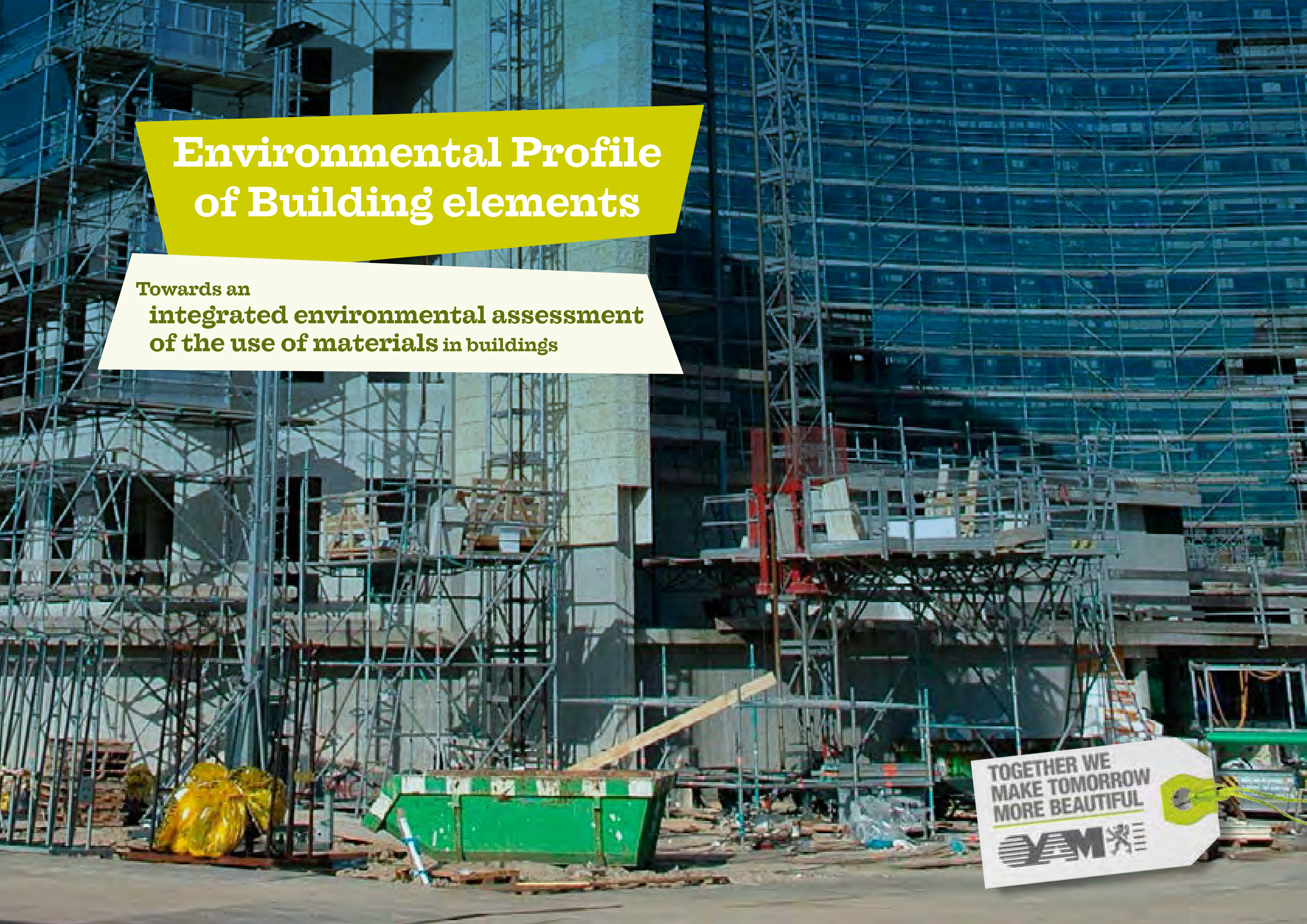
Environmental Profile of Building elements

Towards an integrated environmental assessment of the use of materials in buildings



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Building professionals and the government 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 Flemish-Belgian building context. This publication proposes a database of environmental profiles of 115 variants of building elements, all of which are specific for the Flemish-Belgian building context. It offers an open and transparent presentation of the MMG method of determination that was used as the basis for the calculation of the environmental profiles. Although the resulting building materials methodology is far from final, it is a dynamic model (including a determination method) 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 producents, proprietors) in the future.

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12. *Other titles on this subject*
Milieugerelateerde Materiaalprestatie van Gebouwelementen (MMG report) (www.ovam.be/bouwmaterialenmethodiek)

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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.

In the past two years, OVAM has been developing a transparent methodological framework for unequivocal calculation and communication of Environmental Performance of Materials used in Building Elements (MMG). The current proposal 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 determination method was developed within a framework 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.

Delivering the MMG determination method and the environmental profiles database of 115 building elements is the first step towards sustainable materials management within the Flemish-Belgian construction industry, i.e. the supply of transparent and objective environmental information. In the (near) future, we will be expanding and refining the information, as well as translating it into tools for a broad audience (and the government) 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 stages: during 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 life span 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” (v2.2, 2010), 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 Flemish-Belgian building methods and scenarios.

For these reasons, the Public Waste Agency of Flanders, OVAM took in 2011 the initiative towards the development of a methodology designed for the Flemish-Belgian construction industry.

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 determination method) for the quantification of environmental performance of building elements. The model served as the basis for a limited database of 115 building variants that is representative of the Flemish-Belgian construction industry.

1.2.1. MMG determination method

The parameters of the determination method were selected after due consideration. A brief explanation of the choices can be found in this chapter. For a detailed description of the MMG determination method we refer to Chapter 2 “Determination method”.

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 recent 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.

However, consultation with Flemish policy-makers revealed that the simple use of European (CEN) environmental indicators was too limited. Additional environmental indicators were selected to cover all the Flemish-Belgian policy themes and to acquire optimum insight into the environmental impact of building elements. The added environmental indicators are reported separately under the name “CEN+ indicators” (see Chapter 2 “Determination method”, and Chapter 3 “Environmental profile of building elements: database”).

The following environmental indicators are included in the MMG determination method:

- climate change
- depletion of the stratospheric ozone layer
- acidification of land and water
- eutrophication
- photochemical oxidant formation (low ozone; summer smog)
- depletion of abiotic resources: non-fossil resources
- depletion of abiotic resources: fossil resources
- human toxicity (cancer effects and non-cancer effects)
- particulate matter formation
- ionising radiation effects on humans
- ecotoxicity (land, fresh water, marine)
- land use: land occupation
- land use: land transformation
- water depletion

1.2.1.2. Data selection

In order to avail of sufficient generic environmental data, the extensive Swiss LCI database ecoinvent was harmonised as much as possible into the Flemish-Belgian building context.
In the scope of the MMG research project, 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 cost method (see Chapter 2 “Determination method”). For each individual environmental indicator, the characterisation values are multiplied by a monetisation factor (e.g.: X kg CO^2 equivalents times Y €/kg CO^2 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 cost method as the weighting method is explained in Chapter 2 “Determination method”.

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 determination 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; processed materials 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, exterior walls, interior walls, roof, etc.), which in turn consist of several processed materials (e.g. a masonry wall). The processed materials are again built up of different building materials (e.g. hollow brick and mortar).

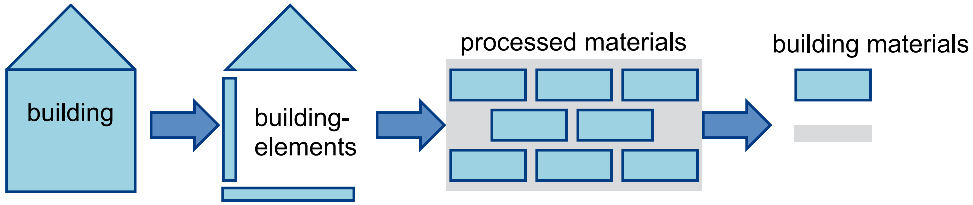

Figure 1: Illustration of the hierarchical structure of the calculation model and its four levels of analysis.

1.2.2.2. Three databases

In this project, for the three lowest levels of the above-mentioned hierarchical structure – i.e. materials, processed materials 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”), processed materials (“Processed Materials Database”) and elements (“Elements Database”) (see figures 2 and 3; Allacker, 2010; Allacker et al. 2011). A database for buildings was not developed in the scope of this study. In the scope of the research project “Sustainability, Financial and Quality Evaluation of Dwelling types in Belgium” (SuFiQuaD, by order of BelSPo) a database of representative dwelling types was built in addition to the above-mentioned databases (Allacker, 2010; Allacker et al. 2011).

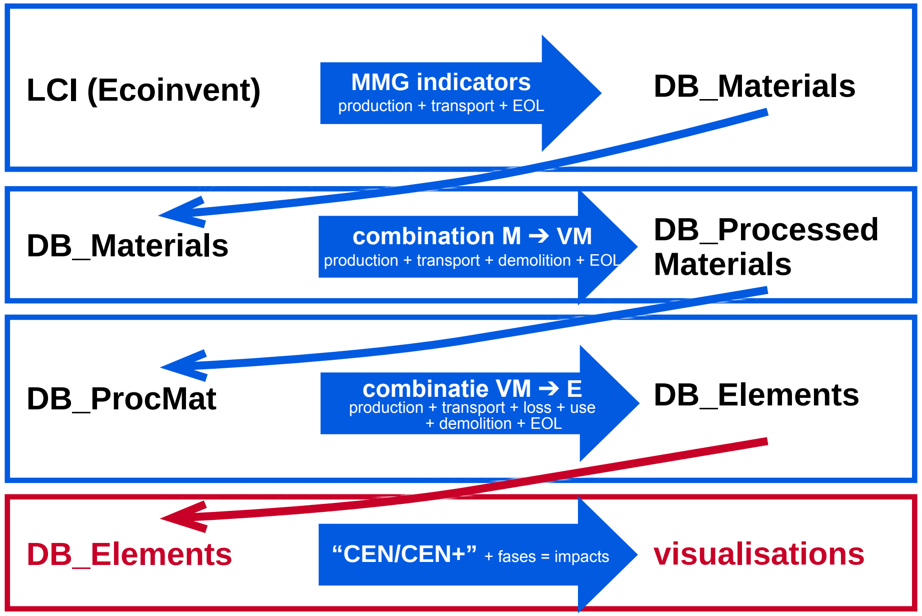

Figure 2: Overview of the three consecutive steps that successively create the databases at a materials, processed materials and element level. A visual of the results at each level constitutes a fourth step.

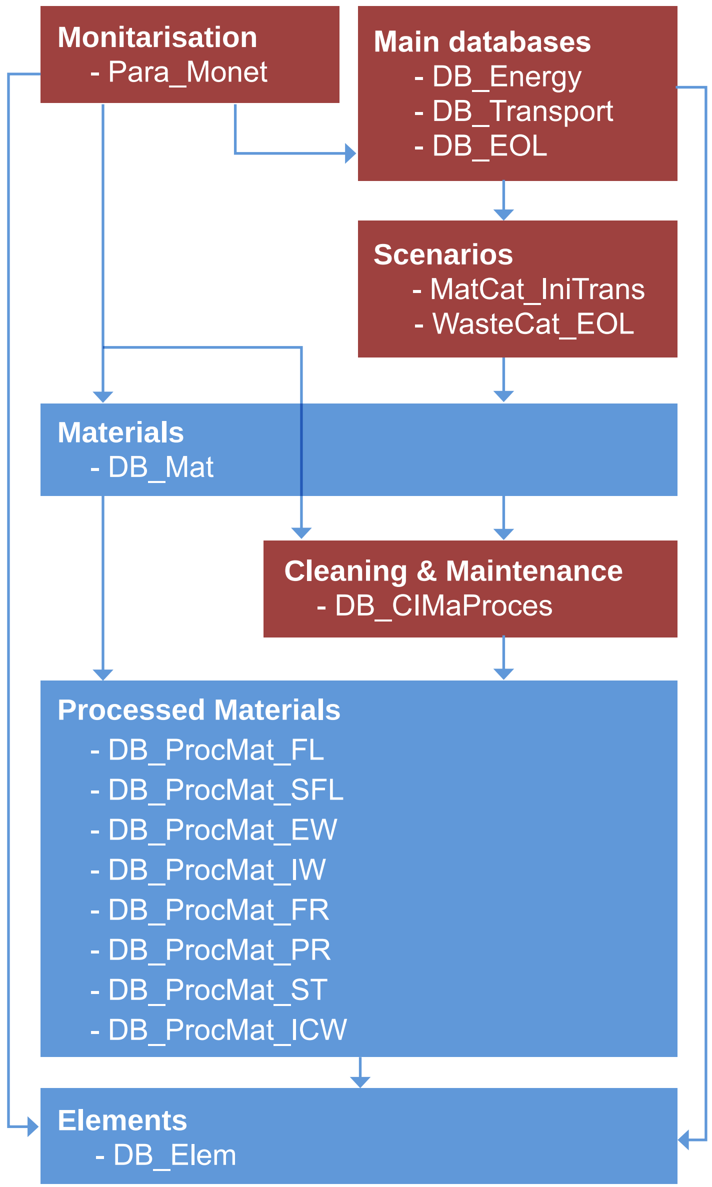

Figure 3: Overview of the structure and accompanying databases in the expert calculation model.

The main databases at the three separate levels, i.e. the Materials Database, Processed Materials Database and Elements Database, are shown in blue; the underlying databases, i.e. Monetisation, Basic Databases, Scenario Databases and the Cleaning and Maintenance Database, are shown in brown.

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 determination method generate a large amount of information, which can be used:

- either to obtain a detailed insight into the environmental profile of materials, processed materials and building elements, by using eighteen individual environmental scores and taking into account all the separate life cycle stages; or
- to compare the environmental profiles of different building element variants – regardless of different (technical) performances – by using sixteen monetised and/or three aggregated environmental scores (CEN, CEN+ and total).

Chapter 3 “Environmental profile of building elements: database”, contains an illustration of the environmental information available for one element variant.

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?

The MMG study carried out building element sensitivity analyses for the following aspects: final processing, transport scenarios, construction waste on the site, life cycle and monetisation.
Based on the performed LCA study of 115 element variants, a building’s life span is a very important assessment parameter. Based on Ammar and Longuet 1980; Allacker, 2010, the MMG research project allows for a standard life span of sixty years. When enhancing the expert calculation model (into a user-friendly software tool or dynamic classification system), it is preferable that this parameter remains 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.

Changing the final processing scenario has a negligible effect on the aggregated environmental scores of the 115 element variants for the entire lifecycle. In this study, 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 final treatment scenario at a materials and processed materials 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 'Determination method'.

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/bouwmaterialenmethodiek.

2. Assessment method

2.1. Introduction

Calculation and clear communication of the environmental performance of the use of materials in buildings - and in particular building elements – require a transparent methodological framework. In this chapter, we discuss in detail the assessment method underlying the expert calculation model developed within this project. 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 TC350 [2]:

- EN 15804 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products (CEN 2012)
- 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 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).

2 CEN TC350: Technical Committee on Sustainability (assessment) of construction works of the European normalisation centre (CEN)

2.2. Objective and scope

The objective of the expert calculation model developed here is to calculate, for a number of building elements, their environmental impact 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 Flemish/Belgian context, taking into account the entire life cycle of the building of building element. Aspects of importance to the life cycle assessment are given below.

2.2.1. Functional Unit[3]

The expert calculation model and its related assessment tool, both developed in this project, are intended primarily for assessments at the building element level.[4] The functional unit is defined as 1 m^2 of an element (e.g. 1 m² of exterior or interior wall or 1 m² 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 m² of floor area can vary (e.g. m² of roof for an apartment block or a bungalow). The 'element method' should, however, be seen as the first step towards a possible future extension to the building level.

3 In line with EN 15978:2011 §7.2 and EN 15804:2012 §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 installations. Account is taken of the entire life cycle of this element in its particular application in 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

5 In line with EN 15978:2011 §7.2

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).

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 finishings (e.g. false ceilings, floor coverings).

2.2.3. System boundaries[8]

In the European standards (CEN 2011a, CEN 2012), the life cycle of a building is divided into several stages or modules (see Figure 1), 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 15804:2012 §6.3.4

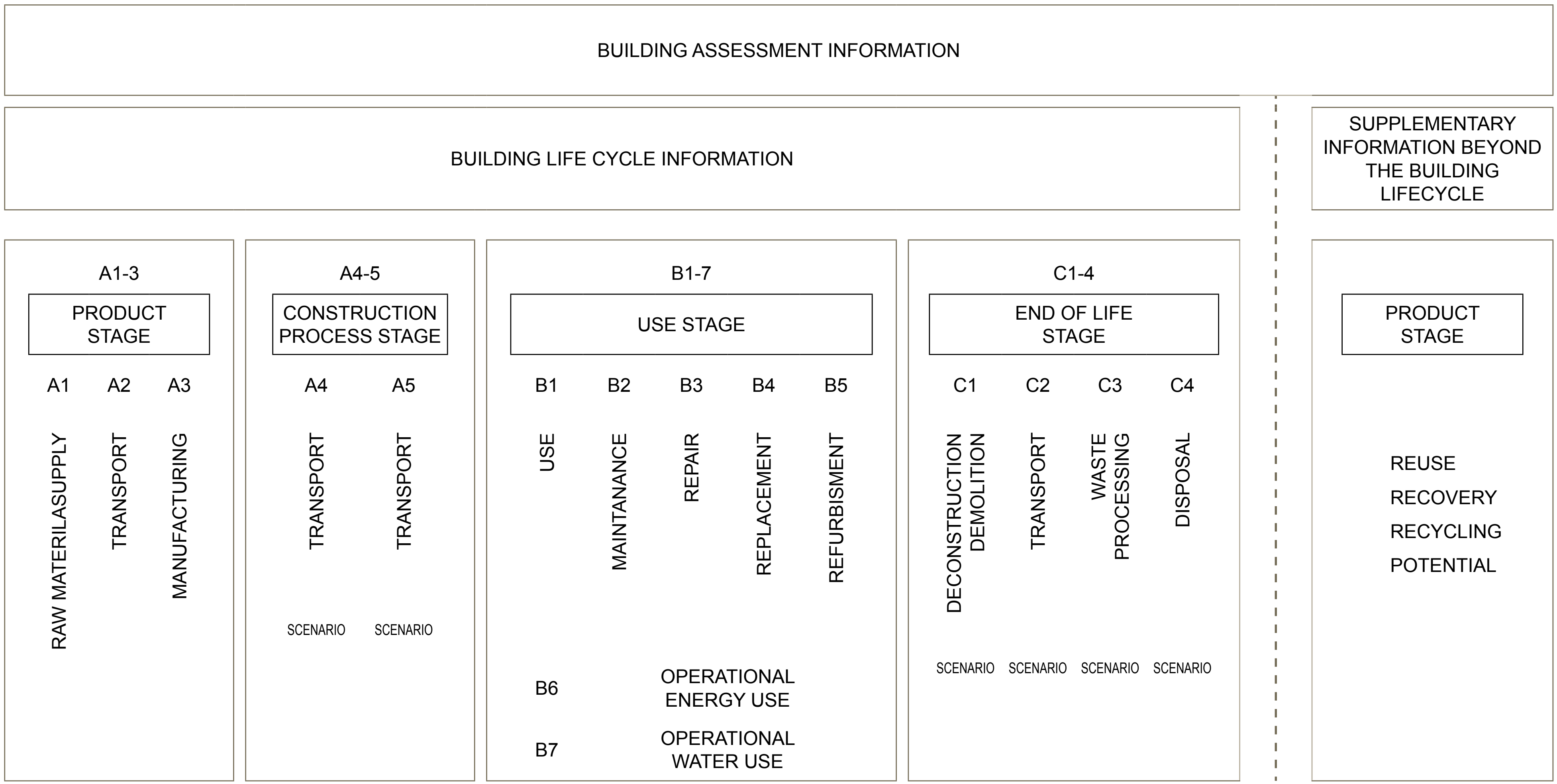

Figure 1: Overview of the life cycle stages and system boundaries within the European standard EN 15978:2011 (CEN 2011a)

2.2.3.1. Product stage (information modules A1-A3)[9]

In principle, only the impact of the production of the packaging 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 v2.2), 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.

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 2012). Consequently, the impact of capital goods will indeed be 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 the absence of data, the transportation of the construction equipment (cranes, concrete mixers, etc.) to the building site is left out of account.

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. water consumption 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.

9 According to EN 15804:2012 §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.

10 According to EN 15804:2012 §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 explicitly 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 as developed.

2.2.3.3. Usage phase (information modules B1-B7)[12]

For practical reasons, periodic repairs are modelled together with maintenance activities. Given that the analysis here is carried out for elements and that refurbishment activities by definition[13] relate to a significant portion of the building, no refurbishment activities are included in the calculation.
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.

12 According to EN 15804:2012 §6.2.4, the usage 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".

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 and the fact that it falls outside the system boundaries of the building, Module D has not been taken into account in this project (CEN 2012, 2011a).

14 According to EN 15804:2012 §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 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.

2.3. Scenarios for defining the building life cycle

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]

In the absence of specific Belgian EPDs, the generic LCI data used here is adapted to the Belgian context as follows:
To ensure geographical representativeness, for the production of the materials in question we have consistently opted for processes that are representative of Western Europe. Where no Western European processes are available in the database, the electricity mix for production is replaced for the available processes by the European mix[19], and for the transportation of the raw materials to the factory we have opted consistently for transportation processes (e.g. impact of transportation with a 16 tonne truck) which are representative of Western Europe[20]. With 'production' is meant only the production that relates to the analysed product. The electricity mix in the underlying processes (e.g. production of raw materials used in the production process) is not modified to the Western European version. A sensitivity analysis revealed indeed 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 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 m³ of sawn timber. For the portion of tropical timber transported as roundwood (logs), the necessary conversion factors have been applied (i.e. 2 m³ roundwood for 1 m³ of sawn timber) (Delem & Spirinckx 2009).

17 In line with EN 15978:2011 §8

18 In line with EN 15978:2011 §8.4

19 For energy consumption during the construction process stage (e.g. blowing of cellulose), we have, however, opted for specifically Belgian processes, e.g. Belgian electricity mix.

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.

Table 1: Transportation scenarios for different groups of wood

	Heavy truck (km)	Sea-going vessel (km)	River boat (km)	Train (km)
Hardwood: (42% local; 58% import)				
Local production[21]	125			
Imported tropical timber	350[22]	9900[23]	225	20
Imported non-tropical timber[24]	1280	1010	/	/
Belgian mix[25]	360	2100	45	40
Softwood: (60% local; 40% import)				
Local production	50			
Imported softwood[26]	740	1400	/	130
Belgian mix	450	830		75

Finally, for a limited number of products containing a portion of secondary raw materials (steel, glass wool, cellular glass, cellulose, MDF, OSB, concrete and others), we examined whether the percentage of secondary raw materials adopted on a default basis in the ecoinvent processes differs from Belgian practice. We also examined 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 15804:2012 and the assessment method established in this document.

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 A27. 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).

21 Transportation from forest to sawmill

22 Transport from forest to foreign port

23 Weighted average transportation distance from foreign ports to Port of Antwerp

24 Is partly by truck and partly by truck and boat (including truck transport to the port)

25 Average transport based on share of different countries of origin (including local production) on the Belgian market

26 Transport from forest in foreign country to distributor in Belgium

27 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)

2.3.2. Scenarios for the construction process stage[28]

The construction process stage is limited here to 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.

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 group (see Table 3). In the present project, a total of 12 product groups or material categories have been considered and included in the expert calculation model. 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 primarily on a survey conducted as part of the SuFiQuaD project (Putzeys et al 2008) and adjusted based on expert judgement and limited additional surveys[29]. The average transport distances were selected arbitrarily based on the number of production points and their location relative to Brussels. Where production takes place abroad, the distance from the factory to the building merchant is also estimated based on the travelling distance from the foreign location to Brussels.

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. 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).

Table 2: Load factors taken for calculating the environmental impact per tonne-km for different means of transportation (Spielman et al., 2007)

Truck type	Average load (tonnes)
<3.5 tonnes	0.19
3.5-7.5 tonnes	5
7.5-16 tonnes	7.5
16-32 tonnes	10
>32 tonnes	18
3.5-16 tonnes	6.41
>16 tonnes	15.07

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28 In line with EN 15978:2011 §8.5

29 Federations have had an opportunity to provide feedback on the proposed scenarios.

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

product group/material category	Arrangement of transportation		Means of transportation from							Average transport distance of transportation from		
	% directly from factory to site	% via an inter-mediary supplier	factory to site			factory to supplier	supplier to site			factory to site	factory to supplier	supplier to site
			heavy truck (> 16 tonnes)	light truck (3.5-16 tonnes)	delivery van (<3.5 tonnes)	heavy truck (> 16 tonnes)	heavy truck (> 16 tonnes)	light truck (3.5-16 tonnes)	delivery van (<3.5 tonnes)	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%	nvt	nvt	nvt	nvt	35	nvt	nvt
prefabricated products for structural work (e.g. vaults, purlins)	100%	0%	100%	0%	0%	100%	100%	0%	0%	100	100	35
loose structural products (e.g. interior bricks, aircrete, roofing (tiles, epdm, ...))	40%	60%	100%	0%	0%	100%	85%	15%	0%	100	100	35
sand-lime brick	40%	60%	100%	0%	0%	100%	85%	15%	0%	200	200	35
insulation	40%	60%	100%	0%	0%	100%	85%	15%	0%	125	125	35
finishing products: floor coverings (e.g. carpet, linoleum, laminate)	10%	90%	90%	10%	0%	100%	90%	10%	0%	150	150	35
ceramic tiles[30]	0%	100%	nvt	nvt	nvt	100%	90%	10%	0%	1500	1500	35
finishing products: plaster (e.g. gypsum plaster, plasterboard, 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%	nvt	nvt	nvt	100%	0%	80%	20%	nvt	100	35

30 Ceramic tiles are mainly from Italy and Spain (Sezzi 2009)

2.3.2.2. Scenario regarding the loss of material during the construction process stage[31]

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.[32]. 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[33]

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 assumptions:

- 1200 equivalent degree-days[34] (Allacker 2010);
- Non-condensing gas boiler with an overall efficiency of 67% (Allacker 2010).

For the electricity consumption of the non-condensing gas boiler, the Belgian electricity mix is used (i.e. ecoinvent process: “electricity, low voltage, at grid/ BE”).

31 In line with EN 15978:2011 §9.3.1.

32 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).

33 In line with EN 15978:2011 §8.6.5.

34 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.

Ecoinvent does not offer any Belgian process for natural gas at the consumer end, but this is construed by taking the available Swiss process “natural gas, low pressure, at consumer”, and replacing the underlying process “natural gas, high pressure, at consumer, CH” by “natural gas, high pressure, at consumer, BE”[35].

2.3.4. Scenario regarding the end-of-life stage of building materials36

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. Demolition processes are, however, associated with the consumption of energy and emissions of particulate matter. Regardless of the composition of the material, the following assumptions are made[37]:

- diesel consumption for mechanical operations: 0.0437 MJ/kg
- emissions of particulate matter:
  - PM < 2.5µm: 1.66 x 10^{-5} kg/kg material
  - PM > 2.5µm and < 10µm: 6.34 x 10^{-5} kg/kg material
  - PM > 10µm: 8.35 x 10^{-5} kg/kg material

35 CH stands for processes that are representative of Switzerland, BE for processes that are representative of Belgium.

36 In line with EN 15978:2011 §8.7.

37 In reality, the composition of the materials and the method of connecting with other materials/ work sections are decisive for the type of demolition and/or deconstruction. Given the limited LCI data in ecoinvent v.2.2, this refinement is not applied here and the same demolition process is assumed for all categories of materials.

2.3.4.2. Basis for the transportation and final disposal of construction and demolition waste

It is assumed that, with the exception of soil, all construction and demolition waste, whether or not sorted on site, is taken first to a collection point (e.g. metal dealer, crusher) or sorting facility[38]. From there the various waste fractions are transported to a landfill, incinerator or recycling/reuse facility according to the scenarios given in Table 4. For soil, it is assumed that 90% is taken directly from the site to the final destination.
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)[39]. 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[40]. The environmental impact of sorting on the site is neglected. 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 for mechanical sorting processes: 0.0022 kWh/kg material
- heat emission from mechanical sorting processes: 0.00792 MJ/kg material
- diesel for loading and unloading (depending on the density of the material)
- sorting infrastructure including land occupation and transformation and energy for administrative facilities: 1 x 10^{-10} plant/kg material

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 inert waste, metals and aircrete.

38 Based on the overview of COPRO-certified products (COPRO 2009), about 20% of the total amount of certified aggregates are crushed at construction and demolition sites, but we assume that three-quarters of this applies to road works and that this applies only to very large demolition sites. Consequently, for the stony fraction it is assumed that all waste goes first to a sorting facility or a crusher.

39 In line with EN 15804 §6.3.4.5.

40 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.

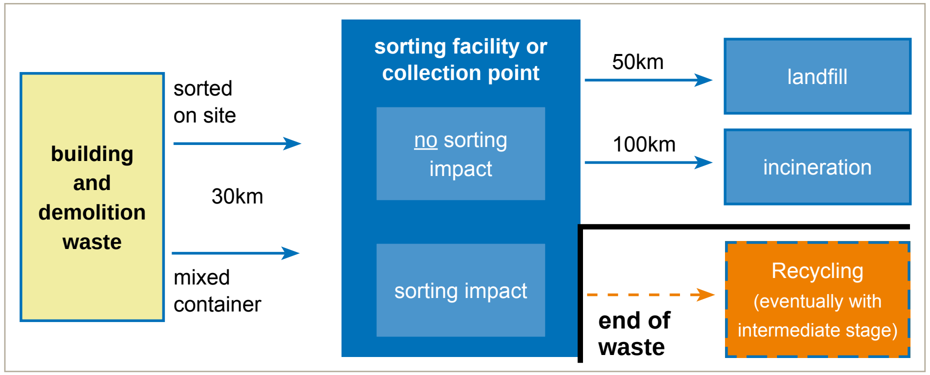

Figure 5: General modelling of waste processing after deconstruction or demolition. Impacts falling within the system boundaries are shown in blue and impacts outside the system boundaries are shown in orange.

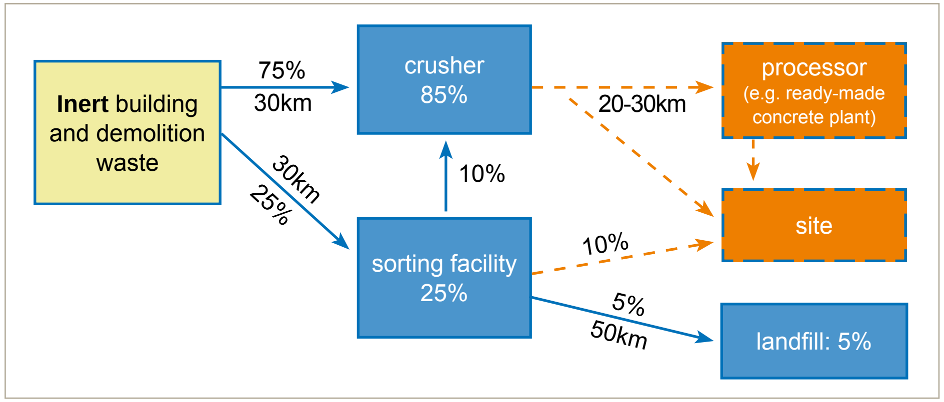

Figure 6: Specific modelling for inert construction and demolition waste.
75% of inert waste is sorted on site and then goes directly to a crusher, while the remaining 25% goes to a sorting facility. 10% of the inert waste that passes via a sorting facility, after sorting goes directly to a building 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 (30km) in principle lies within the system boundaries, but is, however, neglected (indicated in red). 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.

For the fraction of inert materials that is crushed before the end-of-waste status is attained (i.e. 85%; see Figure 6), the following assumptions are made:

- electricity for mechanical crushing processes: 0.0015 kWh/kg material
- heat emission from mechanical crushing processes: 0,00054 MJ/kg material

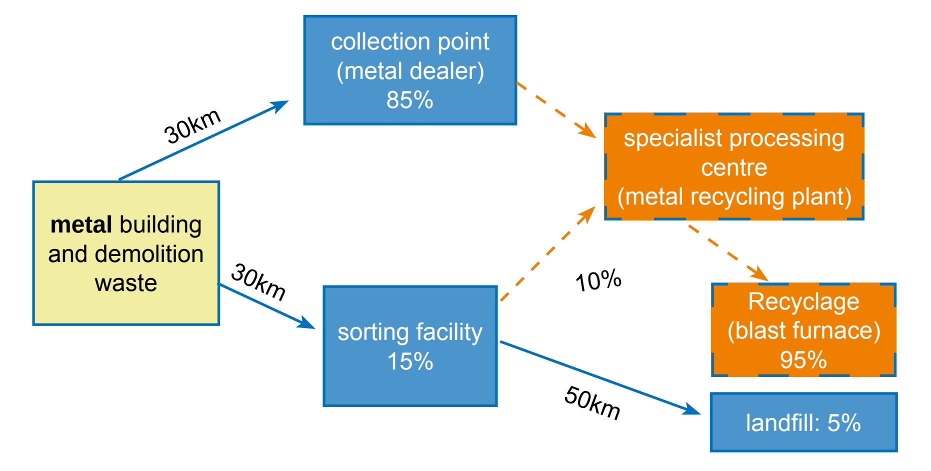

Figure 7: Specific modelling for metallic building and demolition waste.

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'.

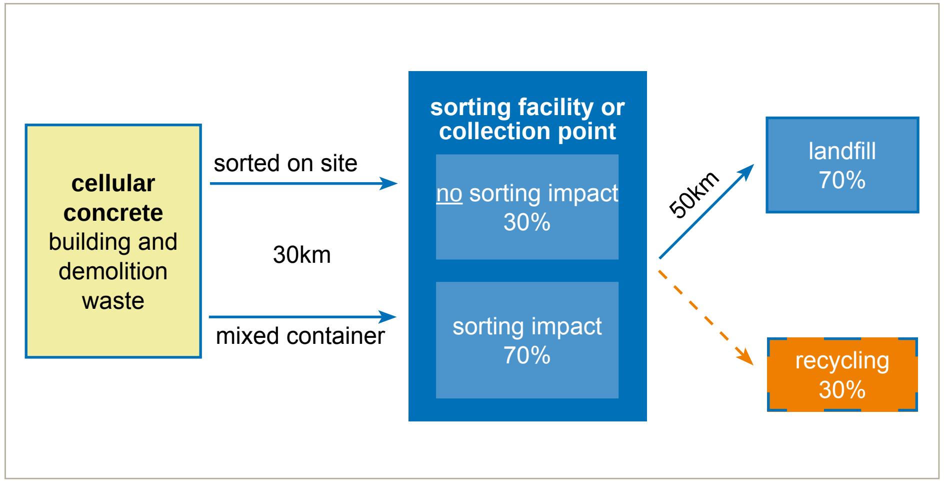

Figure 8: Specific modelling for aircrete waste from construction and demolition activities.

30% of the aircrete 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[41]. Consequently, the environmental damage is assigned entirely to the material incinerated and not to the energy produced.

41 Recently it became clear that the Belgian incinerators are categorised as R1 installations. This means that these waste incinerations fall within the criteria for being classified as energy valorisation, thereby placing the environmental impact of the combustion outside the system boundaries.

2.3.4.3. Transportation of construction and demolition waste

Based on the Dutch standard NEN 8006 (2004) and a consultation of interested parties, the following average values are used for the transportation of construction and demolition waste:

Transportation distances:

a. From demolition site to sorting facility or collection point: 30 km
b. From collection point or sorting facility to landfill: 50 km
c. From collection point or sorting facility to incinerator: 100 km

Means of transport:

a. Transport of waste from the building site to the sorting facility or collection point:
   i. fraction **sorted** at the building site (see table 4 for % for each waste type):
      1. container with inert waste or soil:
         . 100% by heavy truck > 16t
      2. other fractions for sorting:
         . 90% by heavy truck > 16t
         . 5% with a truck from 7.5 to 16 tonnes
         . 5% with a light truck from 3.5 to 7.5 tonnes
   ii.unsorted waste (transported away in **mixed container**):
         . 90% by heavy truck > 16t
         . 10% with a truck from 7.5 to 16 tonnes
b. From sorting facility or collection point to final destination (incineration, landfill or recycling):
c. 100% by heavy truck > 16t
   i. Average load factor (by weight): standard load factor assumed in ecoinvent (see Table 2).

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 26 different waste categories which are considered in this project and included in the expert calculation model. The percentages are based on the results of a survey conducted as part of the SuFiQuaD project (Putzeys et al. 2008), the scenarios included in the Dutch standard NEN 8006 (NEN 2004), own insights and consultation with representatives of federations, OVAM and other sector representatives (e.g. sorting facility, recycling plant).

Product group / Waste category	Description	Landfill (%)	Incineration[42] (%)	Recycling / reuse (%)	sorted on building site[43] (%)
Inert waste	including concrete (e.g. structural elements in concrete and concrete roofing tiles), ceramic products (e.g. floor and wall tiles, bricks, roof tiles) and loose material (e.g. sand, gravel)	5	0	95	75
aerated concrete	including elements, blocks	70	0	30	30
Polyolefins (PP, PE)	including pipes, foils (e.g. waterproofing and airtight membranes), excluding packaging	10	85	5	0
PVC profiles	including window frames	10	45	45	0
PVC cabling	including electrical cables and wire insulation	10	40	50	0
PVC films	including roofing and waterproof membranes (e.g. for swimming pools) and floor coverings	15	65	20	0
PVC pipes	including for sewage[44]	10	30	50	0
Elastomers	including roofing (EPDM)	100	0	0	0
Bitumen	including flat roofing	100	0	0	0
Metals	including aluminium profiles, metal fasteners (e.g. nails, screws), steel, copper (plates and pipes) and zinc (e.g. roofing)	5	0	95	85
Gypsum	including blocks and boards (plasterboard)	95	0	5	5
Plaster	interior and exterior plastering	100	0	0	0
Glass	including flat glazing glass	30	0	70	70
Chemically treated wood	including for roof trusses and treated cladding	5	95	0	40
Non-treated wood (but can be painted)	including solid wood parquet flooring, cedar cladding and painted window frames	5	20	75	40
Composite wood products	including OSB, MDF, chipboard, veneer and laminate	5	75	20	40
Insulation (flammable)	including PUR, EPS, wood wool, cellulose and XPS	0	100	0	0
Insulation (not flammable)	including glass wool and rock wool	100	0	0	0
Finishing layer glued to wood, plastic or metal	including paint, coatings and adhesives	0	100	0	0

Product group / Waste category	Description	Landfill (%)	Incineration[42] (%)	Recycling / reuse (%)	sorted on building site[43] (%)
Finishing layer glued to rubble	including paint, coatings and adhesives	100	0	0	0
Packaging[45]	paper and cardboard (Val-i-Pack 2009)	3	3	94	50
Packaging[45]	plastic foils (Val-i-Pack 2009)	30	10	60	50
Packaging[45]	wood (e.g. pallets) (Val-i-Pack 2009)	20	20	60	50
Soil[46]		0	0	100	90
Small hazardous waste	including paint remains, white spirit and form stripping oils	0	75	25	100
Remaining waste (flammable)	other waste fractions (e.g. carpet, linoleum and blinds)	0	100	0	0

Table 4 Waste scenarios for the 26 waste categories considered in this project.

42 Destination of the waste by product group (% by weight calculated on the total amount of waste per product group: e.g. 5% of inert 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 column does not sum to 100%

45 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.

46 The model assumes zero soil contamination.

2.4. Life Cycle Inventorisation

2.4.1. Replacements[48]

When the service life of materials/products 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 building material or product over the service life of the building is obtained by dividing the service life of the building by the service life of the product and reducing this result by 1 (the initial installation). Where the result is an integer, this is the number of replacements of the product.
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.
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=1.2. In this case, there are two possible approaches: either the windows are 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 the building is too old for such a (large) investment.

To ensure an unambiguous approach, the following principles are applied:

- It is assumed that a material will always be replaced, where this is necessary for the viability and habitability of the building regardless of the remaining service life of the building (e.g. installations). In this case, the fraction is always rounded up.
- Where replacements are required for aesthetic reasons only (mainly finishes), it is assumed that the material is not replaced when the remaining service life of the building at the time of replacement is less than half the service life of the element considered. For example, where the service life of interior plastering is 40 years and that of the dwelling is 90 years, it is assumed that the plaster will be replaced after 40 years, but not after 80 years, since the remaining 10 years (90-80 years = 10 years) of the house are less than half of the lifetime of the plaster, namely 20 years (40/2).

47 In line with EN 15978:2011 §9.3

48 In line with EN 15978:2011 §9.3.3

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 2.2. This choice was based on the following criteria:

- Completeness: some 4100 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 2.2 dated May 2010).
- 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).

49 In line with EN 15978:2011 §9.4

50 In line with EN 15978:2011 §9.4.2, EN 15804: 2012 §6.3.7 and TR 15941:2010

2.5. Life cycle impact assessment[51]

During the life cycle impact assessment 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 TC350 standards (CEN 2012, 2011a), their presence in the International Reference Life Cycle Data System (ILCD) Handbook (JRC 2011) and consultation of Flemish and federal environmental authorities.

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 TC350 standards (CEN 2012, 2011a) and the ILCD Handbook (JRC 2011). For certain categories (see section 2.5.2.1), the CEN TC350 standards recommend a particular indicator. For this reason the ILCD recommendations cannot always serve as a basis.

Besides single environmental impact scores, the environmental impact is also communicated, at the request of OVAM, 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. This means that the selection of impact methods is different for the single

51 In line with EN 15978:2011 §11

environmental scores and for the aggregated score(s). To avoid a rigid calculation tool we have opted for a maximum overlap between the methods for the single environmental scores and the aggregated score. In the following paragraphs we set out in greater depth the selection process at both score levels.
OVAM 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).

2.5.2. Determination of individual environmental impact scores

The environmental impact indicators chosen in the CEN TC350 standards at product and building level (CEN 2012, 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 potential;
- depletion potential of the stratospheric ozone layer;
- acidification potential of land and water;
- eutrophication potential;
- formation potential of tropospheric ozone photochemical oxidants;
- abiotic resource depletion potential: fossil and non-fossil resources.

Further indicators are proposed in the CEN TC350 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 importance for the Flemish environmental policy, and taking into account the on-going initiatives in 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;
- ecotoxicity: terrestrial, freshwater and marine;
- land use: occupation and transformation;
- water depletion.

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.

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

environmental indicator (CEN)	unit	selected impact method
Global warming potential	kg CO_2 eqv.	ReCiPe midpoint[52]
Depletion potential of the stratospheric ozone layer	kg CFC^{-11} eqv.	ReCiPe midpoint[53]
Acidification potential of land and water	kg SO_2 eqv.	ReCiPe midpoint[54]
Eutrophication potential	kg $(PO_4)^{3-}$ eqv.	CML 2002[55]
Formation potential of tropospheric ozone photochemical oxidants	kg ethene eqv.	CML 2002[56]
Abiotic resource depletion potential: non-fossil resources Abiotic resource depletion potential: fossil resources	kg Sb* eqv. MJ, net calorific value	CML 2002[57] Cumulated energy demand[58]

** Sb: antimony*

52 The ReCiPe midpoint method is based on the IPCC 2007 (100y) method for assessing impacts due to climate change and is allowed by the ILCD.

53 The ReCiPe midpoint method refers to the method of World Meteorological Organisation (WMO) for assessing impacts due to stratospheric ozone depletion. The WMO method is recommended by the ILCD.

54 The ILCD recommends the use of the “accumulated exceedance” method for assessing impacts due to acidification with local effects included. However, for the Belgian building context this data are only partially available, if at all. The scientific basis of the ReCiPe midpoint for the assessing of impacts due to acidification is positively received by the ILCD and is taken here as an alternative.

55 The ILCD recommends the ReCiPe midpoint or ReCiPe endpoint for the assessing of impacts due to eutrophication. Given that the CEN TC350 standards (CEN 2012, 2011a), however, prescribe kg $(PO_4)^{3-}$ equiv. as a unit, we have opted for the CML 2002 method as the best alternative.

56 The ILCD recommends the ReCiPe midpoint for the assessing of impacts due to formation of photochemical oxidants. Given that the CEN TC350 standards (CEN 2012, 2011a), however, prescribe kg ethene equiv. as a unit, we have opted for the CML 2002 method as the best alternative.

57 The CML method includes both fossil and non-fossil abiotic resources. The characterisation of fossil fuels is not taken into account here.

58 Given that CEN TC350 standards prescribe MJ, net calorific value, as a unit, we have opted for this LCI-based method. This method is directly related to the LCI data from ecoinvent. For fossil resources ecoinvent gives only the upper calorific value.

2.5.2.2. CEN+ set: additional environmental indicators

In addition to the seven CEN impact categories, at the request of OVAM, a number of additional environmental indicators are analysed and reported in the MMG project. Where recommended by the ILCD Handbook (JRC 2011), we have opted here for an 'endpoint method'. This type of LCIA method translates environmental impacts into damage profiles (like damage to human health and quality of ecosystems) and allows for monetary valuation (as an optional weighting factor - see section 2.5.3) in a simple way.
Based on the selection process described above, as good as all environmental indicators are selected. From consultation with government environmental departments we have inferred that the environmental aspects related to ionising radiation effects (on both humans and ecosystems) were regarded as less important (but not nil). Moreover, it appears that the ILCD Handbook (JRC 2011) does not recommend any practicable impact assessment methods for the 'ionising radiation effects on ecosystems' category. This last category was not selected, therefore, in the assessment method. Water scarcity was considered important in the Flemish-Belgian environmental policy. However, there is no data available for the Belgian and West European building context which also takes into account the impact on local water resources. This is why this aspect is merely quantified (in m^3 water) based on LCI data. An overview of the selected additional environmental impact categories (CEN+) and the associated units and environmental impact methods is given in Table 6.

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

environmental indicator (CEN+)	unit	selected impact method
Human toxicity, cancer and non-cancer effects	DALY*	ReCiPe endpoint[59]
Particulate matter	DALY*	ReCiPe endpoint[60]
Ionising radiation, human health	DALY*	ReCiPe endpoint[61]
Ecotoxicity: terrestrial freshwater marine	 kg 1.4 DB** eqv. kg 1.4 DB** eqv. kg 1.4 DB** eqv.	 ReCiPe midpoint[62] ReCiPe midpoint[63] ReCiPe midpoint[64]
Land occupation: agricultural/forest urban	 species x year species x year	 ReCiPe endpoint[65] ReCiPe endpoint[66]
Land transformation: natural tropical rain forest	 species x year species x year	 ReCiPe endpoint[67] ReCiPe endpoint[68]
Water depletion	m^3 water use	ReCiPe midpoint[69]

** DALY: disability-adjusted life year   ** DB: dichlorobenzene*

59 ILCD gives the USEtox-method as the best option. The ReCiPe method (both midpoint and endpoint) also receives a very good assessment and is considered the best alternative. Aiming at maximum overlap between impact methods for the aggregated score we have opted here for the ReCiPe endpoint method.

60 According to the ILCD the ReCiPe endpoint method is the preferred assessment method.

61 The underlying model of the ReCiPe method (both midpoint and endpoint) as described in 'Goedkoop et al 2008' is for the ILCD the preferred assessment method. Aiming at maximum overlap with impact methods for the aggregated score we have opted here for the ReCiPe endpoint method.

62 ILCD gives the USEtox-method as the best option. The ReCiPe midpoint method also receives a very good assessment and is considered the best alternative. Aiming at maximum overlap with impact methods for the aggregated score we have opted here for the ReCiPe midpoint method.

63 idem

64 idem

65 ILCD recommends using the "Soil Organic Matter" method for the assessment of impacts due to land use, with the inclusion of local effects of land use. However, for the Belgian and West European building context this data is only partially available, if at all. The ReCiPe endpoint method is recommended by the ILCD as the best alternative.

66 idem

67 idem

68 idem

69 ILCD recommends the use of the Swiss EcoScarcity midpoint method, with the inclusion of local effects of water scarcity. However, for the Belgian and West European building context this data is only partially available, if at all. The ReCiPe midpoint method offers a way of expressing m^3 water consumption based on the LCI.

2.5.3. Determination of the aggregated environmental score

The intention of the assessing environmental material performances of building elements, 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 OVAM, 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).
As already mentioned in the selection procedure (see section 2.5.1), monetary valuation is dependent on the choice of unit and will therefore influence the selection of the underlying impact method. Moreover, in the case of aggregation, it is recommended to use matching impact methods for the different impact categories, so as to avoid gaps and duplication. Within this project, we have opted – with respect to determining the aggregate score – for the recent ReCiPe methods. According to the JRC (2011), the compatible ReCiPe endpoint and/or midpoint methods have a solid scientific basis for all selected impact categories. Below we summarize the impact methods and the corresponding units selected for the CEN and CEN+ environmental indicators (see Table 7 and Table 8).

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

environmental indicator (CEN)	unit	selected impact method
Global warming	kg CO^2 eqv.	ReCiPe midpoint
Depletion of the stratospheric ozone layer	kg CFC^{-11} eqv.	ReCiPe midpoint
Acidification of land and water	kg SO^2 eqv.	ReCiPe midpoint
Eutrophication Fresh water Marine water	 kg P equiv. kg N equiv.	 ReCiPe midpoint ReCiPe midpoint
Formation of tropospheric ozone photochemical oxidants	kg NMVOC* equiv.	ReCiPe midpoint
Abiotic resource depletion: non-fossil resources Abiotic resource depletion potential: fossil resources	kg Fe equiv.	ReCiPe midpoint n/a[70]

**NMVOC: Volatile organic components, excluding methane[70]*

70 The monetisation factor for the 'abiotic depletion of fossil resources' indicator is 0€/MJ, net calorific value, given that the monetary valuation is strongly related to greenhouse gas emissions. The monetary valuation for climate change {due to greenhouse gas emissions) implies the choice of an emission trajectory and of energy sources whereby the use of fossil fuels is limited in favour of energy efficiency and renewable energy sources. See MMG report for further details.

environmental indicator (CEN+)	unit	selected impact method
Human toxicity, cancer and non-cancer effects	DALY*	ReCiPe endpoint
Particulate matter	DALY*	ReCiPe endpoint
Ionising radiation, human health	DALY*	ReCiPe endpoint
Ecotoxicity: terrestrial fresh water marine	 kg 1.4 DB** equiv. kg 1.4 DB** equiv. kg 1.4 DB** equiv.	ReCiPe midpoint
Land occupation: agricultural/forest urban	 m²a m²a	 ReCiPe midpoint ReCiPe midpoint
Land transformation natural tropical rain forest	 m²	 n/a[71] ReCiPe midpoint
Water depletion		n/a[72]

** DALY: disability-adjusted life year*

*** DB: dichlorobenzene*

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

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.

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.

To determine the uncertainty interval for each indicator, we use the uncertainty

71 The monetarisation factor for the 'land transformation natural' indicator is nil, owing to a lack of reliable monetary data. See MMG report for further details.

72 The monetarisation factor for the 'water depletion' indicator is nil, owing to a lack of reliable monetary data. See MMG report for further details.

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 "depletion of the (stratospheric) ozone layer", "acidification", "formation of photochemical oxidants", "human toxicity", "ecotoxicity" and "ionising radiation on humans" (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 non-fossil resources", "land occupation" (both from forestry and from agricultural or urban use) and "land transformation".
The valuation of the impacts with respect to "climate change" 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.
As can be seen from Tables 9 and 10 the value of the standard deviation (σg) has an important effect on the bandwidth of the monetary values per environmental indicator.
Not all the environmental indicators were monetised (separately). The indicators "land transformation from natural land to agriculture or forestry (excluding tropical rainforests)" and "water shortage" could not be monetised due to a lack of reliable monetary data. A figure of € 0 per MJ Net calorific value was assumed for the indicator "depletion of fossil resources", as the objectives for reduced use of fossil resources are strongly related to the reduction of greenhouse emissions (e.g. via the Kyoto protocol). In other words, it is assumed here that the environmental costs caused by depletion of fossil resources are included indirectly through monetisation of potential impacts regarding climate change (as a result of greenhouse gas emissions).

Table 9: overview of monetary values (median, minimum, maximum) for the CEN indicators.

environmental indicator (CEN)	unit	σg	Median (€/unit)	Minimum (€/unit)	Maximum (€/unit)
Global Warming	kg CO^2 eqv.	5	0.060	0.012	0.30
Ozone degradation	kg CFC^{-11} eqv.	4	49.1	12.3	196.3
Soil and water acidification	kg SO^2 eqv.	4	0.85	0.21	3.4
Eutrophication fresh water marine	 kg P eqv. Kg N eqv.	 5 5	 100 18	 20 3.6	 500 90
photochemical oxidant formation	kg NMVOS* eqv.	4	7.40	1.85	29.6
Depletion of non-fossil resources Depletion of fossil resources	kg Fe eqv. na[73]	5	0.0520 /	0.0104 /	0.26 /

**NMVOS: Volatile organic compounds, excluding methane*

73 The monetisation value for the indicator “depletion of fossil resources” is € 0/MJ net calorifoc value, as the monetary valuation is strongly related to greenhouse gas emission. The monetary valuation of climate change (as a result of greenhouse gas emissions) implies a choice for an emission path and for energy resources whereby the use of fossil fuels is limited in favour of energy-efficient and renewable energy resources.

Table 10: overview of monetary values (median, minimum, maximum) for the CEN+ indicators.

environmental indicator (CEN)	unit	σg	Median (€/unit)	Minimum (€/unit)	Maximum (€/unit)
human toxicity: cancer and non-cancer effects	DALY*	4	60000	15000	240000
particulate matter formation	DALY*	3	60000	20000	180000
ionising radiation effects on humans	DALY*	4	60000	15000	240000
ecotoxicity: terrestrial, fresh water marine	 kg 1.4 DB** eqv. kg 1.4 DB** eqv. kg 1.4 DB** eqv.	 4 4 4	 4.310 0.0190 1.40E-06	 1.078 0.00475 3.50E-07	 17.24 0.0760 5.60E-06
land use: occupation: forestry and agriculture urban	 m^2a m^2a	 5 5	 0.0360 0.181	 0.00700 0.0360	 0.182 0.907
land use: transformation nature (excl. rainforests) tropical rainforest	 na[74] m^2	 / 5	 / 0.80	 / 0.16	 / 4.0
water shortage	na[75]	/	/	/	/

74 The monetisation value for the indicator “land transformation of natural land to agriculture or forestry (excluding rainforest)” is nil due to a lack of reliable monetary data.

75 The monetisation value for the indicator “water shortage” is nil due to a lack of reliable monetary data.

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 (18 at individual level, 16 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 relevance for Flemish-Belgian environmental policy.
- 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 (2012, 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 materials, work sections and building elements, as well as decision-making, for example when comparing different variants of elements. In this way the assessment method is available to various players, from producers and industry organisations to users/developers, designers, contractors and environmental administrations.
- 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 established 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, for the percentage loss of material during the construction process stage 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.
- The underlying environmental data are hierarchically arranged: i.e. material - work section - building element - ...
- 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 impact 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 total building and 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.

3. Environmental profile of building: database

A calculation of the MMG determination method was carried out for 115 element variants frequently used in Belgian construction practice. The element variants are built up of “materials” and “processed materials” in conformity with the MMG model

The following types of building elements appear in the database:

1. **Floor on solid ground** (10 variants)
2. **Exterior wall** (25 variants)
3. **Load-bearing interior wall** (7 variants)
4. **Non-load-bearing interior wall** (12 variants)
5. **Storey floor** (16 variants)
6. **Flat roof** (13 variants)
7. **Pitched roof** (13 variants)
8. **Window** (11 variants)
9. **Staircase** (5 variants)
10. **Interior cabinet work** (3 variants)

3.1. Presentation of tables and diagrams

3.1.1. Titles

For each building element, both the individual score per environmental indicator and the summed (monetised) impact are shown, respectively in a table and in a figure.

The following information is available for each type of building:

- a description of the variants (table V);
- the individual environmental impact per **CEN** environmental indicator for the variants (CEN table);
- the individual environmental impact per **CEN+** environmental indicator for the variants (CEN+ table);
- the summed (monetary) impact for each variant showing the energy losses through **T**ransmission (figure T);
- the summed (monetary) impact for each variant compared to the different environmental **I**ndicators (figure **I**);
- the summed (monetary) impact for each variant compared to the different **L**ife cycle stages (figure L).

The following conventions apply to the diagrams:

- CEN indicators: hatched
- CEN+ indicators: in solid colours
- the effects from energy losses from transmission: separate on top

3.1.2. Selection of variants

To solve some typical design issues, the selection of the different building element variants is characterised in the following way:

- identical composition of the variants, however: two separate thicknesses for the insulation layer with the same insulation material; e.g. for the building element "floor on solid ground", two variants are distinguished, i.e. PUR1 and PUR2. The first variant represents the current building method (in accordance with today's energy performance regulations), whereas the second variant represents the passive standard;
- identical composition of variants, save for different insulation material with a thickness available on the market and which results in (approximately) the same total heat resistance;
- an identical composition of variants, save for a different finishing layer (interior or exterior).

3.1.3. Detailed environmental profile per variant

A detailed description of the composition of the different variants of the building elements and the selected characteristics of the processed materials[1], can be found in the manual “Environmental profile of Building Elements: details per variant”.

1 R-value (m^2K/W), λ-value (W/mk), thickness (m), ratio (= quantity of processed material per unit of element), frequencies as regards minor and major maintenance and replacements (year), replacement for ‘aesthetic reasons’ only or ‘necessary from a technological point of view’,

For significant energy losses from heat transmission, a best estimate was already made (via the ‘equivalent degree day’ method) for the calculated building element variants. If this were omitted, applying insulation in the elements of the outer frame would have a negative effect on the environment (namely by including in the calculation the environmental effects upon manufacture, but excluding the environmental benefits during usage).

3.2. Which information is available in the database?

This chapter illustrates the available environmental information upon calculation of one or more building elements:

- This chapter explains the analysis of one single building element. For extensive consultation of all variants we refer to the additional publications per building element type, i.e. "Environmental profile of building elements: details per variant".
- This chapter explains the (comparative) analysis of several variants of a building element. For extensive consultation please refer to chapter 3.3 - Database.

The example gives an analysis of a floor with trass lime whose composition is described in Table 11 below.

Description	u	MiM (years)	MaM (years)	Repl (years)	Repl Type	Ratio	t (m)	λ (W/m.K)	R (m².K/W)
floor5_trass lime									
Excavations for floor beds - with machine - without transport	m³			120	necessary	0.47	0.47	na	
Infrastructure for floor beds - filling with gravel - with machine	m³			120	necessary	0.1	0.1	na	
Infrastructure for floor beds - filling with expanded clay - with machine	m³			120	necessary	0.32	0.32	0.13	01/02/46
Floor bed - expanded clay grains with trass lime mortar	m³			120	necessary	0.05	0.47	0.13	01/03/62
Infrastructure for floor beds - levelling of ground surface	m²			120	necessary	1		na	
Floor bed - sealing membrane - PE 2/10	m²			120	necessary	1	0	na	
Floor finish - tiles - ceramic (extruded, glazed stoneware) 30 x 30 cm - glued	m²		15	60	aesthetic	1	0.01	01/02/13	0.01
Floor, supporting structure for finish - screed - cement based - 5 cm	m²			120	necessary	1	0.05	0.84	0.06
Floor, supporting structure for finish - trass lime mortar - 3 cm	m²			120	necessary	1	0.03	na	
Floor, supporting structure for screed - reinforcement net	m²			120	necessary	1	0	na	

Table 1.1: overview of the detailed composition of variant 'floor5_trass lime'.

Legend to Table 1.1:

u: unit;

MiM: minor maintenance frequency;

MaM: major maintenance frequency;

Repl: replacement frequency;

type Repl: type of replacement (necessary or aesthetic);

ratio: quantity per m²;

t: layer thickness (in m);

λ: heat conduction coefficient (in W/m.K);

R: thermal resistance = t/λ (in m2.K/W)

3.2.1. Analysis of one single element variant

For a detailed insight into the environmental profile of one single building element, one can:

1. zoom in on the 18 individual environmental indicators (CEN and CEN+ environmental indicators);
2. on the basis of the 18 monetised environmental indicators, obtain an aggregated environmental score (the sum of the CEN environmental indicators, the sum of the CEN+ environmental indicators, or the sum of CEN and CEN+ environmental indicators).

3.2.1.1. Analysis of one single element variant based on the individual environmental indicators

Table 12 provides an overview of the 7 individual CEN environmental indicators for the element "floor5_trass lime', whereby each environmental indicator is expressed as its specific unit.

Table 13 gives an overview of the 11 individual CEN+ environmental indicators for the element 'Floor5_trass lime'.

Table 12: overview of the 7 individual CEN indicators for the variant 'Floor5_trass lime'

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion - non-fossil	depletion - fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
floor5_trass lime	3,80E+02	2,97E-05	1,42E+00	2,95E-01	8,26E-02	2,15E-03	6,59E+03

Table 13:overview of the individual 11 CEN indicators for the variant 'Floor5_trass lime'

	human toxicity	particulate matter formation (PM)	ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1.4 DB eq	kg 1.4 DB eq	kg 1.4 DB eq	species.yr	species.yr	species.yr	species.yr	m^3
floor5_trass lime	4,07E-05	1,20E-03	1,29E-06	2,22E-02	1,34E+00	1,49E+00	8,23E-05	5,35E-08	1,72E-07	5,06E-09	5,14E+00

3.2.1.2. Analysis of one single element variant based on an aggregated (monetised) environmental scoree

Figure 9 gives an initial overview for the element “Floor5_trass lime”. The monetised values are shown (on the vertical axis, in €/m² of floor) to enable comparison of the different environmental indicators. The CEN and CEN+ indicators are shown separately, as hatched band and in colour, respectively. The aggregated values for CEN and CEN+ and the sum are shown in the upper right corner.

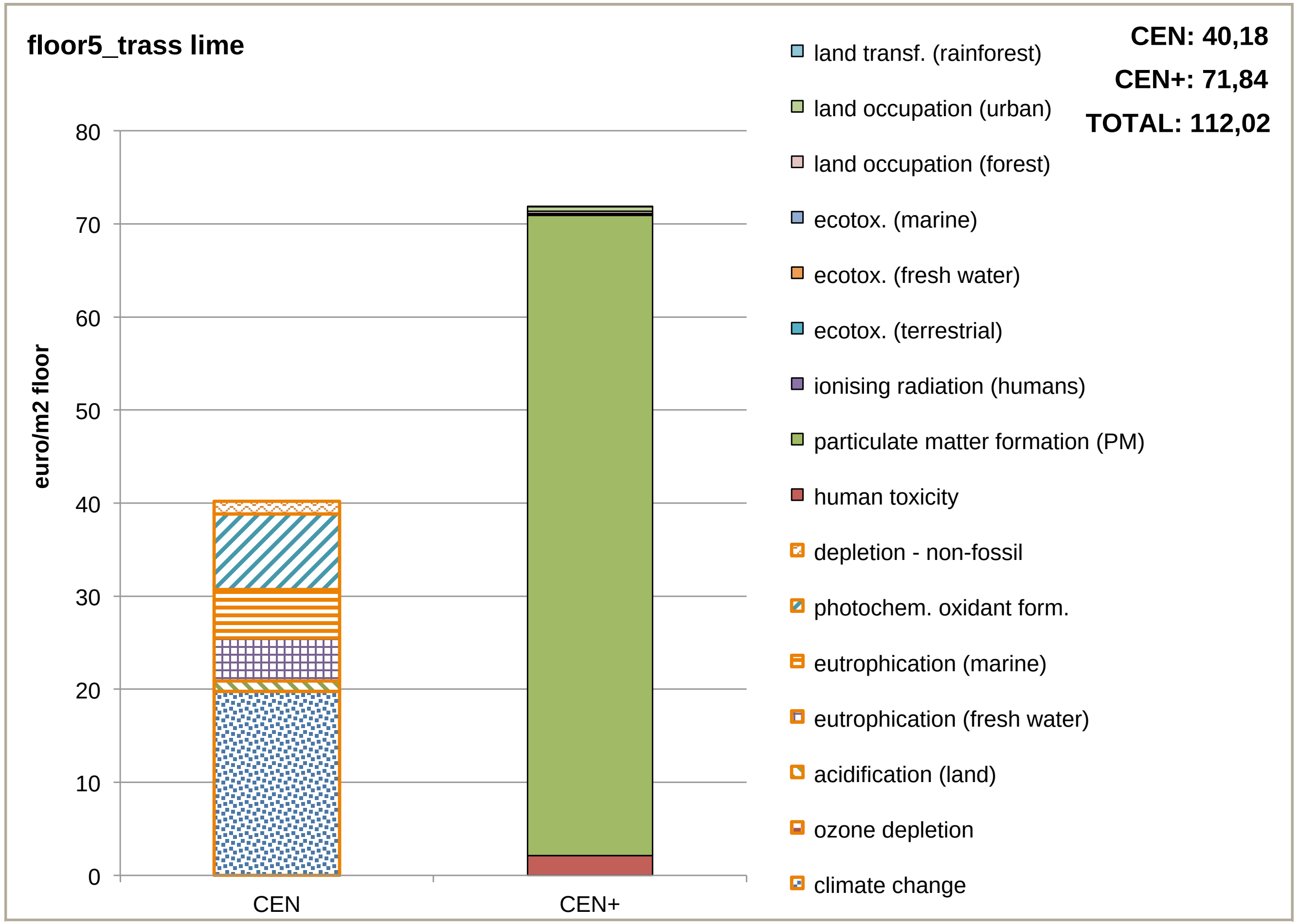

Figure 9:
Aggregated environmental profile (split into CEN and CEN+) of one single building element variant 'Floor5_trass lime' per environmental indicator, expressed in monetary units.

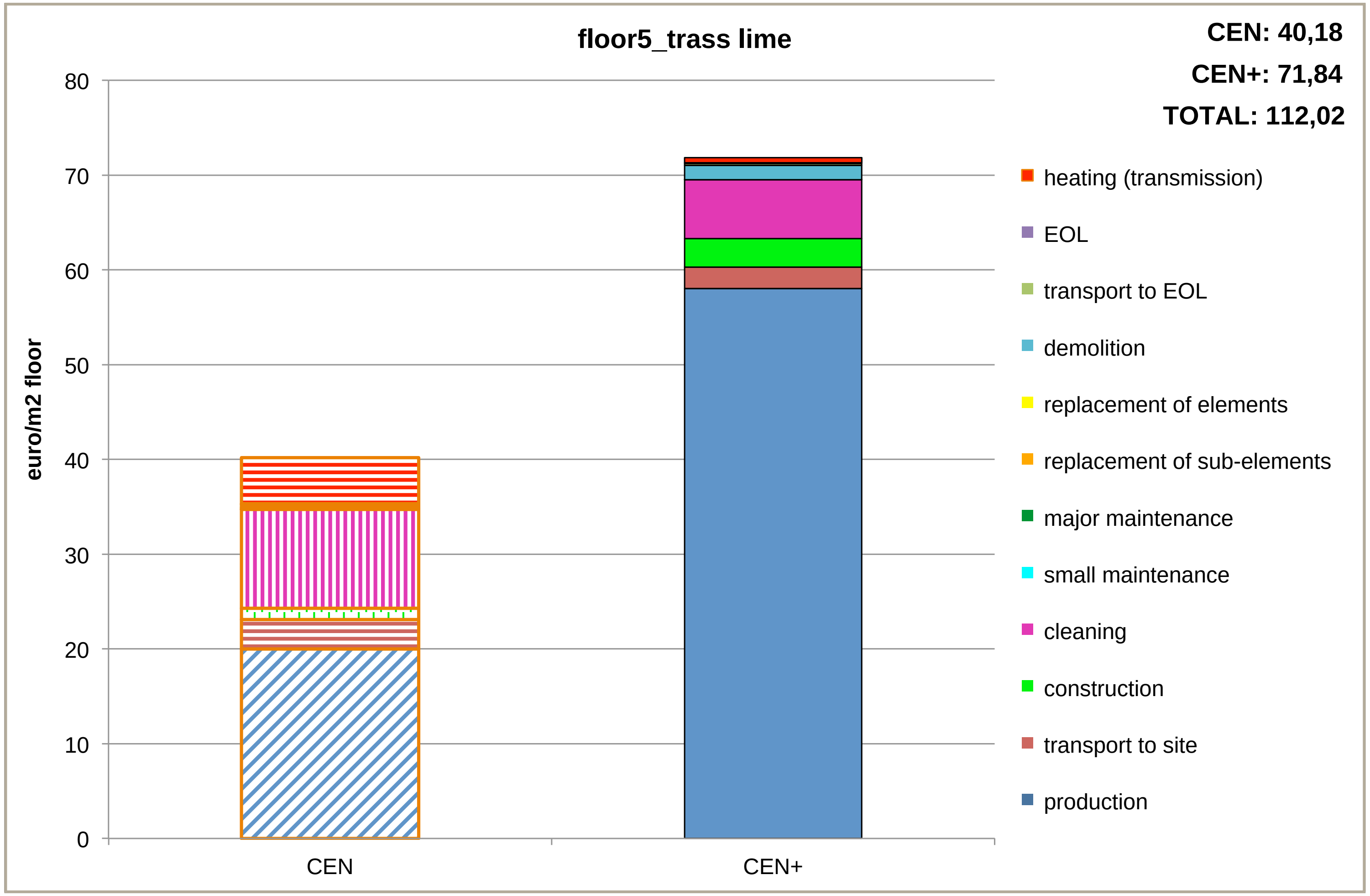

Figure 10: Aggregated environmental profile (split into CEN and CEN+) of one single building element variant per life cycle stage, expressed in monetary units.

The same element, obviously with the same general results, is viewed differently in figure 10, namely as the contribution of the different life cycle stages (from production up to and including final treatment (i.e. End Of Life or EOL). The effects of energy generation by the element (due to heat loss via transmission) are shown on top to provide for easy reading of the results exclusive of the transmission losses. CEN and CEN+ are again presented separately (as hatched bars and in solid colours, respectively). Each environmental effect is assigned its own colour code throughout the document.

Figure 11 gives a total picture, i.e. the same end results, however split per life cycle stage and per environmental indicator. The aggregated values for CEN and CEN+ and the sum are still indicated in the upper right corner.

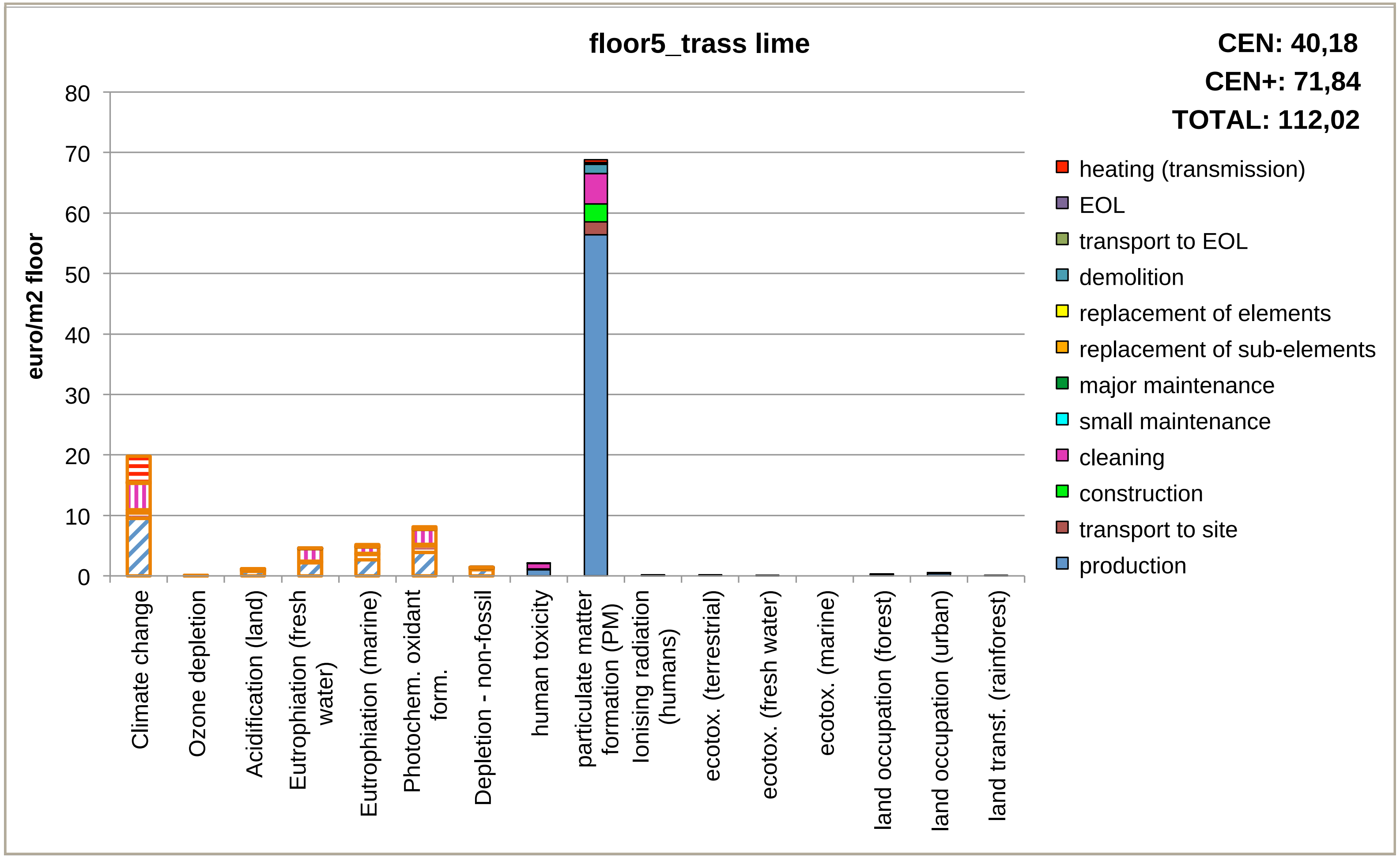

Figure 11: Aggregated environmental profile (split into CEN and CEN+) of the element variant 'floor5_trass lime' per life cycle stage and per individual environmental indicator, expressed in monetary units.

3.2.1.3. Analysis of the contributions of the different processed materials in one single element variant

Figure 12 indicates how for the above discussed element variant ("floor on solid ground type 5: trass lime") a certain life cycle stage (in this figure: "production") can be analysed in detail by verifying the contribution of the different "processed materials". The CEN and CEN+ environmental indicators and the sum of both are pictured separately.

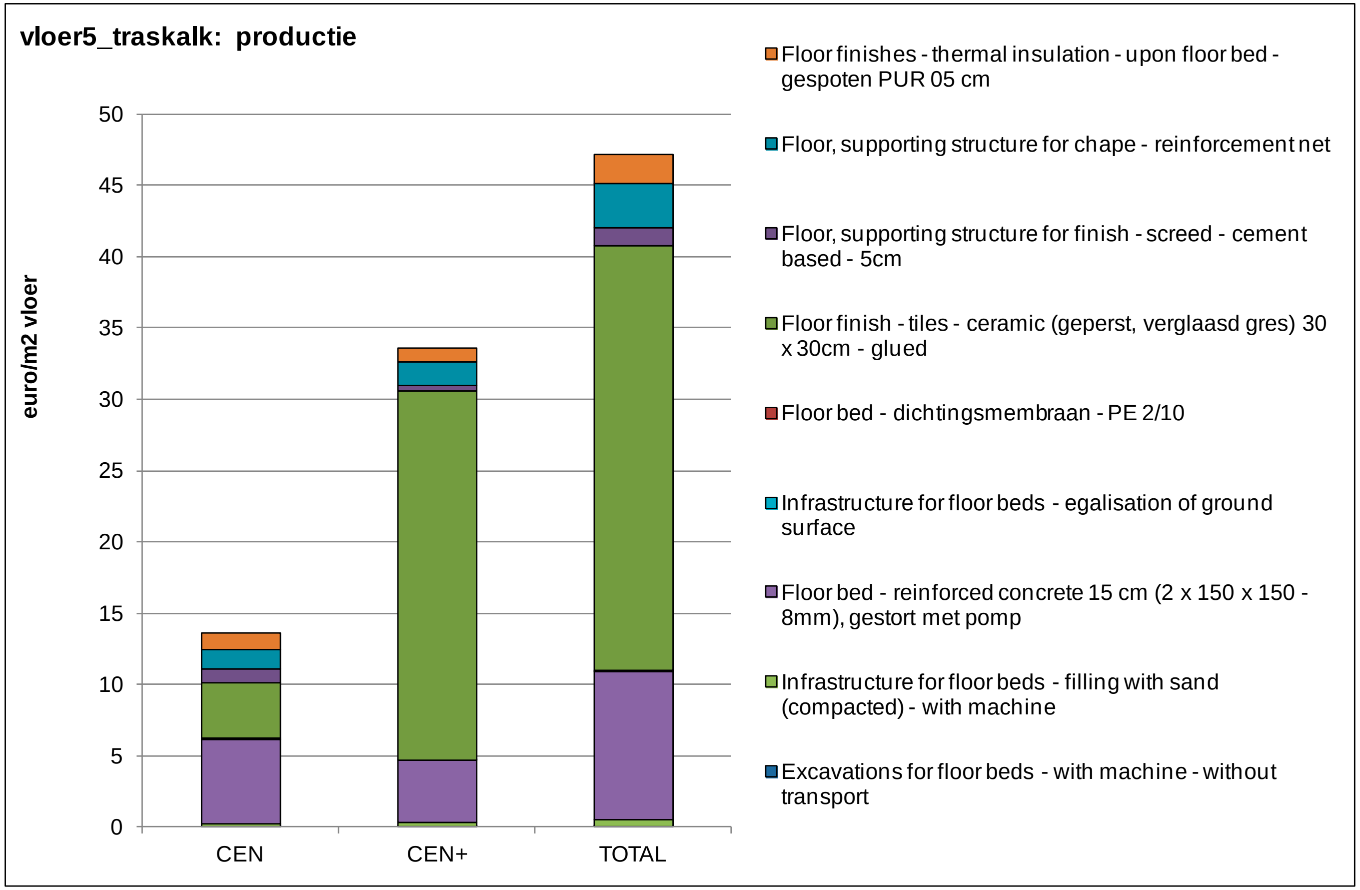

Figure 12: The contribution of the different "processed materials" to the aggregated environmental profile of the element variant "Floor5_trass lime" for one specific life cycle stage (here: production)

3.2.2. Comparison of different element variants

To enable a detailed analysis and comparison of the environmental profile of several building element variants, one can:

3. 1. compare the 18 individual environmental indicators (CEN and CEN+ environmental indicators) of the variants;
4. 2. on the basis of the 18 monetised environmental indicators, obtain an aggregated environmental score of the variants (i.e. the sum of the CEN environmental indicators, the sum of the CEN+ environmental indicators, or the sum of CEN and CEN+ environmental indicators).

3.2.2.1. Comparison of variants based on the individual environmental indicator

Table 14 provides an overview of the 7 individual CEN environmental indicators for different building element variants 'floor on solid ground', whereby each environmental indicator is expressed as its specific unit.

Table 14: overview of the individual CEN indicators for the variants 'floor on solid ground'

	climate change	ozone depletion	acidification (land)	eutrophic-ation	photochem. oxidant form.	depletion - non-fossil	depletion - fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Floor on solid ground							
floor1_PUR05	4,65E+02	3,04E-05	8,09E-01	2,87E-01	6,95E-02	2,15E-03	8,24E+03
floor2_PUR15	3,34E+02	1,94E-05	8,06E-01	2,90E-01	6,10E-02	2,14E-03	5,85E+03
floor3_XPS8	4,75E+02	4,12E-04	8,15E-01	2,85E-01	6,91E-02	2,15E-03	8,04E+03
floor4_REC_PUR05	4,65E+02	3,04E-05	8,08E-01	2,87E-01	6,95E-02	2,15E-03	8,24E+03
floor5_trass lime	3,80E+02	2,97E-05	1,42E+00	2,95E-01	8,26E-02	2,15E-03	6,59E+03
floor6_PUR04_screed floor EPS	7,18E+02	3,72E-05	1,30E+00	3,94E-01	9,12E-02	2,24E-03	1,02E+04
floor7_PUR05_screed anhydrite	4,64E+02	3,10E-05	8,17E-01	2,92E-01	7,04E-02	2,58E-03	8,36E+03
floor8_PUR05_parquet	3,78E+02	3,30E-04	5,53E-01	1,93E-01	4,42E-02	6,22E-04	5,80E+03
floor9_PUR05_parquet	3,77E+02	3,30E-04	5,48E-01	1,92E-01	4,40E-02	6,17E-04	5,77E+03
floor10_kurk08_parquet	2,75E+02	3,21E-04	6,04E-01	2,10E-01	3,82E-02	6,39E-04	3,74E+03

Table 15 provides an overview of the 11 individual CEN+ environmental indicators for different building element variants ‘floor on solid ground’, whereby each environmental indicator is expressed in its specific unit.

Table 15: overview of the 11 individual CEN+ environmental indicators for different building element variants ‘floor on solid ground

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m3
Floor on solid ground											
floor1_PUR05	4,73E-05	7,93E-04	1,35E-06	1,97E-02	1,58E+00	1,71E+00	8,22E-05	5,28E-08	9,85E-08	3,34E-09	4,39E+00
floor2_PUR15	4,72E-05	7,85E-04	1,26E-06	2,09E-02	1,73E+00	1,66E+00	8,22E-05	3,89E-08	6,38E-08	2,12E-09	4,48E+00
floor3_XPS8	4,77E-05	7,92E-04	1,36E-06	2,70E-02	2,01E+00	1,78E+00	8,22E-05	5,35E-08	9,86E-08	3,32E-09	4,25E+00
floor4_REC_ PUR05	4,73E-05	7,93E-04	1,34E-06	1,97E-02	1,58E+00	1,71E+00	8,22E-05	5,12E-08	9,63E-08	3,30E-09	4,12E+00
floor5_trass lime	4,07E-05	1,20E-03	1,29E-06	2,22E-02	1,34E+00	1,49E+00	8,23E-05	5,35E-08	1,72E-07	5,06E-09	5,14E+00
floor6_PUR04_ screed floor EPS	5,87E-05	9,88E-04	1,64E-06	2,70E-02	1,96E+00	1,98E+00	8,22E-05	5,84E-08	1,09E-07	3,80E-09	5,25E+00
floor7_PUR05_ screed anhydrite	4,80E-05	8,06E-04	1,37E-06	2,06E-02	1,60E+00	1,74E+00	8,22E-05	5,07E-08	9,48E-08	4,21E-09	4,41E+00
floor8_PUR05_ parquet	3,02E-05	4,07E-04	1,12E-06	3,17E-02	1,53E+00	1,31E+00	3,21E-04	8,83E-08	1,14E-07	2,82E-09	2,12E+00
floor9_PUR05_ parquet	3,02E-05	4,03E-04	1,12E-06	3,16E-02	1,53E+00	1,30E+00	3,21E-04	8,47E-08	1,08E-07	2,79E-09	2,07E+00
floor10_cork08_ parquet	3,14E-05	4,33E-04	1,07E-06	3,40E-02	1,72E+00	1,30E+00	3,21E-04	8,77E-08	1,02E-07	1,87E-09	2,56E+00

3.2.2.2. Comparison of variants based on the aggregated (monetised) score

Figure 13 gives an overview of the different variants for the element “floor on solid ground”. The same conventions apply as previously:

- CEN indicators: hatched;
- CEN+ indicators: in solid colours;
- the effects of energy losses from transmission: separate on top.

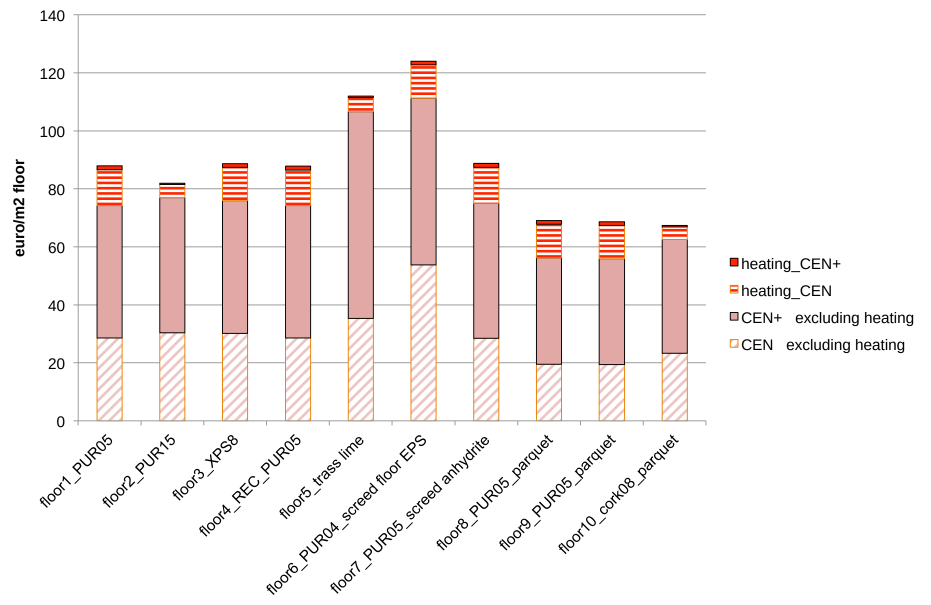

Figure 13: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants, expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

In Figure 14, the environmental impact is split up according to the viewed environmental indicators and in Figure 15, according to the life cycle stages.

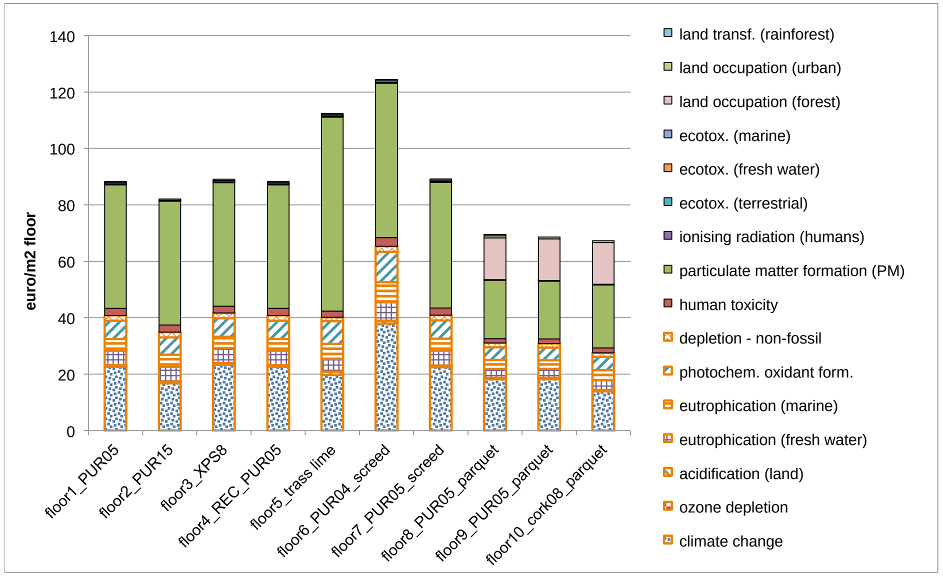

Figure 14: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'floor on solid ground' per environmental indicator, expressed in monetary units.

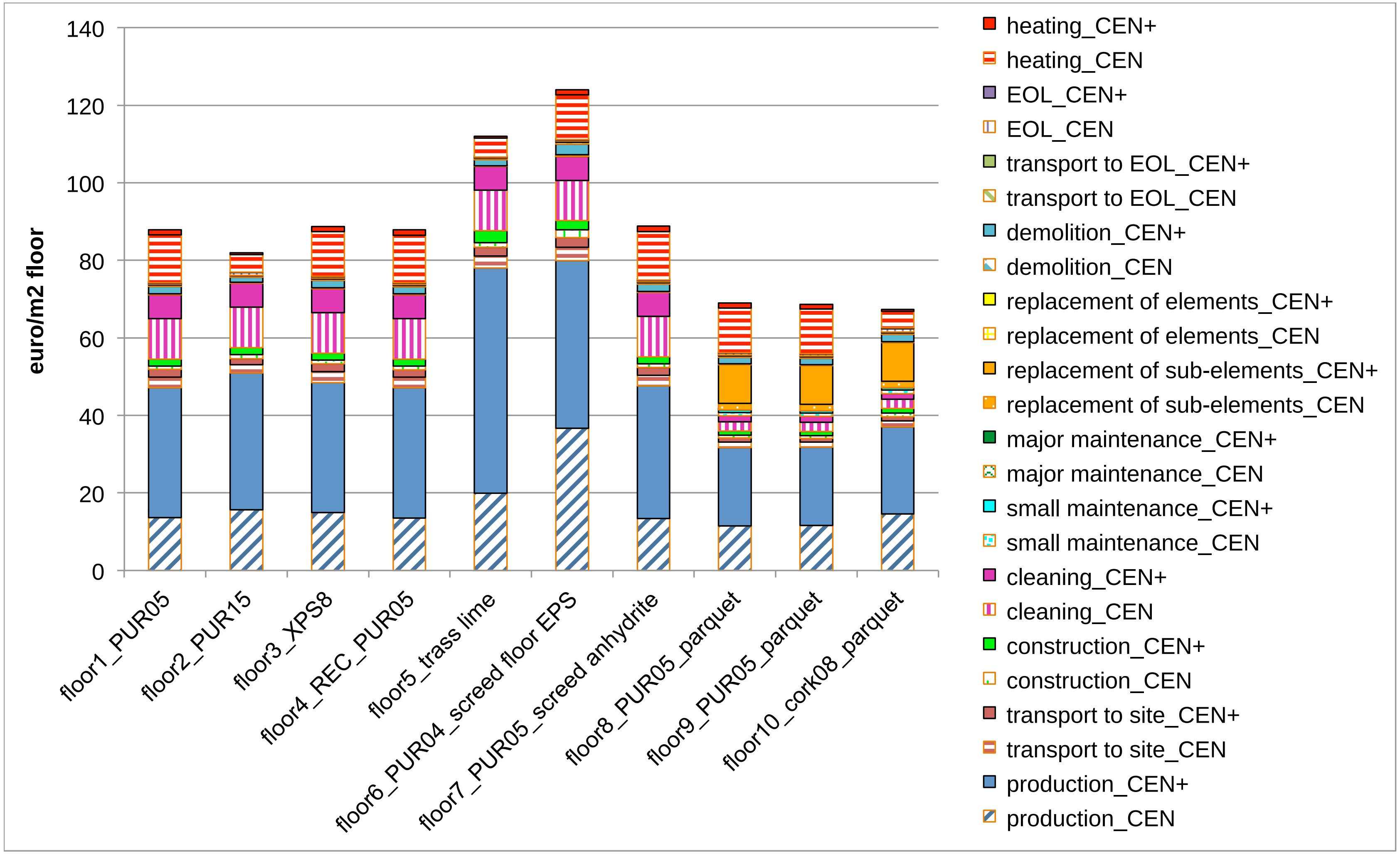

Figure 15: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'floor on solid ground' per life cycle stage, expressed in monetary units..

3.3. Database

3.3.1. Floor on solid ground

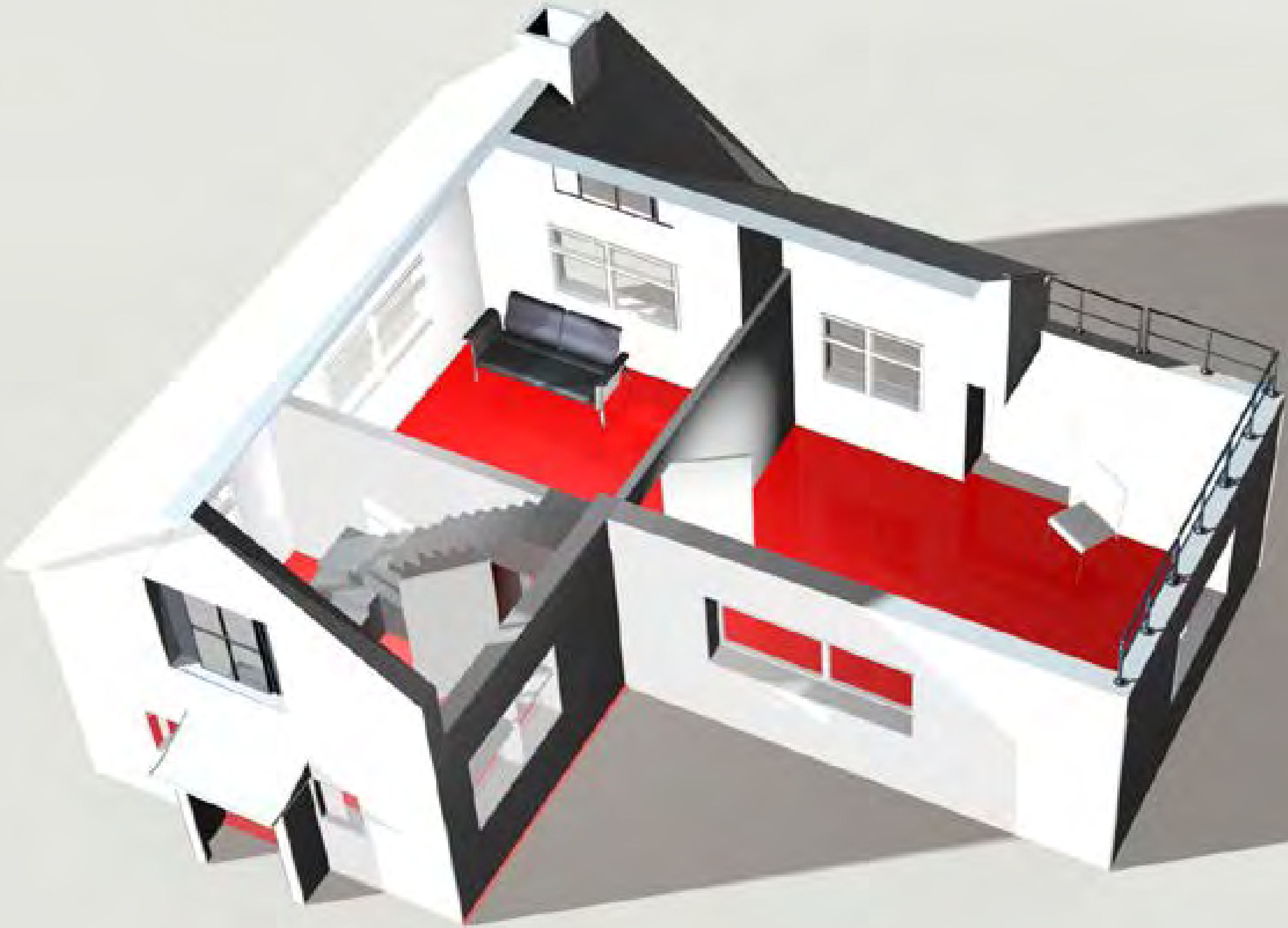

Table V 1: overview of the composition of the variants “floor on solid ground”

(13)+ floor on solid ground: environmental impact per m² of floor, 10 types (from outside inwards =>)						
1	floor1_PUR05	sand	concrete new	PUR1 (injected over concrete): 5 cm (U = 0.40)	screed mix	fired clay tiles
2	floor2_PUR15	sand	concrete new	PUR2 (injected over concrete): 15 cm (U=0.15)	screed mix	fired clay tiles
3	floor3_XPS8	sand	concrete new+filling layer	XPS1 above the load-bearing floor: 4 cm (U=0.38)	screed mix	fired clay tiles
4	floor4_REC_PUR05	sand	concrete 100 recycled	PUR1 (injected over concrete): 5 cm (U = 0.40)	screed mix	fired clay tiles
5	floor5_trass lime	gravel+clay grains	trass lime (mortar)		screed mix	fired clay tiles
6	floor6_PUR04_screed floor EPS	sand	concrete new	PUR1 (injected over concrete): 4 cm (U=0.38)	insulating screed mix with EPS grains	fired clay tiles
7	floor7_PUR05_screed anhydrite	sand	concrete new	PUR1 (injected over concrete): 5 cm (U=0.41)	anhydrite	fired clay tiles
8	floor8_PUR05_ parquet	sand	concrete new	PUR1 (injected over concrete): 5 cm (U = 0.38)	screed mix	parquet
9	floor9_PUR05_ parquet	concrete	concrete new	PUR1 (injected over concrete): 5 cm (U = 0.38)	screed mix	parquet
10	floor10_cork08_ parquet	sand	concrete new+filling layer	cork: 8 cm	screed mix	parquet

Table CEN 1: overview of the individual CEN indicators for the variants 'floor on solid ground'

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Floor on solid ground							
floor1_PUR05	4.65E+02	3.04E-05	8.09E-01	2.87E-01	6.95E-02	2.15E-03	8.24E+03
floor2_PUR15	3.34E+02	1.94E-05	8.06E-01	2.90E-01	6.10E-02	2.14E-03	5.85E+03
floor3_XPS8	4.75E+02	4.12E-04	8.15E-01	2.85E-01	6.91E-02	2.15E-03	8.04E+03
floor4_REC_PUR05	4.65E+02	3.04E-05	8.08E-01	2.87E-01	6.95E-02	2.15E-03	8.24E+03
floor5_trass lime	3.80E+02	2.97E-05	1.42E+00	2.95E-01	8.26E-02	2.15E-03	6.59E+03
floor6_PUR04_screed floor EPS	7.18E+02	3.72E-05	1.30E+00	3.94E-01	9.12E-02	2.24E-03	1.02E+04
floor7_PUR05_screed anhydrite	4.64E+02	3.10E-05	8.17E-01	2.92E-01	7.04E-02	2.58E-03	8.36E+03
floor8_PUR05_parquet	3.78E+02	3.30E-04	5.53E-01	1.93E-01	4.42E-02	6.22E-04	5.80E+03
floor9_PUR05_parquet	3.77E+02	3.30E-04	5.48E-01	1.92E-01	4.40E-02	6.17E-04	5.77E+03
floor10_cork08_parquet	2.75E+02	3.21E-04	6.04E-01	2.10E-01	3.82E-02	6.39E-04	3.74E+03

Table CEN+ 1: overview of the individual CEN+ indicators for the variants 'floor on solid ground'

	human toxicity	particulate matter formation (PM)	ionising radiation (humans)	ecotox. (terrest-rial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1.4 DB eq	kg 1.4 DB eq	kg 1.4 DB eq	species.yr	species.yr	species.yr	species.yr	m^3
Floor on solid ground											
floor1_PUR05	4,73E-05	7,93E-04	1,35E-06	1,97E-02	1,58E+00	1,71E+00	8,22E-05	5,28E-08	9,85E-08	3,34E-09	4,39E+00
floor2_PUR15	4,72E-05	7,85E-04	1,26E-06	2,09E-02	1,73E+00	1,66E+00	8,22E-05	3,89E-08	6,38E-08	2,12E-09	4,48E+00
floor3_XPS8	4,77E-05	7,92E-04	1,36E-06	2,70E-02	2,01E+00	1,78E+00	8,22E-05	5,35E-08	9,86E-08	3,32E-09	4,25E+00
floor4_REC_PUR05	4,73E-05	7,93E-04	1,34E-06	1,97E-02	1,58E+00	1,71E+00	8,22E-05	5,12E-08	9,63E-08	3,30E-09	4,12E+00
floor5_trass lime	4,07E-05	1,20E-03	1,29E-06	2,22E-02	1,34E+00	1,49E+00	8,23E-05	5,35E-08	1,72E-07	5,06E-09	5,14E+00
floor6_PUR04_screed floor EPS	5,87E-05	9,88E-04	1,64E-06	2,70E-02	1,96E+00	1,98E+00	8,22E-05	5,84E-08	1,09E-07	3,80E-09	5,25E+00
floor7_PUR05_screed anhydrite	4,80E-05	8,06E-04	1,37E-06	2,06E-02	1,60E+00	1,74E+00	8,22E-05	5,07E-08	9,48E-08	4,21E-09	4,41E+00
floor8_PUR05_parquet	3,02E-05	4,07E-04	1,12E-06	3,17E-02	1,53E+00	1,31E+00	3,21E-04	8,83E-08	1,14E-07	2,82E-09	2,12E+00
floor9_PUR05_parquet	3,02E-05	4,03E-04	1,12E-06	3,16E-02	1,53E+00	1,30E+00	3,21E-04	8,47E-08	1,08E-07	2,79E-09	2,07E+00
floor10_cork08_parquet	3,14E-05	4,33E-04	1,07E-06	3,40E-02	1,72E+00	1,30E+00	3,21E-04	8,77E-08	1,02E-07	1,87E-09	2,56E+00

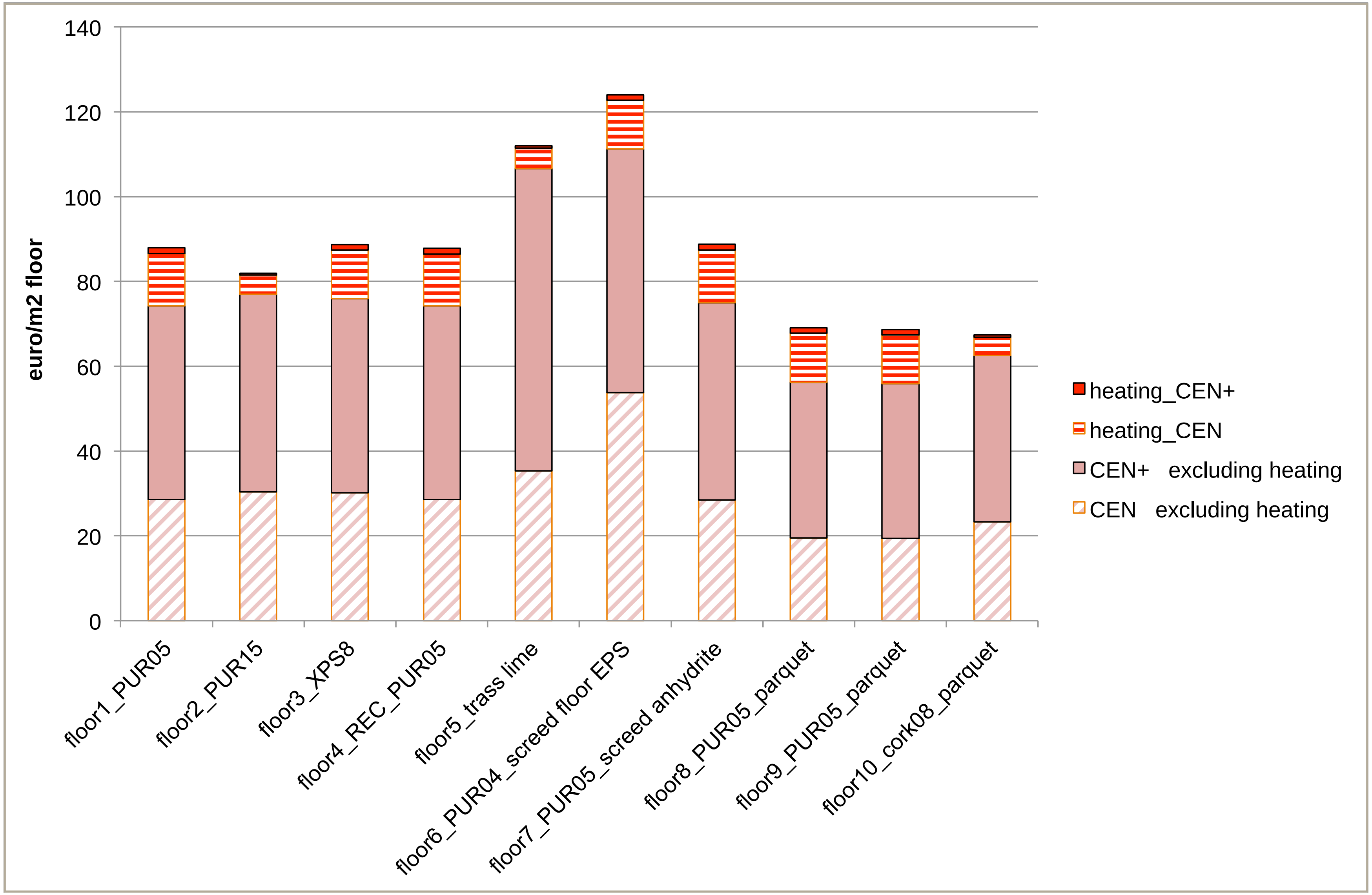

Figure E1: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants "floor on solid ground", expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

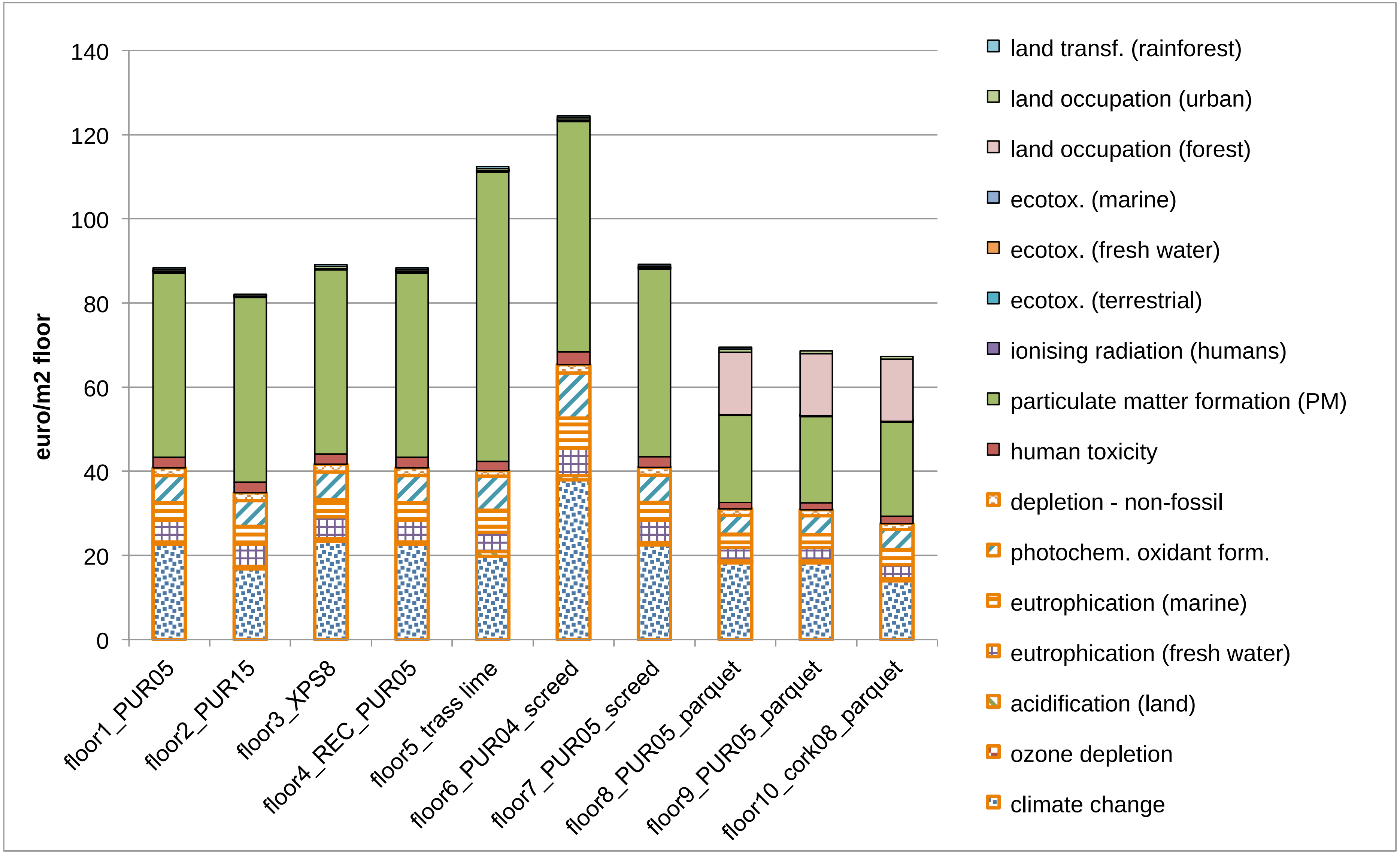

Figure I 1: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'floor on solid ground' per environmental indicator, expressed in monetary units.

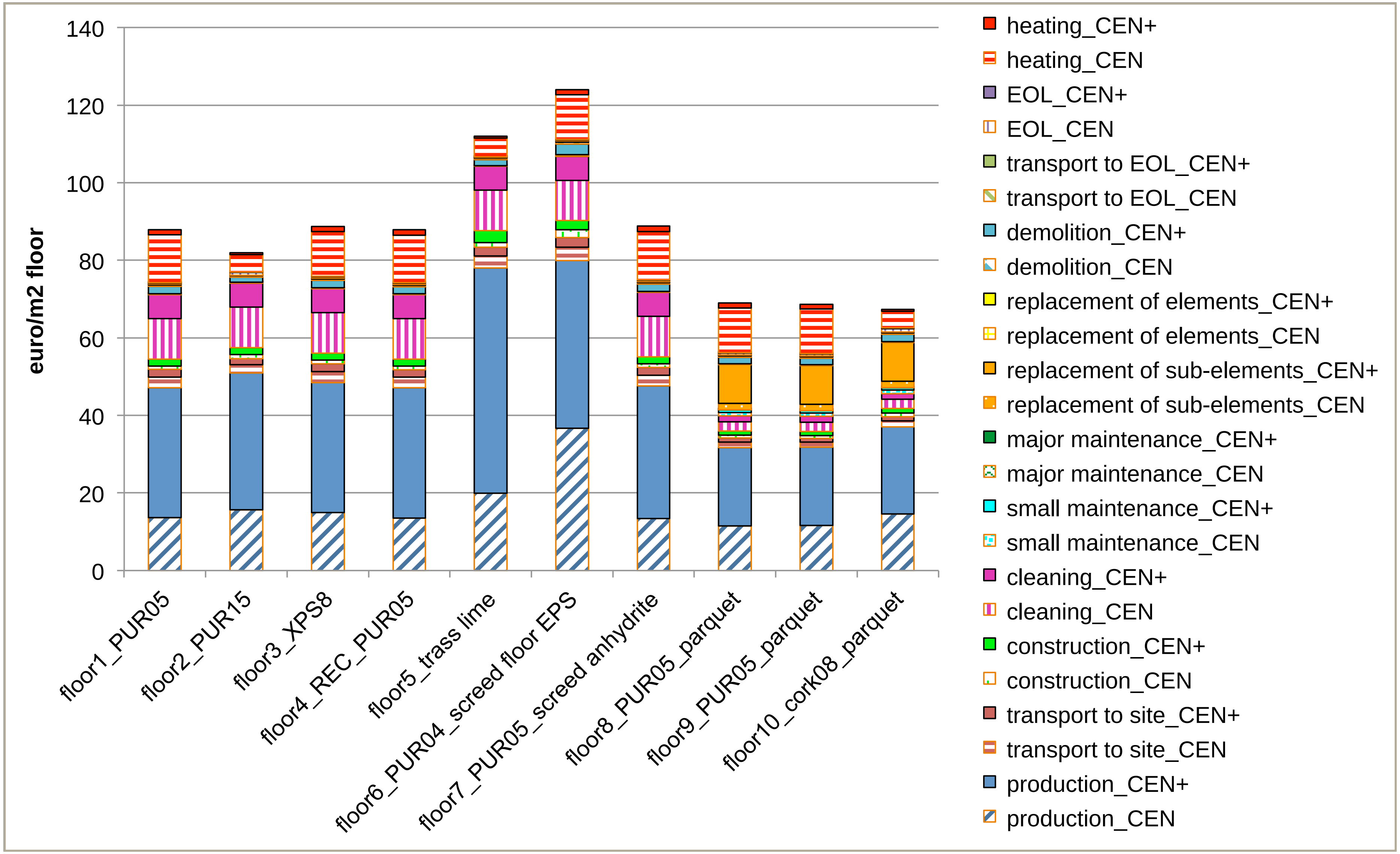

Figure L 1: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'floor on solid ground' per life cycle stage, expressed in monetary units.

3.3.2. Exterior wall

Table V 2: overview of the composition of the variants "exterior wall"

(21)+ exterior wall (load-bearing and non-load-bearing): environmental impact per m² of wall, 25 types (from outside inwards =>)						
1	BW1_timber frame_ RW14_facing brick	facing brick (clay)	timber frame (14 cm)	RW (complete filling)	plasterboard	acrylic paint
2	BW2_timber frame_ RW22_facing brick	facing brick (clay)	timber frame (22cm)	RW (complete filling)	plasterboard	acrylic paint
3	BW3_timber frame_ cellulose22_facing brick	facing brick (clay)	timber frame (22cm)	cellulose (complete filling)	plasterboard	acrylic paint
4	BW4_timber frame_ RW14_fibre cement board	fibre cement boards	timber frame (14 cm)	RW (complete filling)	plasterboard	acrylic paint
5	BW5_FJI_cellulose24_ facing brick	facing brick (clay)	FJI 24cm	cellulose	plasterboard on wooden lathwork	acrylic paint
6	BW6_FJI_cellulose36_ facing brick	facing brick (clay)	FJI 36 cm	cellulose	plasterboard on wooden lathwork	acrylic paint
7	BW7_FJI_cellulose36_ roughcast_gypsum blocks	roughcast on wood fibre board	FJI 36 cm	cellulose	OSB+gypsum blocks	acrylic paint
8	BW8_timber frame_RW14_planks	untreated cedar planks	timber frame (14 cm)	RW (complete filling)	plasterboard	acrylic paint
9	BW9_concrete stone_ hollow_RW7.5_facing brick	facing brick (clay)	concrete stone1 (hollow)	RW1 - 7.5 cm (U = 0.38)	gypsum plaster	acrylic paint
10	BW10_concrete stone_ hollow_RW22_facing brick	facing brick (clay)	concrete stone1 (hollow)	RW2 - 22 cm (10+12) (U = 0.15)	gypsum plaster	acrylic paint
11	BW11_concrete stone_ hollow_PUR5_facing brick	facing brick (clay)	concrete stone1 (hollow)	PUR1 - 5 cm (U = 0.37)	gypsum plaster	acrylic paint
12	BW12_concrete stone_ hollow_PUR15_facing brick	facing brick (clay)	concrete stone1 (hollow)	PUR2 - 15 cm (7+8) (U = 0.14)	gypsum plaster	acrylic paint
13	BW13_concrete stone_ full_RW7.5_facing brick	facing brick (clay)	concrete stone2 (full)	RW1 - 7.5 cm (U = 0.38)	gypsum plaster	acrylic paint

(21)+ exterior wall (load-bearing and non-load-bearing): environmental impact per m² of wall, 25 types (from outside inwards =>)						
14	BW14_hollow brick_ insul_RW6_facing brick	facing brick (clay)	hollow brick Clay1 (insulating)	RW1 - 6 cm (U = 0.39)	gypsum plaster	acrylic paint
15	BW15_hollow brick_ insul_RW8_roughcast	roughcast	hollow brick Clay1 (insulating)	RW1 - 8 cm (U = 0.35)	gypsum plaster	acrylic paint
16	BW16_hollow brick_ insul_EPS7_roughcast	roughcast	hollow brick Clay1 (insulating)	EPS1 - 7cm (U = 0.38)	gypsum plaster	acrylic paint
17	BW17_hollow brick_ RW7.5_facing brick	facing brick (clay)	hollow brick Clay2 (common)	RW1 - 7.5 cm (U = 0.35)	gypsum plaster	acrylic paint
18	BW18_hollow brick_ insul_RW6_facing brick_ loam plaster	facing brick (clay)	hollow brick Clay1 (insulating)	RW1 - 6 cm (U = 0.40)	loam plaster	/
19	BW19_concrete stone_ hollow_PUR5_concrete stone	facing brick (concrete)	concrete stone1 (hollow)	PUR1 - 5 cm (U = 0.37)	gypsum plaster	acrylic paint
20	BW20_aircrete30_facing brick	facing brick (clay)	aircrete 1: 30 cm (thickness to attain epb level)	/	gypsum plaster	acrylic paint
21	BW21_aircrete48_ roughcast	roughcast	aircrete 48 cm	/	gypsum plaster	acrylic paint
22	BW22_aircrete30_ RW14_facing brick	facing brick (clay)	aircrete: 30 cm	RW - 14 cm (req'd thickness to attain U=0.15 in combination with aircrete)	gypsum plaster	acrylic paint
23	BW23_calcarenite_ RW7.5_facing brick	facing brick (clay)	calcarenite (glued)	RW1 - 7.5 cm (U = 0.35)	gypsum plaster	acrylic paint
24	BW24_hollow brick_ concrete prefab panel	sandwich panels in concrete with PUR filling		gypsum plaster	acrylic paint	
25	BW25_concrete_insitu_ RW7.5_concrete board	architectural concrete slab	reinforced concrete (in situ) - 14 cm	RW1 - 7.5 cm (U = 0.39)	gypsum plaster	acrylic paint

** vapour barriers and wind screens are added where necessary*

Table CEN 2: overview of the individual CEN indicators for the variants 'exterior wall'

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC_{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Exterior wall							
BW1_timber frame_RW14_facing brick	2,53E+02	1,92E-05	3,59E-01	1,29E-01	3,18E-02	5,94E-04	4,03E+03
BW2_timber frame_RW22_facing brick	2,10E+02	1,63E-05	3,82E-01	1,38E-01	3,04E-02	6,03E-04	3,26E+03
BW3_timber frame_cellulose22_facing brick	2,07E+02	1,63E-05	3,42E-01	1,33E-01	2,81E-02	7,64E-04	3,22E+03
BW4_timber frame_RW14_fibre cement board	2,42E+02	2,43E-05	3,27E-01	1,31E-01	3,09E-02	6,30E-04	3,94E+03
BW5_FJI_cellulose24_facing brick	1,70E+02	1,36E-05	2,81E-01	1,03E-01	2,12E-02	7,70E-04	2,57E+03
BW6_FJI_cellulose36_facing brick	1,47E+02	1,20E-05	2,90E-01	1,10E-01	2,01E-02	8,89E-04	2,15E+03
BW7_FJI_cellulose36_roughcast_gypsum blocks	1,60E+02	1,09E-05	3,05E-01	1,06E-01	2,25E-02	3,23E-03	1,95E+03
BW8_timber frame_RW14_planks	2,28E+02	1,76E-05	3,33E-01	1,32E-01	3,10E-02	6,08E-04	3,87E+03
BW9_concrete stone_hollow_RW7.5_facing brick	3,36E+02	2,32E-05	3,83E-01	1,15E-01	3,17E-02	2,51E-04	4,86E+03
BW10_concrete stone_hollow_RW22_facing brick	2,07E+02	1,41E-05	3,94E-01	1,15E-01	2,46E-02	2,60E-04	2,62E+03
BW11_concrete stone_hollow_PUR5_facing brick	3,36E+02	2,27E-05	3,83E-01	1,16E-01	3,29E-02	2,54E-04	4,81E+03
BW12_concrete stone_hollow_PUR15_facing brick	2,23E+02	1,37E-05	4,01E-01	1,20E-01	2,98E-02	2,72E-04	2,78E+03
BW13_concrete stone_full_RW7.5_facing brick	3,42E+02	2,38E-05	4,05E-01	1,22E-01	3,26E-02	2,86E-04	4,94E+03
BW14_hollow brick_insul_RW6_facing brick	3,30E+02	2,40E-05	3,51E-01	1,08E-01	3,29E-02	1,88E-04	5,03E+03
BW15_hollow brick_insul_RW8_roughcast	3,14E+02	2,22E-05	4,52E-01	1,28E-01	3,58E-02	1,05E-03	4,73E+03
BW16_hollow brick_insul_EPS7_roughcast	3,24E+02	2,25E-05	3,31E-01	1,01E-01	4,34E-02	9,99E-04	4,91E+03

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC_{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
BW17_hollow brick_RW7.5_facing brick	3,15E+02	2,30E-05	3,76E-01	1,15E-01	3,30E-02	1,98E-04	4,69E+03
BW18_hollow brick_insul_RW6_facing brick_loam plaster	3,16E+02	2,25E-05	2,86E-01	8,43E-02	2,99E-02	1,36E-04	4,86E+03
BW19_concrete stone_hollow_PUR5_concrete stone	3,27E+02	2,14E-05	3,59E-01	1,07E-01	2,99E-02	2,83E-04	4,66E+03
BW20_aircrete30_facing brick	3,58E+02	2,55E-05	4,14E-01	1,32E-01	3,46E-02	3,87E-04	4,90E+03
BW21_aircrete48_roughcast	3,49E+02	2,45E-05	4,38E-01	1,37E-01	3,32E-02	1,26E-03	4,64E+03
BW22_aircrete30_RW14_facing brick	2,45E+02	1,74E-05	4,27E-01	1,34E-01	2,86E-02	3,97E-04	2,93E+03
BW23_calcarenite_RW7.5_facing brick	3,13E+02	2,37E-05	3,65E-01	1,09E-01	3,28E-02	2,53E-04	4,71E+03
BW24_hollow brick_concrete prefab panel	2,80E+02	1,78E-05	6,11E-01	2,54E-01	5,71E-02	4,08E-04	3,61E+03
BW25_concrete_insitu_RW7.5_concrete board	3,45E+02	2,26E-05	4,31E-01	1,70E-01	4,70E-02	2,32E-04	5,13E+03

Table CEN+ 2: overview of the individual CEN+ indicators for the variants 'exterior wall'

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m^3
Exterior wall											
BW1_timber frame_ RW14_facing brick	1,56E-05	1,88E-04	3,34E-07	3,00E-02	4,89E-01	5,87E-01	6,88E-03	3,63E-08	5,60E-08	5,50E-09	5,71E-01
BW2_timber frame_ RW22_facing brick	1,69E-05	2,12E-04	3,32E-07	3,32E-02	5,17E-01	5,91E-01	6,88E-03	4,72E-08	6,18E-08	5,30E-09	6,04E-01
BW3_timber frame_ cellulose22_facing brick	1,65E-05	1,76E-04	3,15E-07	3,30E-02	5,06E-01	5,81E-01	6,88E-03	4,53E-08	5,77E-08	5,12E-09	5,54E-01
BW4_timber frame_ RW14_fibre cement board	1,83E-05	1,67E-04	3,77E-07	3,33E-02	5,42E-01	6,56E-01	2,78E-02	3,90E-08	5,62E-08	6,19E-09	6,65E-01
BW5_FJI_cellulose24_ facing brick	1,23E-05	1,45E-04	2,46E-07	1,73E-02	4,15E-01	4,75E-01	6,88E-03	2,53E-08	3,79E-08	4,78E-09	4,45E-01
BW6_FJI_cellulose36_ facing brick	1,34E-05	1,58E-04	2,47E-07	1,91E-02	4,42E-01	4,89E-01	6,88E-03	2,93E-08	3,83E-08	4,66E-09	4,74E-01
BW7_FJI_cellulose36_ roughcast_gypsum blocks	1,47E-05	1,73E-04	2,49E-07	2,74E-02	4,69E-01	5,13E-01	2,43E-02	3,41E-08	1,93E-08	2,43E-09	7,41E-01
BW8_timber frame_RW14_planks	1,68E-05	1,80E-04	3,43E-07	4,47E-02	5,16E-01	6,14E-01	1,66E-02	8,04E-08	8,90E-08	4,88E-09	5,15E-01
BW9_concrete stone_ hollow_RW7.5_facing brick	1,35E-05	1,83E-04	3,51E-07	1,43E-02	3,70E-01	4,95E-01	6,88E-03	1,90E-08	4,68E-08	4,80E-09	1,01E+00
BW10_concrete stone_ hollow_RW22_facing brick	1,38E-05	2,08E-04	3,03E-07	1,37E-02	3,94E-01	4,52E-01	6,88E-03	1,97E-08	3,87E-08	4,05E-09	1,03E+00
BW11_concrete stone_ hollow_PUR5_facing brick	1,35E-05	1,73E-04	3,38E-07	1,49E-02	4,09E-01	5,01E-01	6,88E-03	1,79E-08	4,37E-08	4,64E-09	1,10E+00
BW12_concrete stone_ hollow_PUR15_facing brick	1,39E-05	1,82E-04	2,74E-07	1,59E-02	5,19E-01	4,83E-01	6,88E-03	1,66E-08	3,11E-08	3,69E-09	1,30E+00

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m^3
BW13_concrete stone_ full_RW7.5_facing brick	1,44E-05	1,98E-04	3,63E-07	1,48E-02	3,97E-01	5,25E-01	6,88E-03	2,06E-08	4,89E-08	5,41E-09	1,03E+00
BW14_hollow brick_insul_ RW6_facing brick	1,20E-05	1,61E-04	3,12E-07	1,36E-02	3,37E-01	4,63E-01	6,88E-03	1,44E-08	4,24E-08	3,83E-09	5,36E-01
BW15_hollow brick_insul_ RW8_roughcast	1,62E-05	2,64E-04	3,96E-07	1,47E-02	4,88E-01	6,06E-01	2,51E-02	2,17E-08	4,17E-08	4,85E-09	8,83E-01
BW16_hollow brick_insul_ EPS7_roughcast	1,23E-05	1,53E-04	3,29E-07	2,28E-02	9,08E-01	5,90E-01	2,51E-02	1,50E-08	2,83E-08	4,26E-09	6,96E-01
BW17_hollow brick_ RW7.5_facing brick	1,29E-05	1,75E-04	3,15E-07	1,39E-02	3,61E-01	4,75E-01	6,88E-03	1,54E-08	4,25E-08	3,84E-09	5,55E-01
BW18_hollow brick_insul_ RW6_facing brick_loam plaster	9,74E-06	1,37E-04	2,69E-07	5,70E-03	2,63E-01	3,92E-01	3,69E-04	1,20E-08	4,01E-08	3,45E-09	3,88E-01
BW19_concrete stone_ hollow_PUR5_concrete stone	1,30E-05	1,66E-04	3,36E-07	1,47E-02	3,93E-01	4,86E-01	6,87E-03	1,90E-08	4,34E-08	5,09E-09	1,31E+00
BW20_aircrete30_facing brick	1,54E-05	1,85E-04	4,22E-07	1,49E-02	4,32E-01	5,48E-01	6,88E-03	1,96E-08	3,32E-08	4,94E-09	9,63E-01
BW21_aircrete48_ roughcast	1,70E-05	2,13E-04	4,64E-07	1,58E-02	5,08E-01	6,18E-01	2,54E-02	2,30E-08	2,01E-08	5,65E-09	1,21E+00
BW22_aircrete30_RW14_ facing brick	1,58E-05	2,11E-04	3,81E-07	1,45E-02	4,58E-01	5,14E-01	6,88E-03	2,03E-08	2,64E-08	4,30E-09	9,82E-01
BW23_calcarenite_ RW7.5_facing brick	1,23E-05	1,76E-04	3,18E-07	1,56E-02	3,58E-01	4,83E-01	6,88E-03	1,78E-08	4,73E-08	5,16E-09	8,62E-01
BW24_hollow brick_ concrete prefab panel	3,70E-05	3,54E-04	4,97E-07	2,06E-02	1,24E+00	1,28E+00	6,51E-03	3,14E-08	5,13E-08	2,88E-09	1,85E+00
BW25_concrete_insitu_ RW7.5_concrete board	2,88E-05	2,61E-04	4,08E-07	1,73E-02	8,36E-01	9,75E-01	6,51E-03	2,26E-08	4,86E-08	2,93E-09	1,62E+00

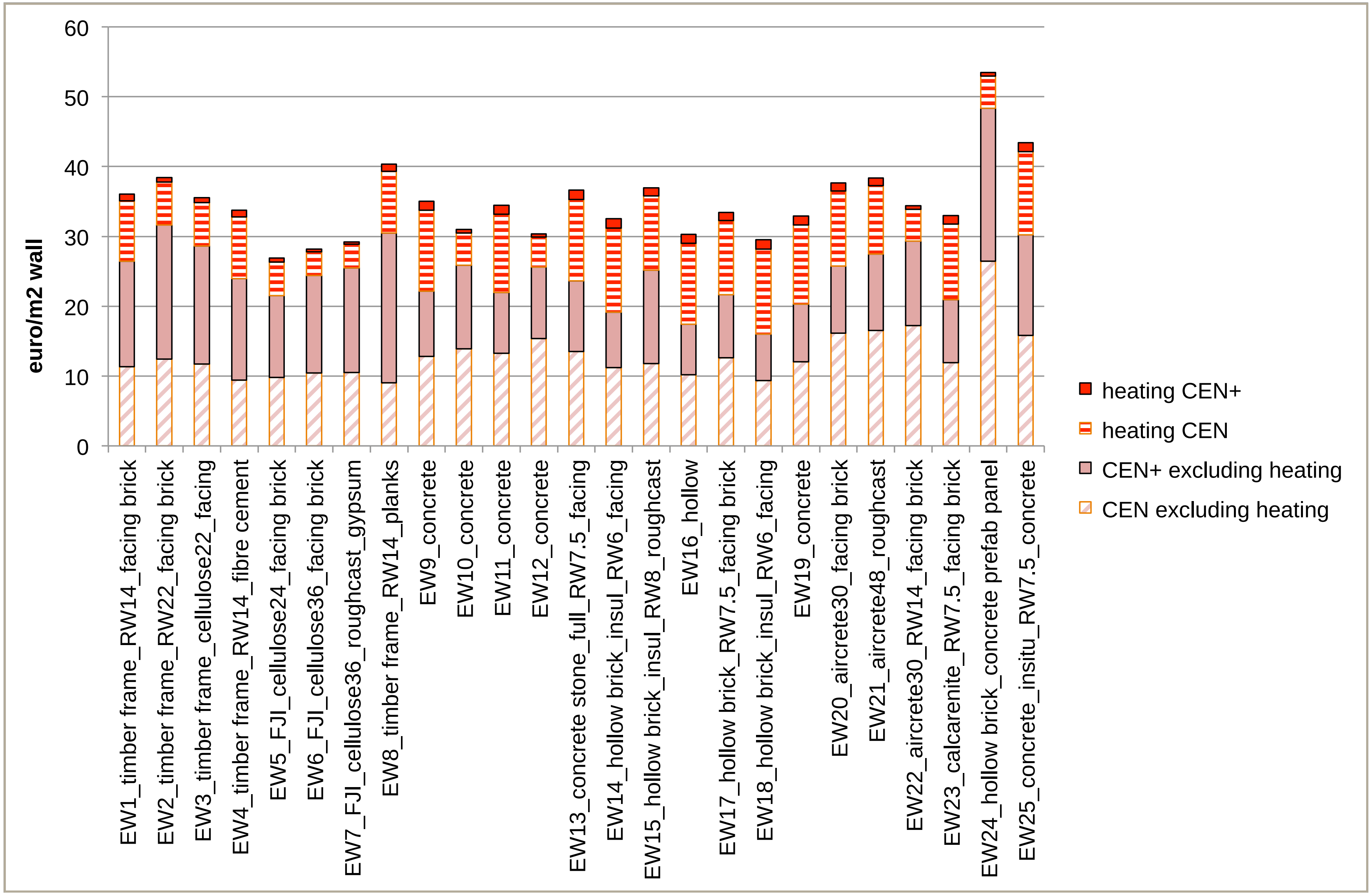

Figure E 2: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants "exterior wall", expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

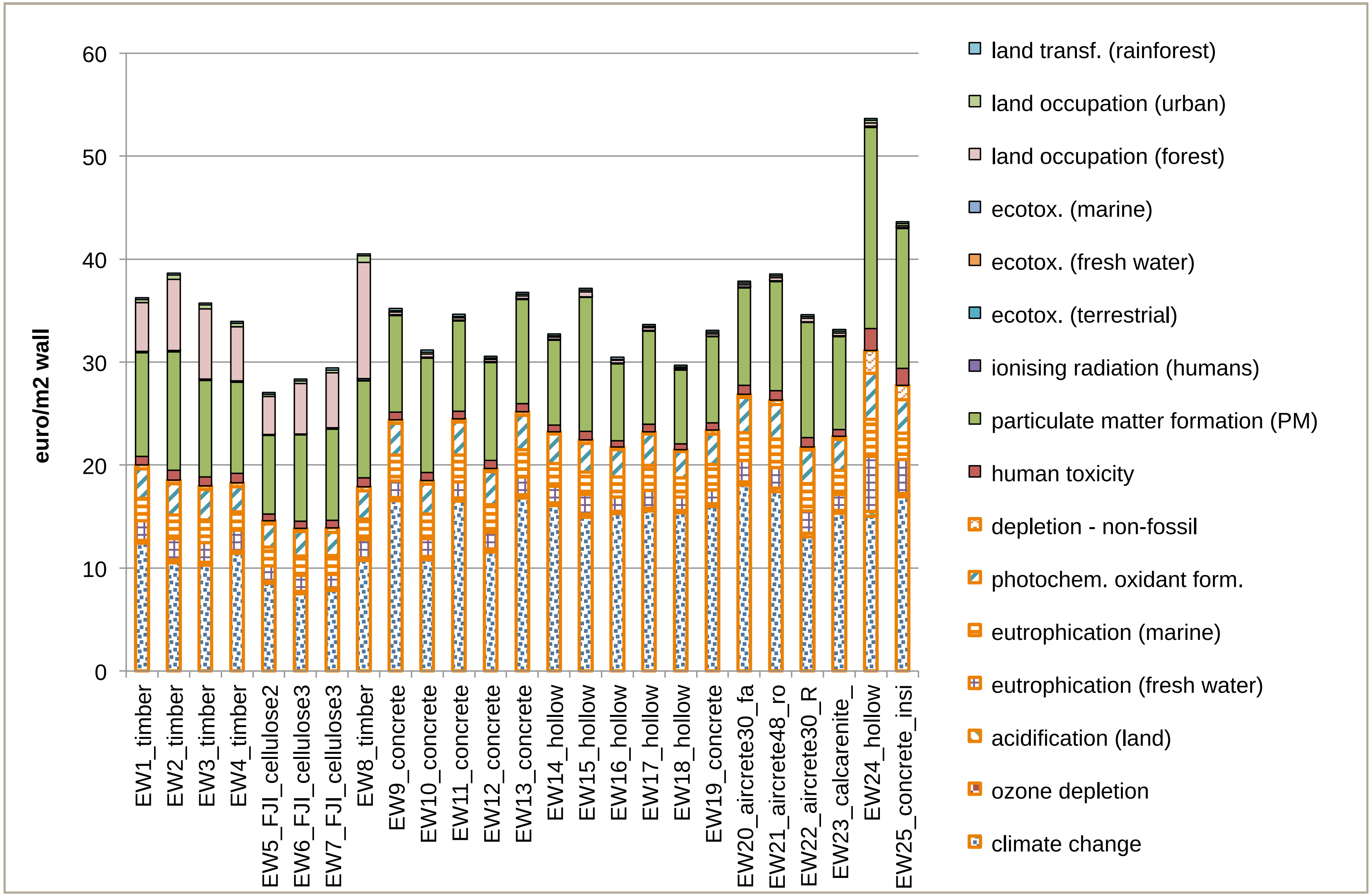

Figure I 2: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'exterior wall' per environmental indicator, expressed in monetary units.

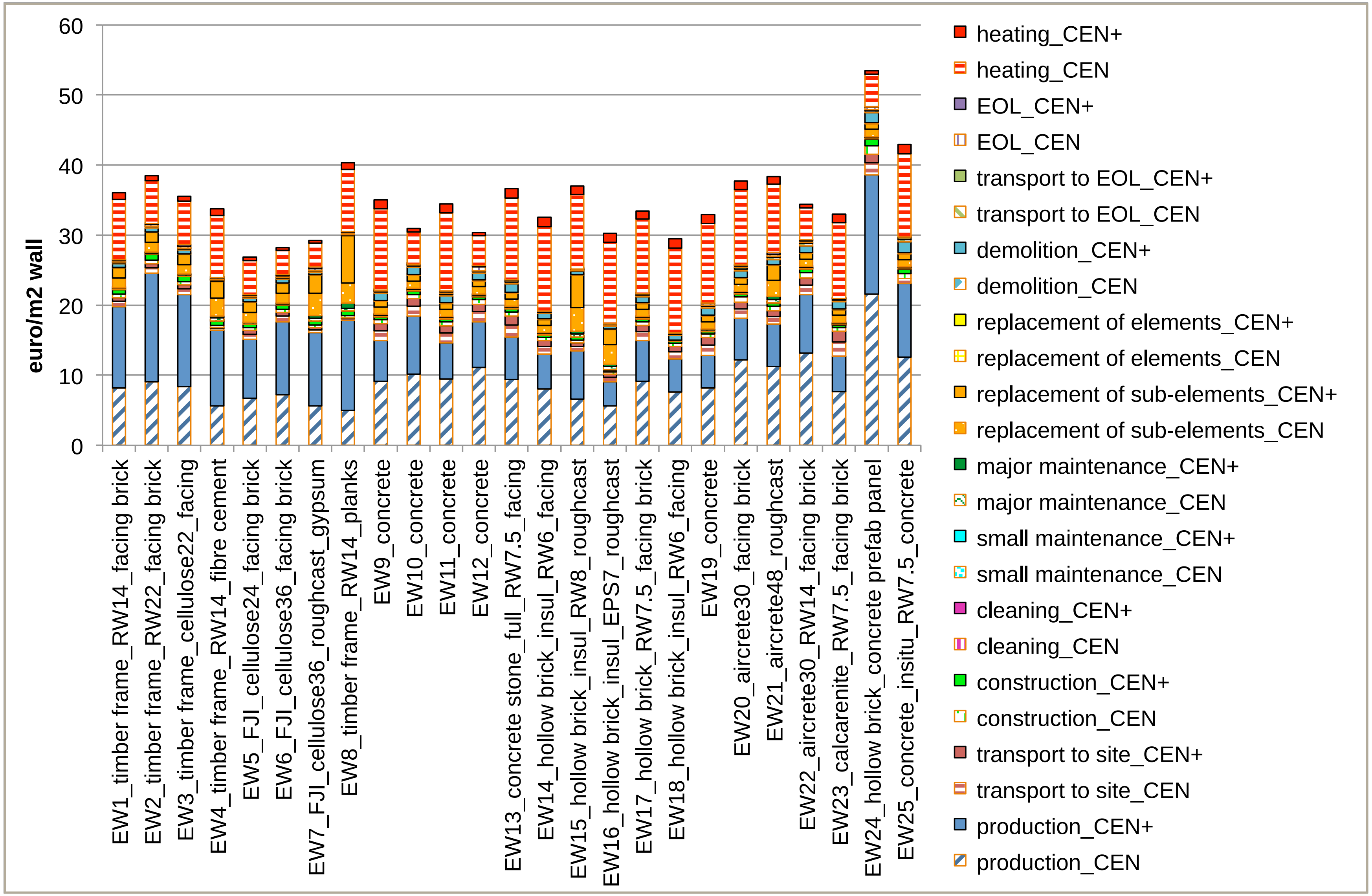

Figure L 2: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'exterior wall' per life cycle stage, expressed in monetary units.

3.3.3. Load-bearing interior walls

Table V 3: overview of the composition of the variants “load-bearing interior wall”

(22)+ interior wall (load-bearing and non-load-bearing): environmental impact per m² wall, 7 types load-bearing							
1	DBiW1_hollow brick	acrylic paint	gypsum plaster	hollow brick (brickwork) 14 cm clay	gypsum plaster	acrylic paint	load-bearing
2	DBiW2_concrete	acrylic paint	gypsum plaster	concrete (in situ) 14 cm new	gypsum plaster	acrylic paint	load-bearing
3	DBiW3_timber frame	acrylic paint	gypsum plaster	timber frame (14 cm, filled with glass wool)	gypsum plaster	acrylic paint	load-bearing
4	DBiW4_calcarinite	acrylic paint	gypsum plaster	calcarenite (glued) 14 cm	gypsum plaster	acrylic paint	load-bearing
5	DBiW5_aircrete	acrylic paint	gypsum plaster	aerated concrete 15 cm	gypsum plaster	acrylic paint	load-bearing
6	DBiW6_hollow concrete	acrylic paint	gypsum plaster	hollow concrete 14 cm	gypsum plaster	acrylic paint	load-bearing
7	DBiW7_fair-faced concrete block	/	/	fair-faced blocks (concrete)	/	/	load-bearing

Table CEN 3: overview of the individual CEN indicators for the variants ‘load-bearing interior walls’

	Climate change	Ozone depletion	Acidification (land)	Eutrophication	Photochem. oxidant form.	Depletion - non-fossil	Depletion - fossil
	kg CO^2 eq	kg CFC_{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Load-bearing interior wall							
DBiW1_hollow brick	7,03E+01	6,20E-06	2,27E-01	7,67E-02	1,22E-02	1,44E-04	7,91E+02
DBiW2_concrete	8,66E+01	5,94E-06	2,87E-01	1,17E-01	2,12E-02	1,75E-04	9,28E+02
DBiW3_timber frame	4,99E+01	5,92E-06	2,36E-01	9,28E-02	1,22E-02	1,07E-03	7,67E+02
DBiW4_calcarinite	7,09E+01	7,19E-06	2,32E-01	7,57E-02	1,27E-02	2,06E-04	8,07E+02
DBiW5_aircrete	7,72E+01	6,21E-06	2,19E-01	7,60E-02	1,12E-02	2,26E-04	7,51E+02
DBiW6_hollow concrete	8,02E+01	5,66E-06	2,47E-01	8,01E-02	1,06E-02	2,02E-04	7,08E+02
DBiW7_fair-faced concrete block	4,91E+01	2,77E-06	1,29E-01	3,74E-02	4,77E-03	1,18E-04	3,30E+02

Table CEN+ 3: overview of the individual CEN+ indicators for the variants 'load-bearing interior wall'

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m^3
Load-bearing interior wall											
DBiW1_hollow brick	7,95E-06	9,33E-05	1,47E-07	1,76E-02	2,36E-01	2,36E-01	1,30E-02	8,93E-09	1,27E-08	1,58E-09	4,18E-01
DBiW2_ concrete	1,82E-05	1,58E-04	2,15E-07	2,01E-02	5,39E-01	5,48E-01	1,30E-02	1,43E-08	1,75E-08	1,24E-09	1,08E+00
DBiW3_timber frame	1,06E-05	1,16E-04	2,00E-07	2,73E-02	4,00E-01	4,11E-01	1,30E-02	3,05E-08	2,98E-08	7,47E-09	4,17E-01
DBiW4_ calcarinite	7,96E-06	1,02E-04	1,58E-07	1,96E-02	2,48E-01	2,58E-01	1,30E-02	1,19E-08	1,84E-08	2,98E-09	7,37E-01
DBiW5_aircrete	8,25E-06	8,94E-05	1,82E-07	1,75E-02	2,47E-01	2,45E-01	1,30E-02	9,90E-09	6,05E-09	1,84E-09	5,86E-01
DBiW6_hollow concrete	9,02E-06	1,08E-04	1,83E-07	1,81E-02	2,57E-01	2,60E-01	1,30E-02	1,30E-08	1,66E-08	2,52E-09	8,84E-01
DBiW7_fair-faced concrete block	4,90E-06	7,04E-05	1,02E-07	2,80E-03	1,25E-01	1,34E-01	2,91E-08	8,90E-09	1,25E-08	2,20E-09	5,60E-01

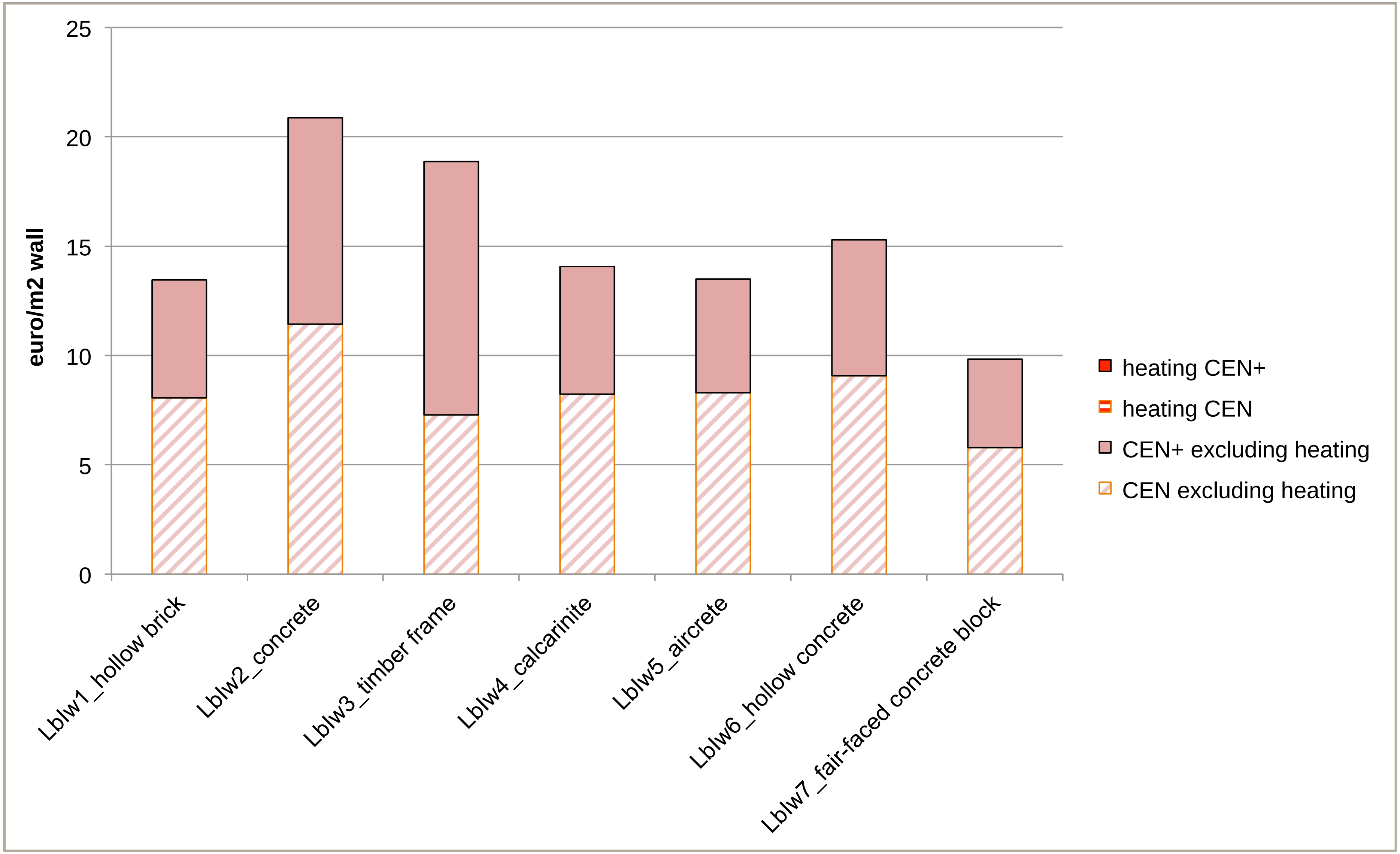

Figure E 3: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants 'load-bearing interior wall', expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

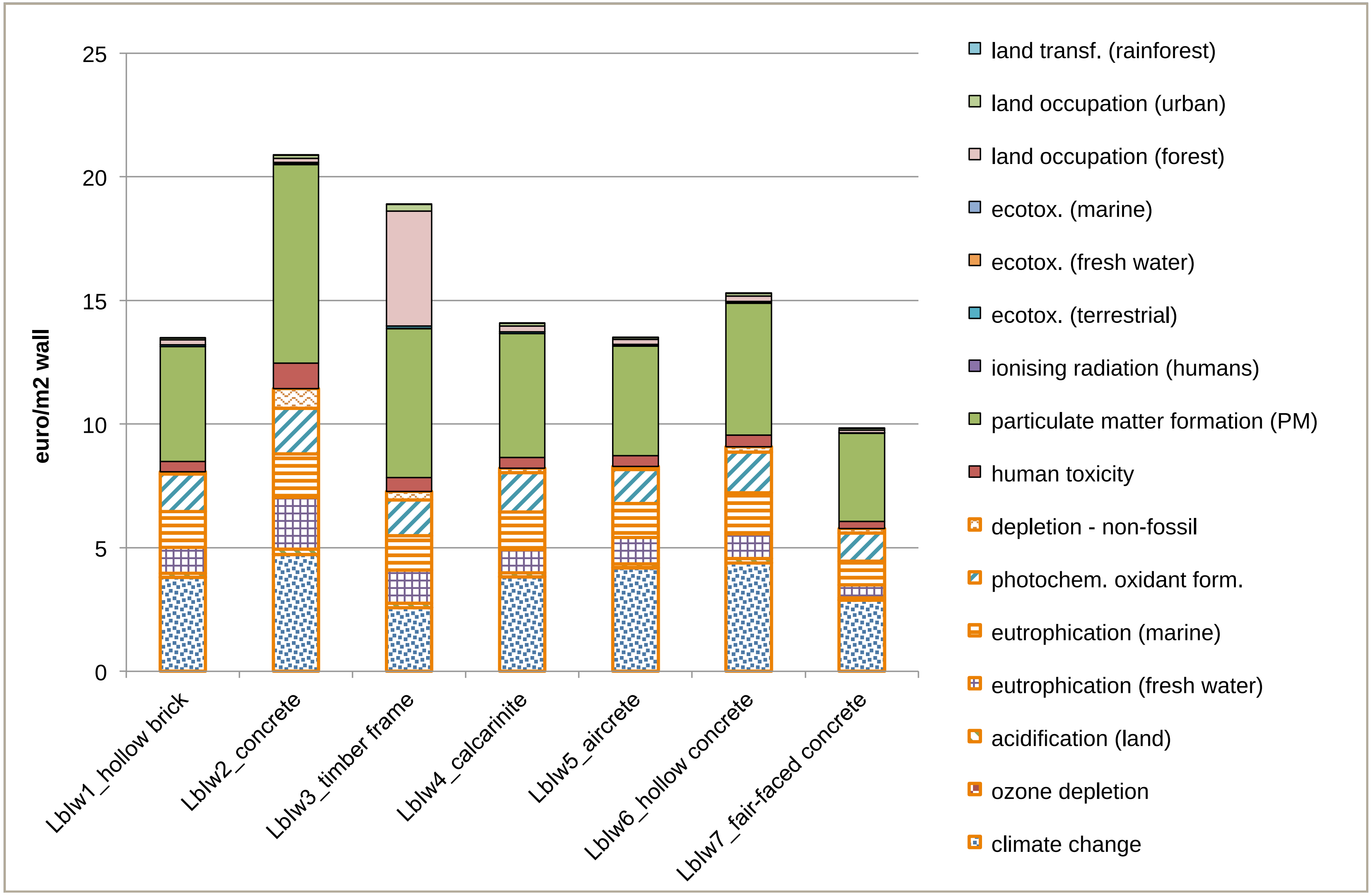

Figure I 3: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variant 'load-bearing interior wall' per environmental indicator, expressed in monetary units.

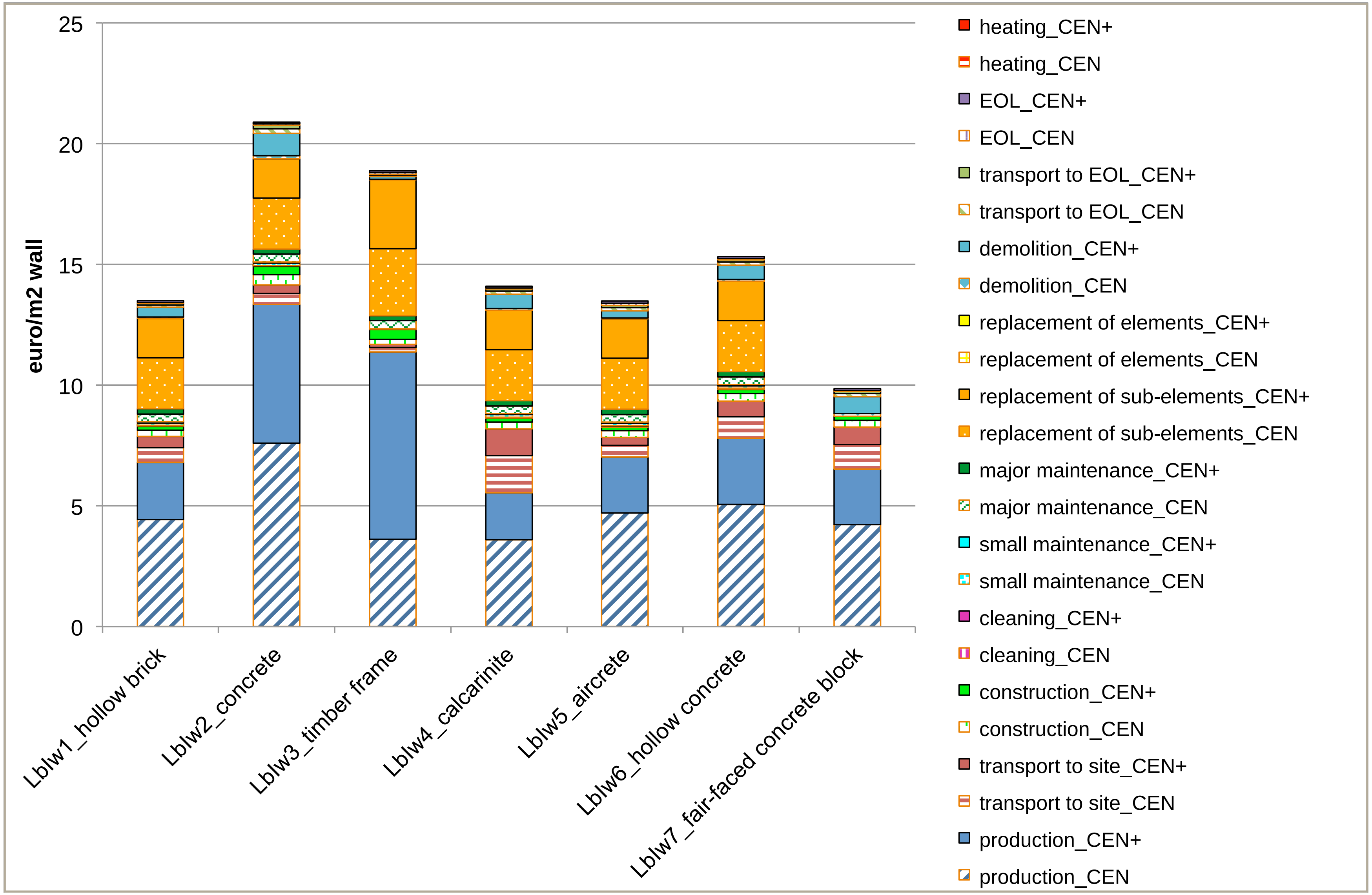

Figure L 3: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'load-bearing interior wall' per life cycle stage, expressed in monetary units.

3.3.4. Non-load-bearing interior walls

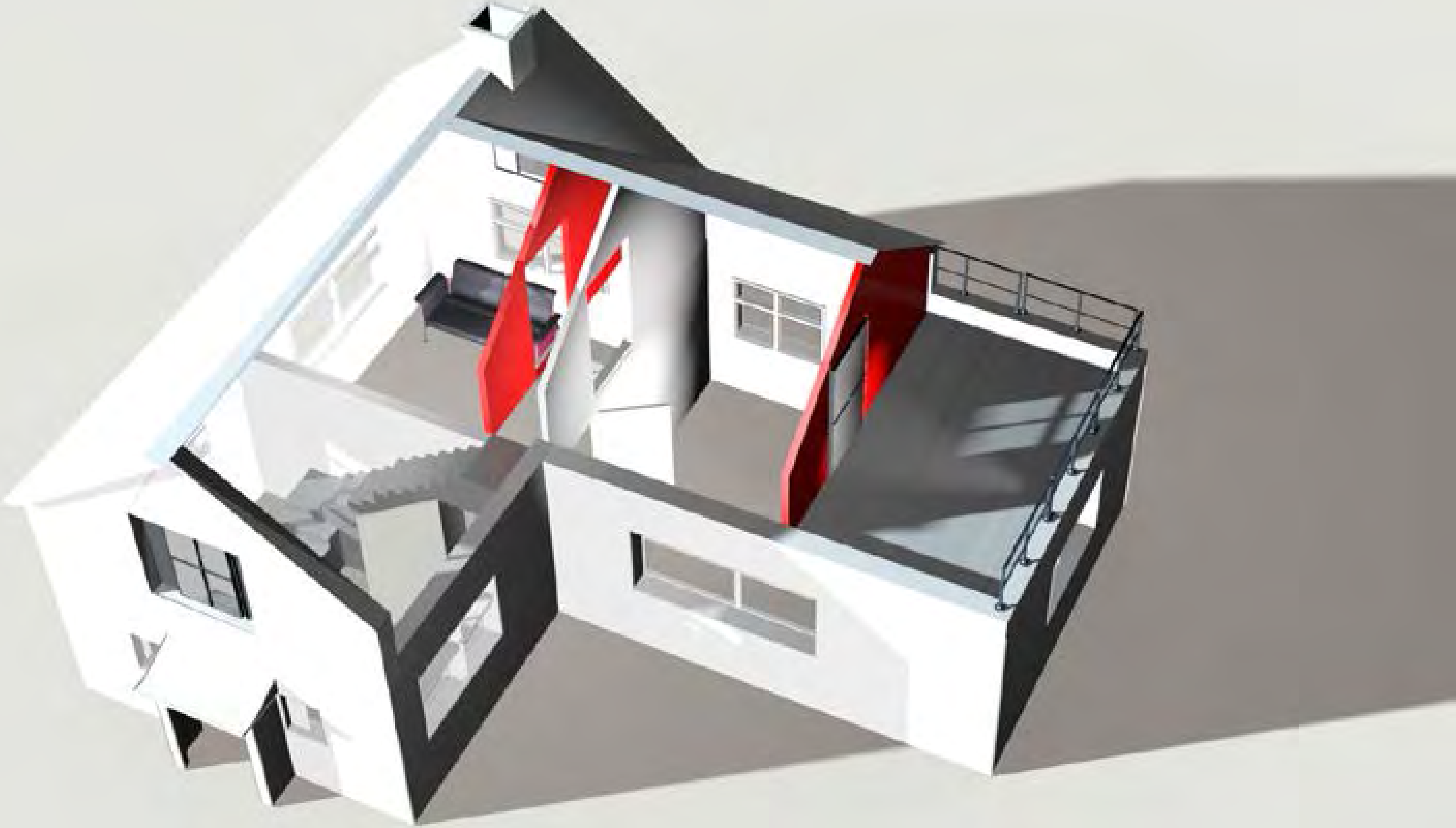

Table V 4: overview of the composition of the variants "non-load-bearing interior wall"

(22)+ interior wall (non-load-bearing): environmental impact per m² wall, 12 types							
1	NDBiW1_timber frame_1plasterboard	acrylic paint	plasterboard (1 layer)	timber frame (10 cm, filled with glass wool)	plasterboard (1 layer)	acrylic paint	non-load-bearing
2	NDBiW2_timber frame_2plasterboard	acrylic paint	plasterboard (2 layers)	timber frame (10 cm, filled with glass wool)	plasterboard (2 layers)	acrylic paint	non-load-bearing
3	NDBiW3_ metalstud_1plasterboard	acrylic paint	plasterboard (1 layer)	metal stud (10 cm, filled with glass wool)	plasterboard (1 layer)	acrylic paint	non-load-bearing
4	NDBiW4_ metalstud_2plasterboard	acrylic paint	plasterboard (2 layers)	metal stud (10 cm, filled with glass wool)	plasterboard (2 layers)	acrylic paint	non-load-bearing
5	NDBiW5_hollow brick	acrylic paint	gypsum plaster	hollow brick (brickwork) 9cm clay	gypsum plaster	acrylic paint	non-load-bearing
6	NDBiW6_concrete	acrylic paint	gypsum plaster	concrete (in situ) 9cm new	gypsum plaster	acrylic paint	non-load-bearing
7	NDBiW7_recycled concrete	acrylic paint	gypsum plaster	concrete (in situ) 9cm 100% recycled	gypsum plaster	acrylic paint	non-load-bearing
8	NDBiW8_gypsum blocks	acrylic paint	prefab wall full panels				non-load-bearing
9	NDBiW9_timber frame_plasterboard	acrylic paint	prefab wall 100% glazed				non-load-bearing
10	NDBiW10_prefab wall_full	acrylic paint	gypsum plaster	gypsum blocks: 10 cm	gypsum plaster	acrylic paint	non-load-bearing
11	NDBiW11_prefab wall_glass	acrylic paint	plasterboard	timber frame (10 cm, filled with glass wool)	plasterboard	acrylic paint	non-load-bearing
12	NDBiW12_prefab wall_50%glass	acrylic paint	prefab wall 50% glazed			acrylic paint	non-load-bearing

Table CEN 4: overview of the individual CEN indicators for the variants 'non-load-bearing interior wall"

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC_{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Non-load-bearing interior wall							
NDBiW1_timber frame_1plasterboard	4,57E+01	5,46E-06	2,14E-01	8,21E-02	1,10E-02	1,00E-03	7,08E+02
NDBiW2_timber frame_2plasterboard	6,42E+01	7,59E-06	2,78E-01	1,03E-01	1,37E-02	1,71E-03	9,62E+02
NDBiW3_metalstud_1plasterboard	5,55E+01	6,18E-06	2,44E-01	1,02E-01	1,47E-02	1,17E-03	8,50E+02
NDBiW4_metalstud_2plasterboard	7,40E+01	8,31E-06	3,09E-01	1,23E-01	1,74E-02	1,88E-03	1,10E+03
NDBiW5_hollow brick	6,02E+01	5,42E-06	2,02E-01	6,89E-02	1,06E-02	1,33E-04	6,93E+02
NDBiW6_concrete	6,71E+01	4,96E-06	2,31E-01	9,21E-02	1,58E-02	1,50E-04	7,44E+02
NDBiW7_recycled concrete	6,71E+01	4,97E-06	2,31E-01	9,19E-02	1,58E-02	1,50E-04	7,44E+02
NDBiW8_gypsum blocks	6,61E+01	4,66E-06	1,95E-01	5,77E-02	1,00E-02	1,94E-03	4,89E+02
NDBiW9_timber frame_plasterboard	4,71E+01	5,85E-06	2,23E-01	8,41E-02	1,13E-02	1,14E-03	7,42E+02
NDBiW10_prefab wall_full	1,61E+02	1,29E-05	6,61E-01	3,35E-01	5,94E-02	1,05E-03	2,49E+03
NDBiW11_prefab wall_glass	6,38E+01	3,74E-06	3,15E-01	1,08E-01	1,44E-02	1,81E-04	8,81E+02
NDBiW12_prefab wall_50%glass	1,27E+02	9,12E-06	5,62E-01	2,50E-01	4,21E-02	6,80E-04	1,96E+03

Table CEN+ 4: overview of the individual CEN+ indicators for the variants 'non-load-bearing interior wall'

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m3
Non-load-bearing interior wall											
NDBiW1_timber frame_1plasterboard	9,28E-06	9,79E-05	1,80E-07	2,54E-02	3,65E-01	3,75E-01	1,30E-02	2,38E-08	2,44E-08	7,00E-09	3,79E-01
NDBiW2_timber frame_2plasterboard	1,16E-05	1,39E-04	2,45E-07	2,93E-02	4,59E-01	4,84E-01	1,63E-02	2,71E-08	2,81E-08	1,26E-08	5,04E-01
NDBiW3_ metalstud_1plasterboard	1,22E-05	1,11E-04	2,26E-07	2,24E-02	4,72E-01	4,83E-01	1,30E-02	1,43E-08	1,74E-08	8,20E-09	4,97E-01
NDBiW4_ metalstud_2plasterboard	1,45E-05	1,52E-04	2,91E-07	2,64E-02	5,67E-01	5,93E-01	1,63E-02	1,76E-08	2,11E-08	1,38E-08	6,23E-01
NDBiW5_hollow brick	7,08E-06	8,10E-05	1,31E-07	1,71E-02	2,13E-01	2,12E-01	1,30E-02	7,85E-09	1,06E-08	1,35E-09	3,83E-01
NDBiW6_concrete	1,33E-05	1,18E-04	1,69E-07	1,86E-02	3,99E-01	4,04E-01	1,30E-02	1,10E-08	1,30E-08	1,08E-09	8,03E-01
NDBiW7_recycled concrete	1,33E-05	1,18E-04	1,66E-07	1,86E-02	3,98E-01	4,03E-01	1,30E-02	1,00E-08	1,17E-08	1,06E-09	6,42E-01
NDBiW8_gypsum blocks	5,24E-06	7,40E-05	9,58E-08	1,67E-02	1,62E-01	1,60E-01	1,30E-02	7,60E-09	-1,07E-10	9,27E-10	4,36E-01
NDBiW9_timber frame_plasterboard	9,34E-06	1,06E-04	1,81E-07	2,56E-02	3,66E-01	3,81E-01	1,14E-02	2,44E-08	2,45E-08	1,68E-09	3,67E-01
NDBiW10_prefab wall_full	5,07E-05	4,18E-04	6,17E-07	4,47E-02	2,00E+00	2,08E+00	9,20E-02	4,65E-08	6,27E-08	1,45E-09	1,55E+00
NDBiW11_prefab wall_glass	1,48E-05	1,07E-04	3,52E-07	5,03E-03	4,56E-01	4,53E-01	1,94E-02	5,11E-09	1,19E-08	1,04E-09	5,12E-01
NDBiW12_prefab wall_50%glass	3,64E-05	3,00E-04	5,23E-07	3,83E-02	1,40E+00	1,42E+00	6,29E-02	3,01E-08	4,19E-08	1,66E-09	1,85E+00

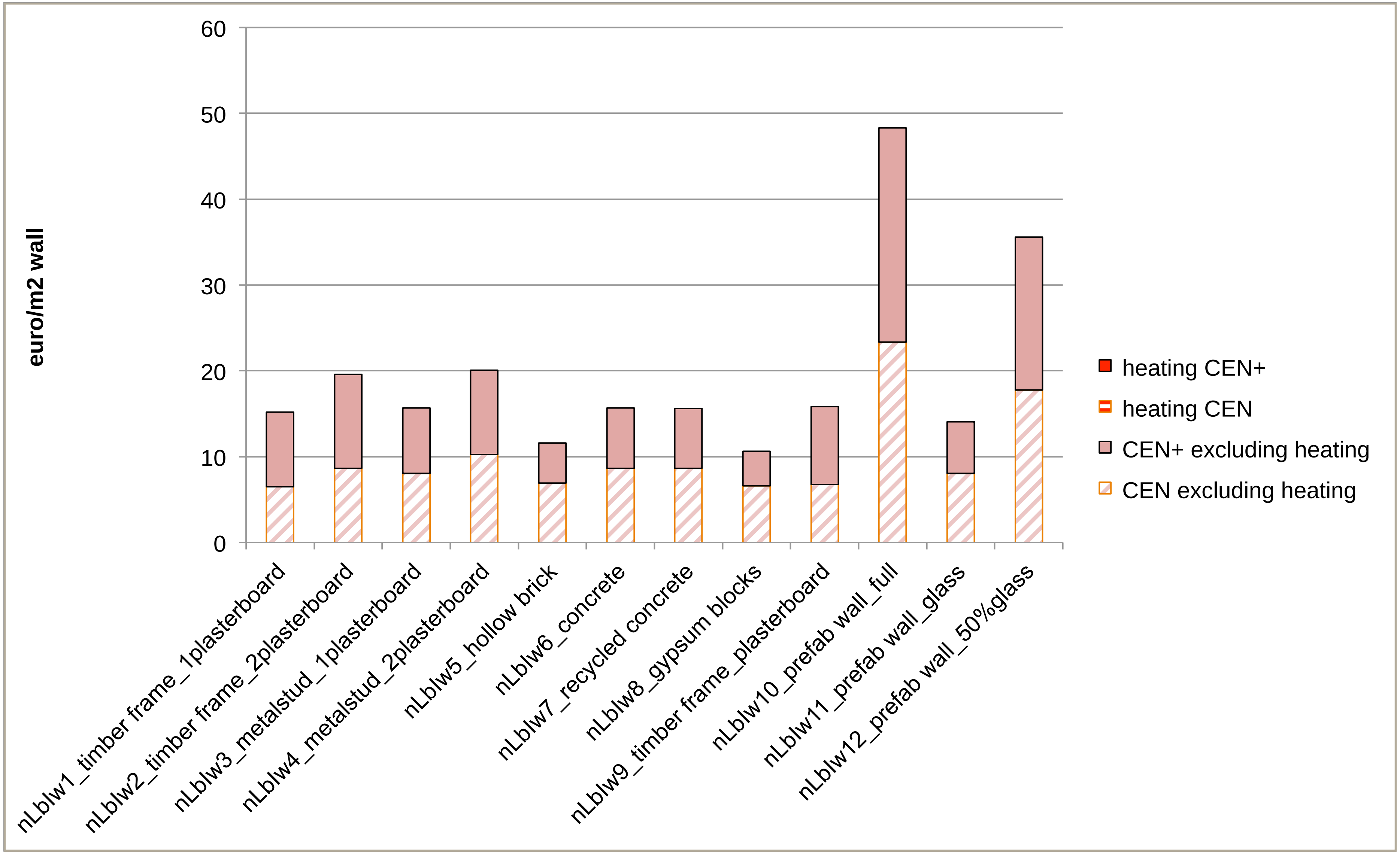

Figure E 4: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants 'non-load-bearing interior wall', expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

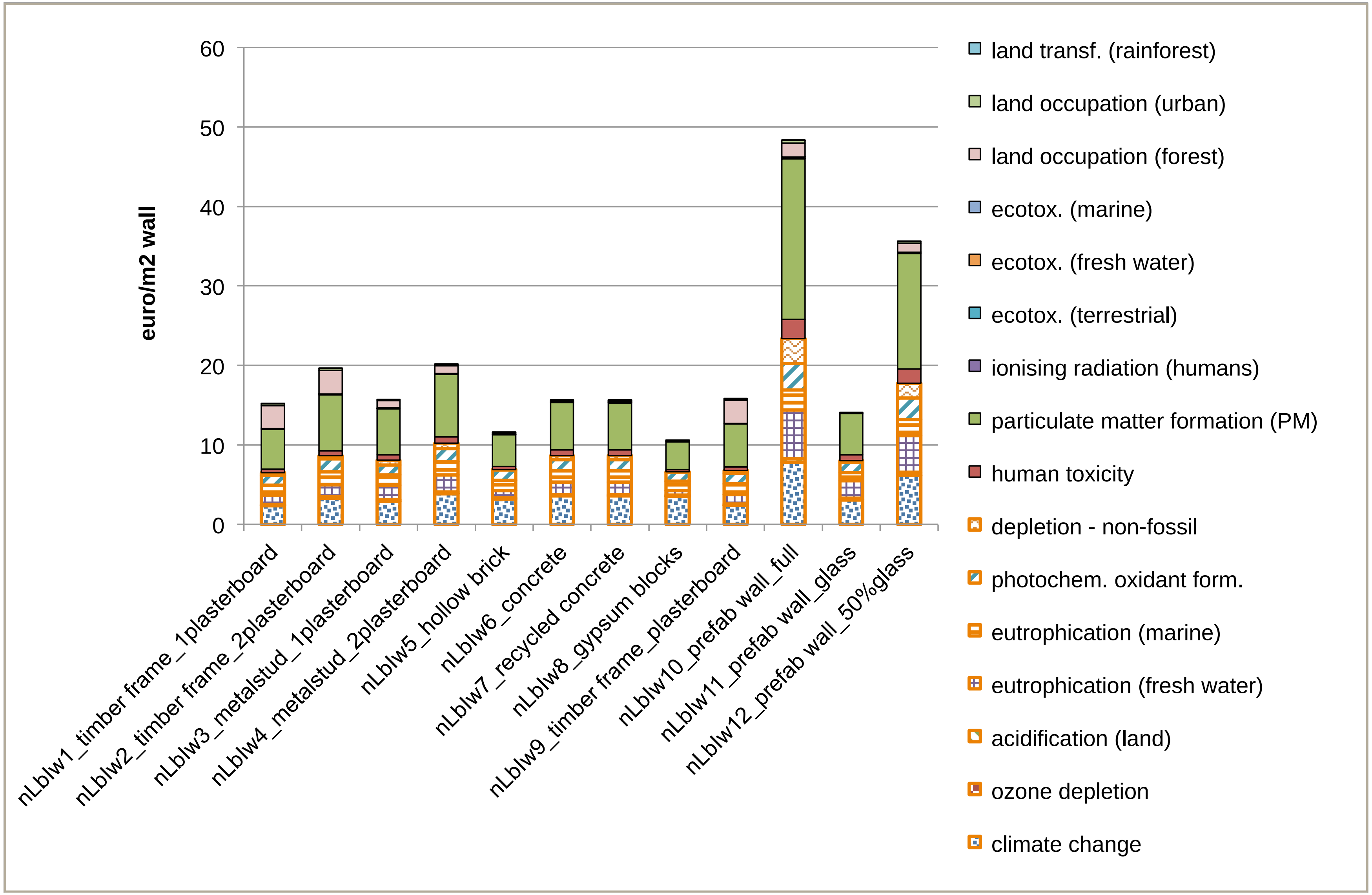

Figure I 4: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variant 'non-load-bearing interior wall' per environmental indicator, expressed in monetary units.

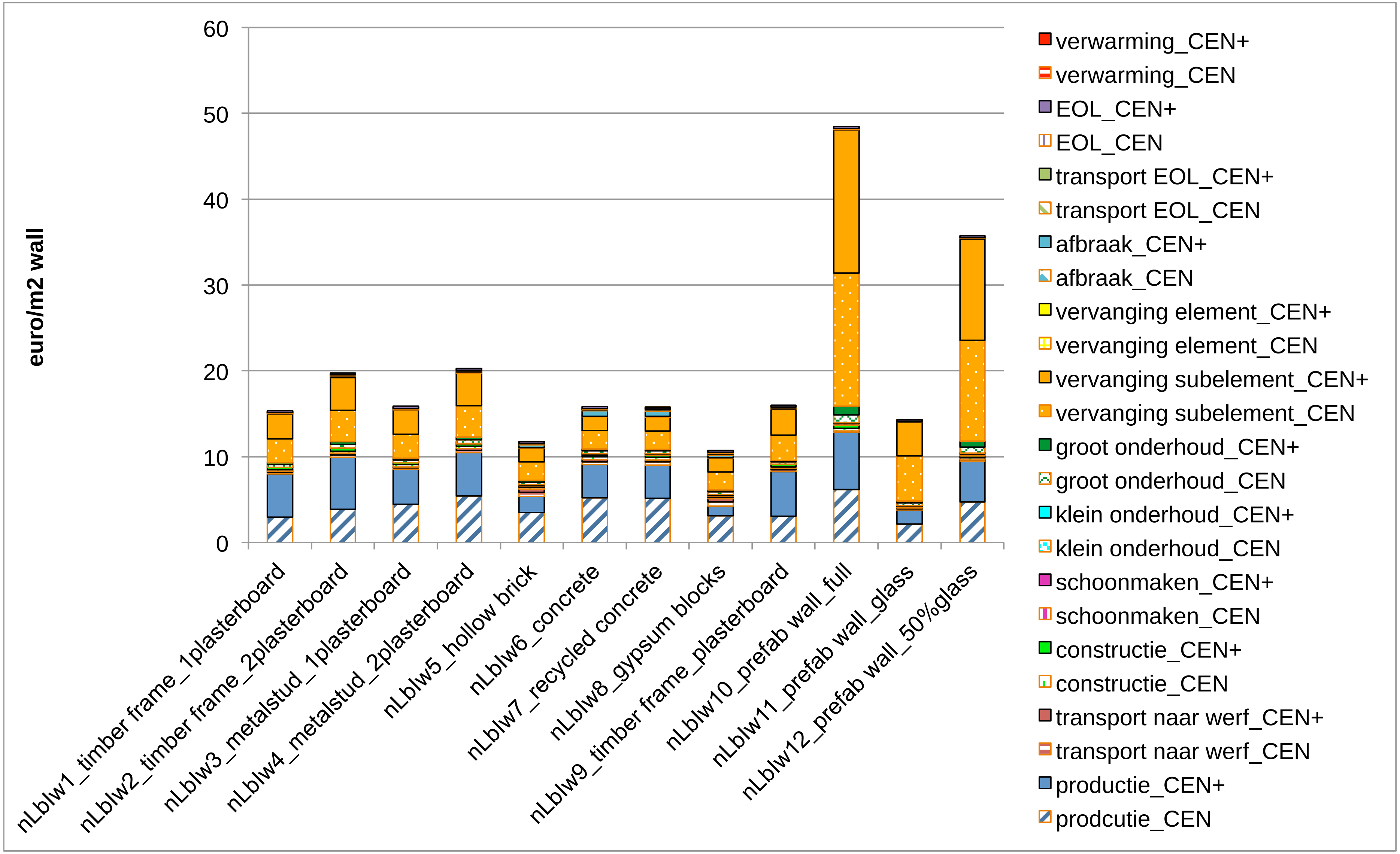

Figure L 4: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'non-load-bearing interior wall' per life cycle stage, expressed in monetary units.

3.3.5. Storey floor

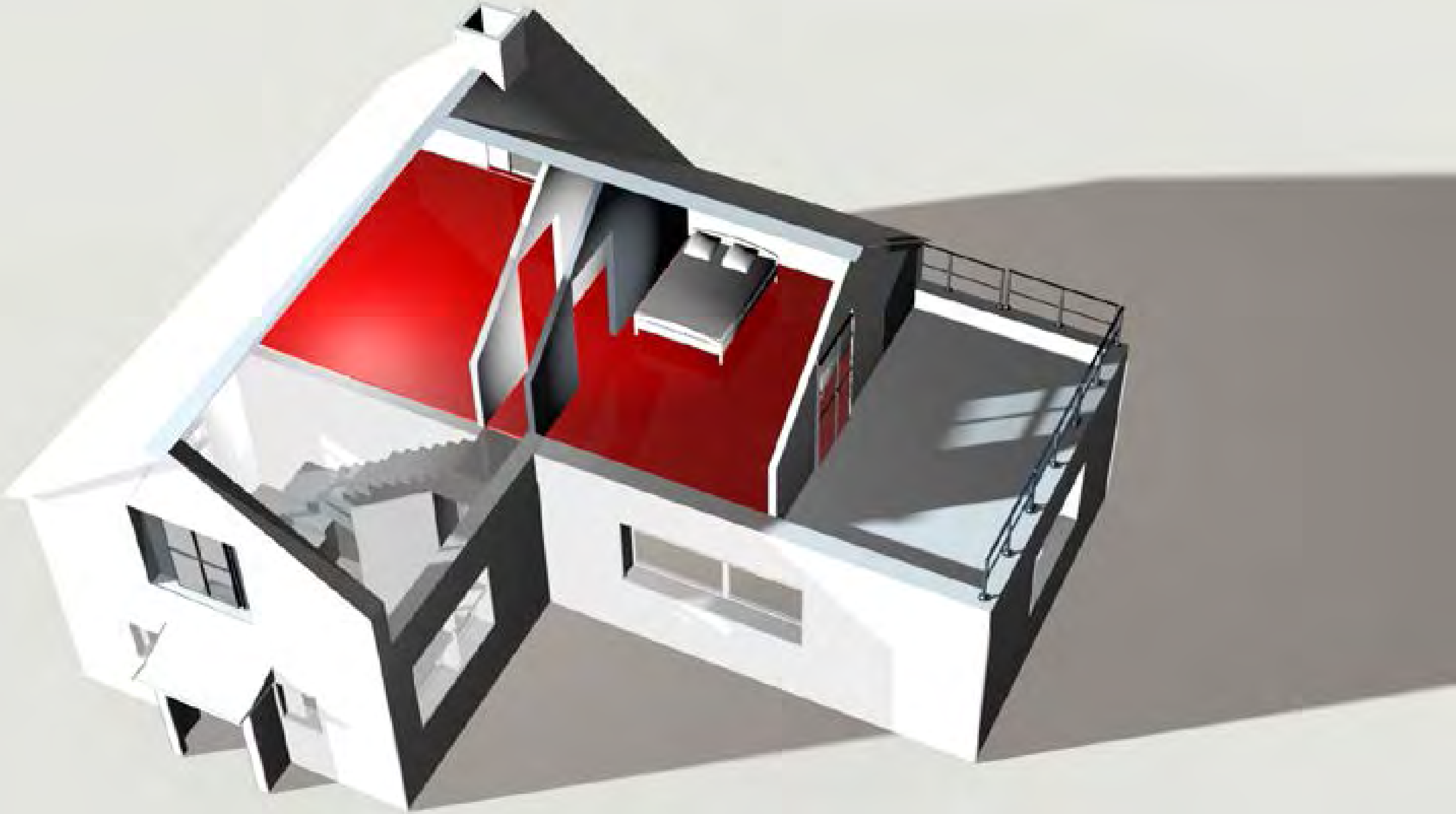

Table V 5: overview of the composition of the variants “storey floor”

(23)+ storey floor: environmental impact per m² of floor, 16 types (from down upwards =>)						
1	VV1_concrete_tiles	acrylic paint	gypsum plaster	15 cm concrete new	screed mix	fired earth tiles
2	VV2_concrete_linoleum	acrylic paint	gypsum plaster	15 cm concrete new	screed mix	linoleum
3	VV3_concrete_steel plate_linoleum	acrylic paint	plasterboard+insulation (on a metal structure)	concrete + permanent steel formwork	screed mix	linoleum
4	VV4_beam and block (clay)_tiles	acrylic paint	gypsum plaster	15 cm beam and block	screed mix	fired earth tiles
5	VV5_concrete_parquet	acrylic paint	gypsum plaster	15 cm concrete new	screed mix	parquet
6	VV6_hollow core slabs16.5_NVG_linoleum	acrylic paint	gypsum plaster	hollow core slabs (non-prestressed)	screed mix	linoleum
7	VV7_hollow core slabs12_VG_linoleum	acrylic paint	gypsum plaster	hollow core slabs (prestressed)	screed mix	linoleum
8	VV8_concrete_cork	acrylic paint	gypsum plaster	15 cm concrete new	screed mix	cork
9	VV9_hollow core slabs12_VG_ linoleum_rock wool plates	/	suspended ceiling: rock wool plates on a metal structure	hollow core slabs (prestressed)	screed mix	linoleum
10	VV10_wood_RW03_parquet	acrylic paint	plasterboard on wooden structure	wooden beams (22 cm) + osb + RW (3 cm)		parquet
11	VV11_concrete_laminate	acrylic paint	gypsum plaster	15 cm concrete new	screed mix	laminate
12	VV12_hollow core slabs12_VG_RW3_tiles	acrylic paint	gypsum plaster	hollow core slabs (prestressed)	screed mix	fired earth tiles
13	VV13_hollow core slabs12_VG_RW3_carpet	acrylic paint	gypsum plaster + RW insulation	hollow core slabs (prestressed)	screed mix	carpet
14	VV14_woodRW22_RW3_tiles	acrylic paint	plasterboard on wooden structure	wooden beams (22 cm) + osb + RW (3 cm)	screed mix	fired earth tiles
15	VV15_woodRW22_RW3_dry screed_tiles	acrylic paint	plasterboard on wooden structure	wooden beams (22 cm) + osb + RW (3 cm)	dry screed	fired earth tiles
16	VV16_hollow core slabs12_VG_RW3_laminate	acrylic paint	gypsum plaster	hollow core slabs (prestressed)	screed mix	laminate

Table CEN 5: overview of the individual CEN indicators for the variants ‘storey floor’

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Storey floor							
VV1_concrete_tiles	2,16E+02	1,39E-05	7,01E-01	2,58E-01	5,07E-02	1,84E-03	3,98E+03
VV2_concrete_linoleum	1,91E+02	1,06E-05	6,42E-01	2,77E-01	4,00E-02	7,18E-04	3,53E+03
VV3_concrete_steel plate_linoleum	2,14E+02	1,20E-05	7,29E-01	3,50E-01	5,36E-02	8,71E-04	3,92E+03
VV4_beam and block (clay)_tiles	2,08E+02	1,42E-05	6,70E-01	2,38E-01	4,68E-02	1,82E-03	3,94E+03
VV5_concrete_parquet	1,50E+02	3,15E-04	4,74E-01	1,75E-01	2,80E-02	5,97E-04	1,87E+03
VV6_hollow core slabs16.5_NVG_linoleum	2,00E+02	1,11E-05	6,58E-01	2,79E-01	4,05E-02	7,28E-04	3,57E+03
VV7_hollow core slabs12_VG_linoleum	1,82E+02	1,02E-05	6,03E-01	2,47E-01	3,25E-02	7,05E-04	3,36E+03
VV8_concrete_cork	1,55E+02	1,10E-05	4,73E-01	2,05E-01	3,50E-02	4,58E-04	1,86E+03
VV9_hollow core slabs12_VG_linoleum_rock wool plates	2,04E+02	1,07E-05	7,01E-01	3,05E-01	4,59E-02	9,41E-04	3,68E+03
VV10_wood_RW03_parquet	9,79E+01	3,14E-04	4,03E-01	1,42E-01	2,10E-02	6,81E-04	1,59E+03
VV11_concrete_laminate	2,06E+02	1,57E-04	7,83E-01	2,71E-01	3,57E-02	1,05E-03	2,77E+03
VV12_hollow core slabs12_VG_RW3_tiles	2,12E+02	1,38E-05	6,98E-01	2,37E-01	4,52E-02	1,84E-03	3,89E+03
VV13_hollow core slabs12_VG_RW3_carpet	1,97E+02	1,12E-05	5,58E-01	1,81E-01	3,00E-02	8,76E-04	2,50E+03
VV14_woodRW22_RW3_tiles	1,89E+02	1,37E-05	7,32E-01	2,53E-01	4,89E-02	2,24E-03	3,95E+03
VV15_woodRW22_RW3_dry screed_tiles	1,81E+02	1,39E-05	7,13E-01	2,50E-01	4,81E-02	2,54E-03	3,95E+03
VV16_hollow core slabs12_VG_RW3_laminate	2,02E+02	1,57E-04	7,80E-01	2,50E-01	3,02E-02	1,05E-03	2,67E+03

Tabel CEN+ 5: overzicht van de individuele CEN+ indicatoren voor de varianten 'verdiepingsvloer'

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m^3
Storey floor											
VV1_concrete_ tiles	4,34E-05	7,15E-04	1,22E-06	2,26E-02	1,12E+00	1,17E+00	6,59E-03	3,50E-08	5,05E-08	1,82E-09	3,83E+00
VV2_concrete_ linoleum	3,86E-05	2,74E-04	1,17E-06	2,22E-02	1,08E+00	1,07E+00	6,51E-03	2,43E-08	3,80E-08	1,58E-09	5,08E+00
VV3_ concrete_steel plate_linoleum	4,74E-05	3,27E-04	1,30E-06	2,43E-02	1,48E+00	1,47E+00	6,51E-03	3,25E-08	4,62E-08	1,59E-09	5,30E+00
VV4_beam and block (clay)_tiles	3,83E-05	6,79E-04	1,18E-06	2,12E-02	9,66E-01	1,02E+00	6,59E-03	3,16E-08	4,75E-08	1,93E-09	3,37E+00
VV5_concrete_ parquet	2,87E-05	3,57E-04	1,01E-06	3,55E-02	1,44E+00	1,15E+00	6,83E-03	7,21E-08	6,79E-08	1,46E-09	1,60E+00
VV6_hollow core slabs16.5_ NVG_linoleum	3,86E-05	2,79E-04	1,17E-06	2,24E-02	1,08E+00	1,07E+00	6,51E-03	2,46E-08	3,91E-08	1,63E-09	5,08E+00
VV7_hollow core slabs12_ VG_linoleum	3,15E-05	2,38E-04	1,13E-06	2,05E-02	8,67E-01	8,47E-01	6,51E-03	2,17E-08	3,55E-08	1,53E-09	4,87E+00
VV8_concrete_ cork	3,42E-05	2,31E-04	1,14E-06	3,23E-02	8,79E-01	9,17E-01	3,02E-02	3,56E-08	4,59E-08	1,35E-09	1,71E+00
VV9_hollow core slabs12_ VG_linoleum_ rock wool plates	4,15E-05	3,37E-04	1,24E-06	1,60E-02	1,39E+00	1,39E+00	9,79E-03	2,98E-08	4,74E-08	1,48E-09	5,15E+00
VV10_wood_ RW03_parquet	2,13E-05	2,92E-04	9,61E-07	4,46E-02	9,64E-01	6,58E-01	6,14E-03	9,19E-08	8,14E-08	3,73E-09	8,25E-01

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m^3
VV11_ concrete_ laminate	4,30E-05	3,35E-04	1,17E-06	3,93E-02	1,54E+00	1,51E+00	4,94E-02	2,89E-08	5,84E-08	1,94E-09	3,56E+00
VV12_hollow core slabs12_ VG_RW3_tiles	3,74E-05	7,08E-04	1,20E-06	2,12E-02	9,33E-01	9,81E-01	6,59E-03	3,40E-08	5,15E-08	1,92E-09	3,67E+00
VV13_hollow core slabs12_ VG_RW3_ carpet	2,74E-05	2,46E-04	1,18E-06	2,91E-02	1,01E+00	9,96E-01	2,78E-02	2,12E-08	5,01E-08	2,49E-07	1,59E+00
VV14_ woodRW22_ RW3_tiles	4,05E-05	7,32E-04	1,23E-06	3,34E-02	1,06E+00	1,11E+00	5,90E-03	6,30E-08	7,71E-08	4,43E-09	3,29E+00
VV15_ woodRW22_ RW3_dry screed_tiles	4,00E-05	7,19E-04	1,23E-06	3,43E-02	1,05E+00	1,11E+00	5,90E-03	5,91E-08	6,90E-08	4,37E-09	3,17E+00
VV16_hollow core slabs12_ VG_RW3_ laminate	3,70E-05	3,28E-04	1,16E-06	3,79E-02	1,36E+00	1,32E+00	4,94E-02	2,79E-08	5,95E-08	2,05E-09	3,41E+00

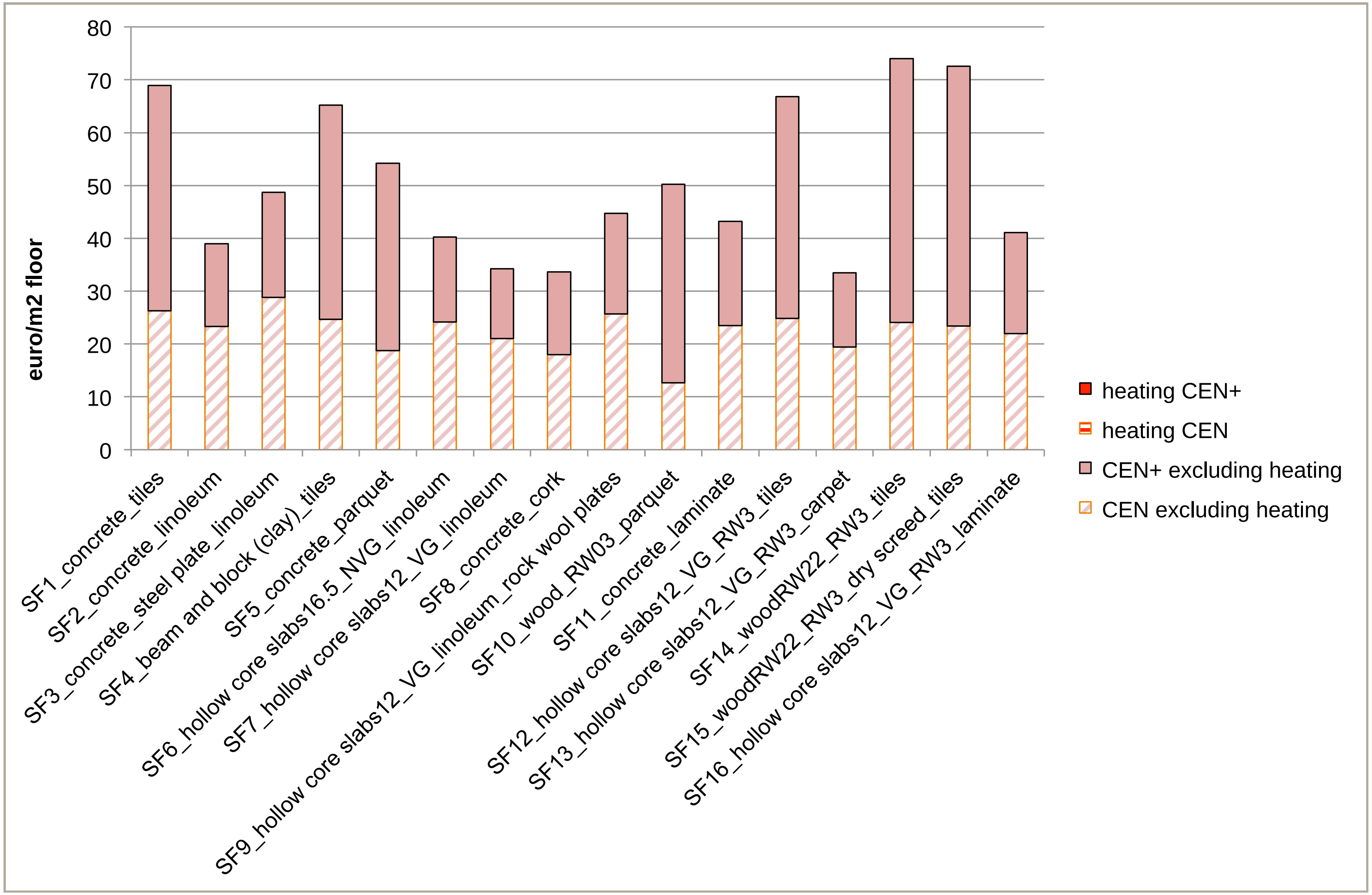

Figure E 5: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants 'storey floor', expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

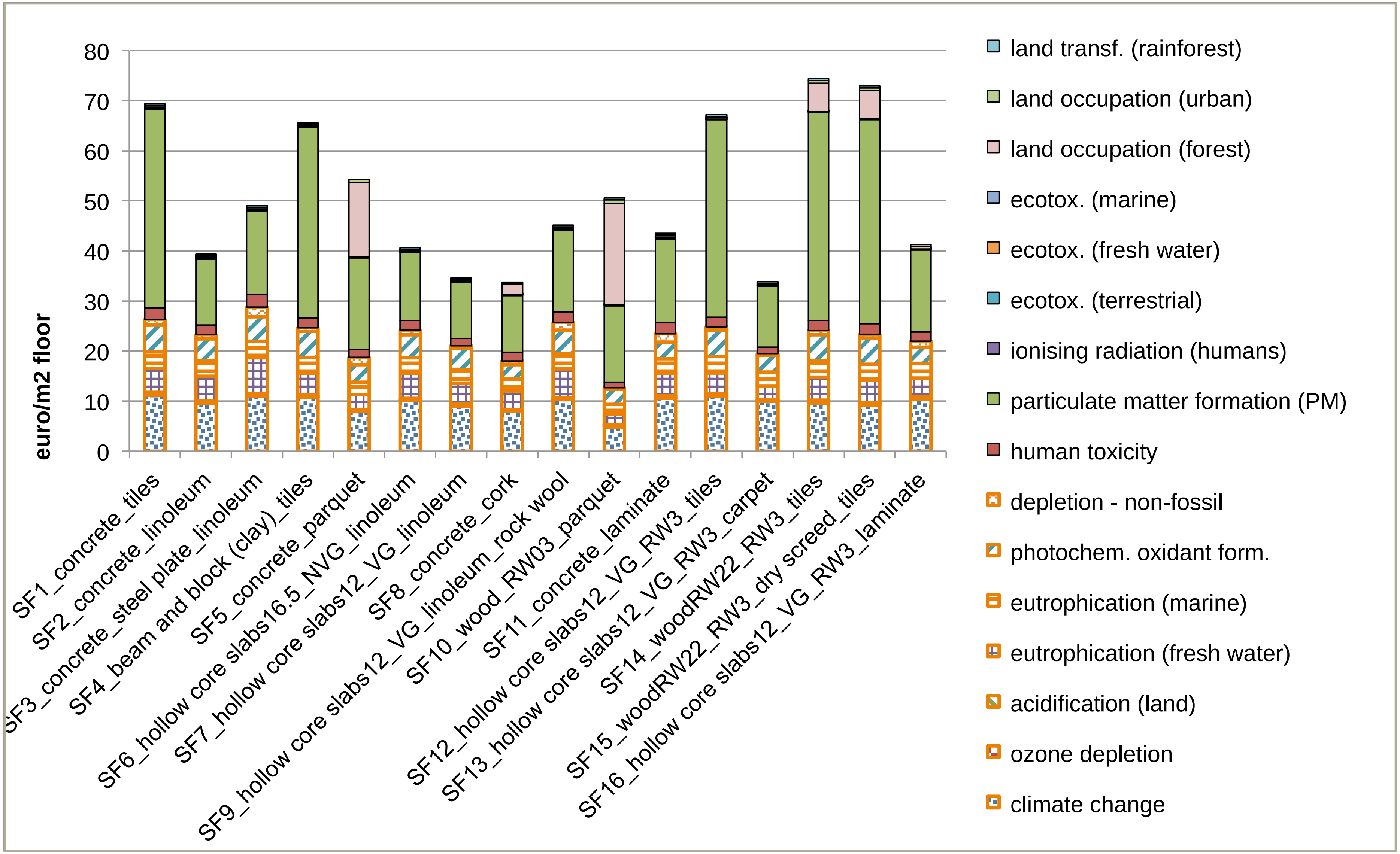

Figure I 5: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variant 'storey floor' per environmental indicator, expressed in monetary units.

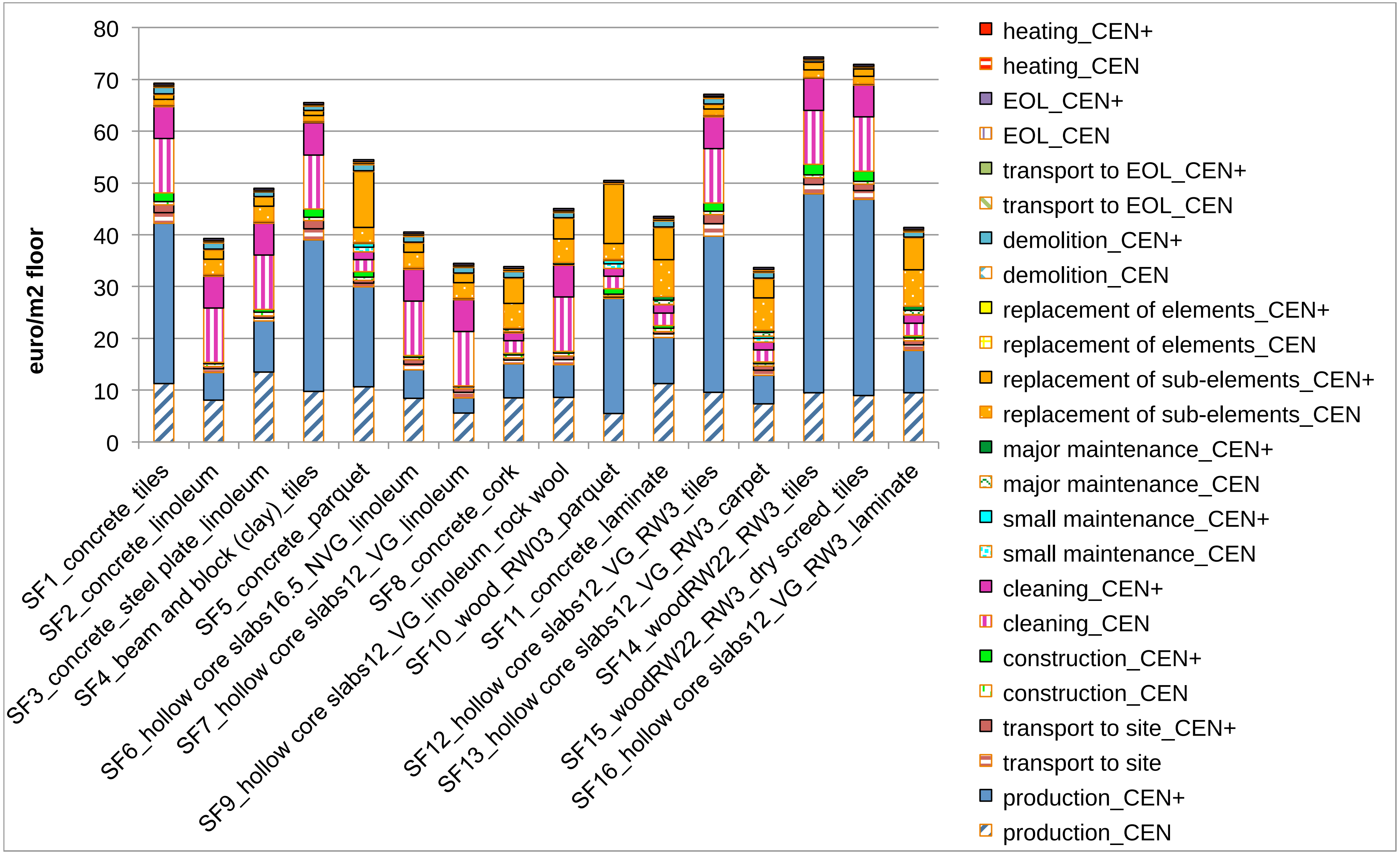

Figure L 5: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'storey floor' per life cycle stage, expressed in monetary units.

3.3.6. Flat roof

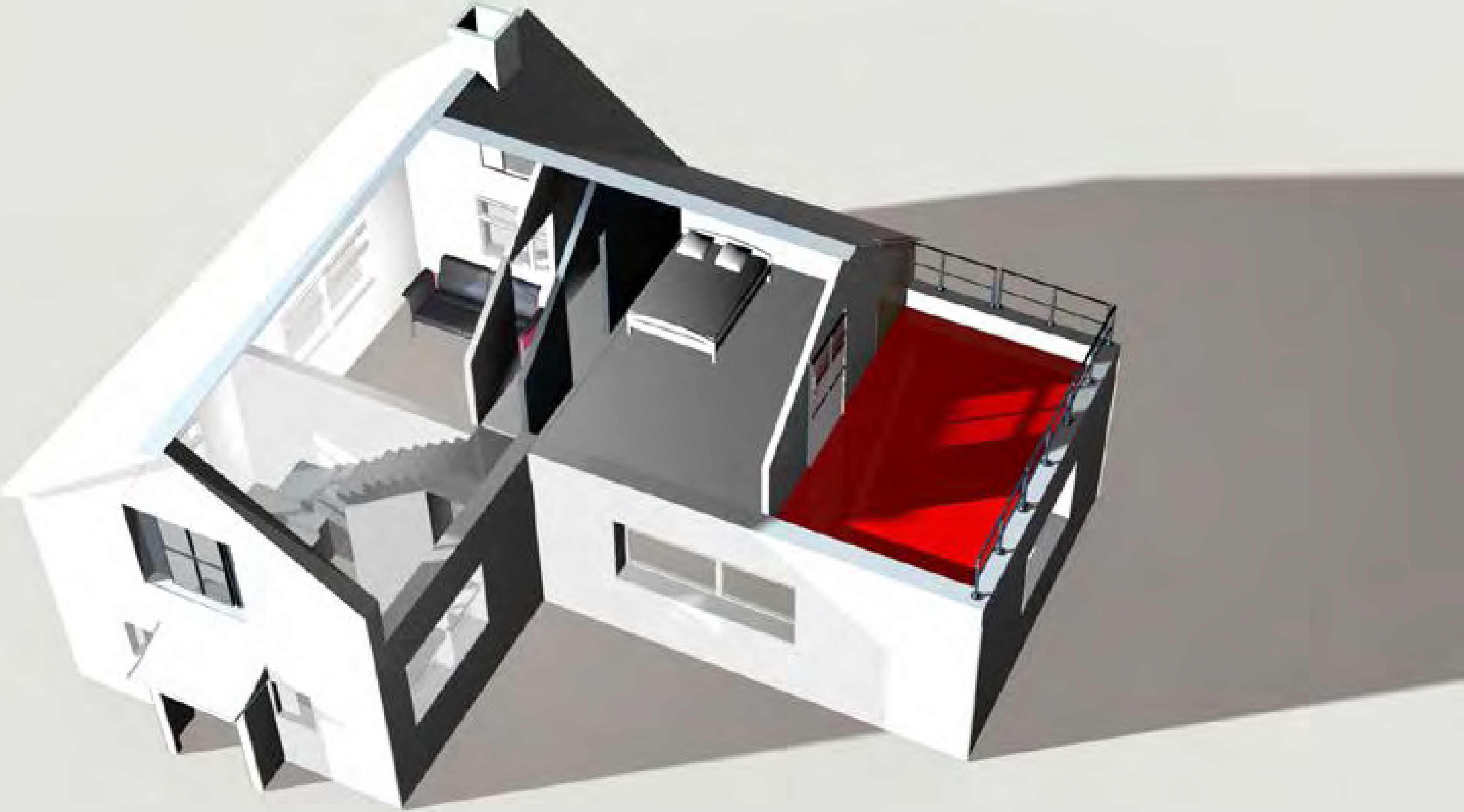

Table V 6: overview of the composition of the variants "flat roof"'

(27.1)+ flat roof: environmental impact per m² of roof, 13 types* (from outside inwards =>)							
1	PD1_concrete_PUR10_EPDM	acrylic paint	gypsum plaster	15 cm concrete new	concrete slope layer	PUR1: 10 cm (U = 0.25)	EPDM
2	PD2_concrete_PUR17_EPDM	acrylic paint	gypsum plaster	15 cm concrete new	concrete slope layer	PUR3: 17 cm (U = 0.15)	EPDM
3	PD3_concrete_PUR10_bitumen	acrylic paint	gypsum plaster	15 cm concrete new	concrete slope layer	PUR1: 10 cm (U = 0.25)	bitumen
4	PD4_hollow core slabs16.5_NVG_PUR10_EPDM	acrylic paint	gypsum plaster	hollow core slabs (non-prestressed): 16.5 cm	concrete slope layer	PUR1: 10 cm (U = 0.25)	EPDM
5	PD5_hollow core slabs_VG_PUR10_EPDM	acrylic paint	gypsum plaster	hollow core slabs (prestressed): 12 cm	concrete slope layer	PUR1: 10 cm (U = 0.25)	EPDM
6	PD6_concrete_ PURslope6.75_10.5_EPDM	acrylic paint	gypsum plaster	15 cm concrete new	/	PUR1 (slope insulation): 6.75 - 10.5 cm (U = 0.29)	EPDM
7	PD7_concrete_RWslope6.11_14_ EPDM	acrylic paint	gypsum plaster	15 cm concrete new	/	RW1: (slope insulation): 5 - 8 cm + 6 cm fixed (U = 0.3)	EPDM
8	PD8_beams and blocks_clay_PUR10_EPDM	acrylic paint	gypsum plaster	15 cm beams and blocks clay (12+3 cm)	concrete slope layer	PUR1: 10 cm (U = 0.24)	EPDM
9	PD9_aircrete_PUR6_EPDM	acrylic paint	gypsum plaster	aircrete	concrete slope layer	PUR1: 6 cm (U = 0.30)	EPDM
10	PD10_TT_PUR10_EPDM	acrylic paint	plasterboard	TT profiles1: 33 cm	concrete slope layer	PUR1: 10 cm (U = 0.25)	EPDM
11	PD11_wooden beams_PUR10_EPDM	acrylic paint	plasterboard	wooden beams (22)	slope wedges	OSB+PUR1: 10 cm (U = 0.23)	EPDM
12	PD12_wooden beams_cellulose22_RW6_EPDM	acrylic paint	plasterboard	wooden beams (22) with cellulose	slope wedges	OSB + RW: 6 cm	EPDM
13	PD13_FJI_cellulose24_RW6_ EPDM	acrylic paint	plasterboard	FJI 24 cm + cellulose	slope wedges	OSB + RW: 6 cm	EPDM

* vapour barrier (VP40/15) is added where necessary

Table CEN 6: overview of the individual CEN indicators for the variants 'flat roof'

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Flat roof							
PD1_concrete_PUR10_EPDM	2,59E+02	1,76E-05	4,06E-01	1,31E-01	3,70E-02	2,35E-04	3,91E+03
PD2_concrete_PUR17_EPDM	2,16E+02	1,38E-05	4,28E-01	1,37E-01	3,72E-02	2,46E-04	3,10E+03
PD3_concrete_PUR10_bitumen	2,84E+02	2,46E-05	5,19E-01	1,81E-01	4,58E-02	5,75E-04	4,81E+03
PD4_hollow core slabs16.5_NVG_PUR10_EPDM	2,67E+02	1,80E-05	4,22E-01	1,33E-01	3,74E-02	2,45E-04	3,93E+03
PD5_hollow core slabs_VG_PUR10_EPDM	2,50E+02	1,72E-05	3,66E-01	1,01E-01	2,95E-02	2,22E-04	3,73E+03
PD6_concrete_PURslope6.75_10.5_EPDM	2,72E+02	1,86E-05	3,81E-01	1,25E-01	3,70E-02	2,21E-04	4,21E+03
PD7_concrete_RWslope6.11_14_EPDM	2,62E+02	1,83E-05	3,61E-01	1,19E-01	3,33E-02	1,94E-04	4,06E+03
PD8_beams and blocks_clay_PUR10_EPDM	2,46E+02	1,76E-05	3,73E-01	1,11E-01	3,28E-02	2,18E-04	3,79E+03
PD9_aircrete_PUR6_EPDM	2,73E+02	1,98E-05	3,35E-01	9,60E-02	2,92E-02	2,81E-04	4,17E+03
PD10_TT_PUR10_EPDM	2,42E+02	1,68E-05	3,46E-01	9,89E-02	2,98E-02	2,10E-04	3,71E+03
PD11_wooden beams_PUR10_EPDM	2,04E+02	1,51E-05	3,45E-01	1,13E-01	3,20E-02	6,17E-04	3,47E+03
PD12_wooden beams_cellulose22_RW6_EPDM	1,53E+02	1,22E-05	2,97E-01	1,03E-01	2,39E-02	7,45E-04	2,61E+03
PD13_FJI_cellulose24_RW6_EPDM	1,21E+02	9,58E-06	2,44E-01	8,70E-02	2,00E-02	7,87E-04	2,10E+03

Table CEN+ 6: overview of the individual CEN+ indicators for the variants 'flat roof'

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species. yr	species. yr	species. yr	species. yr	m3
Flat roof											
PD1_concrete_PUR10_EPDM	1,91E-05	2,01E-04	2,97E-07	1,63E-02	6,41E-01	6,66E-01	7,51E-03	1,64E-08	3,85E-08	2,20E-09	1,45E+00
PD2_concrete_PUR17_EPDM	1,97E-05	2,11E-04	2,72E-07	1,72E-02	7,17E-01	6,71E-01	7,51E-03	1,58E-08	3,31E-08	1,80E-09	1,60E+00
PD3_concrete_PUR10_bitumen	2,77E-05	2,52E-04	4,33E-07	2,25E-02	9,98E-01	1,05E+00	4,18E-02	2,05E-08	7,26E-08	3,15E-09	1,66E+00
PD4_hollow core slabs16.5_NVG_PUR10_EPDM	1,91E-05	2,07E-04	3,01E-07	1,66E-02	6,39E-01	6,65E-01	7,51E-03	1,66E-08	3,95E-08	2,25E-09	1,46E+00
PD5_hollow core slabs_VG_PUR10_EPDM	1,20E-05	1,65E-04	2,59E-07	1,46E-02	4,27E-01	4,46E-01	7,51E-03	1,38E-08	3,60E-08	2,15E-09	1,25E+00
PD6_concrete_PURslope6.75_10.5_EPDM	1,85E-05	1,84E-04	2,90E-07	1,57E-02	6,14E-01	6,58E-01	7,51E-03	1,47E-08	3,76E-08	2,25E-09	1,25E+00
PD7_concrete_RWslope6.11_14_EPDM	1,75E-05	1,92E-04	2,98E-07	1,41E-02	5,40E-01	6,37E-01	7,51E-03	1,61E-08	3,88E-08	2,40E-09	1,08E+00
PD8_beams and blocks_clay_PUR10_EPDM	1,39E-05	1,65E-04	2,51E-07	1,49E-02	4,91E-01	5,09E-01	7,51E-03	1,29E-08	3,50E-08	2,28E-09	9,98E-01
PD9_aircrete_PUR6_EPDM	1,12E-05	1,37E-04	2,83E-07	1,37E-02	3,80E-01	4,34E-01	7,51E-03	1,26E-08	3,03E-08	2,96E-09	9,00E-01
PD10_TT_PUR10_EPDM	1,23E-05	1,54E-04	2,44E-07	1,44E-02	4,42E-01	4,61E-01	7,51E-03	1,24E-08	3,39E-08	2,05E-09	1,13E+00
PD11_wooden beams_PUR10_EPDM	1,50E-05	1,46E-04	2,60E-07	3,48E-02	5,59E-01	5,69E-01	6,82E-03	4,27E-08	5,36E-08	4,25E-09	6,77E-01
PD12_wooden beams_cellulose22_RW6_EPDM	1,40E-05	1,36E-04	2,45E-07	3,27E-02	4,68E-01	5,21E-01	6,82E-03	4,30E-08	4,99E-08	4,06E-09	4,45E-01
PD13_FJI_cellulose24_RW6_EPDM	1,16E-05	1,14E-04	1,91E-07	2,45E-02	4,23E-01	4,64E-01	6,69E-03	2,24E-08	2,98E-08	3,74E-09	3,79E-01

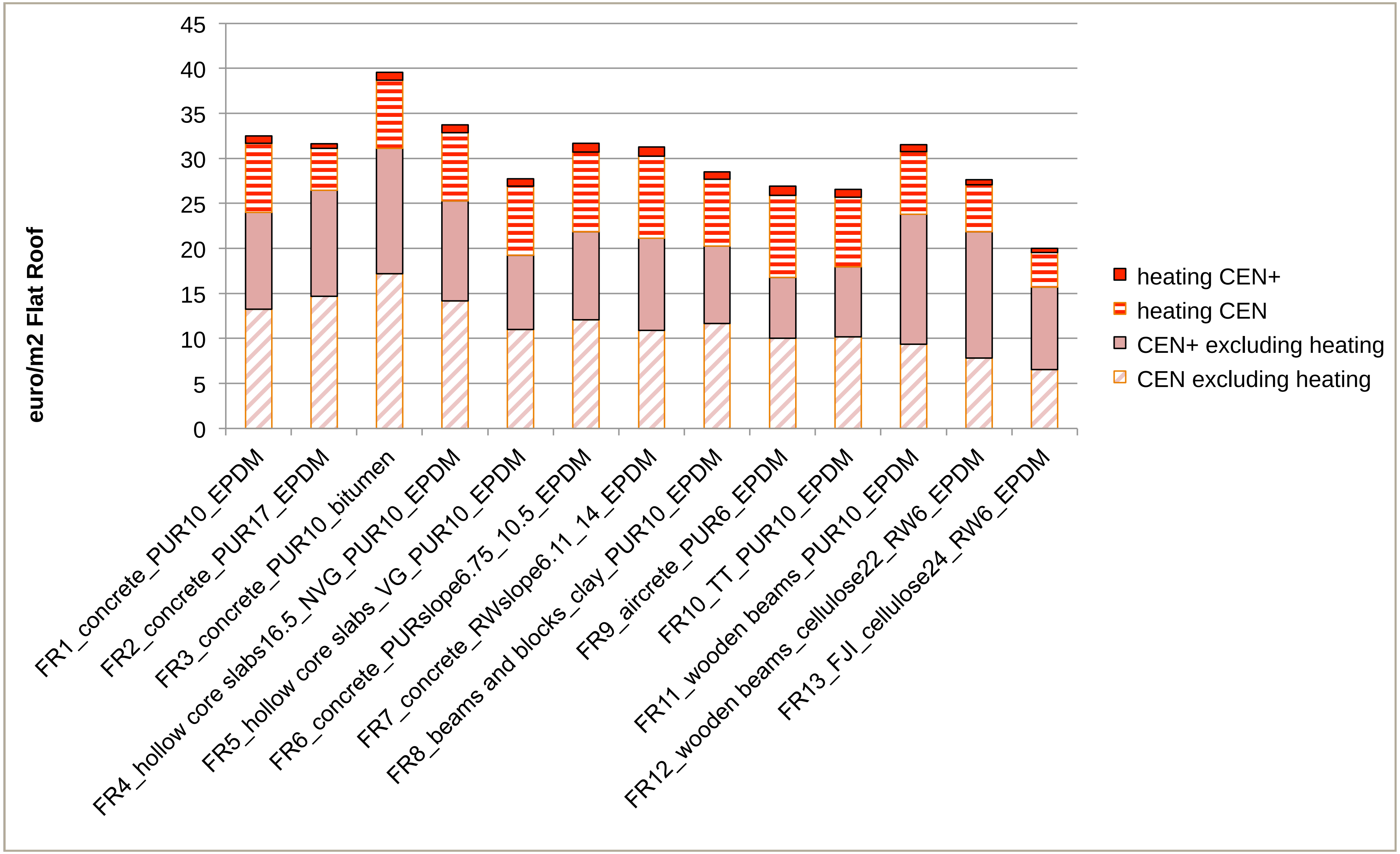

Figure E 6: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants 'flat roof', expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

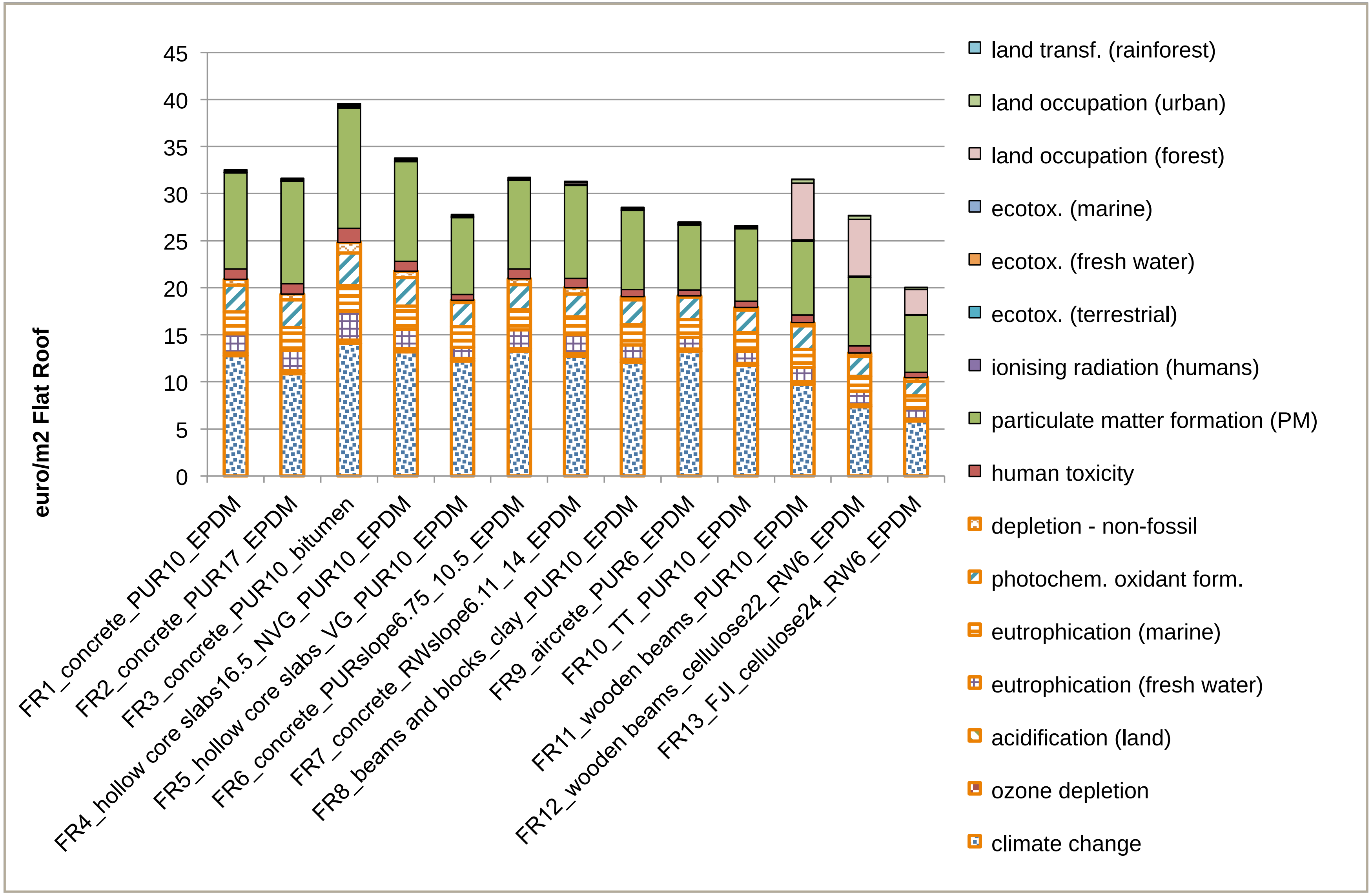

Figure I 6: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variant 'flat roof' per environmental indicator, expressed in monetary units.

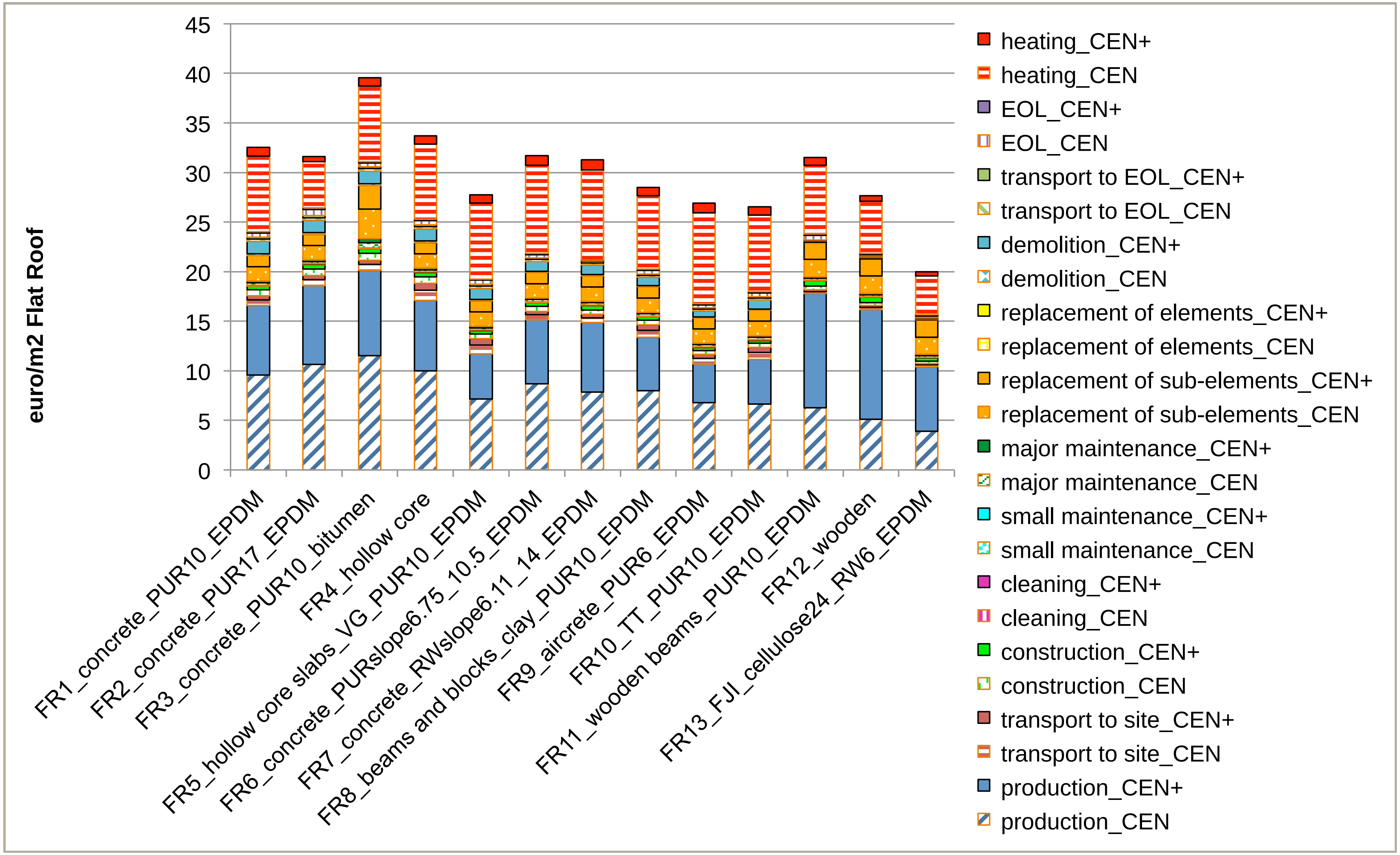

Figure L 6: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'flat roof' per life cycle stage, expressed in monetary units.

3.3.7. Pitched roof

Table V 7: overview of the composition of the variants "pitched roof" (45°))

(27.2)+ pitched roof (45°): environmental impact per m2 of horizontally projected roof, 13 types* (from outside inwards =>)							
1	HD1_purlin_RW18_ clay roof tile	acrylic paint	plasterboard	purlins and jack rafters with 8 cm RW between jack rafters and 10 cm between purlins (U=0.2)	wood fibre board		clay tiles
2	HD2_FJI_RW24_ clay roof tile	acrylic paint	plasterboard	FJI 24 cm + RW	wood fibre board		clay tiles
3	HD3_FJI_RW36_ clay roof tile	acrylic paint	plasterboard	FJI 36 cm+RW	wood fibre board		clay tiles
4	HD4_FJI_celllulose24_ clay roof tile	acrylic paint	plasterboard	FJI 24 cm + cellulose	wood fibre board		clay tiles
5	HD5_rafters_RW18_ clay roof tile	acrylic paint	plasterboard	rafters	wood fibre board	RW (complete filling between rafters)	clay tiles
6	HD6_rafters _PUR08_ clay roof tile	acrylic paint	plasterboard	rafters	wood fibre board	PUR1 (sarking): 8 cm (U = 0.26)	clay tiles
7	HD7_rafters_PUR16_ clay roof tile	acrylic paint	plasterboard	rafters	wood fibre board	PUR2 (sarking): 16 (6+10) cm (U = 0.14)	clay tiles
8	HD8_rafters_RW18_ zinc	acrylic paint	plasterboard	rafters + RW (complete filling)	wood fibre board	substructure	zinc on PE studded foil
9	HD9_rafters_RW18_ fibre cement	acrylic paint	plasterboard	rafters	wood fibre board	RW (complete filling between rafters)	slates in fibre cement
10	HD10_steel_sandwich RW12_steel	acrylic paint	plasterboard	steel structure	metal sandwich panels filled with rock wool		
11	HD11_rafters_RW18_ wooden shingles	acrylic paint	plasterboard	rafters	wood fibre board	RW (complete filling between rafters)	cedar wood (shingles)
12	HD12_rafters_RW18_ concrete roof tile	acrylic paint	plasterboard	rafters	wood fibre board	RW (complete filling between rafters)	concrete roof tiles
13	HD13_rafters_sandwich panel PUR8_ clay roof tile	acrylic paint		rafters	prefab panels filled with PUR + laths		clay tiles

* vapour barriers and wind screens are added where necessary

Table CEN 7: overview of the individual CEN indicators for the variants 'pitched roof"

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Pitched roof							
HD1_purlin_RW18_clay roof tile	2,85E+02	2,24E-05	4,47E-01	1,75E-01	3,67E-02	8,24E-04	4,59E+03
HD2_FJI_RW24_clay roof tile	1,70E+02	1,39E-05	3,97E-01	1,56E-01	2,78E-02	7,80E-04	2,62E+03
HD3_FJI_RW36_clay roof tile	1,70E+02	1,40E-05	3,99E-01	1,57E-01	2,81E-02	7,82E-04	2,64E+03
HD4_FJI_celllulose24_clay roof tile	1,64E+02	1,39E-05	3,22E-01	1,46E-01	2,35E-02	1,08E-03	2,53E+03
HD5_rafters_RW18_clay roof tile	2,85E+02	2,21E-05	4,47E-01	1,74E-01	3,67E-02	1,09E-03	4,59E+03
HD6_rafters _PUR08_clay roof tile	3,26E+02	2,39E-05	4,49E-01	1,78E-01	4,21E-02	1,11E-03	5,21E+03
HD7_rafters_PUR16_clay roof tile	2,55E+02	1,77E-05	4,85E-01	1,87E-01	4,25E-02	1,13E-03	3,89E+03
HD8_rafters_RW18_zinc	3,47E+02	2,44E-05	1,38E+00	5,96E-01	7,37E-02	2,39E-02	5,42E+03
HD9_rafters_RW18_fibre cement	3,34E+02	2,86E-05	5,93E-01	2,74E-01	4,60E-02	1,37E-03	5,14E+03
HD10_steel_sandwich RW12_steel	3,72E+02	2,56E-05	6,34E-01	2,93E-01	6,94E-02	1,06E-03	5,96E+03
HD11_rafters_RW18_wooden shingles	3,03E+02	2,46E-05	6,00E-01	2,70E-01	4,63E-02	1,30E-03	4,98E+03
HD12_rafters_RW18_concrete roof tile	2,76E+02	2,11E-05	4,27E-01	1,72E-01	3,44E-02	1,11E-03	4,45E+03
HD13_rafters_sandwich panel PUR8_clay roof tile	3,19E+02	2,21E-05	3,87E-01	1,34E-01	4,29E-02	7,16E-04	5,20E+03

Table CEN+ 7: overview of the individual CEN+ indicators for the variants 'pitched roof"

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m^3
Pitched roof											
HD1_purlin_RW18_clay roof tile	2,07E-05	2,22E-04	4,59E-07	3,15E-02	6,74E-01	7,83E-01	2,29E-02	5,56E-08	7,56E-08	6,50E-09	6,63E-01
HD2_FJI_RW24_clay roof tile	1,78E-05	2,12E-04	3,71E-07	2,28E-02	5,98E-01	6,51E-01	2,28E-02	3,41E-08	4,93E-08	5,69E-09	5,99E-01
HD3_FJI_RW36_clay roof tile	1,80E-05	2,13E-04	3,74E-07	2,36E-02	6,02E-01	6,55E-01	2,28E-02	3,43E-08	4,95E-08	5,69E-09	6,05E-01
HD4_FJI_celllulose24_ clay roof tile	1,72E-05	1,46E-04	3,39E-07	2,26E-02	5,78E-01	6,32E-01	2,28E-02	3,05E-08	4,14E-08	5,34E-09	5,06E-01
HD5_rafters_RW18_clay roof tile	2,13E-05	2,39E-04	4,52E-07	2,76E-02	9,91E-01	1,11E+00	2,29E-02	4,36E-08	6,49E-08	6,46E-09	6,60E-01
HD6_rafters _PUR08_ clay roof tile	2,14E-05	2,13E-04	4,41E-07	2,94E-02	1,09E+00	1,16E+00	2,29E-02	4,11E-08	6,09E-08	6,36E-09	8,55E-01
HD7_rafters_PUR16_ clay roof tile	2,24E-05	2,29E-04	4,00E-07	3,08E-02	1,22E+00	1,18E+00	2,29E-02	4,03E-08	5,22E-08	5,70E-09	1,10E+00
HD8_rafters_RW18_zinc	2,25E-04	5,21E-04	7,49E-07	1,66E-01	3,72E+00	5,45E+00	2,03E-01	9,05E-08	1,05E-07	7,02E-09	2,76E+00
HD9_rafters_RW18_ fibre cement	3,56E-05	3,02E-04	7,29E-07	3,37E-02	1,46E+00	1,60E+00	3,53E-02	6,03E-08	8,22E-08	1,01E-08	1,28E+00
HD10_steel_sandwich RW12_steel	4,02E-05	3,96E-04	6,47E-07	2,53E-02	1,51E+00	1,66E+00	1,01E-02	3,99E-08	7,18E-08	6,85E-09	1,54E+00
HD11_rafters_RW18_ wooden shingles	3,31E-05	3,20E-04	6,61E-07	5,83E-02	1,41E+00	1,54E+00	6,19E-02	1,35E-07	1,41E-07	6,83E-09	9,37E-01
HD12_rafters_RW18_ concrete roof tile	2,08E-05	2,32E-04	4,51E-07	2,74E-02	9,94E-01	1,12E+00	2,33E-02	4,42E-08	6,40E-08	6,65E-09	7,63E-01
HD13_rafters_sandwich panel PUR8_clay roof tile	1,85E-05	1,86E-04	3,33E-07	2,95E-02	1,07E+00	1,15E+00	1,55E-02	3,37E-08	5,36E-08	2,41E-09	7,61E-01

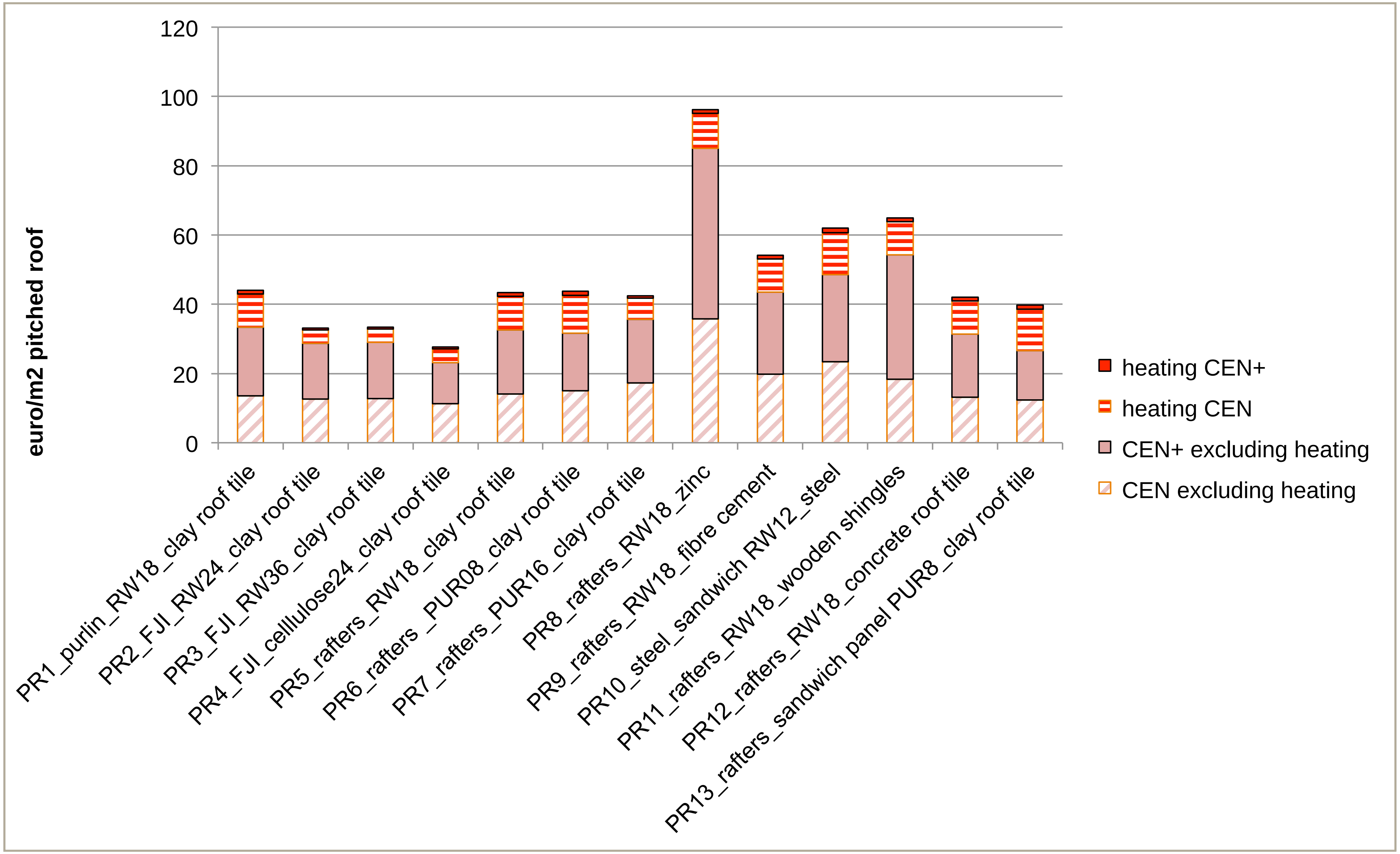

Figure E 7: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants "pitched roof', expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

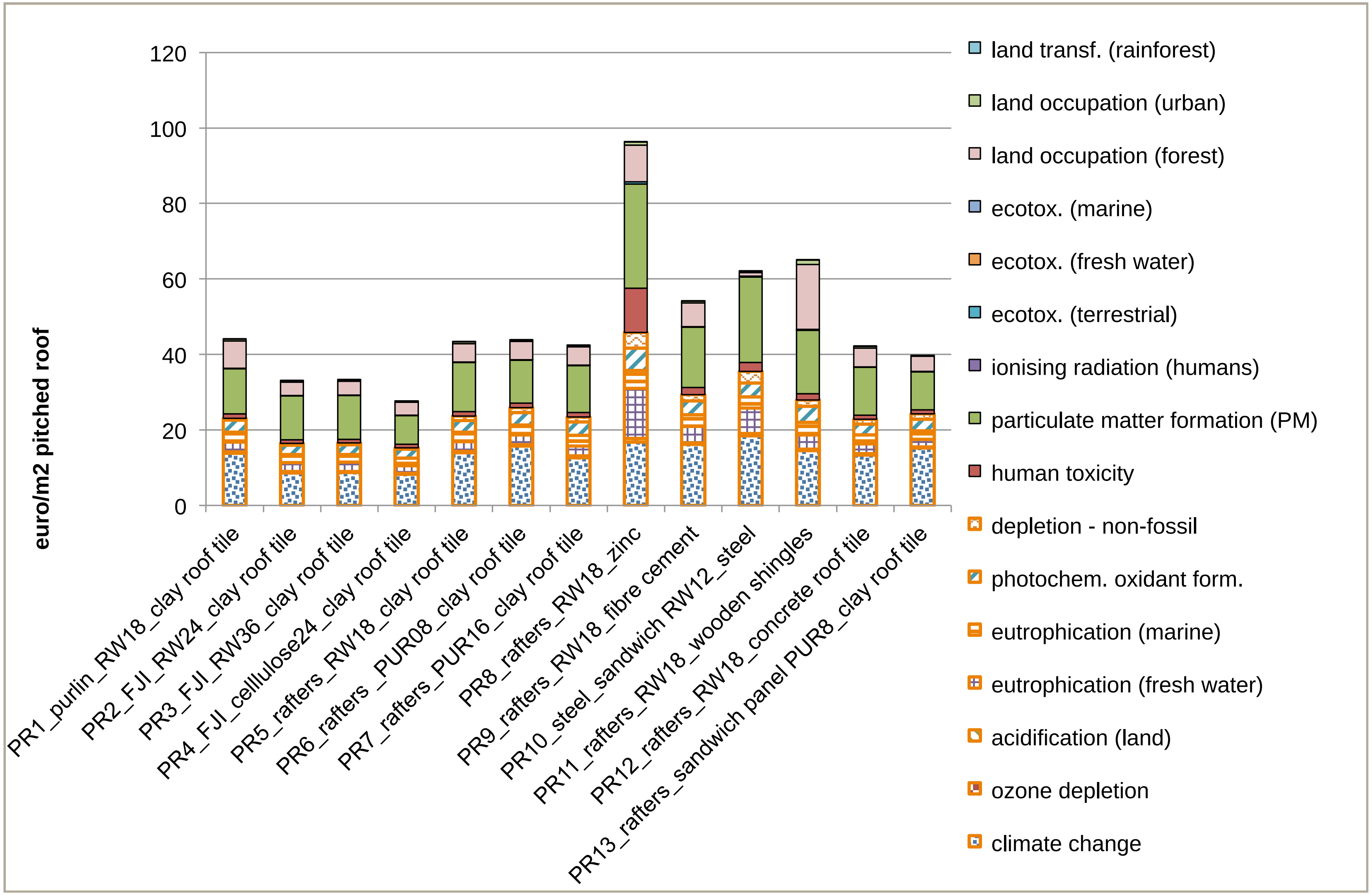

Figure I 7: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variant 'pitched roof' per environmental indicator, expressed in monetary units.

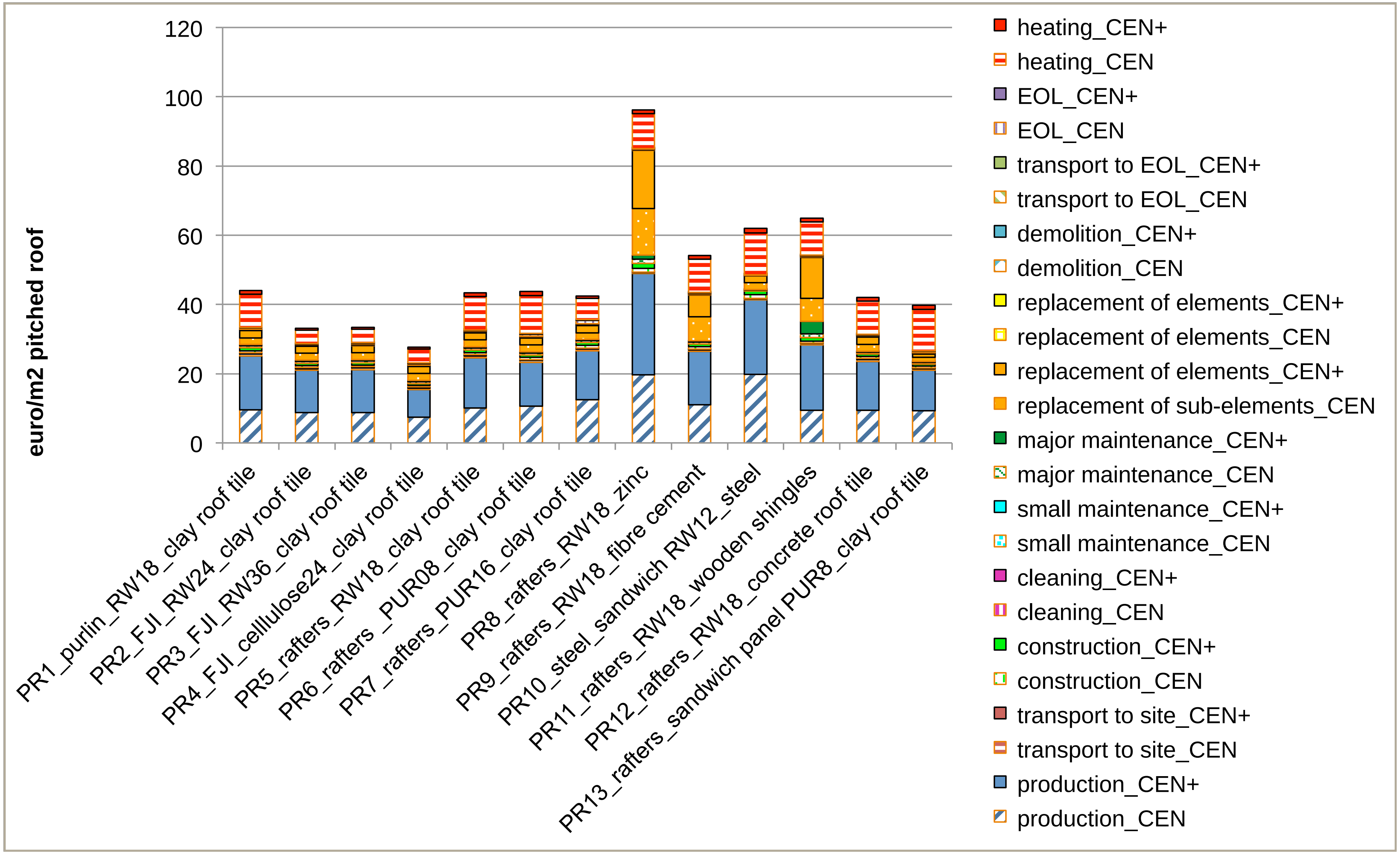

Figure L 7: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'pitched roof' per life cycle stage, expressed in monetary units.

3.3.8. Window openings

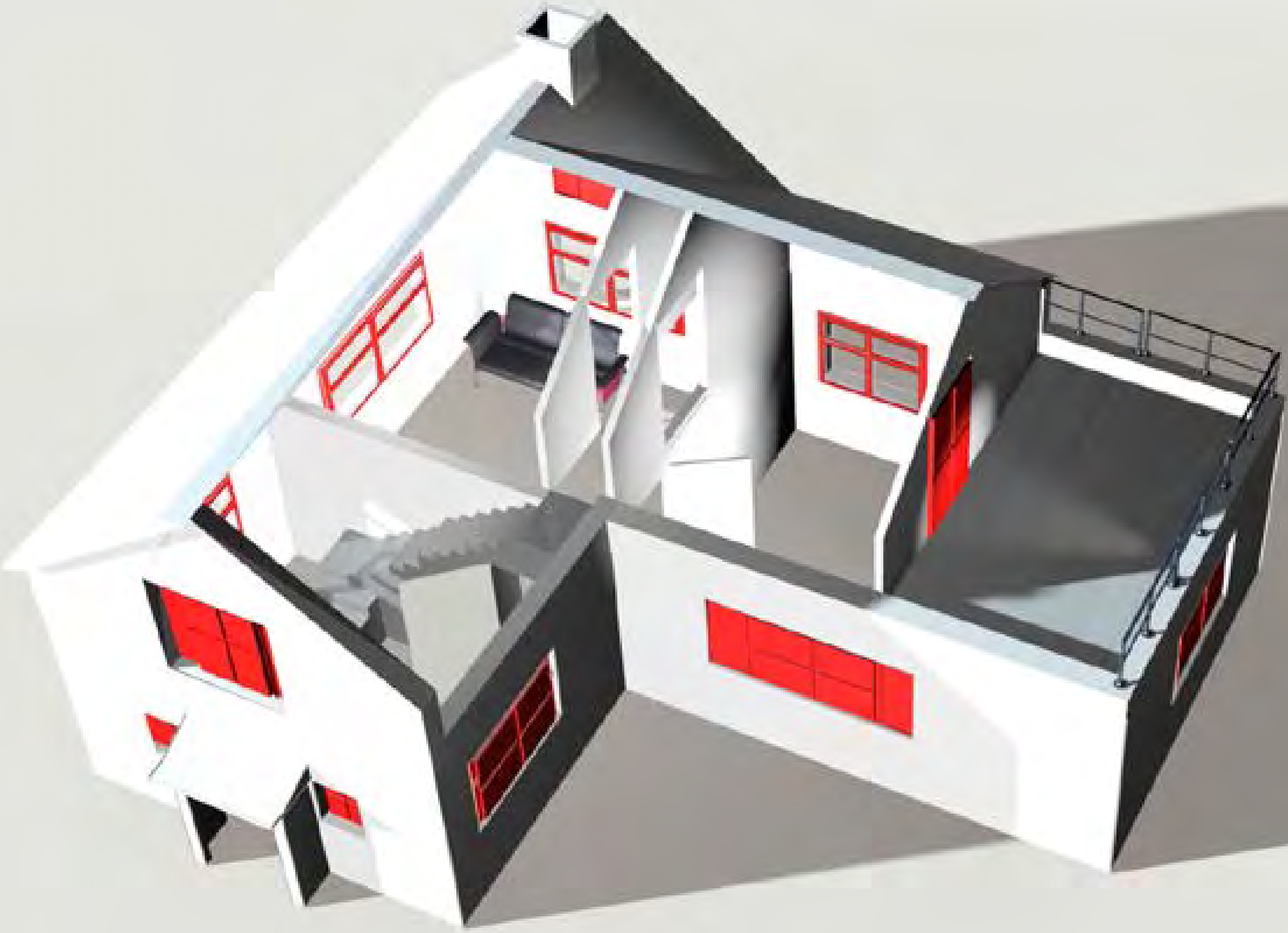

Table V 8: overview of the composition of the variants "window openings" (including cabinet work)

(31) window openings including cabinet work: environmental impact per m² of window, 11 types			
1	PVC_glass1.1	PVC frame1	standard double-glazed (U=1.1 W/m²K)
2	ALU_glass1.1	ALU frame1	standard double-glazed (U=1.1 W/m²K)
3	wood_tropical hardwood_glass1.1	Tropical hardwood frame1	standard double-glazed (U=1.1 W/m²K)
4	wood painted_glass1.1	painted wood frame1	standard double-glazed (U=1.1 W/m²K)
5	wood_alu_glass1.1	Wood-alu frame 1	standard double-glazed (U=1.1 W/m²K)
6	PVCtherm_glass0.5	PVC frame2	standard triple-glazed (U=0.65W/m²K)
7	ALUtherm_glass0.6	ALU frame2	standard triple-glazed (U=0.65W/m²K)
8	wood therm_tropical hard_glass0.8	Tropical hardwood frame2	standard triple-glazed (U=0.65W/m²K)
9	wood therm_painted_glass0.8	painted wood frame2	standard triple-glazed (U=0.65W/m²K)
10	PVC_glass1.1_safe	PVC frame 1	standard double wire glass (U=1.1 W/m²K)
11	PVC_glass1.1_acoust	PVC frame 1	standard double acoustic glazing (U=1.1 W/m²K)

Table CEN 8: overview of the individual CEN indicators for the variants ‘window openings’

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Window							
PVC_glass1.1	2,94E+02	1,59E-05	1,74E+00	5,60E-01	7,38E-02	4,83E-03	3,87E+03
ALU_glass1.1	3,94E+02	3,02E-05	1,68E+00	6,21E-01	1,22E-01	2,40E-03	4,85E+03
wood_tropical hardwood_glass1.1	2,02E+02	1,72E-05	1,08E+00	3,69E-01	5,88E-02	2,04E-03	2,57E+03
wood painted_glass1.1	1,86E+02	1,58E-05	1,01E+00	4,02E-01	5,43E-02	2,09E-03	2,46E+03
wood_alu_glass1.1	3,15E+02	2,46E-05	1,51E+00	6,08E-01	9,63E-02	2,69E-03	3,94E+03
PVCtherm_glass0.5	3,75E+02	2,11E-05	2,14E+00	7,55E-01	9,16E-02	7,38E+00	4,91E+03
ALUtherm_glass0.6	5,01E+02	3,75E-05	2,20E+00	8,68E-01	1,50E-01	7,69E+00	6,13E+03
wood therm_tropical hard_glass0.8	2,92E+02	2,36E-05	1,54E+00	5,94E-01	8,11E-02	7,53E+00	3,73E+03
wood therm_painted_glass0.8	2,76E+02	2,21E-05	1,46E+00	6,26E-01	7,65E-02	7,53E+00	3,62E+03
PVC_glass1.1_safe	3,18E+02	1,74E-05	1,87E+00	6,04E-01	7,91E-02	4,87E-03	4,22E+03
PVC_glass1.1_acoust	3,03E+02	1,68E-05	1,81E+00	5,70E-01	7,65E-02	4,87E-03	3,99E+03

Table CEN+ 8: overview of the individual CEN+ indicators for the variants 'window openings'

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m^3
Window											
PVC_glass1.1	1,03E-04	5,54E-04	8,83E-07	3,62E-02	3,53E+00	3,64E+00	1,02E-07	7,44E-08	7,25E-08	8,81E-08	2,46E+00
ALU_glass1.1	1,03E-04	7,06E-04	1,55E-06	3,28E-02	3,68E+00	3,76E+00	1,11E-07	5,87E-08	1,03E-07	1,08E-08	2,36E+00
wood_tropical hardwood_glass1.1	6,12E-05	1,98E-03	9,17E-07	7,99E-02	1,77E+00	1,87E+00	5,72E-05	6,21E-08	-2,65E-03	2,65E-03	2,30E+00
wood painted_glass1.1	6,61E-05	3,96E-04	9,84E-07	6,81E-02	1,94E+00	2,01E+00	7,48E-06	1,88E-07	1,52E-07	2,34E-08	2,51E+00
wood_alu_glass1.1	1,04E-04	6,25E-04	1,62E-06	9,13E-02	3,28E+00	3,39E+00	6,19E-06	1,85E-07	1,89E-07	4,22E-08	5,15E+00
PVCtherm_glass0.5	1,30E-04	6,92E-04	1,54E-06	4,26E-02	4,38E+00	4,48E+00	1,22E-07	8,28E-08	8,60E-08	8,89E-08	3,12E+00
ALUtherm_glass0.6	1,39E-04	8,98E-04	2,35E-06	4,17E-02	4,84E+00	4,93E+00	1,35E-07	6,99E-08	1,23E-07	1,23E-08	3,13E+00
wood therm_tropical hard_glass0.8	9,34E-05	2,15E-03	1,67E-06	9,78E-02	2,72E+00	2,82E+00	5,78E-05	8,33E-08	-2,65E-03	2,65E-03	3,03E+00
wood therm_ painted_glass0.8	9,82E-05	5,58E-04	1,74E-06	8,63E-02	2,88E+00	2,95E+00	8,15E-06	2,10E-07	1,76E-07	2,43E-08	3,24E+00
PVC_glass1.1_safe	1,08E-04	5,96E-04	1,03E-06	3,80E-02	3,69E+00	3,80E+00	1,11E-07	7,62E-08	7,71E-08	8,85E-08	2,65E+00
PVC_glass1.1_ acoust	1,04E-04	5,77E-04	8,97E-07	3,68E-02	3,55E+00	3,67E+00	1,05E-07	7,54E-08	7,55E-08	8,83E-08	2,54E+00

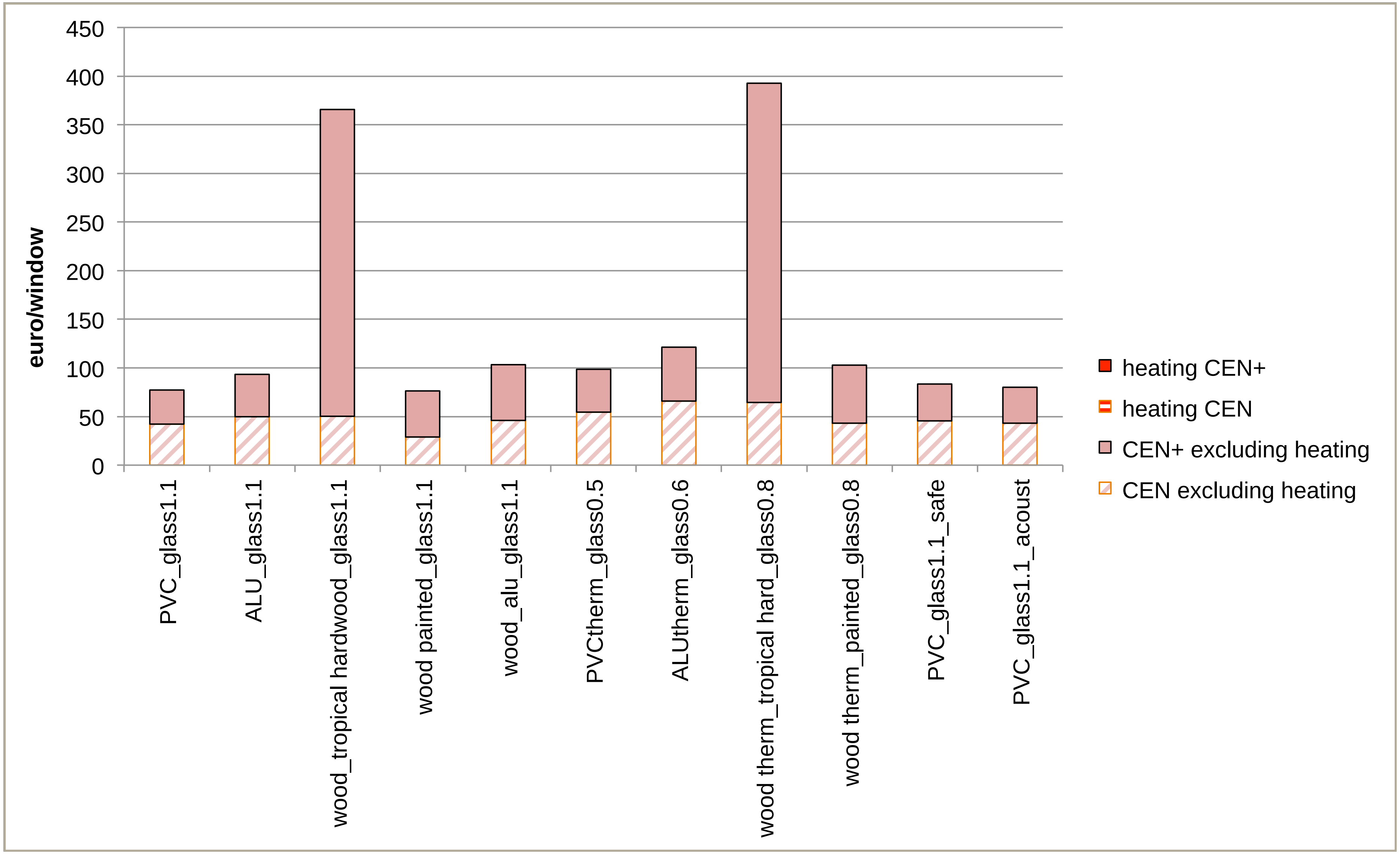

Figure E 8: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants 'window openings', expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

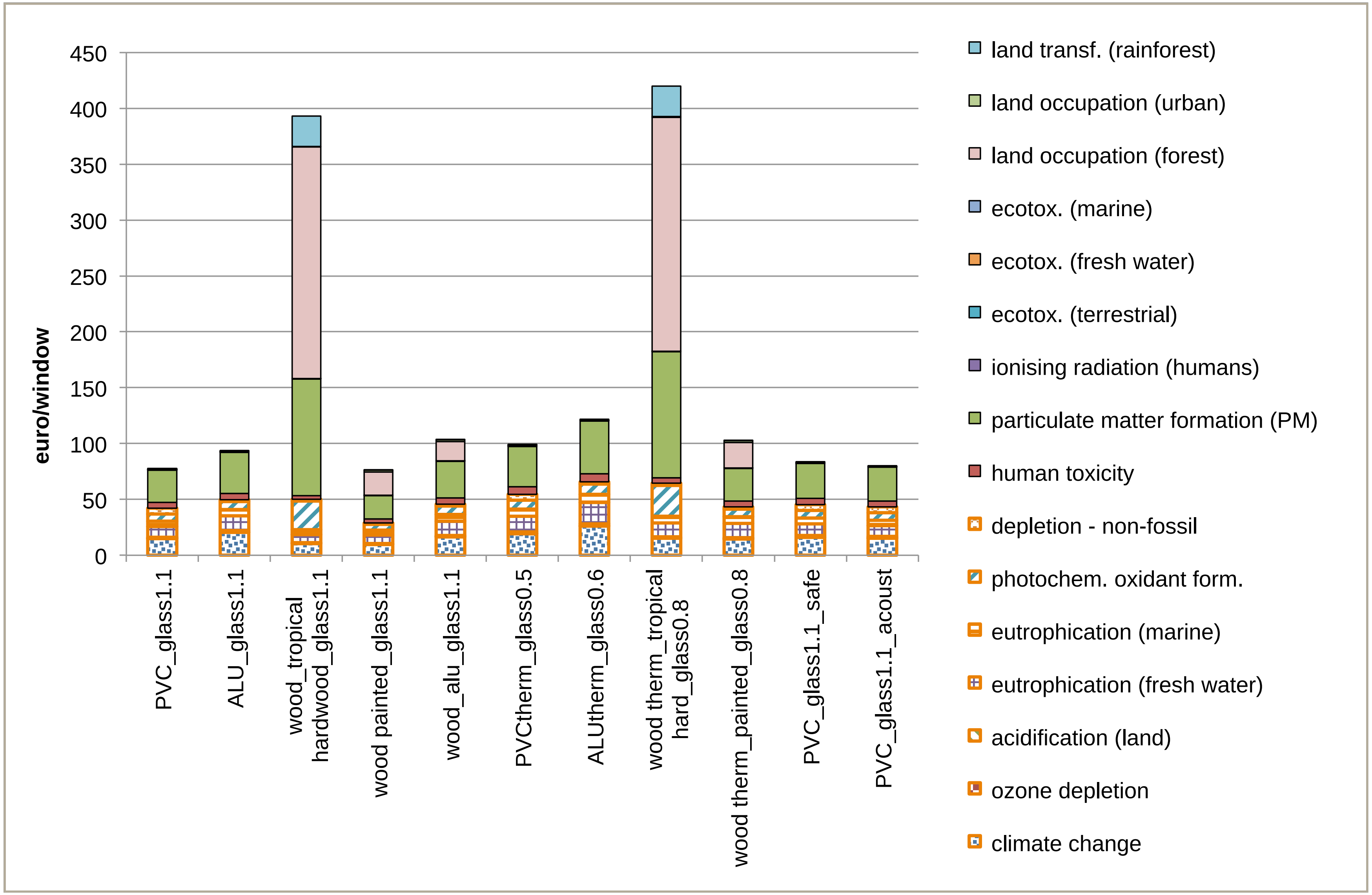

Figure I 8: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variant 'window openings' per environmental indicator, expressed in monetary units.

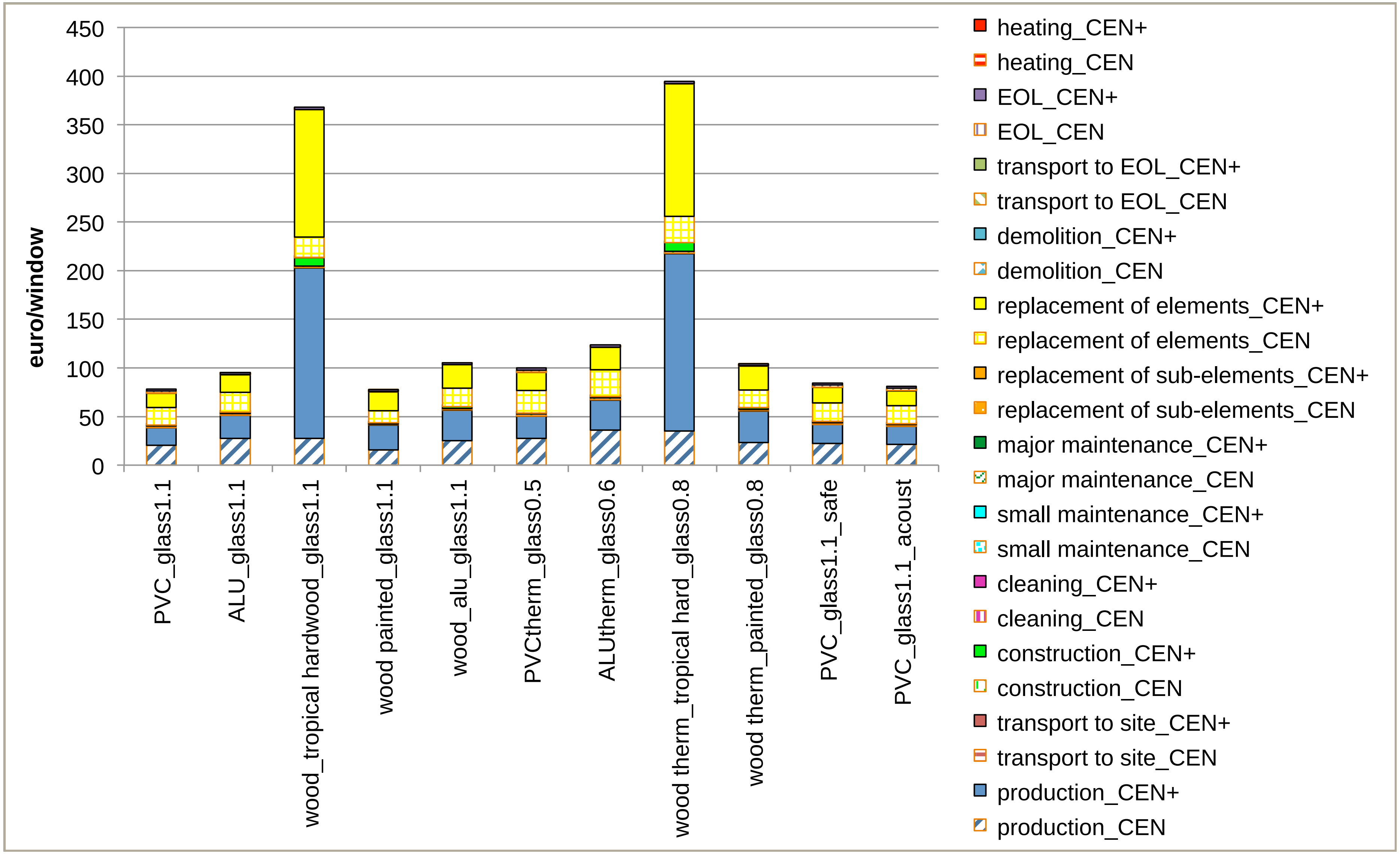

Figure L 8: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'window openings' per life cycle stage, expressed in monetary units.

3.3.9. Stairs

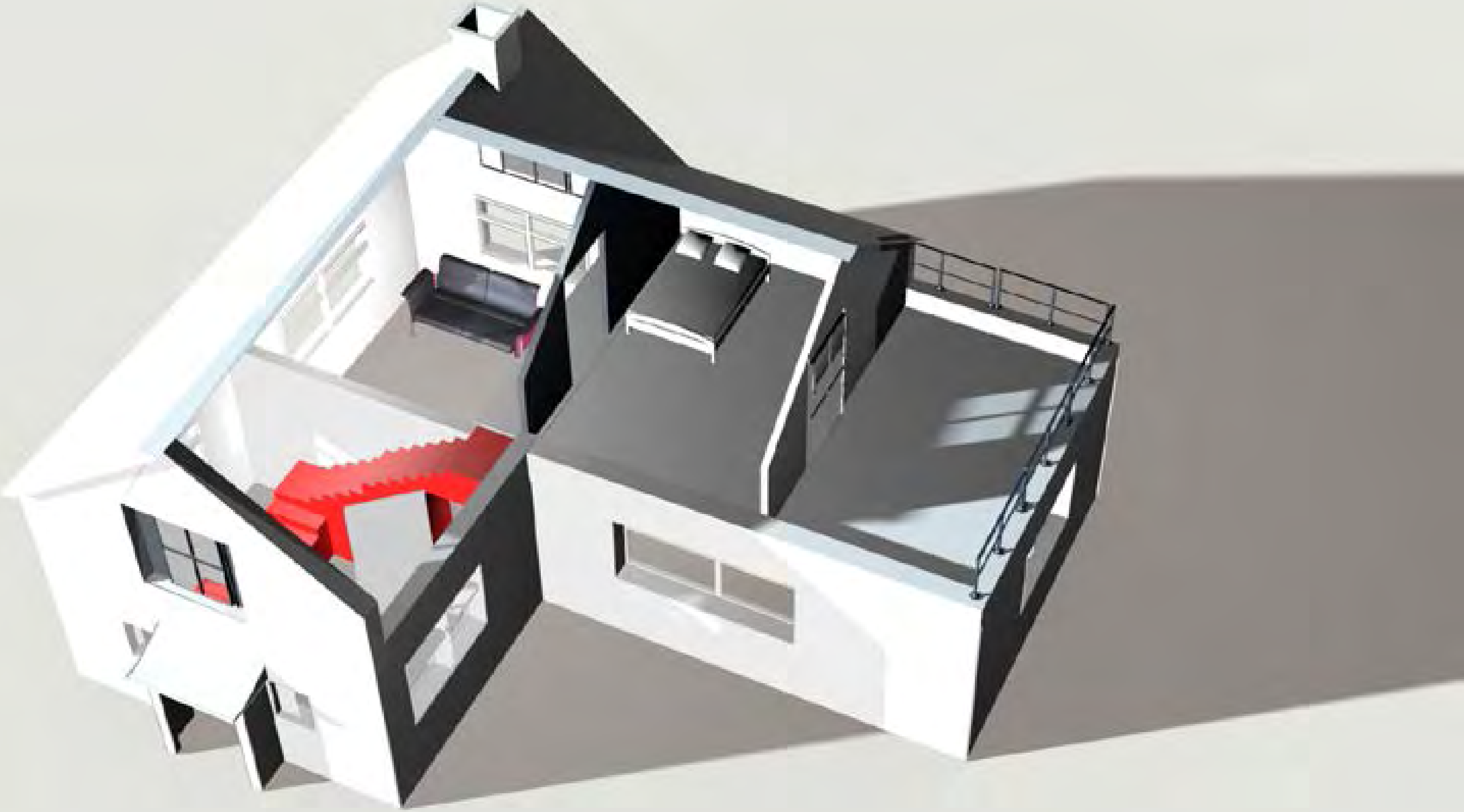

Table V 9: overview of the composition of the variants “stairs”

Stairs: 5 types				
1	staircase1_wood_open	wood open	varnish	wooden banister
2	staircase2_wood_closed	wood closed	varnish	wooden banister
3	staircase3_concrete	concrete	natural/polished	metal banister
4	staircase4_concrete_tiles	concrete	tiles	metal banister
5	staircase5_steel	steel	paint	steel banister

Table CEN 9: overview of the individual CEN indicators for the variants ‘staircases’

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Staircase							
staircase1_wood_open	3,66E+02	3,95E-05	1,63E+00	6,44E-01	8,22E-02	1,52E-03	4,95E+03
staircase2_wood_closed	4,82E+02	5,04E-05	1,98E+00	8,21E-01	1,04E-01	2,12E-03	6,60E+03
staircase3_concrete	1,46E+03	7,47E-05	4,51E+00	1,91E+00	3,75E-01	5,66E-03	2,50E+04
staircase4_concrete_tiles	1,73E+03	1,03E-04	5,50E+00	2,29E+00	4,75E-01	1,40E-02	3,02E+04
staircase5_steel	1,95E+03	1,10E-04	6,43E+00	4,24E+00	8,05E-01	7,66E-03	2,56E+04

Table CEN+ 9: overview of the individual CEN+ indicators for the variants 'staircases'

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m3
Staircase											
staircase1_ wood_open	8,77E-05	1,65E-03	3,93E-06	2,06E-01	2,46E+00	2,55E+00	4,41E-05	5,08E-07	3,99E-07	3,99E-09	3,36E+00
staircase2_ wood_closed	1,29E-04	1,49E-03	6,37E-06	3,66E-01	3,35E+00	3,48E+00	3,68E-05	4,78E-07	3,94E-07	4,32E-09	4,72E+00
staircase3_ concrete	2,88E-04	2,33E-03	3,85E-06	9,20E-02	9,25E+00	9,58E+00	2,58E-07	2,22E-07	3,09E-07	8,64E-09	2,65E+01
staircase4_ concrete_tiles	3,50E-04	5,68E-03	4,69E-06	1,16E-01	1,08E+01	1,11E+01	3,66E-07	3,09E-07	4,14E-07	1,20E-08	2,87E+01
staircase5_steel	6,36E-04	4,12E-03	1,23E-05	1,79E-01	2,36E+01	2,41E+01	5,20E-07	4,73E-07	5,33E-07	8,31E-09	2,37E+01

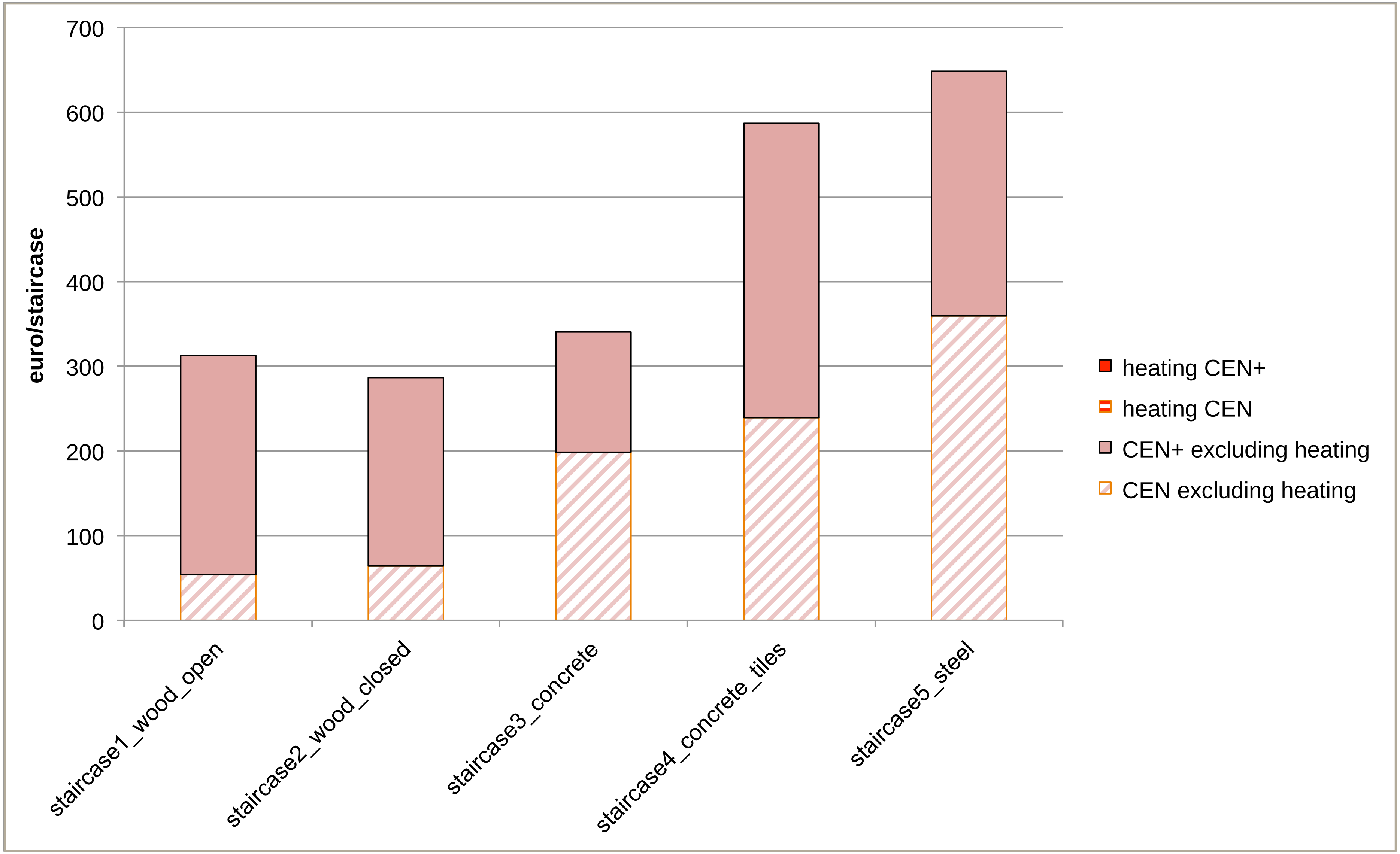

Figure E 9: Aggregated environmental profiles (split up into CEN and CEN+) of several building element variants 'staircase', expressed in monetary units and distinguishing between purely materials-related and heat-transfer-related environmental impact.

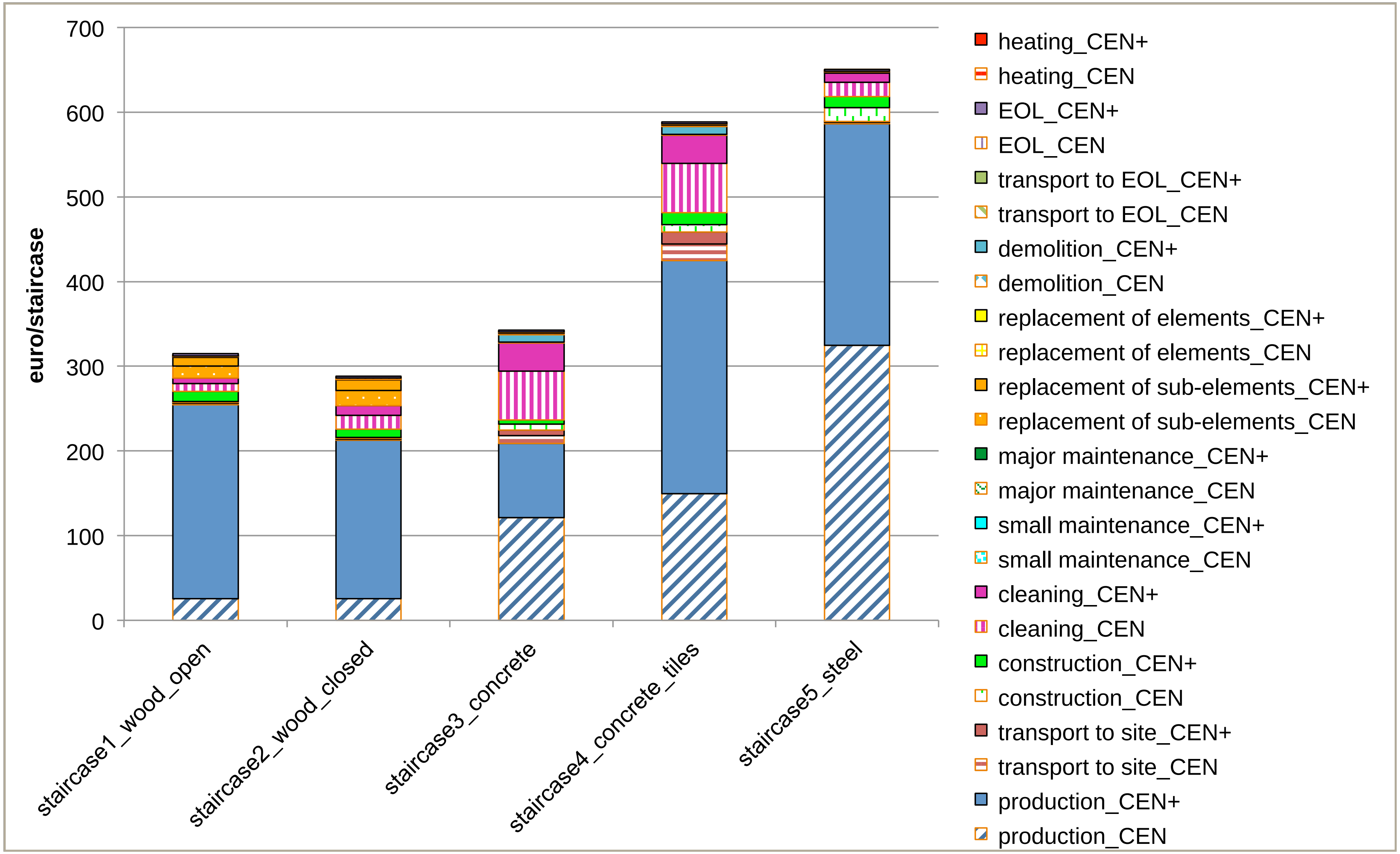

Figure I 9: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variant 'staircase' per environmental indicator, expressed in monetary units.

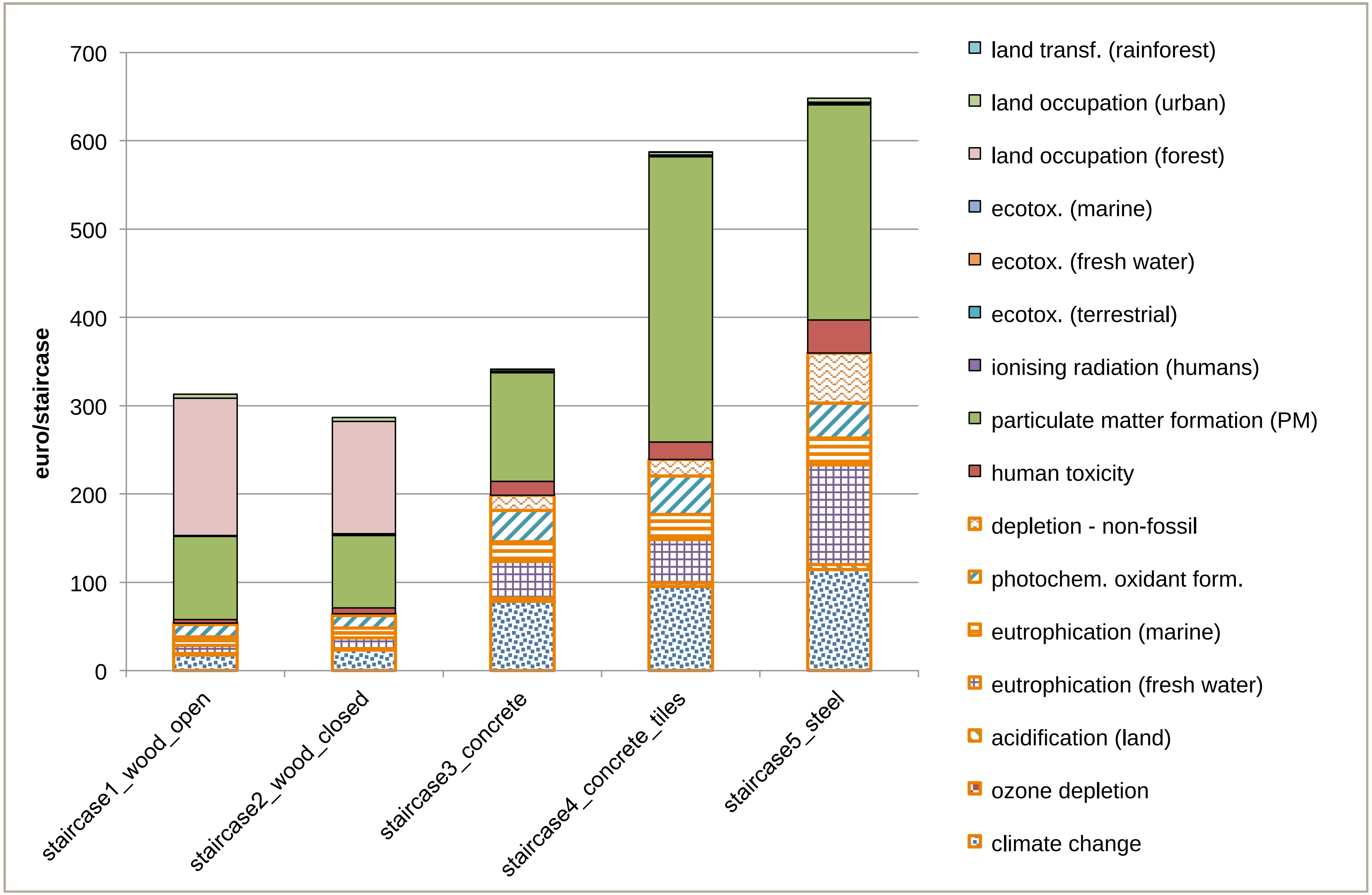

Figure L 9: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'staircase' per life cycle stage, expressed in monetary units.

3.3.10. Interior cabinet work

Table V 10: overview of the composition of the variants "interior cabinet work"

interior cabinet work: 3 types			
1	D1_MDF	plain doors	MDF frame
2	D2_oak	solid oak	Oak frame
3	D3_glass	glass	MDF frame

Table CEN 10: overview of the individual CEN indicators for the variants 'interior cabinet work"

	climate change	ozone depletion	acidification (land)	eutrophication	photochem. oxidant form.	depletion non-fossil	depletion fossil
	kg CO^2 eq	kg CFC^{-11} eq	kg SO_2 eq	kg PO_4--- eq	kg C_2H_4	kg Sb eq	MJ, net cal
Interior door							
D1_MDF	1,45E+03	1,54E-04	5,78E+00	2,89E+00	3,48E-01	4,47E-03	2,67E+04
D2_oak	6,47E+02	7,08E-05	4,56E+00	1,66E+00	2,35E-01	1,89E-03	8,88E+03
D3_glass	1,51E+03	1,57E-04	6,16E+00	2,99E+00	3,61E-01	4,54E-03	2,75E+04

Table CEN+ 10: overview of the individual CEN+ indicators for the variants 'interior cabinet work'

	human toxicity	particulate matter formation (PM)	Ionising radiation (humans)	ecotox. (terrestrial)	ecotox. (fresh water)	ecotox. (marine)	land occupation (forest)	land occupation (urban)	land transf. (nature)	land transf. (rainforest)	water
	DALY	DALY	DALY	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	species.yr	species.yr	species.yr	species.yr	m3
Interior door											
D1_MDF	4,95E-04	2,73E-03	8,06E-06	1,39E+00	1,00E+01	1,06E+01	3,09E-02	4,13E-07	5,90E-07	1,85E-08	8,12E+00
D2_oak	1,98E-04	8,68E-03	3,08E-06	7,30E-01	4,10E+00	4,44E+00	4,66E-02	3,34E-06	-9,08E-03	9,08E-03	4,87E+00
D3_glass	5,06E-04	2,85E-03	8,47E-06	1,38E+00	1,04E+01	1,09E+01	3,76E-03	4,12E-07	5,96E-07	1,26E-08	8,60E+00

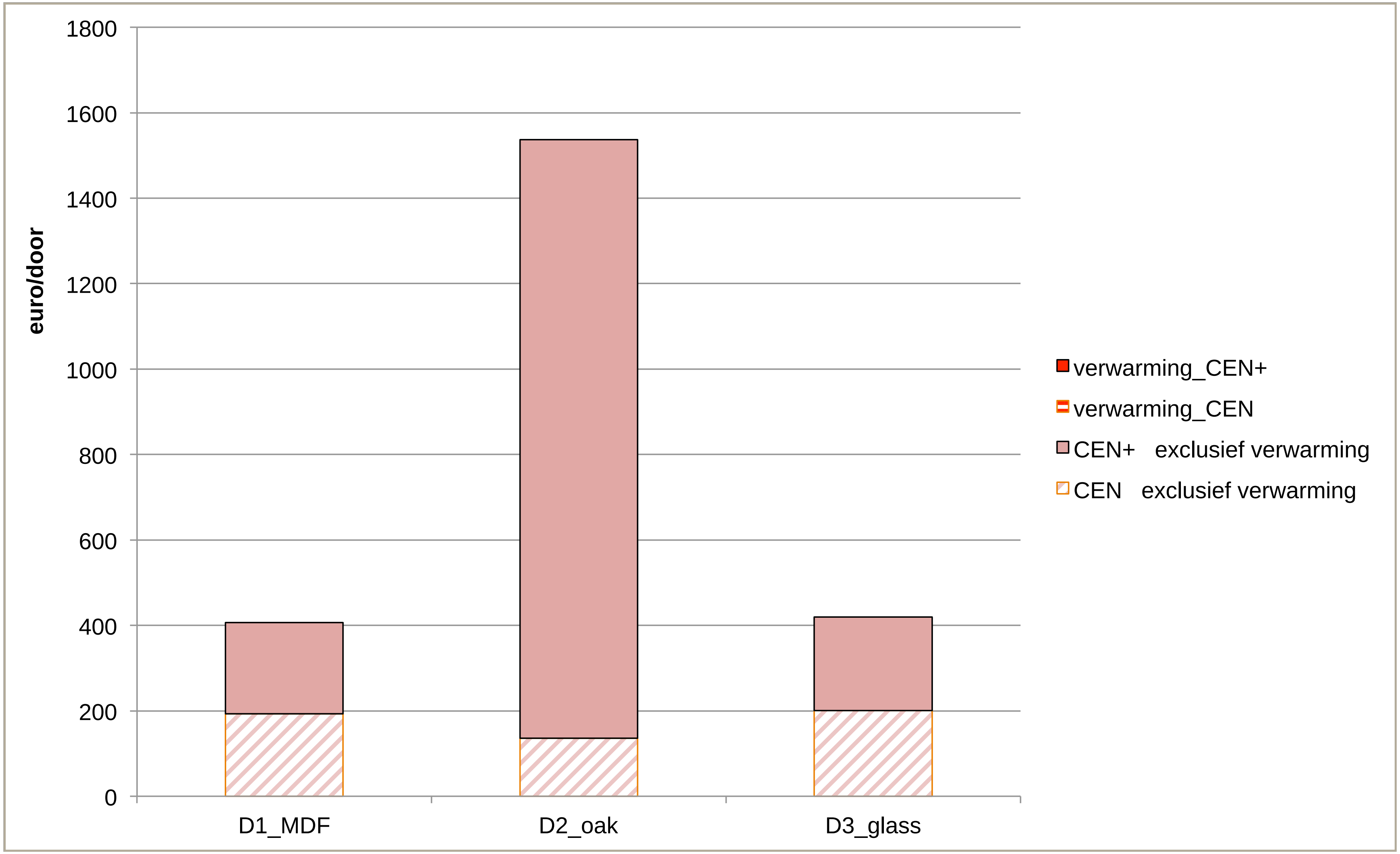

Figure L 10: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants ‘interior cabinet work ’ per life cycle stage, expressed in monetary units.

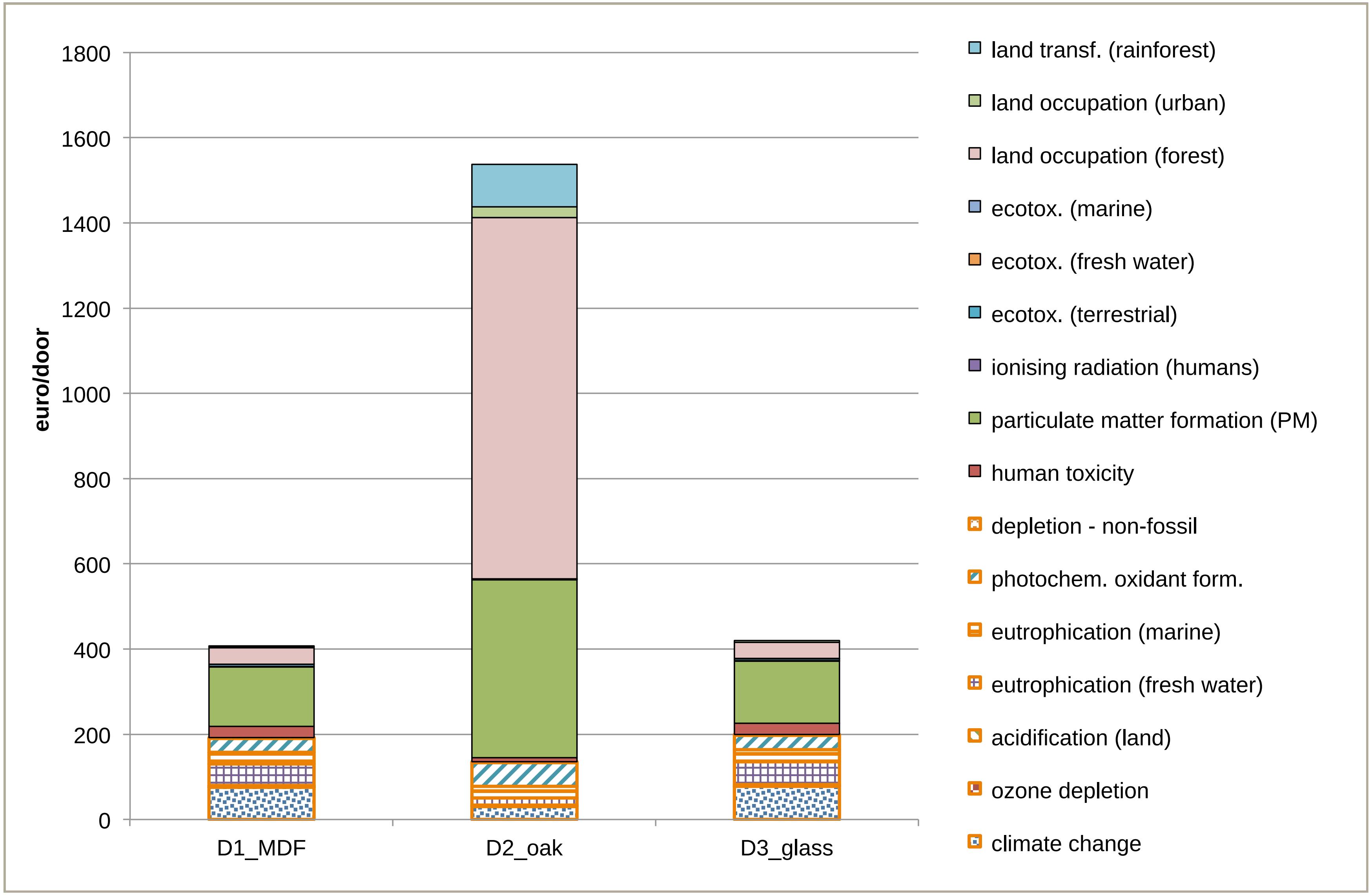

Figure I 10: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variant 'interior cabinet work ' per environmental indicator, expressed in monetary units.

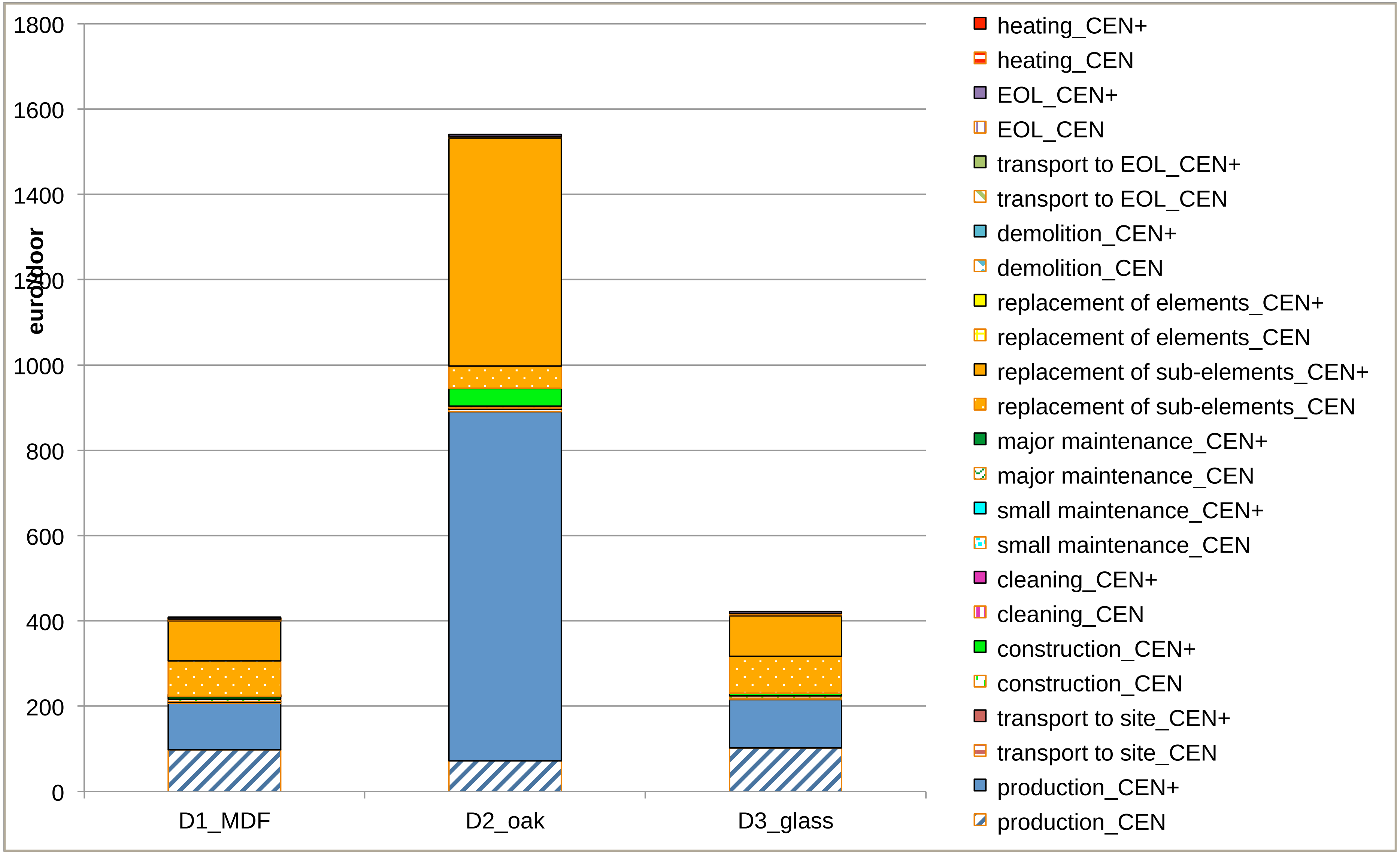

Figure L 10: Aggregated environmental profiles (split up into CEN and CEN+) for several building element variants 'interior cabinet work ' per life cycle stage, expressed in monetary units.

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