VKaLCA-Tool; methodology for adaptation of generic data in the Life Cycle Inventory (LCI) of the building-elements database

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1. Goal and scope of the LCA calculation by means of VKaLCA-tool

The goal of the analysis performed by means of the VKaLCA-tool is to assess: a) the life cycle environmental impacts of building- elements (i.e. taking into account life cycle stages such as material production and end-of-life as considered within the EN 15804:2012+A1:2013 standard [1]) and b) to allow life cycle environmental impacts assessment of whole buildings (i.e., taking into account not only materials- production, but also building construction, building- use, building demolition and EOL as described by the EN 15978:2011 standard [2]).

In its totality the tool offers the possibility of performing analysis and comparisons at building-element level (e.g., analysing and comparing different external walls or roof design options) and at building- level in its totality (e.g., analysing and comparing different full scale- building design options). The geographical applicability of the LCA-study performed with VKaLCA-Tool is Europe.

2. Problem framing

Among the most important issues generally observed during LCA-modelling of buildings, especially during early- design stage, is the quality of data used for compiling the Life Cycle Inventory (LCI) perhaps the most frequently reported.

Such aspect is not of minor importance as it could affect the quality -hence the representativeness- of the results. The standard CEN/TR 15941:2010 [3] defines the following typologies of data to be used for EPDs and LCA-calculations:

- System specific data: data specific to the production system under study;
- Site specific data: data derived from one production site (data might include different production lines);
- Average data: data combined from different manufactures or production sites for the same declared unit (average data can relate to a number of issues e.g., location or time);
- Generic data: surrogate data used if no system specific data are available (data can be site specific or average);

According to EN 15804, specific- data or average- data derived from specific production processes should be used for modelling foreground processes in EPD and LCA-calculations; while, for the upstream and downstream processes (that the producer cannot influence), generic data may be used.

However, when the LCA-study has to occur in the early design stage of the project, specific- data can hardly be used in the modelling as the source of construction materials is usually unknown at this stage (e.g., producers and/or production country). In such circumstances, generic- data are the sole viable alternative for undertaking the LCA- study.

According to CEN/TR 15941:2010, in case generic data are used, technological and geographical -compensation must take place and time- representativeness must be documented, see section 4.3.4 in [3].

According to the standard, compensation based on a *quantitative empirical- approach* is always the best option for representing local conditions. Nevertheless, this compensation approach implies the LCA-practitioners has to collect a great amount of information on materials- technology, raw -material extraction processes, transports, etc. Again, not always all this information can be gathered at the initial design-stage of a project. When *quantitative empirical- approach* is not applicable, the standard allows to perform data-compensation based on so called *informed assumptions- approach*, see § 4.3.4 in CEN 15941:2010 [3]. Assumptions are common in LCA modelling since often no field data are available. According to the standard the application of the latter approach implies all the assumptions to be reported in the LCA-report. The methodology for the data adaptation is explained in section 3 and 4 of this document in compliance with the standard methodology.

In the proposed VKaLCA-Tool, the data- adaptation process is based on the “informed assumption-approach as foreseen by the CEN 15941: 2010.

3. Quality of data from EN 15804 and EN 15978

The data quality requirements to be verified within the framework of LCA studies undertaken in accordance to EN15804 and EN15978 are based on the data quality requirements provided by ISO14044 [4] and can be summarized as below:

1. Time-representativeness - datasets should be recent or updated within the last 10 years for generic data and 5 years for specific data from producers;
2. Geographical representativeness – according to the aim of the study, the geographical area from which data is collected should be representative;
3. Technological representativeness – all relevant technologies should be covered, and these should reflect the reality for each product;
4. Completeness – datasets should be complete according to the goal and scope of the LCA-study.

Requirement 1 exclusively depends on the data provided by the database. Hardly it could be performed an adjustment at this level by the LCA- practitioner. However, data responding to requirements from 2 to 4 can be adjusted (read compensated) by the LCA-practitioner in accordance to the aim of the LCA-study.

The scopes of the LCA- studies that can be performed with the VKaLCA-Tool are reported in Table 1 as well as the targeted data- quality -requirements.

Goals and Scopes of LCA- modelling in VKaLCA-Tool

1st level => Life cycle modelling of building- elements
2nd level => Life cycle modelling of building

Time Representativeness	Geographic Representativeness	Technological Representativeness	Completeness
<10 years	Average Europe	Average Europe (*) (*) with possibility of selecting also Belgian technology for specific materials	Data quality to be guaranteed at 1st and 2nd level of LCA-study

Table 1; Data- quality requirements targeted in the VKaLCA-Tool according to CEN/TR 15941:2010.

4. Data adaptation within VKaLCA-tool

In the VKaLCA-Tool, generic data, provided by Ecoinvent database (professional database, version 3.5), were used for creating the inbuilt LCI of the building-elements and building- processes. The LCI was modelled by means of SimaPro, version 9.0.0.48.

Considering that in Ecoinvent 3.5, the age of data is less than 5 years, it can be concluded that requirement 1 is complaint with the data quality- requirements provided by EN 15804:2011-A1:2013. As such, the data adaptation in the VKaLCA-Tool only focusses on geographical and technological coverage.

1.1 Geographical coverage -adaptation

The inbuilt materials- database of the VKaLCA-tool was developed opting for a European geographical representativeness instead of a Belgian- one. This because

1) In the Belgian construction industry, a large share of building materials is imported by neighbouring countries [5];

2) In the early design stage, not always it is known which material producer will be specified during the development;

3) VK Architects and Engineers is a company that operates not only in Belgium but also in other EU-countries. As the VKaLCA-Tool will be used in different EU -countries for testing at the early design stage the environmental impact of our developments, it is important to provide a materials-library representative for the EU-countries.

With this purpose, within the Ecoinvent- library it were selected materials and processes representative of the EU-average rather than country- specific ones; namely RER -processes. In lack of RER- materials or processes - in line with the methodology proposed at section 6.3 in the CEN/TR 15941:2010- country specific materials or processes were adjusted as to represent the European average. In such cases, both electricity mix of specific countries (e.g., DE) and water input were replaced by the average European mix instead (e.g., RER). This geographical compensation-methodology was also implemented in the Belgian- MMG-Tool. This LCA modelling- tool is currently used within the framework of governmental environmental assessment frameworks such as TOTEM; see Note 21, pag. 18, section 2.3.1 in [5].

In the VKcaLCA-Tool, this adaptation was limited to the production processes at plant and neglected the upstream processes such as material extraction and transports to the production- plant (A1 and A2 in Fig. 1). In other words, the adaptation occurred at A3-module level and not at A1 and A2- modules. The latter two modules stayed unmodified. It is worth mentioning that the adaptation limited to the A3-module is a simplification that unlikely affects the results by a remarkable extent; this was also reported in the MMG- report [5] and in a study from C. Spirinckx [6].

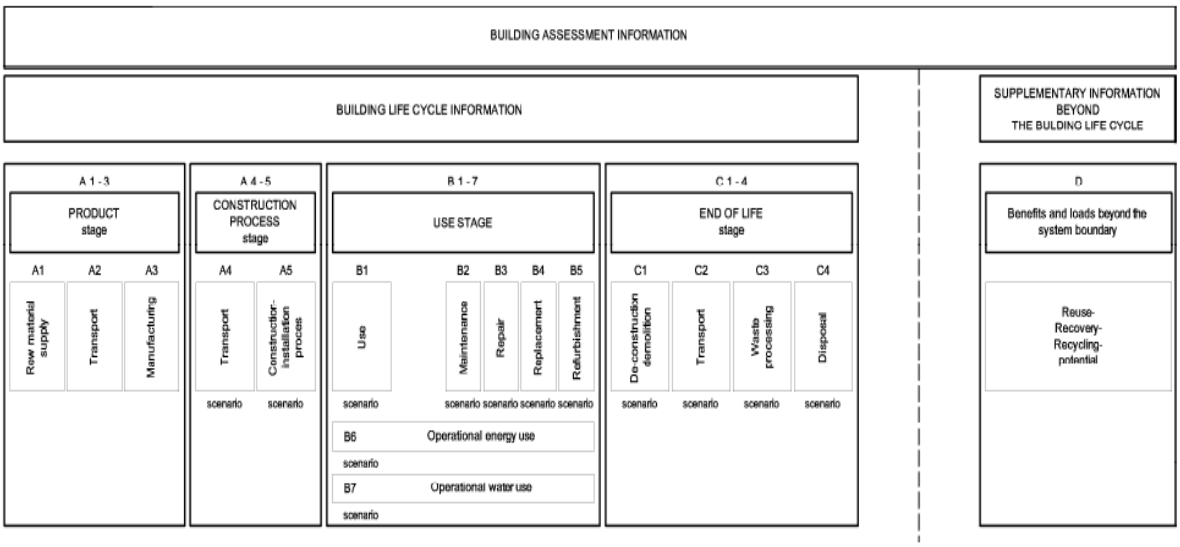


Fig. 1; module of the building life cycle, from Fig. 6 in EN 15978:2011

In [6], C. Spirinckx highlighted that the modification of the upstream processes of material- production (e.g., A1 and A2- modules) has negligible effect on the impact- results of materials production.

As mentioned above, geographical adaptation consisted in the replacement of energy and water input considering the average European ones instead of European- country specific. The replacement of EU-average inputs instead of country -specific ones did not yield to significant impact- results variations. This because the used country-specific data in Ecoinvent, adapted within the VKaLCA-Tool for the LCI, belonged to Western-EU countries (e.g., DE, CH…) that do not significantly deviate from the EU average.

This consideration is in line with what observed for the case of concrete and steel- production in a study from the EU Joint Research Centre [7]. The study highlights that impacts of concrete production in Germany (considering various concrete grades and the German electricity mix) were only slightly different from the ones if concrete was supposed to be produced with the average electricity mix from European Countries.

In order to build up a homogeneous database, representative for the entire Europe, also materials typically produced in Belgium (e.g. concrete) were modelled considering the average European energy mix instead of the specific Belgian-one. The general idea was to build-up an inventory with equal and homogeneous geographical coverage.

It is worth mentioning that for life cycle modules as from A5 (building construction, see Fig. 1), it is offered to the user the possibility to opt for Belgian processes (with Belgian electricity mix) or generic-processes (with the average European electricity mix) depending on the building location. In other words, if the study is scoped to a building to be constructed in Belgium, the user will use the construction processes representative for Belgium, while if the building is going to be constructed in Luxemburg, the user will select the generic construction processes.

1.2 Technological coverage- adaptation

For materials used in Belgium with different technology compared to other EU-countries, a technological compensation was foreseen. The objective of this compensation was to represent the current Belgian construction practice though still relying on the hypothesis these materials are produced not necessarily in Belgium, but in surrounding EU-countries.

With this purpose, generic- data or country specific- data from Ecoinvent, were adjusted if needed to better represent the material- technology in Belgium. This is the case of poured concrete.

There are a number of different cement types, referred to as CEM I up to and including CEM V, with a smaller or larger content of Portland cement and slag or fly ash. Below is given a summary of the different type of concrete.

CEM I: Portland cement with a maximum of 5% other materials.
CEM II: all kind of hybrids of Portland cement with for example slate, fly ash, slag… minimum 65% Portland cement.
CEM III: blast furnace/Portland cement mixture in 3 classes: A, B and C; whereby CEM III/A contains the least (40%) and CEM III/C contains the most (90%) slag.
CEM IV: Pozzolana cement varieties (this type of cement is not produced in Belgium).
CEM V: composite cements, with mixtures of Portland cement, slag and Pozzolana.

Overview of different cement types

In several EU-countries and Switzerland, poured concrete (e.g., concrete, normal (CH) market for) is modelled considering CEM II -concrete type. However, in Belgium poured concrete is generally made of CEM III (class A).

In order to take into account the specific technological coverage, it was modified the concrete typology (e.g., grade) as to represent the Belgian construction practice.

At this time, no other technological adaptations were applied to the modelled building-elements database in the VKaLCA-Tool.

1.3 Data compensation reporting

In order to inform the VKaLCa -Tool user of the occurred data compensation – as requested by the CEN 15941 standard- the any performed adaptation to generic data is explicitly indicated in the database. Therefore, In the column: "Ecoinvent record (Input-Output) it is indicated between brackets (e.g. (adjusted FROM/TO)) which kind of adaptation occurred per record (e.g., per material or process); see Fig. 2.

Units per m/2 (or units-amount if differently specified)	Material (M)/ Process (P)	Ecoinvent record (Input-Output)	Ecoinvent unit
1,00	M	Concrete, normal {adjusted CH/BE}| unreinforced concrete production, | Cut-off, U	m3
-	M	Reinforcing steel {RER}| production | Cut-off, U	kg
-	M	Tap water {Europe without Switzerland}| tap water production, underground water with chemical treatment | Cut-off, U	kg
1,00	M	Sand-lime brick {adjusted DE/RER}| production | Cut-off, U	kg
-	M	Cement mortar {adjusted-CH/RER}| production | Cut-off, U	kg
-	M	Tap water {Europe without Switzerland}| tap water production, underground water with chemical treatment | Cut-off, U	kg
1,00	M	Concrete block {adjusted DE/RER}| production | Cut-off, U	kg
-	M	Cement mortar {adjusted-CH/RER}| production | Cut-off, U	kg
-	M	Tap water {Europe without Switzerland}| tap water production, underground water with chemical treatment | Cut-off, U	kg
1,00	M	Autoclaved aerated concrete block {adjusted CH/RER}| production | Cut-off, U	kg
-	M	Cement mortar {adjusted-CH/RER}| production | Cut-off, U	kg
-	M	Tap water {Europe without Switzerland}| tap water production, underground water with chemical treatment | Cut-off, U	kg
1,00	M	Concrete block {adjusted DE/RER}| production | Cut-off, U	kg
-	M	Cement mortar {adjusted-CH/RER}| production | Cut-off, U	kg
-	M	Tap water {Europe without Switzerland}| tap water production, underground water with chemical treatment | Cut-off, U	kg
1,00	M	Clay brick {RER}| production | Cut-off, U	kg
-	M	Cement mortar {adjusted-CH/RER}| production | Cut-off, U	kg
-	M	Tap water {Europe without Switzerland}| tap water production, underground water with chemical treatment | Cut-off, U	kg

Figure 2; Indication of the adaptation process for each record in the VKaLCA-Tool, see column Ecoinvent record (Input-Output)

For instance, a material modified as to represent the mean production in Europe instead of the one in Switzerland is indicated with: "(adjusted CH/RER)". While a material representing the production in Belgium instead of the one in Switzerland is indicated with: "(adjusted CH/BE)". In such a way, the user is informed about the original record within the Ecoinvent -library.

Furthermore, a section in the database is dedicated for providing further information about the typology of undertaken adaptation for each record; see column: "Quality Criteria of data (following CEN TR 15941:2010) for the A1 -A3 module"; in Fig. 3 below.
In this section, the user may read more in details which kind of data- adaptation occurred to each record. This information is given in line with the quality of data- requirements stressed by the CEN/TR 15941:2010.

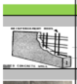
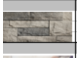
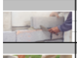
Picture	Base material (data requested to fill in are indicated in red and have a grey background)	Ecoinvent unit	Components surface mass (kg/m2 or differently specified)	Material-density (kg/m^3) (or automatic conversion)	Quality Criteria of inventory data (following CEN TR 15941:2010) for the A1 -A3 module			
					data directly (geographically) applicable Y/N	Geographically adapted (Y/N)	Age of data (years)	Ecoinvent-data adaptation description
	in situ cast concrete (wall thickness | - | - | units per m2)	m3	0,25		no	yes	<5	Modelled as to represent RER production (instead of CH-production) considering the Belgian concrete technology
	reinforcement (- |- | - | -)	kg	98,13	7850,00	yes			-
	water (- |- | - | -)	kg	0,15	-	yes	no	<5	-
	sand-lime brick (- | bricks dimension | - | amount of leaf)	kg	98,50	-	no	yes	<5	Modelled as to represent RER production (instead of DE-production)
	glue mortar joint (- |- | - | -)	kg	35,00	-	no	yes		Modelled as to represent RER production (instead of CH-production)
	water (- |- | - | -)	kg	1,40	-	yes		<5	-
	solid concrete block (block density | blocks dimension | - | amount of leaf)	kg	113,83	-	no	yes	<5	Modelled as to represent RER production (instead of DE-production)
	cement mortar joint (- |- | - | -)	kg	35,00	-	no	yes	<5	Modelled as to represent RER production (instead of CH-production)
	water (- |- | - | -)	kg	1,40	-	yes		<5	-
	areated concrete block (block type | blocks dimension | - | amount of leaf)	kg	61,70	-	no	yes	<5	Modelled as to represent RER production (instead of CH-production)
	cement mortar joint (- |- | - | -)	kg	35,00	-	no	yes	<5	Modelled as to represent RER production (instead of CH-production)
	water (- |- | - | -)	kg	1,40	-	yes		<5	-
	hollow concrete block (block type | blocks dimension | - | amount of leaf)	kg	158,00	-	no	yes	<5	Modelled as to represent RER production (instead of DE-production)
	cement mortar joint (- |- | - | -)	kg	35,00	-	no	yes	<5	Modelled as to represent RER production (instead of CH-production)
	water (- |- | - | -)	kg	1,40	-	yes		<5	-
	building bricks (bricks type | bricks dimension | - | amount of leaf)	kg	106,50	-	yes		<5	-
	cement mortar joint (- |- | - | -)	kg	35,00	-	no	yes	<5	Modelled as to represent RER production (instead of CH-production)
	water (- |- | - | -)	kg	1,40	-	yes		<5	-

Figure 3; section in LCI showing "Quality criteria of data (following CEN/TR15941:2010) for A1 to A3 modules"

The four columns in the section, from left to right report the following information:

- 1st column: *Data directly (geographically) applicable Y/N*
- 2nd columns: *Data geographically or technologically adapted (Y/N)*
- 3rd columns: *Age of data (years)*
- 4th columns: *Ecoinvent-data adaptation description*

In the specific case of the first material: *in situ cast concrete*, the following can be read from the *quality criteria of data*-section:

1) the generic data record is not directly geographically applicable considering the scope of the LCA study in the VKaLCA-Tool;

2) adaptation (either geographical or technological) occurred to the generic data;

3) the generic data is <5 years old.

4) the generic data was: "*Modelled as to represent RER production (instead of CH-production) considering the Belgian concrete technology".*

By controlling the *quality criteria of data*- section in the building elements database of the VKaLCA-Tool, the user is fully informed about the quality of the generic data used in the study as well as of the occurred compensation for making the data fitting the scope of the LCA- study.

2 References

[1] EN 15804:2012+A1:2013; Sustainability of construction works- Environmental products declaration – core rules for the product category of construction products;
[2] EN 15978: 2011; Sustainability of construction works- Assessment of environmental performance of buildings – calculation method;
[3] CEN 15941:2010; Sustainability of construction works- Environmental product declaration- Methodology for selection and use of generic data;
[4] ISO 14044:2006; Environmental management- Life Cycle Assessment- Requirements and Guidelines;
[5] W. Debacker, K. Allacker, et al.; Milieugerelateerde materaalprestatie van gebouw-elementen; OVAM; 2012;
[6] C. Spirinckx; Note on elaboration of refined methodology and work instrument, Chapter 3, Harmonisation process of the life cycle inventory data, SuFiQuaD, June 2009;
[7] H. Gervasio, S. Dimova; Model for Life Cycle Assessment (LCA) of buildings; Joint Research Centre; EUR 29123 EN; 2018