as well as energy and water provisions, waste processing up to the end-of-waste status or disposal of final residues during this part of the usage stage.

13 Cf. EN 15804:2012 §6.3.4.4.2: "B5-refurbishment: these activities cover a concerted programme of maintenance, repair and/or replacement activity, across a significant part or whole section of the building".

14 According to EN 15804:2013 §6.2.6, the end-of-life stage includes deconstruction and demolition of the building (element), transport to waste processing (either or not via a sorting plant), waste processing for reuse, recovery and/or recycling and disposal (incineration or landfill), including provision of all transport, provision of materials, products and related energy and water use.

15 According to EN 15804:2013 § 7.2.5, NOTE 4: waste incineration with utilisation of energy where the thermal energy efficiency rate is
≥ 0.60 for installations licensed before 1 January 2009,
≥ 0.65 for installations licensed after 31 December 2008.

16 Various interpretations are possible in case of waste incineration with utilisation of energy.

back to content

2.3. Scenarios for defining the building life cycle[17]

Within the environmental performance assessment of buildings or building elements, a number of scenarios (e.g. concerning transport) and, in certain cases, default values (e.g. concerning the service life of materials) need to be established. Scenarios that are specific to the present assessment method are given below. The actual values for the service life and for the type and frequency of cleaning and maintenance and replacement of materials and building elements are technical data that are established per individual building element, based mainly on a number of reference works (BCIS 2006; Jacobs et al. 2005; Ten Hagen & Stam 2000; SBR 1998; Perret 1995; den Hollander et al. 1993, Pasman et al. 1993; CSTC et al. 1991, BBRI et al. 2011).

2.3.1. SCENARIOS FOR THE PRODUCT STAGE[18]

Specific Belgian environmental product declarations (EPDs) from the Federal database[19] are not included yet in the first version of the tool and only generic LCI data can be used. In the first MMG study and expert calculation model ecoinvent 2.2 was used as a basis for the generic LCI data. For the recent update of the MMG assessment framework and the tool ecoinvent 3.3 is used. With ecoinvent 3, market and transformation processes were introduced. The difference between the two types of processes is that the market processes include inputs from production in several countries as well as inputs of transport processes. When a specific supplier is unknown, it is recommended to use the market processes. Therefore ecoinvent has comprised their transformation processes , which corresponds with data of the product stage (Module A1-A3), of market processes, e.g. the inputs of a transformation process of a building product consist of market processes of the raw materials used within the building product.

To make the generic LCI data more specific to the Belgian context, the following adaptations are made:
To ensure geographical representativeness, for the production of the materials in question we have consistently opted for transformation processes that are representative of Western Europe. Where no Western European[20] processes are available in the database, the energy (i.e. electricity, heat and certain fuels) and water (inputs as well as outputs) related material flows for production is replaced for the available processes by the European mix[21]. With 'production' is meant only the production that relates to the analysed product. The energy and water related flows in the underlying market processes (e.g. production of raw materials used in the production process) are not modified to the Western European version. A sensitivity analysis revealed that changing the electricity mix in the underlying processes has no significant influence on the results (Spirinckx 2009).

For certain raw materials where the import ratio is very significant, specific transportation scenarios have been established for the transportation of the raw materials to Belgium. Based on these scenarios, specific processes can then be created for the imported versions of these goods. This applies to the following products:

- Bluestone/natural stone plates from Asia (Delem & Spirinckx 2009):
  - 580 km transportation by heavy truck from quarry to port in Asia
  - 19500 km transportation by boat to the Port of Antwerp
- timber: In this case, average transport scenarios have been prepared for several large groups (see Table 1). These scenarios are based on the average transportation distances from the main countries of origin and their share on the Belgian market (cf. weighted average). Note that the number of kilometres is calculated per m^2 of sawn timber. For the portion of tropical timber transported as roundwood (logs), the necessary conversion factors have been applied (i.e. 2 m^2 roundwood for 1 m^2 of sawn timber) (Delem & Spirinckx 2009).

17 In line with EN 15978:2011 §8
18 In line with EN 15978:2011 §8.4
19 https://www.health.belgium.be/en/database-environmental-product-declarations-epd
20 We have opted for Western European processes because for most product groups no Belgian data is available and because a certain proportion of products on the Belgian market is imported with mainly only the last production process step in the production chain happening in Belgium. The latter is based upon an input-output analysis of the Belgian construction sector.
21 For energy consumption during the construction process stage (e.g. blowing of cellulose) and the use stage, we have, however, opted for specifically Belgian processes, e.g. Belgian electricity mix.
In the previous version of MMG with ecoinvent 2.2 LCI data, the transportation processes within the production processes were also replaced by a representative Western-European version. However with the introduction of market and transformation processes in ecoinvent 3 and by selecting the transformation process for the generic LCI data, the replacement of transportation processes is not needed anymore.

back to content

	Heavy truck (km)	Sea-going vessel (km)	River boat (km)	Train (km)
Hardwood: (42% local; 58% import)				
Local production[22]	125			
Imported tropical timber	350[23]	9900[24]	225	20
Imported non-tropical timber[25]	1280	1010	/	/
Belgian Mix[26]	360	2100	45	40
Softwood: (60% local, 40% import)				
Local production	50			
Imported softwood[27]	740	1400	/	130
Belgan mix	450	830		75

Table 1: Transportation scenarios for different groups of wood

Finally within the first MMG study, for a limited number of products containing a portion of secondary raw materials (steel, glass wool, cellular glass, cellulose, MDF, OSB, concrete and others), it was examined whether the percentage of secondary raw materials adopted on a default basis in the ecoinvent processes differs from Belgian practice. Also the check was made whether the system boundaries and allocation rules for recycling and co-products applied in the ecoinvent LCI data are consistent with the principles of EN 15804 (at that time still version of 2012) and the MMG assessment method established.

On this basis, it was decided to adapt the product data for concrete to Belgian practice. In the ecoinvent database, concrete is produced from CEM I cement. In Belgium, however, furnace cement (CEM III A) is commonly used for poured concrete. Therefore, for poured concrete, in the standard Ecoinvent process CEM I is replaced for 10% by CEM III B and 55% by CEM III A[28]. For precast concrete products the default ecoinvent process is used (CEM 1-based concrete), because furnace cement is rarely used for this application (due to the need for rapid stripping of precast products from their formwork).

22 Transportation from forest to sawmill
23 Transport from forest to foreign port
24 Weighted average transportation distance from foreign ports to Port of Antwerp
25 Is partly by truck and partly by truck and boat (including truck transport to the port)

26 Average transport based on share of different countries of origin (including local production) on the Belgian market
27 Transport from forest in foreign country to distributor in Belgium
28 Sales of furnace cement in Belgium = 2302 kt., deliveries for ready-mixed concrete+deliveries to construction sites+in the trade = 3522 kt. 2302/3522=0.65 (Febelcem 2008)

back to content

2.3.2. SCENARIOS FOR THE CONSTRUCTION PROCESS STAGE[29]

The construction process stage mainly consists in the transportation of building materials from factory to building site, as well as a standard % of construction waste that is produced on the building site. A limited number of construction activities (e.g. excavation, energy related processes, and specific emissions at the construction site) are included in Module A5.

2.3.2.1. SCENARIO FOR THE TRANSPORTATION OF BUILDING MATERIALS FROM FACTORY TO BUILDING SITE

Means of transport and distances
For the transportation of construction materials from factory to building site a specific transportation scenario has been constructed by major product groups (see Table 3). For each product group or material category, average transport distances and means of transport have been determined according to whether the product is taken directly from the factory to the site, or from the factory to an intermediate building merchant and from there to the building site. The figures are based on the default transport scenarios of the BE-PCR (NBN 2017).

Load factor
For the calculation of the environmental impacts associated with the transportation of materials or waste, we have used the default LCI data from ecoinvent 3.3. The LCI data in ecoinvent are given per tkm for different vehicle types (LCI data for carrying 1 tonne over a distance of 1 km with a particular vehicle) and were calculated based on average European load factors (see Table 2).

Lorry size class	Average load factor (tonnes)	Gross vehicle weight (tonnes)
3.5-7.5 tonnes	0.98	4.98
7.5-16 tonnes	3.29	9.29
16-32 tonnes	5.79	15.79
>32 tonnes	15.96	29.96

Table 2: Load factors and gross vehicle weights taken for calculating the environmental impact per tonne-kilometre for different means of transportation (ecoinvent 2016)

29 In line with EN 15978:2011 §8.5

product group/material category	Arrangement of transportation		Means of transportation from							Average transport distance of transportation from		
	% directly from factory to site	% via an intermediary supplier	factory to site			factory to supplier	supplier to site			factory to site	factory to supplier	supplier to site
			Lorry 16-32 ton (EURO 5)	Lorry 7.5-16 ton (EURO 5)	Lorry 3.5-7.5 ton (EURO 5)	Lorry >32 ton (EURO 5)	Lorry 16-32 ton (EURO 5)	Lorry 7.5-16 ton (EURO 5)	Lorry 3.5-7.5 ton (EURO 5)	km	km	km
bulk materials for structural work (e.g. cement, sand, gravel, ...)	75%	25%	100%	0%	0%	100%	90%	10%	0%	100	100	35
poured concrete	100%	0%	100%	0%	0%	n/a	n/a	n/a	n/a	100	100	35
prefabricated products for structural work (e.g. beams, columns, ...)	100%	0%	100%	0%	0%	100%	100%	0%	0%	100	100	35
loose products (e.g. blocks, bricks, roof tiles, plasterboard, ...)	40%	60%	100%	0%	0%	100%	85%	15%	0%	100	100	35
insulation	40%	60%	100%	0%	0%	100%	85%	15%	0%	100	100	35
finishing products: floor coverings (e.g. carpet, linoleum, ceramic tiles, ...)	10%	90%	90%	10%	0%	100%	90%	10%	0%	100	100	35
finishing products: plasters (e.g. gypsum plaster, external plaster, ...)	40%	60%	50%	50%	0%	100%	50%	50%	0%	100	100	35
finishing products: cabinet work (e.g. window frames, stairs, ...)	90%	10%	50%	45%	5%	100%	40%	50%	10%	100	100	35
finishing products: paints and varnishes	10%	90%	0%	100%	0%	100%	0%	80%	20%	100	100	35
installations (e.g. heating boiler, radiators, ventilation, ...)	0%	100%	n/a	n/a	n/a	100%	0%	80%	20%	100	100	35

Table 3: General scenario for the transportation of building materials from factory to building site (NBN 2017).

2.3.2.2. SCENARIO REGARDING THE LOSS OF MATERIAL DURING THE CONSTRUCTION PROCESS STAGE[30]

During the construction process stage a portion of the materials is always lost (e.g. during storage or cutting to size). The extent of the loss is, however, largely dependent on the nature of the construction (e.g. size, type or how far it is designed with standard sizes), the product group (e.g. materials with limited service life, custom manufactured materials or materials needing to be cut to size on-site), the care with which materials are handled, etc.[31]. In the absence of detailed data for each material and each application, but also for practical reasons, a global add-on of 5% has been applied in the model regardless of product group.

2.3.3. SCENARIOS FOR OPERATIONAL ENERGY USE DURING THE USE STAGE[32]

For the analysis at element level, only the operational energy use for heating due to transmission losses is taken into account. This is calculated using the equivalent degree-day method, based on the following formula and assumptions:

yearly environmental impact due to transmission losses on element level=

$$U_{EL} \times A_{EL} \times DD_{eq} \div (\eta_{distribution} \times \eta_{emission} \times \eta_{control}) \times EI_{heating}$$

With:

- U_{EL} = the u-value of an element, calculated by taking the inverse of the sum of R-values of the work sections within the element, the surface interior (Rsi) and surface exterior (Rse) (Belgisch Staatsblad 2010);
- A_{EL} = the surface area of the element;
- DD_{eq} = 1200 equivalent degree-days[33] (Allacker 2010) multiplied with ((24*60*60)/106) to convert days into seconds and joules into mega joules;
- $\eta_{distribution}$ = a distribution efficiency of 0.95, based on a distribution length between 2 and 20 m of an individual central heating system (VEA 2013);
- $\eta_{emission}$ = an emission efficiency of 0.96, based on a situation in which radiators and floor heating is used for heat emission (VEA 2013);
- $\eta_{control}$ = a control efficiency of 0.94, based on a heating control system with a room thermostat, thermostatic valves and no outdoor temperature sensor (VEA 2013);
- $EI_{heating}$ = the environmental impact of heating produced by a condensing modulating natural gas boiler (<100 kW) with a production efficiency (with reference to the lower heating value) of 102% (Villigen and Uster 2007).

For the electricity consumption of the condensing modulating natural gas boiler, the Belgian electricity mix is used (i.e. ecoinvent process: “Electricity, low voltage {BE}| market for | Alloc Rec, U”). Ecoinvent does not offer any Belgian process for natural gas from a low pressure distribution network, but this is construed by taking the available Swiss process “Natural gas, low pressure {CH}| market for | Alloc Rec, U”, and replacing the underlying Swiss processes by Belgian processes (some of which are original ecoinvent processes representative for Belgium and some are adapted Swiss ones made more specifically for the Belgian region[34]).

2.3.4. SCENARIO REGARDING THE END-OF-LIFE STAGE OF BUILDING MATERIALS

2.3.4.1. SCENARIO FOR DECONSTRUCTION AND DEMOLITION

Given that deconstruction often consists exclusively of manual operations, there are no environmental impacts attributed to the non-destructive removal of building materials. The composition of the materials and the method of connecting with other materials/work sections determined the type of demolition process which could also lead to no environmental impacts (Doka 2009).

30 In line with EN 15978:2011 §9.3.1.
31 Depending on the type of building and construction materials, the weight percentage of the quantities purchased per project usually varies between 1 and 10% (FVSB 1997).
32 In line with EN 15978:2011 §8.6.5.
33 The lower the K-value of a building, the lower the number of equivalent degree-days. 1200 equivalent degree-days correspond to a well-insulated dwelling and an average indoor temperature of 18°C.
34 {CH} stands for processes that are representative of Switzerland, {BE} for processes that are representative of Belgium.
35 In line with EN 15978:2011 §8.7.

2.3.4.2. BASIS FOR THE TRANSPORTATION AND FINAL DISPOSAL OF CONSTRUCTION AND DEMOLITION WASTE

With the exception of soil, all construction and demolition waste, whether or not sorted on site, is transported from the construction/demolition site to a sorting facility/ collection point (e.g. metal dealer or crusher) and from there it is eventually further dispatched to recycling, reuse facility, incineration, energy recovery or landfill. This assumption and the end-of-life scenarios per waste type as given in Table 4 are based on the BE-PCR (NBN 2017).

For materials that go on to be recycled, the boundary between the current life cycle and the next life cycle (i.e. material incorporating secondary raw materials) corresponds to the point where the materials are considered no longer as waste but as a secondary raw material (i.e. where the end-of-waste status reached)[36]. For all materials that are recycled or reused, the default assumption is that the "end-of-waste" status is attained at the exit gate of the sorting facility or collection point. The fact is that based on the available information, the precise point at which waste turns into secondary raw materials is difficult to determine for each separate product. The consequence of this assumption is that the impact up to and including the sorting facility (or for the stony fraction up to and including the crusher) is allocated to the waste producing product, but that all subsequent impacts (i.e. of transportation from the sorting facility to the recycling facility and the impact of the recycling process itself) for these fractions lie outside the system boundaries and are therefore allocated to the material for which the secondary materials are used[37]. The environmental impact of sorting on the site is neglected. Based on the BE-PCR, the following processes are taken into account when modelling the sorting of materials in a sorting facility (i.e. the fraction not sorted on the site itself):

- Electricity use (Belgian low voltage electricity mix) for mechanical sorting processes:
  - Sorting plant without a crusher: 0.0022 kWh/kg material (for materials sorted out prior to the crusher (e.g. mineral wool ,boards, ...) or causing no resistance in crushing (e.g. paints);
  - Sorting plant with a crusher: 0.0037 kWh/kg material (e.g. concrete materials);
- Diesel for loading and unloading waste: 5.9 MJ diesel burned in a hydraulic digger/ m3 bulk volume of waste[38]
- Sorting plant infrastructure including land occupation and transformation and energy for administrative facilities: 1 x 10^{-10} plant/kg material (NBN 2017).

Given that fuel consumption for loading and unloading depends on the density of the material, a different sorting process is modelled per waste type.
The general modelling of the waste processing stage (after demolition or dismantling for replacement) is shown schematically in Figure 5. By way of illustration, in Figure 6, Figure 7 and Figure 8 we also give the specific modelling for concrete, metals and aerated autoclaved concrete.

36 In line with EN 15804 §6.3.4.5.
37 An advantage here is that the chosen system boundaries match those used in putting together the ecoinvent database. This avoids the risk of double counting or failing to factor in certain impacts.
38 As an approximation, the bulk density of waste can be calculated as 0.9 x material density.

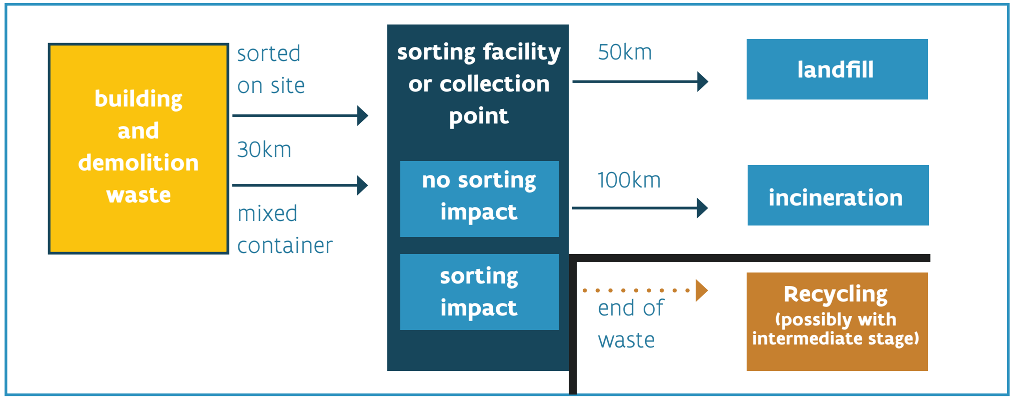

Figure 5: General modelling of waste processing after deconstruction or demolition. Impacts falling within the system boundaries are shown in blue and impacts outside the system boundaries are shown in orange.

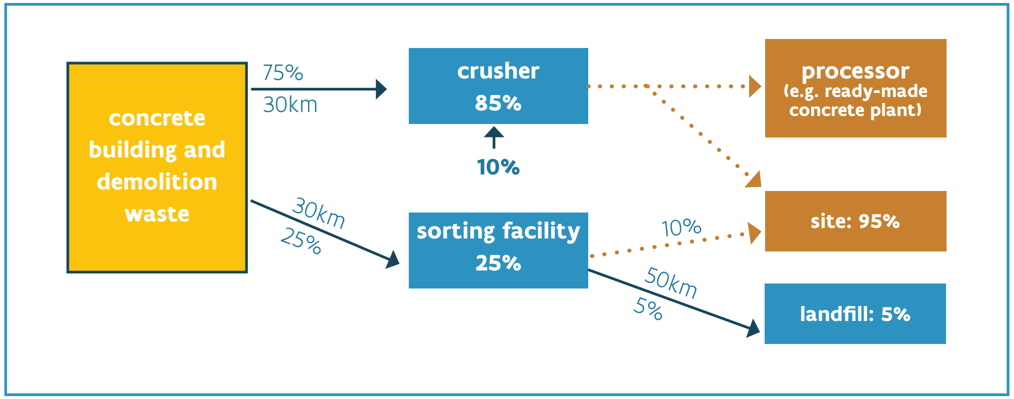

Figure 6: Specific modelling for concrete construction and demolition waste.
75% of concrete waste is sorted on site and then goes directly to a crusher, while the remaining 25% goes to a sorting facility. 10% of the inert waste that passes via a sorting facility, after sorting goes directly to a building site or a processor (sieve sand), but 10% still needs to be crushed after the sorting process for use as a secondary raw material. Transportation between crusher and sorting facility in principle lies within the system boundaries, but is, however, neglected. In practice, some sorting facilities crush the rubble themselves (using their own or a mobile crusher). In this way transportation between crusher and sorting facility is relatively limited (also in distance) (Jacobs et al 2005). Impacts falling within the system boundaries are shown in blue and impacts outside the system boundaries are shown in orange.

back to content

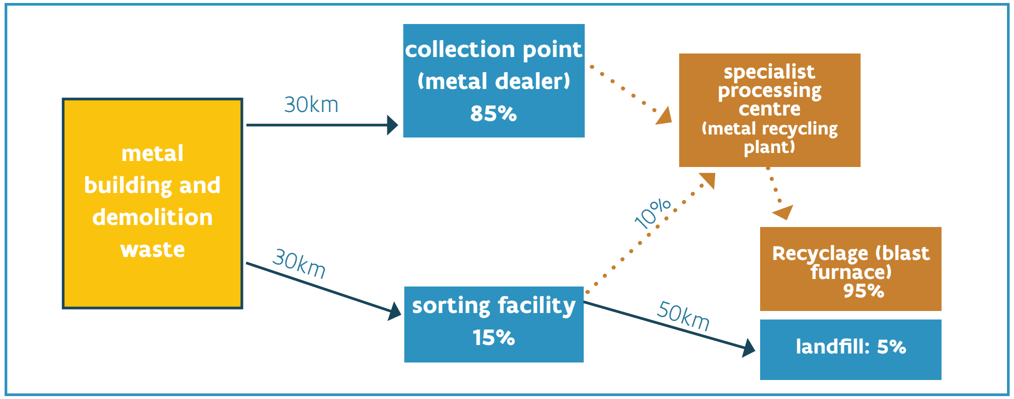

Figure 7: Specific modelling for metallic building and demolition waste.
85% of the metal waste is sorted on the building site and 15% is mechanically sorted in a sorting facility. While in reality the end-of-waste status should probably be situated on the far side of the specialised processing centre, by convention it is located at the gate of the collection point or sorting facility. Note that part of the 85% sorted on the building site may still end up passing through a sorting facility. But since in this case there is no further need for mechanical sorting, for the sake of clarity it is classified under ' collection point'.

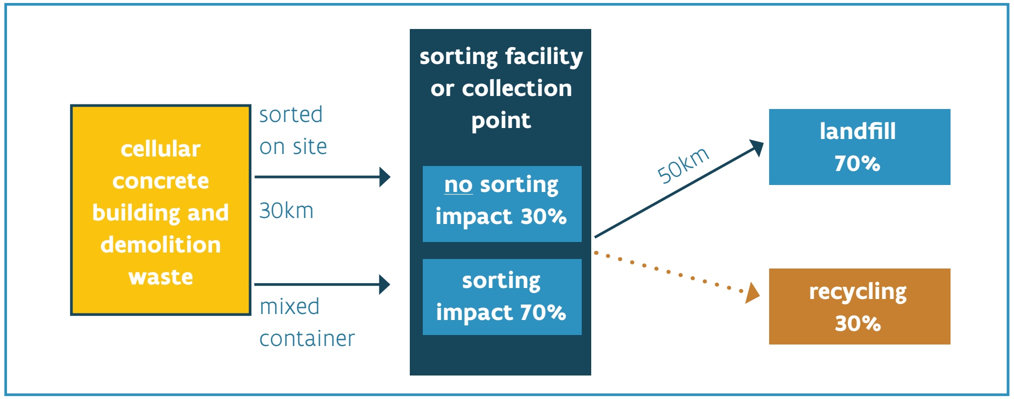

Figure 8: Specific modelling for aerated autoclaved concrete waste from construction and demolition activities. 30% of the aerated autoclaved concrete waste is sorted directly on the building site, while the rest is mechanically sorted in a sorting facility. For the portion sorted on the building site, the collection point can be a sorting facility or a storage site, where the contractor groups his waste and then takes it directly to the recycling facility. While in reality, the end-of-waste status ought to be attained at the latter facility, by convention it is located at the gate of the sorting facility (or collection point).

In the absence of clear data on the efficiency of Belgian incinerators and in the spirit of the principles of the European Waste Framework Directive (EU 2008), it is assumed by convention that the impact of the incineration of construction and demolition waste falls within the considered system boundaries.
Consequently, the environmental damage is assigned entirely to the material incinerated and not to the energy produced.

2.3.4.3. TRANSPORTATION OF CONSTRUCTION AND DEMOLITION WASTE

Based on the BE-PCR, the following default scenario is used for the transportation of construction and demolition waste:

Transportation distances:

- From demolition site to sorting facility or collection point: 30 km
- From collection point or sorting facility to landfill: 50 km
- From collection point or sorting facility to incinerator: 100 km

Means of transport:
100% with lorry 16-32 ton (EURO 5)

2.3.4.4. FINAL PROCESSING OF CONSTRUCTION AND DEMOLITION WASTE

Table 4 gives the assumed destination, as well as the proportion of waste sorted directly at the building site (% by weight) of the 37 different waste categories which are considered in MMG, based on the default end-of-life scenarios of the BE-PCR (NBN 2017).

Product group / Waste category	Description	Landfill (%)	Incineration[39] (%)	Reuse (%)	Recycling (%)	sorted on building site[40] (%)
Stony & glass	Bricks, roof tiles	5%	0%	0%	95%	75%
	Bulk materials (e.g. sand, gravel, expanded clay grains)	5%	0%	95%	0%	90%
	Concrete	5%	0%	0%	95%	75%
	Flat glass	5%	0%	0%	95%	70%
	Other stony waste (e.g. tiles, natural stone, slates, sand-lime blocks)	5%	0%	0%	95%	75%
	Porcelain and ceramics (e.g. toilet, bath, washbasin)	15%	0%	0%	85%	75%
Wood	Chemically treated, impregnated wood (e.g. railway sleepers, wood used for carports, outdoor playsets, garden screens)	0%	100%	0%	0%	40%
	Composite wood products (e.g. fibreboards (like plywood, chipboard, OSB, MDF), veneer, laminate)	0%	95%	0%	5%	40%
	Surface treated, solid wood (e.g. painted or varnished (like window frames, solid parquet))	0%	85%	0%	15%	40%
	Untreated, uncontaminated wood (e.g. roofs, structures, formworks, auxiliary timber)	0%	25%	0%	75%	40%
Metals	Metals: iron, steel, non-ferro (copper, brass, aluminium, lead, zinc, tin)	5%	0%	0%	95%	85%
Packaging (on construction site)[41]	EPS packaging	10%	30%	0%	60%	50%
	Pallets	0%	40%	20%	40%	50%
	Paper and cardboard packaging	0%	5%	0%	95%	50%
	Plastic films packaging	5%	60%	0%	35%	50%
Insulation materials	Mineral insulation materials (e.g. stone wool, glass wool)	50%	50%	0%	0%	0%
	Organic insulation materials (e.g. vegetable fibres (like wood, coconut, hemp, flax), cellulose (in bulk or blankets), sheep wool, cork (in bulk or boards))	5%	95%	0%	0%	0%
	Synthetic insulation materials (e.g. polyurethane (PUR), polyisocyanurate (PIR), extruded polystyrene (XPS), phenolic foam, expanded polystyrene (EPS))	5%	95%	0%	0%	0%
Fibre cement products	Fibre cement products (e.g. fibre cement slabs or slates)	100%	0%	0%	0%	75%

39 Destination of the waste by product group (% by weight calculated on the total amount of waste per product group: e.g. 5% of brick waste is landfilled and 95% is recycled).

40 This represents the percentage (by mass) of the waste that is sorted directly at the building site. The remaining share is removed from the construction/demolition site in a mixed container and subsequently mechanically sorted (at sorting facility), e.g. 30% of aircrete waste is sorted directly on site and 70% is removed, mixed in with other wastes.

41 As already mentioned, the waste processing of packaging is already included in the 'cradle to gate' ecoinvent processes (see 2.2.3.1). For practical reasons, the standard ecoinvent waste scenario for packaging will be used, namely 100% incineration.

Product group / Waste category	Description	Landfill (%)	Incineration[42] (%)	Reuse (%)	Recycling (%)	sorted on building site[43] (%)
Gypsum elements	Gypsum elements (e.g. gypsum blocks, gypsum (fibre/plaster)boards)	80%	0%	0%	20%	50%
Aerated / cellular concrete	Aerated autoclaved concrete (e.g. elements, blocks)	70%	0%	0%	30%	30%
Bitumen	Bitumen (e.g. bituminous roofing, vapour barrier, waterproofing membrane)	85%	5%	0%	10%	0%
Polyolefins (PP, PE)	Polyolefins (PP, PE) (e.g. kraft paper or polyethylene (PE) vapour barrier, ducts), excluding packaging	10%	85%	0%	5%	0%
Elastomers	Elastomers (e.g. EPDM roofing)	90%	0%	0%	10%	0%
PVC	PVC cabling (e.g. electric cables and wire insulation)	10%	40%	0%	50%	0%
	PVC pipes (e.g. for sewerage)[44]	10%	30%	0%	50%	0%
	PVC profiles (e.g. window frames)	10%	45%	0%	45%	0%
	PVC sheets (e.g. PVC roofing, waterproofing membranes (like for swimming pools))	20%	65%	0%	15%	0%
Supple flooring	Supple flooring (e.g. linoleum, fixed carpet, vinyl)	0%	95%	0%	5%	0%
Finishing layers[45]	Finishing layer fixed to stony waste (e.g. plaster (like gypsum plaster, calcareous plaster, loam plaster), paint, coatings, adhesives)	5%	0%	0%	95%[46]	0%
	Finishing layer fixed to wood, plastic or metal (e.g. paint, coatings, adhesives)	0%	100%[47]	0%	0%	0%
Remaining waste	Combustible remaining waste	0%	100%	0%	0%	0%
	Non-combustible remaining waste	100%	0%	0%	0%	75%
Other hazardous waste	Aerosols and kits (e.g. PU foam, silicones)	0%	100%	0%	0%	100%
	Asbestos (bounded, unbounded)	100%	0%	0%	0%	100%
	Fluorescent lamps	30%	0%	0%	70%	100%
	Liquid construction site waste (e.g. paints, adhesives, resins, form mould oil, white spirit)	0%	75%	0%	25%	100%

Table 4 Waste scenarios for the 37 waste categories considered in MMG based on the BE-PCR (NBN 2017).

42 Destination of the waste by product group (% by weight calculated on the total amount of waste per product group: e.g. 5% of brick waste is landfilled and 95% is recycled).
43 This represents the percentage (by mass) of the waste that is sorted directly at the building site. The remaining share is removed from the construction/demolition site in a mixed container and subsequently mechanically sorted (at sorting facility), e.g. 30% of aircrete waste is sorted directly on site and 70% is removed, mixed in with other wastes.
44 10% remains in the ground, which is why the columns does not sum to 100%
45 Regards a relative small amount of material that is fixed to other materials.
46 The finishing layer follows the same route as its carrier (e.g. concrete, brick). Thus the finishing layer will be recycled together with the debris when the carrier is crushed into granulates (open loop recycling). It needs to be mentioned that gypsum plaster is a hampering substance which decreases the quality of the stony fraction (cf BE-PCR).
47 The finishing layer follows the same route as its carrier. A finishing layer on wood will end up with the powder fraction of the crushed wood, which will be incinerated. Recycling of metals happens at high temperatures so in practice the finishing layer is also incinerated (cf BE-PCR).

back to content

2.4. Life Cycle Inventory

2.4.1. REPLACEMENTS[48]

When the service life of work sections is shorter than that of the building in which they are used, replacements will be necessary in order to guarantee the technical and functional performance of the building. The number of replacements of a work section over the service life of the building is obtained by dividing the service life of the building by the service life of the work section and reducing this result by 1 (the initial installation). Where the result is an integer, this is the number of replacements of the work section. For example, for a window with a service life of 20 years and a building with a service life of 60 years, the number of replacements is equal to (60/20)-1, which corresponds to 2 replacements (at year 20 and year 40).

It can also happen, however, that the result of this calculation is not an integer. For example, if the service life of the window is 25 years instead of 20. The number of replacements becomes (60/25)-1=1.4. In this case, there are two possible approaches: either the window is replaced after 25 years and after 50 years or it can be assumed that the owner will no longer replace the windows after 50 years because this is too close to the end of the service life of the building for such a (large) investment.

To ensure an unambiguous approach, the concept of "suspension period" is introduced. In this example one could use the rule: since the new window incorporated at year 50 can only be used during 10 years (till the end of the service life of the building) the window will not be replaced. The suspension period is in this example the number of years before the end of life of the building in which the replacement will not be done. By definition it is a period shorter than the expected lifetime of the window. The suspension period is 1 if for safety or comfort reasons the replacement needs to been done, meaning that even if the remaining expected service life of the building is one year, the window will be replaced.

This principle of suspension period is applied in a hierarchical way:

- How long before the end of life of a building, "elements" will still be replaced;
- How long before the end of life of an element, "work sections" will still be replaced;
- How long before the end of life of a "work section", a "big maintenance" will still be organised ("Big maintenance" will never happen the year of the end of the life of a "work section".);
- How long before the organisation of a big maintenance, a "small maintenance" will still be organised ("Small maintenance" will never happen a year when a "big maintenance" is done or at the end of life of a "work section".).

2.4.2. DATA COLLECTION[49]

2.4.2.1. DATA QUALITY AND DATA SOURCES[50]

In the absence of specific product data (e.g. Belgian EPDs), generic data is taken mainly from the Swiss ecoinvent database version 3.3. This choice was based on the following criteria:

- Completeness: over 13.300 LCI datasets, i.e. processes, available including various building materials.
- Transparency: for all data in the database, detailed reports are available with all necessary background information.
- Adaptability/modularity: underlying processes are almost always visible (e.g. electricity use for production) and can be adjusted as desired. Furthermore, the LCI data for production (cradle to gate), transportation and waste processing all exist separately in the database, so that processes can be combined according to scenarios that are representative of the Belgian context.
- Reliability: data are all checked before being entered in the database.
- Availability of information relating to the uncertainty of the data.
- Regularly updated (version 3.3 was released on 15 August 2016).

48 In line with EN 15978:2011 §9.3.3
49 In line with EN 15978:2011 §9.4
50 In line with EN 15978:2011 §9.4.2, EN 15804: 2013 §6.3.7 and TR 15941:2010

back to content

- Availability of data representative of Western Europe and Belgium: the ecoinvent database mainly contains data representative of Western Europe or Switzerland, and some specific Belgian processes (e.g. electricity mix). Where only Swiss data are available, the non-aggregated data can be relatively easily adapted to the Belgian context (see section 2.3.1).

In accordance with EN 15804 § 6.3.7 regarding data quality requirements, the time period over which MMG assesses the environmental impacts is 100 years. However, the standard also states that "a longer time period shall be used if relevant". MMG deviates from this latter point, as the relevance of a longer time period is not the same for all processes and impact categories. Therefore all long term emissions have been excluded within MMG for the transparency and not to further complicate the calculations.

2.5. Life cycle impact assessment[51]

During the life cycle impact assessment (LCIA) of an LCA, the significance of potential environmental impacts is assessed based on the results of the life cycle inventory analysis (LCI). For this, the inventory data are associated with specific environmental impacts. In this way, the overall environmental impact of a building (element) is given on the basis of an environmental profile.

2.5.1. SELECTION PROCEDURE

Determining the particular environmental profile calls for a substantiated selection of both the environmental impact indicators and the associated impact assessment methodologies. The selection of environmental indicators is based on the recommendations found in the CEN/TC 350 standards (CEN 2013, 2011a) and TR (CEN 2016), their presence in the International Reference Life Cycle Data System (ILCD) Handbook (JRC 2011), and the PEF guide (EC 2013).
In accordance with ISO 14040 and 14044 standards (ISO 2006a, 2006b), an assessment method is assigned to each environmental indicator. The selection of these is again based on the CEN/TC 350 standards and TR (CEN 2013, 2011a, 2016), the PEF Guide (EU 2013) and the ILCD Handbook (JRC 2011). For certain categories (see section 2.5.2.1), the CEN/TC 350 standards recommend a particular indicator. For this reason the PEF Guide or ILCD recommendations cannot always serve as a basis.
Besides single environmental impact scores, the environmental impact is also communicated, at the request of the 3 regional authorities, in the form of an aggregated environmental impact score. As explained further in this chapter, the weighting is undertaken based on monetary valuation. Given that the assigning of shadow prices to environmental impacts depends on the indicators used, this influences the choice of the impact method for a selected impact category. With the most recent MMG updates of the selection of impact categories, only the impact methods regarding biodiversity is different for the single environmental score and for the aggregated score. For all the other impact categories the impact methods are the same for the single and aggregated scores.

In the following paragraphs we set out in greater depth the selection process at both score levels.

The 3 regional authorities and the other authors of this study warn for any standard changes or recommendations that would be in force after writing this publication (February 2018).

51 In line with EN 15978:2011 §11

2.5.2. ASSESSMENT OF INDIVIDUAL ENVIRONMENTAL IMPACT SCORES

The environmental impact indicators chosen in the CEN/TC 350 standards at product and building level (CEN 2013, 2011a) form the starting point for the selection of environmental indicators in the present project. We are concerned here more specifically with the following categories:

- global warming;
- ozone depletion;
- acidification for soil and water;
- eutrophication;
- photochemical ozone creation;
- depletion of abiotic resources: elements and fossil fuels.

Further indicators are proposed in the CEN/TC 350 standards, but these are not applied in this assessment method, as they reflect inventory data (e.g. kg of hazardous waste) rather than environmental impact. On the other hand, with regard to the environmental impact categories, these standards include only categories for which sufficient consensus exists for standardisation (CEN 2011b). Based on the availability of evidence-based impact methods according to the ILCD Handbook (JRC 2010) and the PEF Guide (EC 2013), and taking into account the Federal Programme on Environmental Product Declarations (EPDs), we have opted for the following additional environmental indicators:

- human toxicity: cancer and non-cancer effects;
- particulate matter;
- ionising radiation: human health effects;
- ecotoxicity: freshwater;
- water resource depletion;
- land use: occupation and transformation (soil organic matter and biodiversity).

2.5.2.1. CEN SET OF ENVIRONMENTAL INDICATORS

On the basis of the above-described selection procedure (see section 2.5.1) it was decided to include all the environmental impact categories included by the CEN/TC 350 working group in the MMG assessment method. On the one hand, the necessary scientific basis exists to arrive at reliable LCIA results; on the other hand, all impact categories are deemed important by the policy bodies involved. An overview of the selected CEN environmental indicators and the associated units and environmental impact methods is given in Table 5.

environmental indicator (CEN)	unit	selected impact method
Global warming	kg CO_2 eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Ozone depletion	kg CFC^{-11} eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Acidification for soil and water	kg SO_2 eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Eutrophication	kg $(PO4)^{3-}$ eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Photochemical ozone creation	kg ethene eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Depletion of abiotic resources: elements	kg Sb* eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Depletion of abiotic resources: fossil fuels	MJ, net calorific value	EN 15804+A1 (as used in CML version oct. 2012)

Table 5: Selected CEN environmental indicators including the units and environmental impact methods for individual environmental scores.

* *Sb: antimony*

2.5.2.2. CEN+ SET: ADDITIONAL ENVIRONMENTAL INDICATORS

In addition to the seven CEN impact categories, at the request of the 3 regional authorities, a number of additional environmental indicators are analysed and reported in the MMG project.

Based on the selection process described above, all environmental indicators are selected. An overview of the selected additional environmental impact categories (CEN+) and the associated units and environmental impact methods is given in Table 6.

environmental indicator (CEN+)	unit	selected impact method	in line with
Human toxicity, cancer effects	CTUh	Rosenbaum et al., 2008 (as used in USEtox)	PEF
Human toxicity, non-cancer effects	CTUh	Rosenbaum et al., 2008 (as used in USEtox)	PEF
Particulate matter	kg PM2.5 eq	Rabl & Spandaro, 2004 (RiskPoll)	PEF
Ionising radiation, human health effects	kg U235 eq	Frischknecht et al, 2000 (as used in ReCiPe midpoint)	ILCD
Ecotoxicity: freshwater	CTUe	Rosenbaum et al., 2008 (as used in USEtox)	PEF
Water resource depletion	m3 water eq	Frischknecht et al., 2008 (as used in Swiss Ecoscarcity 2006)	PEF
Land use occupation: soil organic matter	kg C deficit	Milà i Canals et al., 2007 (Soil Organic Matter)	PEF
Land use occupation: biodiversity	PDF* m^2yr	Köllner, 2000 (as used in Eco-Indicator 99)	- [52]
Land use transformation: soil organic matter	kg C deficit	Milà i Canals et al., 2007 (Soil Organic Matter)	PEF
Land use transformation: biodiversity	PDF*m^2	Köllner, 2000 (as used in Eco-Indicator 99)	- [53]

Table 6: Selected CEN+ environmental indicators including the units and environmental impact methods for individual environmental scores.

52 Biodiversity impacts related to land use are not taken into account in the PEF. However, due to its importance in the built environment, the Köllner 2000 model as used in Eco-Indicator 99 (in PDFm^2yr and PDF*m^2) is proposed as a best proxy to take into account biodiversity impacts related to land use for the individual environmental scores.*

53 idem

2.5.3. ASSESSMENT OF THE AGGREGATED ENVIRONMENTAL SCORE

The intention of assessing the environmental material performances of buildings, that is to simplify the identification and selection of environmentally friendly materials and work sections, calls for an unambiguous decision model. A multiplicity of individual impact scores is rarely a good basis for decision-making. For this reason and at the request of the 3 regional authorities, the possibility is offered of viewing the environmental profile of a building (element) via an aggregated score. Given that the European standards do not recommend any one aggregation method, a weighting is proposed by means of monetary valuation, i.e. the indicator is multiplied by the monetisation factor (e.g. X kg CO_2 equiv. times Y € /kg CO_2 equiv.). These euro figures express the environmental damage that is not calculated into the price, but which is passed on to society through, for example, sickness and damage to biodiversity. These environmental costs can then be compared with the respective financial costs. This offers significant added value compared with other weighting methods, such as the panel method, the distance-to-target method and damage methods (Allacker 2010, van den Dobbelsteen 2004).

Below we summarize the impact methods and the corresponding units selected for the CEN and CEN+ environmental indicators (see Table 7 and Table 8).

environmental indicator (CEN)	unit	selected impact method
Global warming	kg CO_2 eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Ozone depletion	kg CFC^{-11} eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Acidification for soil and water	kg SO_2 eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Eutrophication	kg $(PO4)^{3-}$ eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Photochemical ozone creation	kg ethene eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Depletion of abiotic resources: elements	kg Sb* eqv.	EN 15804+A1 (as used in CML version oct. 2012)
Depletion of abiotic resources: fossil fuels	MJ, net calorific value	EN 15804+A1 (as used in CML version oct. 2012)

Table 7: Selected CEN environmental indicators including the units and environmental impact methods for the aggregated environmental score.

**Sb: antimony*

environmental indicator (CEN+)	unit	selected impact method
Human toxicity, cancer effects	CTUh	Rosenbaum et al., 2008 (as used in USEtox)
Human toxicity, non-cancer effects	CTUh	Rosenbaum et al., 2008 (as used in USEtox)
Particulate matter	kg PM2.5 eq	Rabl & Spandaro, 2004 (RiskPoll)
Ionising radiation, human health effects	kg U235 eq	Frischknecht et al, 2000 (as used in ReCiPe midpoint)
Ecotoxicity: fresh water	CTUe	Rosenbaum et al., 2008 (as used in USEtox)
Water resource depletion	m^3 water eq	Frischknecht et al., 2008 (as used in Swiss Ecoscarcity 2006)
Land use occupation: soil organic matter	kg C deficit	Milà i Canals et al., 2007 (SOM)
Land use occupation: biodiversity	m^2 yr	Köllner, 2000; characterisation factors set on (-)1 [54]
Land use transformation: soil organic matter	kg C deficit	Milà i Canals et al., 2007 (SOM)
Land use transformation: biodiversity	m^2	Köllner, 2000; characterisation factors set on (-)1 [55]

Table 8: Selected CEN+ environmental indicators including the units and environmental impact methods for the aggregated environmental score.

Damage cost method
The damage cost approach attempts to make an estimate of the demand function as regards environmental quality. The demand depends on people's disposition to pay for environmental quality, generally described as Willingness to Pay. Another approach is to see in how far people are open to accept environmental damage, also described as the Willingness to Accept.
Both concepts are hence defined in terms of individual preferences. (CE Delft 2010)

Prevention cost method
The prevention cost method measures the loss in welfare as a result of a potential environmental effect – emissions, for instance – based on the additional costs other industries are forced to make to (further) reduce their contribution to said environmental effect as compensation. This method requires ample knowledge about the costs of emission reductions in other industries, as well as assumptions on the emission reduction measures that should be taken already by those industries. The costs imposed on the industries reflect the willingness of society to pay for the avoidance of a health or environmental problem. They also reflect the social preferences as they emerge from a political decision-making process, whereby the costs of additional measures are compared to the environmental benefits they entail.

Table 9 and 10 provide an estimate of the monetary value for each environmental indicator that can be monetised. These estimates are either based on the damage cost method or the prevention cost method (see frames). The bibliography lists all the literature that was consulted.

54 Biodiversity impacts related to land use are not taken into account in the PEF. However, due to its importance in the built environment, the Köllner 2000 model as used in Eco-Indicator 99 (in PDFm^2yr and PDF*m^2) is proposed as a best proxy to take into account biodiversity impacts related to land use for the individual MMG scoring. Impacts of land use occupation and land use transformation expressed in m^2a and m^2 have proven to be a better basis to calculate the related environmental costs. For this reason, the land use occupation and transformation processes (expressed per m^2a and m^2) considered in the Eco-Indicator 99 method are taken into account, but characterisation factors are set to "1" or "-1" for the calculation of the environmental costs. By doing so the Köllner 2000 model is used as an inventory method for biodiversity flows in order to calculate the related environmental costs. For the calculation of the individual indicators the Köllner 2000 model as used in Eco-Indicator 99 (in PDF*m^2yr and PDF*m^2) is used.*
55 idem.

back to content

In the first version of MMG (Servaes 2013) the uncertainty interval for each indicator was determined with the use of the uncertainty distribution of the related shadow costs. Based on Sparado & Rabl (2008), it appears that damage costs typically follow a lognormal distribution. They can be assigned a 68% reliability interval based on information of the central value and the standard deviation:

- µg = median of the expected values
- 68% low estimate: µg/σg (σg is the standard deviation)
- 68% high value: µg * σg (σg is the standard deviation)

Monte Carlo analyses show that the standard deviation for damage costs as a result of air emissions typically lies around 3. For less known indicators or those with variable monetary data, a standard variation of 4 is proposed. This would apply to estimates regarding "ozone depletion", "acidification", "photochemical ozone creation", "human toxicity", "ecotoxicity" and "ionising radiation: human health effects" (Spadaro and Rabl, 2008). For indicators whose financial valuation is deemed highly uncertain, a standard deviation of 5 is proposed. This applies to estimates with respect to "depletion of abiotic resources: elements", "land use: occupation" (both from forestry and from agricultural or urban use) and "land use transformation".
The valuation of the impacts with respect to "global warming" are based on prevention costs. To ensure a similar approach for all indicators, we have nonetheless assumed a lognormal distribution of the costs. The financial valuation of the indicator "eutrophication" is based on damage costs as well as prevention costs from the literature. Since these are far apart, a standard deviation of 5 has been applied for this indicator also.

In 2014, the set of impact categories, LCIA methods and monetisation factors have been updated, including the approach to uncertainty in order to be closer to how this is dealt within policy studies. This resulted in following three adaptations:

1. distinction is made between 'variability' and 'uncertainty'. Variability of the monetary values reflects emissions and impacts in different locations have a different value, reflecting differences in the physical environment (e.g. average temperature or dominant soil types), and in the socio-economic environment (e.g. number of people exposed to pollution, differences in habits or diets, differences in income and preferences). To account better for this variation, a distinction is made between emissions and burdens in Flanders/Belgium, Western Europe and the rest of the world. The data for Western Europe are used as the central data set for the public tool based on MMG.
2. The confidence interval for the presentation of the results is narrowed. A narrower band for the low and high estimate is used, which is more in line with ranges used in documents to support policy analysis. For some impact categories, e.g. eutrophication, the central value in different studies is used to define the low and high estimate. For other impact categories, e.g. global warming, we looked at the bandwidth (BW= high estimate/low estimate) used in other guidelines and policy studies[56].
3. The assessment of the scientific analysis of uncertainty has been reviewed, due to the distinction between variability and uncertainty, and the changes in the set of impact categories and LCIA methods.

Tables 9 and 10 show an overview of the monetary values of the region Western Europe and used square root of the uncertainty bandwidth (√BW), which is used to calculate the low and high estimates. For more detailed explanation on the MMG monetisation method and factors and the sources used, we refer to the separate annex[57].

56 We noted that these typical ranges are about half the ranges of the 68 % confidence interval used for the first version of MMG. To be more in line with standard practice for policy studies, we adapted our approach to calculate the low and high estimate.

57 Annex: update monetisation of the MMG method (2017)

environmental indicator (CEN)	unit	√BW	Central (€/unit)	Low (€/unit)	High (€/unit)
Global Warming	kg CO^2 eqv.	2	0.05	0.025	0.10
Ozone depletion	kg CFC^{-11} eqv.	2	49.1	25	100
Acidification for soil and water	kg SO^2 eqv.	2	0.43	0.22	0.88
Eutrophication	kg $(PO4)^{3-}$ eqv.	3	20	6.60	60
Photochemical ozone creation	kg ethene eqv.	2	0.48	0	6.60
Depletion of abiotic resources: elements	kg Sb* eqv	4	1.56	0	6.23
Depletion of abiotic resources: fossil fuels[58]	MJ, net calorific value	/	0	0	0.0065

Table 9: overview of monetary values (central, low, high) for the CEN indicators.

**Sb: antimony*

58 *The central and low value of the indicator "depletion of abiotic resources: fossil fuels" are zero, as this reflects the point of view that resource depletion costs are internalised in market prices. In addition, the valuation of greenhouse gas emissions are based on prevention costs within MMG, which assumes that the emissions of greenhouse gasses are limited to limit global warming to a maximum of 2°C, which is in line with the UN objective. This emission path limits the use of fossil fuels, irrespective of its availability.*

environmental indicator (CEN+)	unit	√BW	Central (€/unit)	Low (€/unit)	High (€/unit)
Human toxicity: cancer effects	CTUh	4	665109	166277	2660434
Human toxicity: non-cancer effects	CTUh	5	144081	28816	720407
Particulate matter	kg PM2.5 eq	2.6	34	12.70	85
Ionising radiation: human health effects	kg U235 eq	3	9.7E-04	3.2E-04	2.9E-03
Ecotoxicity: fresh water	CTUe	5	3.7E-05	7.39E-06	1.85E-04
Water resource depletion	m3 water eq	3	0.067	0.022	0.20
Land use occupation: soil organic matter	kg C deficit	4	1.4E-06	3.4E-07	0.6E-05
Land use occupation: biodiversity (flows, loss of ecosystem services)[59]	m^2yr	4			
- Urban			0.30	0.07	2.35
- Agricultural			6.0E-03	1.5E-03	2.4E-02
- Forestry			2.2E-04	5.5E-05	8.8E-04
Land use transformation: soil organic matter	kg C deficit	4	1.4E-06	3.4E-07	0.6E-05
Land use transformation: biodiversity (flows)[60]	m^2	4			
- From urban land			n/a	n/a	n/a
- From agricultural land			n/a	n/a	n/a
- From forest			n/a	n/a	n/a
- From tropical rainforest			27	6.90	110

Table 10: overview of monetary values (central, low, high) for the CEN+ indicators.

59 The monetisation value for the indicator "land use occupation: biodiversity" is split up into three different sub-flows, due to lack of reliable monetary data for all the flows in one indicator. Within the tool, the results of the biodiversity sub-flows will be all individual summed up, so only one monetary value for the impact category "land use occupation: biodiversity" will be shown for the aggregated score.

60 The monetisation value for the indicator "land use transformation: biodiversity" is not available for the sub-flows transformation from urban land, agricultural land, and forest, due to lack of reliable monetary data. Geographically, loss of tropical rainforest is not applicable within Europe or Flanders. However, as within the MMG tool only the monetary values for Western Europe are taken into account and the other monetary values cannot be chosen, the Rest of the World monetary indicator for transformation from tropical rainforest is used as default for the regions Western Europe and Flanders. Also for the impact category "land use transformation: biodiversity" only one monetary value will be given within the results of the tool instead of per sub-flow.

2.6. Synthesis

The described MMG assessment method is characterised as follows:

Integrated approach:

- So as to have a comprehensive picture of the environmental profile of materials, work sections and elements (and higher), the entire life cycle has been taken into account (cf. 'cradle-to-grave' LCA).
- Similarly, an extensive range of environmental indicators is proposed (17 at individual level, 17 at monetary value level and 3 at aggregated level), to support the development of an expert calculation model - based on the principles of life cycle assessment (LCA), recent European standards and frameworks.
- For this we have selected environmental indicators, for which the contribution to specific environmental impacts is assessed on a quantitative and scientifically founded basis. To avoid double counting, no assessment is done on the basis of (additional) LCI as included in the CEN standards (2013, 2011a), for example, to describe resource use, waste, reuse of materials, components and energy.
- The different assessment levels (based on individual, monetary value or aggregated scores) permit the detailed underpinning of the environmental profile of work sections, building elements, and buildings, as well as decision-making, for example when comparing different variants of elements or buildings. In this way the assessment method is available to various players, from producers and industry organisations to users/developers, designers, contractors and environmental authorities.
- In the first instance we have used an extensive database of generic LCIs, harmonised as far as possible to the Belgian building context. Complementary to this, this assessment method permits the use of manufacturer and sector-specific (cradle-to-gate or cradle-to-grave) LCI data.
- Realistic scenarios have been taken into account for the transportation of materials and work sections to the building site and to the EOL processing site for each material category, for the type of EOL processing for each material category and for the service life of the building.

Modular structure:

- The underlying environmental data are compiled by life cycle stage and can be viewed separately (cf. EN 15804+A1:2013).
- The underlying environmental data are hierarchically arranged: i.e. material - work section - building element – building - ...
- Environmental scores are viewed on 3 levels: by individual indicator (both CEN indicators and additional indicators, defined as CEN+), by monetary value indicator (both CEN and CEN+ indicators) and also aggregated (CEN, CEN+ and total).

Extendable/adjustable:

- The transparent reporting of the assessment method (and the modelling thereof) makes room for future modifications or extensions by third parties. In this way, with better understanding of environmental effects, changes in standards and construction practices, etc., additional environmental indicators, other LCIA methods, improved underlying LCI data and scenarios, as well as future monetary values can be integrated into the assessment method.
- To obtain better construction-related insights, the assessment method can also be extended to district level.
- By monetising environmental impacts, the (external) environmental costs can be set alongside the financial costs related to the construction company and to the use of buildings. As well as this, it is always important to place the environmental (and financial) performance alongside the technical features and qualities of variants of different elements.

back to content

Annex 1: Bibliography

Allacker K., De Troyer F., Trigaux D., Geerken T., Debacker W., Spirinckx C., Van Dessel J., Janssen A., Delem L., Putzeys K. (2011), Sustainability, Financial and Quality evaluation of Dwelling types "SuFiQuaD", Final Report, Belgian Science Policy, Research Programme Science for a Sustainable Development, Brussels, 107 p.

Allacker K. (2010), Sustainable building, the development of an evaluation method, Doctorate dissertation at the Faculty for Engineering Science at the Catholic University of Leuven, K.U. Leuven, 484 p.

ALBON (2008), Het Algemeen Oppervlaktedelfstoffenplan, Government of Flanders – Department for Environment, Nature and Energy – Land and Soil Protection, Subsoil and Natural Resources Division (ALBON), July 2008, 198p.

Ammar, C., Longuet, M., (1980). Belgian Requirements about Buildings Service Life. Durability of Building Materials and Components (American Society for Testing and Materials (ASTM)). 77-90.

Anthoff D., NEEDS Project, FP6, of Greenhouse gas emissions", 2007.

Belgisch Staatsblad (2010), 74848 Bijlage 3 Transmissie referentie document, 08.12.2010

Bickel, P. Friedrich, R., (Eds.), 2001. Environmental External Costs of Transport. Springer, Amsterdam.

BCIS (2006), Life Expectancy of Building Components - Surveyors' experiences of buildings in use - A practical guide, Connelly-Manton Ltd, London, 353 pages.

Braat, L. and Ten Brink, P. (eds.) with J. Bakkes, K. Bolt, I. Braeuer, B. ten Brink, A. Chiabai, H. Ding, H. Gerdes, M., Jeuken, M. Kettunen, U. Kirchholtes, C. Klok, A. Markandya, P. Nunes, M. van, Oorschot, N. Peralta-Bezerra, M. Rayment, C. Travisi,
M. Walpole (2008). The Cost of Policy Inaction. The case of not meeting the 2010 biodiversity target. Report of the COPI project, Wageningen and Brussels, May 2008.

BRE (2011), Green Guide to Specification, webtool, latest update November 2011, BRE, UK, via http://www.bre.co.uk/greenguide/

Brin C. and van Grinsven H. (2011), Costs and benefits of nitrogen in the environment, in Sutton M.A. (2011), The European Nitrogen Assessment, Cambridge University Press, 2011, pp. 513-540

Broekx S., Meynaerts E., Vercaemst P., 2008. Milieukostenmodel Water voor Vlaanderen. Berekeningen voor het stroomgebiedbeheerplan 2009. A study carried out for the Flemish Region 2009/RMA/R/146.

Broekx S., Smets S., Liekens I., Bulckaen D., Smets S., De Nocker L., Designing a long-term flood risk management plan for the Scheldt estuary using a risk based approach, Natural Hazards 2011, 57-2, p. 245-266.

http://www.springerlink.com/content/e43138836415t02n/

CEN (2013), EN 15804:2012+A1 Sustainability of construction works – Environmental product declaration – Core rules for the product category of construction products

CEN (2011a), EN 15978 Sustainability assessment of construction works – assessment of environmental performance of buildings – calculation method

CEN (2011b), EN 15643-2, Sustainability of construction works – assessment of buildings – part 2: Framework for the assessment of environmental performance

CEN (2010), TR 15941 Sustainability of construction works – Environmental product declaration – Methodology for selection and use of generic data

CEN (2015), EN 16627 Sustainability assessment of construction works – assessment of economic performance of buildings – calculation methods

CEN (2016), TR 17005 Sustainability of construction works - Additional environmental impact categories and indicators - Background information and possibilities - Evaluation of the possibility of adding environmental impact categories and related indicators and calculation methods for the assessment of the environmental performance of buildings

Classen M., Althaus H.-J., Blaser S., Tuchschmid M., Jungbluth N., Doka G., Faist Emmengger M., Scharnhorst W. (2009), Life Cycle Inventories of Metals. Final report ecoinvent data v2.1, No 10., EMPA Dübendorf, Swiss Centre for Life Cycle inventories, Dübendorf: ecoinvent

COPRO (2009), Annual Report 2009

CSTC et al. (1991), Guide Pratique pour l'Entretien des Bâtiments, Edition 1991, Collaboration entre le Conseil National de l'Ordre des Architectes, le Collège des Experts Architectes de Belgique, la Confédération Nationale de la Construction (C.N.C.), la Fédération Royale des Sociétés d'Architectes de Belgique (F.A.B.), le Bureau du Contrôle pour la Sécurité de la Construction (SECO) et le Centre Scientifique et Technique de la Construction (C.S.T.C.), D/1991/0611/3, 60 pages.

De Bruyn S.M., Korteland M.H., Markowska A.Z., Davidson M.D., de Jong F.L., Bles M., Sevenster M.N., 2010: Handboek Schaduwprijzen – Waardering en weging van emissies en milieueffecten, CE Delft, Delft

Delem, L., Spirinckx, C. (2009), Note on elaboration of refined methodology and work-instrument, chapter 1, §2.3 Methodology impact of building materials, SuFiQuaD, June 2009

Delem L., Van Dessel J., Debacker W., Spirinckx C., Allacker A., De Troyer F., 2011, Bepalingsmethode Milieugerelateerde Materiaalprestatie van gebouwelementen (MMG), preparatory report for workshop, commissioned by OVAM.

Den Hollander Th.G.M., Kuhlmann W.H., Steenhuis J.D. & Veldkamp I.H.J.T., (1993), Woningbouwkosten - Groot onderhoud en renovatie, No. 3/1993, an edition of Misset bouw, a division of Uitgeversmaatschappij C.Misset bv., Doetinchem, the Netherlands, 305 pages.

De Nocker et al, 2010; Actualisering van de externe milieuschadekosten (algemeen voor Vlaanderen) met betrekking tot luchtverontreiniging en klimaatverandering, A study carried out by order of VMM, MIRA. www.milieurapport.be

De Nocker L., S. Broekx, I. Liekens (2011), Economische waardering van verbetering ecologische toestand oppervlaktewater op basis van onderzoeksresultaten uit Aquamoney, Vito internal report 2011/RMA/R/248, 2011, 58 pages.

De Troyer F., Neuckermans H., Havenne D., Simon F. (1990), BB/SfB Tabellen 1990, Brussels, Regie der Gebouwen, 135 pages.

De Troyer F. (2008), Een functionele hiërarchie voor gebouwelementen, Louvain, Acco (ISBN 978-90-334-7106-3), 96 pages.

De Troyer F. (2012), Bouweconomie en systeembouw, Louvain, ACCO, p. H4-10 and H4-11.

Deutsch F., Veldeman N., Vankerkom J., Peelaerts W., Buekers J., Torfs R., Fierens F., Vanpoucke C., Trimpeneers E., Vancraeynest L., Bossuyt M. (2010), Zwevend stof en fotochemische luchtverontreiniging. Visionair scenario Milieuverkenning 2030, a study carried out by order of the Flemish Environment Company, MIRA, MIRA/2010/09, VITO.

Doka, G. (2009), Life Cycle Inventories of Waste Treatment Services. Ecoinvent report No. 13., Swiss Centre for Life Cycle Inventories, Dübendorf: ecoinvent

EC, 1996, ExternE, Externalities of Energy, Volume 2: Methodology, Luxembourg : European Commission, 1996

EC, 2005, 5, ExternE - Externalities of Energy – Methodology 2005; Update. EUR 21951 EN. European Commission, Office for Official Publications of the European Communities, Luxembourg. 2005, ISBN 92-79-00423-9.

EC, 2013, ANNEX II Product Environmental Footprint (PEF) Guide, in: 2013/179/EU: Commission Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. Official Journal of the European Union, L 124, Volume 56, 4 May 2013.

ecoinvent (2016), ecoinvent v3.3 database, www.ecoinvent.org

European Union, EU Waste Framework Directive 2008/98/EC in Official Journal of the European Union, L312/3 –L312/30

Exiopol (2011), A new accouting framework using externality data and input-output for policy analysis, bottom-up approach, FEEM, 2011 (www.feem-project.net/exiopol/)
Febelcem (2008), Standpoints of the Belgian cement industry

Federal Public Service (FPS) Economy (2009), Eengemaakte technische specificaties – STS 04 Hout en plaarmaterialen op basis van hout – STS04.3 Behandelingen van het hout, edition 2009, FPS Economy, Brussels, via
http://www.ctib-tchn.be/useruploads/files/STS%2004-3_2009(N).pdf

FVSB (1997), Milieuhandleiding voor de algemene bouwaannemer op de werf - PRESTI-project, 1997.

Goedkoop M. and Spriensma R. (2000) , The Eco-indicator 99 A damage oriented method for Life Cycle Impact Assessment, Methodology Report, Second Edition, Pré Consultants, 2000, 142 pages.

Goedkoop M, Heijungs R., Huijbregts M., De Schrijver A., Struijs J., van Zelm R., 2008, ReCiPe 2008 – A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level – First edition – Report 1: characterisation, by order of the Ministry for Housing, Spatial Planning and the Environment.

Goedkoop M., De Schrijver A., Oele M., Durksz S., de Roest D. (Pré Consultants) (2010), Introduction to LCA with SimaPro 7, Pré Consultants, Netherlands, November 2010, 88 pages.

Gren, I.-M. (2008). Costs and Benefits from Nutrient Reductions to the Baltic Sea. The Swedish Environmental Protection Agency, Stockholm, Sweden.

Havenne D., Simon F., De Troyer F., Neuckermans H. (1990), Tables BB/SfB 1990, Bruxelles, Régie des Bâtiments, 135 p.

Hayashi K., Nakagawa A., Itsubo N. and Inaba A. (2006), Expanded Damage Function of Stratospheric Ozone Depletion to Cover Major Endpoints Regarding Life Cycle Impact Assessment, in: The International Journal of Life Cycle Assessment , vol. 11, No. 3, pp. 150–161

Hegger M., Auch-Schwelk V., Fuchs M., Rosenkranz T., et al (2006), Construction Materials Manual, Basel: Birkhäuser.

Intergovernmental Panel on Climate Change (IPCC) (2007), Climate Change 2007: Synthesis Report, 74 pages,
via http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

International Organization for Standardization (ISO) (2005), Environmental management – Life cycle assessment Requirements and guidelines (ISO 14044 – Part 2), Geneva: ISO.

International Standardisation Organisation (ISO) (2006a), ISO 14040, 2006, Environmental management – Life cycle assessment – Principles and framework.

International Standardisation Organisation (ISO) (2006b), ISO 14044 (2006) Environmental management – Life cycle assessment – Requirements and guidelines.
IVAM (2001), IVAM LCA data 4.0, www.ivam.uva.nl

Jacobs, A., et al. (2005), Best Beschikbare technieken voor recyclage van bouw- en sloop-puin, eindrapport, 140 pages."Life Expectancy of Building Components - Surveyors' Experiences of Buildings in Use - A practical Guide", second (revised) edition, BCIS, London, UK, 2006, p. 354

Janssen A., Putzeys K., Debacker W., Geerken T., Allacker K., De Troyer F. (2010), Onderzoek naar mogelijke nieuwe bouwconcepten en het effect ervan op het gebruik van oppervlaktedelfstoffen, a study by order of the Government of Flanders – Department for the Environment, Nature and Energy; Land and Soil Protection, Subsoil and Natural Resources Division (ALBON), 253 pages.

Joint Research Centre (JRC) of European Commission (2010) - Institute for Environment and Sustainability (IES), International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition, March 2010.
Joint Research Centre (JRC) of European Commission (2011) - Institute for Environment and Sustainability (IES), International Reference Life Cycle Data System (ILCD) Handbook – Recommendations for Life Cycle Impact Assessment in the European context – based on existing environmental impact assessment models and factors. First edition.

Kuik, O., Brandera, L., Nikitinaa, N., Navrud, S., Magnussen, K., El Hadji, F., 2008. A Database of Studies on Energy-related External Costs due to Land Use Changes, Acidification and Eutrophication, Visual Intrusion and Climate Change. Delivery of FP6 Cases Project.

Le Goffe, P. (1995):"The Benefits of Improvements in Coastal Water Quality: A Contin gent Approach", Journal of Environmental Management 45, (4): 305-317.

Liekens I., De Nocker L., 2008. Rekenraamwerk voor de economische baten van een betere waterkwaliteit, VITO by order of VMM, September 2008. http://www.milieurapport.be Research reports 2008.

Liekens I., Schaafsma M., Staes J., Brouwer Roy, De Nocker L. en Meire P., 2009. Uitvoeren van een economische waarderingsstudie van natuurlandschappen voor gebruik in MKBA van infrastructuurprojecten. Report by order of the Department for the Environment, Nature and Energy – Environmental, Nature and Energy policy division. VITO, 2009/ RMA/R/308.

Department for the Environment, Nature and Energy (2007), milieubeleidskosten – begrippen en berekeningsmethoden, Government of Flanders, Department for the Environment, Nature and Energy, 2007, www.milieueconomie.lne.be, p. 27 ff.

LNE, 2008 Milieubaten of milieuschadekosten-waarderingsstudies in Vlaanderen, Government of Flanders, Department for the Environment, Nature and Energy, 2008 , www.milieueconomie.lne.be

Loeckx A., Neuckermans H., Dillemans R., et. al. (1993), Wegwijs Wonen, Louvain, Davidsfonds, 398 pages.

Maibach M., C. Schreyer, D. Sutter ; H.P. van Essen, B.H. Boon, R. Smokers, A. Schroten ; C. Doll ; B. Pawlowska, M. Bak (2008), Handbook on estimation of external costs in the transport sector. Internalisation Measures and Policies for All external Costs of Transport (IMPACT), Version 1.1 , Delft : CE Delft, 2008

Markandya, A., Nunes, P.A.L.D., Brauer, I., ten Brink, P. Kuik, O. and M. Rayment (2008) "Review On The Economics Of Biodiversity Loss – Economic Analysis and Synthesis", Final report for the European Commission, Venice, Italy. 140 pages.

MEA (2005). Ecosystems and Human Well-being: Biodiversity Synthesis, World Resources Institute, Washington, D.C.

MIRA (2007) Milieu- en natuurrapport Vlaanderen, Achtergronddocument 2007 Vermesting. Overloop S., Bossuyt M., Ducheyne S., Dumortier M., Eppinger R., Van Gijseghem D., Van Hoof K., Vogels N., Vanden Auweele W., Wustenberghs H., D'hooghe J., Flemish Environment Agency, www.milieurapport.be.

Morton, M. (eds) (1987), Rubber technology, 3rd ed., New York: v Nostrand Reinhold Co.

NBN (2017) Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products - National supplement to NBN EN 15804+A1:2014. NBN/DTD B 08-001:2017

NEN (2004), NEN 8006, Environmental data of building materials, building products and building elements for application in environmental product declaration – Assessment according to the Life Cycle Assessment (LCA) methodology.

NIBE (2011a), NIBE's Basiswerk Millieuclassificaties Bouwproducten – Deel 1: Draagconstructies, NIBE Publishing, The Netherlands.

NIBE (2011b), NIBE's Basiswerk Millieuclassificaties Bouwproducten – Deel 2: Gevels en Daken, NIBE Publishing, The Netherlands.

NIBE (2011c), NIBE's Basiswerk Millieuclassificaties Bouwproducten – Deel 3: Afwerkingen,

NIBE Publishing, The Netherlands.

Ott et al, 2006, Ott, Walter, Baur, Martin and Kaufmann, Yvonne, e c o n c e p t AG, Frischknecht, Rolf and Steiner, Roland, ESU-services, 2006, NEEDS, project, FP6, RS1b_D4.2, "Assessment of Biodiversity Losses".

Pasman W.P.M., Scholten J.A., van Groningen C. & Veldkamp I.H.J.T. (1993), Burgerwerk en kleine aannemingen - onderhoud en herstel, No. 1/1993, an edition of Misset bouw, a division of Uitgeversmaatschappij C.Misset bv., Doetinchem, the Netherlands, 467 pages.

Perret, J. (1995), Guide de la maintenance des bâtiments, Diagnostic d'un patrimoine bâti existant, prévention des désordres et actions pour y remédier, 308 fiches techniques de suivi des ouvrages, Le Moniteur, Paris, France

Putzeys, K., Spirinckx, C. (2008), et al., Final note on extreme cases, chapter 2: Data collection for extreme types, SuFiQuaD, Sustainability, Financial and Quality evaluation of dwelling types, December 2008.

Preiss, Ph, Volker Klotz (2008), revised Description of updated and extended tools for the detailed site-dependent assessment of External costs EcoSenseWeb, Report NEEDS, IER, 2008.

Pretty, J.N., Mason, C.F., Nedwell, D.B. et al. (2003), Environmental costs of freshwater eutrophication in England and Wales. Environmental Science and Technology, 37, 201–208.

Ruijgrok, Dr.ir. E.C.M. , Dr.ir. R. Brouwer, prof. dr. H. Verbruggen, 2004. Waardering van Natuur, Water en Bodem in Maatschappelijke Kosten-batenanalyses. Aanvulling op de Leidraad OEI. By order of the Ministry for Agriculture, Nature and Food Quality, in cooperation with the ministries for Transport and Water, for Economic Affairs, for Finance, and for Housing, Spatial Planning and the Environment. RWS2004

Servaes, R., Allacker, K., Debacker, W., Delem L., De Nocker, L., De Troyer, F. Janssen, A., Peeters, K., Spirinckx, C., Van Dessel, J. (2013). Milieuprofiel van gebouwelementen, maart 2013, OVAM.

Sezzi G. (2009), The ceramic tile market in Europe, Cersaie, September 2009, via http://www.eufgs.com/en/PDF/PresentazioneEUF_giugno2010_sezzi_en.pdf

Söderqvist, T. and Hasselström, L.(2008). The Economic Value of Ecosystem Services Provided by the Baltic Sea and Skagerrak. http://www.naturvardsverket.se/ Documents/publikationer/978–91–620–5874–6.pdf

Spirinckx, C. (2009), Note on elaboration of refined methodology and workinstrument, chapter 3, §1 Harmonisation process of the life cycle inventory data, SuFiQuaD, June 2009

Stichting Bouwresearch (SBR) (1998), Levensduur van bouwproducten, praktijkwaarden, Stichting Bouwresearch (SBR), 1985, revised in 1998, Rotterdam, the Netherlands

Ten Hagen & Stam bv (2000a), Bouwkosten - Burgerwerk - Groot Onderhoud – update 2000, Ten Hagen & Stam uitgevers, The Hague, the Netherlands, ISBN 90.70011.76.X.

Ten Hagen & Stam bv (2000b), Bouwkosten - Burgerwerk - Klein Onderhoud – update 2000, Ten Hagen & Stam uitgevers, The Hague, the Netherlands, ISBN 90.70011.86.7

UNEP (Lead authors: Huovila P., Ala-Juusela M., Melchert L. and Pouffary S.) (2007), Buildings and Climate Change: Status, Challenges and Opportunities, UNEP Sustainable Buildings and Climate Initiative, Paris, France, 78 pages.

Val-i-pack (2009), Annual Report 2009

Van den Dobbelsteen, A., Alberts, K. (2001), Milieueffecten van Bouwmaterialen – duurzaam omgaan met grondstoffen, Delft: TU Delft, consulted on 22 February 2012, via http://www.wegwijzerduurzaambouwen.be/pdf/174.pdf

Van den Dobbelsteen A. (2004), The Sustainable Office – an exploration of the potential for factor 20 environmental improvement of office accommodation, PhD thesis, TU Delft, Delft, The Netherlands, 2004, 520p.

Van den Dobbelsteen, A., Alberts, K. (2005), Bouwmaterialen, milieu & gezondhieid, Amsterdam: WEKA uitgeverij B.V.

Villigen and Uster (2007), Life Cycle Inventories of Energy System, ecoinvent report no. 5, december 2007

Vlaams Energieagentschap (VEA) (2013), Energieprestatiecertificaten voor bestaande residentiële gebouwen in Vlaanderen, formulestructuur.

Vlaams Instiuut voor Bio-Ecologisch bouwen en wonen (VIBE) (2007), VIBE-fiches: Keuzefiche: Bouwmaterialen / isolatiematerialen, February 2007, with support from the Government of Flanders, consulted on 19 February 2012 via http://www.vibe. be/downloads/1. Technische_documentatie/Bouwmaterialen%20en%20 gezondheid/KF_isolatiematerialen.pdf

Watkiss, P., Anthoff, D., Downing, T., Hepburn, C., Hope, C., Hunt, A., Tol, R. (2005): The Social Cost of Carbon (SCC) Review – Methodological Approaches for Using SCC Estimates in Policy Assessment. Final Report. AEA Technology Environment, Harwell, November 2005

Woodforum.be (2012), Toepassingen, consulted on 4 April 2012, via http://www.woodforum.be/nl/toepassingen

WTCB et al (2011), Onderhoudsgids voor duurzame gebouwen, edition 2011, in collaboration with the Confederatie Bouw, the Nationaal College van Deskundigen Architecten van België, the Technisch Controlebureau voor het Bouwwezen (SECO) and the Wetenschappelijk en Technisch Centrum voor het Bouwbedrijf (BBRI), BBRI, Brussels, 69 pages.

WE MAKE TOMORROW BEAUTIFUL

OVAM

Stationsstraat 110
2800 MECHELEN
WWW.OVAM.BE

Legal desposit: OVAM, Stationsstraat 110, 2800 Mechelen / D/2018/5024/01