IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Application of “Element”-Method in Sustainability Assessment

To cite this article: T Lützkendorf 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **290** 012052

Application of "Element"-Method in Sustainability Assessment

T Lützkendorf

Karlsruhe Institute of Technology (KIT), Centre for Real Estate, Germany

thomas.luetzkendorf@kit.edu

Abstract. The application of sustainability assessment in the design of buildings for the analysis, assessment and improvement of design variants is still a long way from becoming an everyday activity. Often, it is only carried out to respond to a special request from investors/building owners or in connection with funding programs. To date, sustainability assessment is often considered as an additional task detached from the rest of the design process and primarily serving sustainability certification. This raises the question of how the task of sustainability assessment can be integrated into the design process even better than before and combined with traditional design tasks. One approach is to use the "Element"-method. Relevant parts of the structure are described in terms of their physical composition and construction work to be performed for their production. It is an approach used in the determination of construction costs. The task of checking compliance with a given cost frame/budget already set in client's brief or at an early design stage comes with a continuous determination and assessment of construction costs along the different design stages. A similar approach can be followed for environmental impacts. The "Element"-method initially supports a combination of LCC and LCA – an approach that is being followed already more frequently. The consideration of elements additionally supports the assessment of the ease of deconstruction and recycling friendliness as well as effects on and risks to health and the local environment. Experiences from Germany will be presented along with a discussion of current applications.

1. Introduction

Since the end of the 1980s at the latest, the element method has been used in Switzerland and Germany as an aid in the determination of construction costs. Unlike the traditional approach using cost metrics for different types of construction work (e.g., masonry work), the element method uses cost information for different types of building parts/components (e.g., exterior wall). The approach of subdividing of building into building parts (elements) is based on national standards in some countries since decades. For example, a basis for the application of the element method in Switzerland was published by the Swiss Center for Rationalisation in Construction (CRB) in 2009 as part of the standard SN 506 511 dealing with the budget for construction costs for buildings. The currently valid version of this standard is called eBKP-H and was published in 2012 [1]. In Germany, DIN 276 in its current version is used for the same purpose [2]. Typical building parts in DIN 276 are roof, exterior wall, building services.

The system of subdividing buildings into their main parts allows elements of different degrees of complexity ("macro elements", "gross elements", "elements", "fine elements", where a "fine element" can correspond to a layer in a component) and different levels of detail (1st level – building component, 2nd level – building element, 3rd level – sub-element).

The element method supports the calculation of costs already in early design stages and allows verification of the completeness of the building's description. In Germany, cost parameters for elements are regularly published by the Construction Costs Information Center of the German Chamber of Architects (BKI) [3]. With the involvement of the author, the element method for life cycle assessment (LCA) of buildings was introduced early on [4]. In addition to a simplified method of quantity determination, the advantage lies in the parallel determination of construction and maintenance/ replacement costs as well as of energy & material flows and impacts to local and global environment. This parallel treatment of LCC and LCA ensures that an identical building model is used for the economic and environmental assessment and that no significant building elements are forgotten in the LCA. Plausible cost parameters serve as a test for the completeness of the calculation.

Since some countries are currently discussing ways of combining LCA and life cycle costing (LCC) [5], the element method has the potential to solve other tasks in addition (like the assessment of a recycling potential) and is an approach to BIM. For this reason, experiences with the use of the element method in the sustainability assessment of individual buildings are discussed, as well as proposals for additional applications. This paper addresses the following questions: (1) Is the element method still up-to-date and can it be recommended for use in countries that have not previously used it? (2) For which tasks beyond a combined consideration of LCA and LCC is this method suitable? On the basis of the author's experience, an attempt is made to summarize information on the possibilities and advantages of the element method. This part of the paper has the character of a state-of-the-art summary, although the element method in this complexity has not been used universally.

The paper also presents an approach to solving a current problem. Both international and European standards for the sustainability assessment of buildings only distinguish between product and building level. When looking at replacement of building components, this leads to problems. The paper presents an approach developed by the author to a more detailed lifecycle models for building structures that integrates the lifecycle of elements – here in the sense of building components. This is linked to the research question of further development of life cycle models to improve transparency and comprehensibility in life cycle analysis.

2. Application possibilities of the element method

Originally developed for the determination of costs, the element method has been used for the LCA of buildings for decades. Nevertheless, this method is not widely used in everyday design practice and should therefore be presented here again. At the same time, the possibility arises of using the element method for new questions. These are discussed below.

2.1. Parallel determination of construction costs and life cycle assessment

Issues of identifying and assessing energy and material flows as well as undesirable impacts on the environment have been debated since at least the 1980s and date from an even earlier period. The questions relating to the primary energy indicator at that time can easily be transferred to the topic of LCA. From the beginning, the question arose as to how such tasks can be integrated into the design process. Early on, designers and architects showed a low willingness to devote themselves to a task that not only involves additional effort and special tools, but was also hardly demanded by clients at that time.

With the involvement of the author, an approach was developed to integrate the determination of resource use and environmental impact into existing processes and tools [6]. The determination of the construction and maintenance/replacement costs using the element method offered such an opportunity. To each component layer both the costs and data on energy consumption and environmental impact could be assigned. This method, using suitable tools, made possible the direct generation of data on energy consumption and environmental impact and without additional effort when calculating costs. If the calculated costs lie in the expected range, it could then be assumed that all layers were also correctly recorded for the LCA.

From this development in the nineties of the last century, the complex design and assessment tool for integrated life-cycle analysis known today as LEGEP [7] emerged with the participation of the author. This tool allows the use of the element method for calculating the construction and operational costs, carrying out an LCA-based environmental performance assessment, and providing proof of compliance with regulatory energy performance requirements. One of the main advantages lies in the use of a uniform building and life cycle model for LCC and LCA. In this way, the replacement cycles of the components required for LCA can be taken over from LCC.

In Germany, eLCA [8] provides another tool for life cycle assessment using the element method and its extension towards LCC is currently under discussion. Possibilities of a combined calculation of LCA and LCC are currently also discussed in the Czech Republic [5].

2.2. Reduce complexity in the design

The subject of assessment in a sustainability assessment is in principle the whole building. The comparability of different design variants is ensured by the description of the functional equivalent, which includes information on the type of building and use as well as on the type and scope of the fulfilment of functional and technical requirements. During design process, the entire building is a complex object of assessment. It may be useful to reduce this complexity. Taking into consideration necessary rules, it is possible to transfer technical and functional requirements from the building level to the component level ("element"). This is the case, amongst others, for heat, sound and moisture protection.

This allows functional equivalents to be defined at the component/element level. These approach enable an economic and environmental comparison of design options at element level. Installed construction products transfer/pass on their characteristics to the building component/element. The “element” thus becomes an important link between the product and the building level – a fact that has often been neglected in previous standardization of ISO TC 59 SC 17 and CEN TC 350. An approach towards solving this problem is presented in section 3.

2.3. Element catalogues as design tools

Already at an early stage, element or component catalogues were developed and published to support the design process. An early example is SIA D 0123 [9] of the year 1994. To ensure comparability, the components contained in the catalogue were described with regard to their technical and structural parameters (including thermal insulation, sound insulation, fire protection). The layer built-up was defined in detail, including the replacement cycles for individual layers or components required to achieve a planned/defined service life. In addition to values for the primary non-renewable and renewable energy consumption, values for the global warming potential (GWP) and acidification potential (AP) for a given service life were also provided. These quantitative data were supplemented by qualitative information, e.g. on harmful substances or on ease of dismantling and recycling. From the author's point of view, SIA D 0123 is still an excellent example of a component/element catalogue. Subsequently, a number of component catalogues have been published, in particular for the elements of energy-efficient building envelopes, i.e. [10], [11]. However, these books focus on the environmental assessment of building components, with no information on construction costs.

In order to better meet the architects’ needs for individually designed and assessed components, network-based tools were developed to combine layers into components and to evaluate these with regard to their environmental performance using LCA. The prerequisite is the existence of databases on LCA data for individual materials and construction products. Examples of such databases are [12] and [13].

At an early stage, the industry recognized that architects/designers prefer information on functional units (in this case components/elements) in the sense of product systems rather than information on the details of individual products. For this reason, they developed themselves information platforms that propose solutions for components by specifying functional and technical parameters. In this respect, it has been and still is important to develop and publish environmental product declarations (EPDs) for complete product systems in terms of elements/components, e.g. for thermal insulation systems and for drywall systems.

It should be noted, however, that current offers of information and tools at the component/element level no longer have the complexity of previous solutions. They are not linked with cost parameters nor with information on risks to health and the environment or on ease of dismantling and recycling. Today, individual solutions (such as WECOBIS [14] und WINGIS [15] are available for working on these topics, but further development and better linking is needed.

2.4. Evaluation of ease of deconstruction and recycling
The assessment of the ease of deconstruction and recycling friendliness of buildings and their components is a partial aspect of a sustainability assessment in Germany, i.e. in the DGNB and BNB systems. The basis is a description of the building structure using the element method. An example of requirements is freely accessible [16], as well as a practical tool [17]. Both the layers of the components and thus their material composition as well as the type of connection of the different layers/materials within a component are provided. This information allows the assessment of the possibilities and effort of a later separation of products, and eventually the assessment of the ease of deconstruction. It is also possible to assess whether materials can be "sorted" and whether and to what extent their recycling properties are adversely affected by a certain buildup. An assignment of waste classification codes is possible. In this respect, beyond the consideration of the material input and the assessment of the current material composition, the element method also supports the prognosis of the material output – see also Section 2.7.

2.5. Characteristic values & benchmarks for the early design phases
Up to the present day, the aim is to obtain initial information on the use of primary energy associated with the manufacturing of construction products and their installation into the building (construction process of the building) or rough estimates of the LCA impacts already in the early design stages. The significance of this task is currently increasing. EN 15643-1 encourages clients to formulate environmental performance targets for buildings [18]. In addition, the specification of budgets for primary energy and CO_2 is discussed in a way comparable to cost budgeting [19].

Early attempts were made to provide design tools for this purpose. An example that has existed for a long time and is still available today is the "System for Evaluating the Sustainability of Architectural Projects for the Environment" (SNARC), described in SIA Documentation D 0200 [20]. References exist to the SIA 2040 [21] and a calculation aid is available. SNARC indicates the amount of primary energy required for manufacturing and construction in MJ/m², depending on the design of building elements/components such as walls, ceilings, windows, roofs, thus providing a basis for estimation in early design stages with the use of elements.

It is currently being discussed whether and to what extent benchmarks can be determined and used for the assessment of design variants with regard to their environmental performance. New publications show how designs can be judged on the basis of benchmarks for elements and how optimization potentials can be identified and tapped [22].

2.6. Links to indoor air and the local environment
For a holistic assessment of the environmental and health compatibility of buildings, to undertake an LCA is not enough. Any existing risks to, and potential effects on, the health of building users, visitors, local residents and the local environment (i.e. outdoor air, soil, ground and surface water) must be additionally recorded and assessed. The group CEN TC 351 developed European standards (e.g. EN [23]) which support the identification of data on the outgassing and runoff of harmful substances from construction products through standardized measurement procedures. Such information may be attached to an environmental product declaration (EPD) as additional information. This information must be processed appropriately at the building level. The consideration of building parts using the element method allows the determination of the layers/products, which are, on the one hand, directly in contact with the indoor air and on the other hand, with the outdoor air, the soil or the surface or groundwater. If

that is the case, the relevant information can be "activated" from the EPD, so that the corresponding data can be processed mechanically.

2.7. Documentation of the material composition of buildings

In connection with the topic of a circular economy, the documentation of the material composition of buildings is becoming more important. This should be created as part of the design and be updated and maintained in the further life cycle of the building. Current research projects suggest the development and use of "material passports" [24] or "material inventories" [25]. One of the aims of this documentation exercise is to support decisions on replacement investments with replacement of components or on the deconstruction of existing buildings. There is an interest in being able to estimate the type and extent of the expected material output. In particular, in the case of replacements, it is therefore not sufficient to know the sum of the materials that are installed in the building. The materials must be assigned to the building parts, which sometimes have different lifetimes and replacement cycles (concrete in the foundation versus concrete in roof tiles). For this purpose, the element approach is suitable.

2.8. Supporting design for major renovation

In connection with the need for a further improvement of the existing building stock, the proportion of design tasks in the building stock is growing. The monitoring and analysis of existing buildings is an important task, which is often associated with high time and cost effort. Element catalogues describing building parts that are typically found in existing buildings in selected regions may be helpful. An example is [26], [27]. It therefore makes sense to archive element catalogues in such a way that they can be accessed even after years and decades to see and understand "elements" of the past.

For the design of refurbishment and renovation measures "refurbishment elements" can be used, in the sense that they comprise the additional layers to be applied to a component (for example in a composite thermal insulation system) and allow the costs and environmental effects of these additional elements to be quickly determined.

Overall, it becomes clear that the element method has numerous possible applications and can support the assessment of environmental, economic and social performance of buildings as well as the documentation tasks. In Germany, it is successfully used within the sustainability assessment systems BNB and DGNB.

3. Consequences for the modelling of the life cycle of buildings

So far, the international (ISO TC 59 SC17) and European (CEN TC 350) series of standards have only made a distinction between the building and product level when modeling the life cycle. The life cycle is described and divided using a modular approach – see EN 15643-1 [18]. An intermediate level is not provided. This leads, among others, to uncertainties about how to use the B4 module on "Replacement" at the building level. The replacement of building elements at the end of their life or service life, but still within the life or useful life of the building or a defined reference study period, requires again the production, delivery and installation of products (modules A1–A5) as well as the deconstruction and disposal of the replaced (obsolete) components (Modules C1–D). This means that deconstruction and recycling processes do not only occur at the end of the useful life of the building, but also within it. In this sense, also contributions to module D – which describes a recycling potential – are resulted through replacements.

Figure 1 presents a suggestion by the author for the evolution of the life cycle model currently presented in the standards. The inclusion of an additional module A0 (already used for economic performance assessment) for planning and management as well as of a life-cycle-accompanying module D is presented, which also includes contributions from the end of life of the building components. Horizontal is the traditional lifecycle model for a building, while vertically the lifecycle model for building components (elements). It is arranged in such a way that a replacement of building parts can also be depicted as production and installation & deconstruction and end of life.

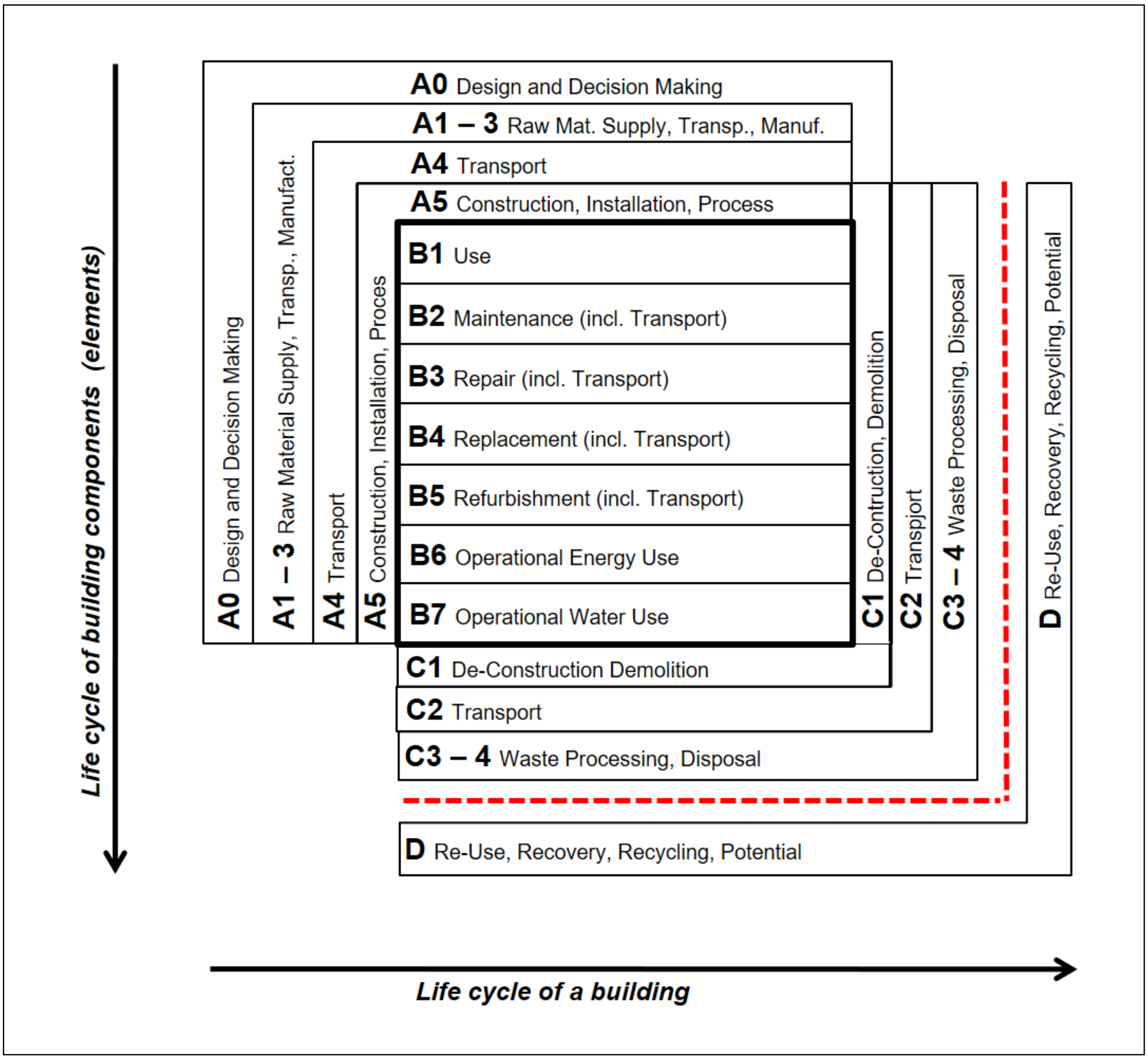

Figure 1. Alternative model of the life cycle of buildings and building components (Lützkendorf)

However, the above-depicted proposal does not conclude the discussion on the further development of life cycle models involving elements. The author puts forward further suggestions for discussion: (1) Since in practice there is hardly any meaningful distinction between the modules B2 and B3, it is proposed to group them together in one module. (2) With the refurbishment of buildings another life cycle generally starts. It is proposed to abandon module B5 or to specify it by the term “refurbishment of building components”. The latter means that module B5 only accounts for the replacement of old building components with technologically more advanced ones to improve building performance and not refurbishment to an extent that the functional equivalent of the building changes. (3) In order to solve open questions concerning the management of energy consumption during operation, it is proposed to divide module B6 into three sub-modules: B6.1 regulated building-specific energy consumption; B6.2 non-regulated building-specific energy consumption (e.g. elevators); B6.3 user- and use-related energy consumption. These proposals are currently being incorporated into the current standardization processes in CEN TC 350.

4. Summary and outlook

Although the element method has been used for decades, especially in the calculation of construction costs, it has not found widespread use so far. The paper has shown that it is well suited for various tasks in sustainability assessment, far beyond the cost calculation. This potential should be exploited and expanded even more in the future. The element method can be combined with "object-oriented" design methods and parametric building models. It can be assumed that the use of the element method will increase in the context of a wider dissemination of BIM – even if the term itself is hardly ever used.

Acknowledgments
The author would like to thank Dr. Maria Balouktsi for her assistance in creating this contribution.

References

[1] CRB Standards 2017 *Baukostenplan BKP, SN 506 500: Ausführungsorientierte Gliederung der Kosten für Bauwerke des Hochbaus* (Zurich: CRB)

[2] Beuth 2017 *DIN 276: 2017-07 Kosten im Hochbau* (Building costs) (Berlin: Beuth Verlag)

[3] BKI 2018 *Baukosten Bauelemente Neubau: Statistische Kostenkennwerte* (Stuttgart: BKI)

[4] Lützkendorf T, Kohler N and Holliger M 1992 Ökobilanzen und Elementkostengliederung: die Anwendung der Elementkostengliederung bei der Erstellung von Energie- und Stoffbilanzen für Gebäude *Schweizer Ingenieur und Architekt* **9** 170-2

[5] Lupisek A, Nehasilová M, Železná J, Hanák M. Hájek P and Pospíšilová B 2018 Potential for interconnection of tools for cost estimation and life cycle assessment of partial carbon footprint in the building sector in Czechia *Proc. Sixth Int. Symposium on Life-Cycle Civil Engineering* (IALCCE 2018) (Ghent: CRC Press LLC)

[6] Kohler N, Lützkendorf T et al. 1996 *Methode zur kombinierten Berechnung von Energiebedarf, Umweltbelastung und Baukosten in frühen Planungsphasen* Schlussbericht zum UBA-Projekt KOBEK (Karlsruhe: Universität Karlsruhe)

[7] Kohler N, Wagner A, Lützkendorf T and König H 2005 Life cycle assessment of passive buildings with LEGEP®: a LCA tool from Germany *Proc. World Sustainable Building Conference* (Tokyo)

[8] Brockmann T, Kusche O and Rössig S 2014 Life Cycle Assessment within BNB-Online Tool eLCA and materials database ÖKOBAU.DAT *Proc. World Sustainable Building Conference* (Barcelona: GBCe)

[9] SIA 1994 *SIA D 0123 Hochbaukonstruktionen nach ökologischen Gesichtspunkten* (Zurich: Schweizer Ingenieur–und Architekten-Verein)

[10] Österreichisches Institut für Baubiologie und -ökologie 2017 *Passivhaus-Bauteil-katalog: Sanierung: Ökologisch bewertete Konstruktionen für den Sanierungseinsatz* (Vienna: IBO)

[11] Österreichisches Institut für Baubiologie und -ökologie 2018 *Passivhaus-Bauteilkatalog: Ökologisch bewertete Konstruktionen für den Neubau* (Vienna: IBO)

[12] Bauteilkatalog. Kostenlose Basisfunktion des Bauteilkatalogs [Internet]. 2011 [cited 20 October 2018]. Availble at: http://www.bauteilkatalog.ch/ch/de/Bauteilkatalog.asp

[13] eLCA [Internet]. 2014 [cited 20 October 2018]. Available at: https://www.bauteileditor.de/

[14] WECOBIS. Ökologisches Baustoffinformationssystem [Internet]. 2013 [cited 20 October 2018] Available at: https://www.wecobis.de, see also [8]

[15] BG BAU. WINGIS online [Internet]. 2017 [cited 20 October 2018]. Available at: https://www.wingisonline.de/

[16] BNB. Büro- und Verwaltungsgebäude [Internet]. 2015 [cited 20 October 2018]. Available at: https://www.bnb-nachhaltigesbauen.de/fileadmin/steckbriefe/verwaltungsgebaeude/neubau/v_2015/BNB_BN2015_414.pdf

[17] Informationsportal Nachhaltiges Bauen des BMI. Kriterien – BNB Büro- und Verwaltungsgebäude – Neubau. Version 2015 [Internet]. 2018 [cited 20 October 2018]. Available at: https://www.bnb-nachhaltigesbauen.de/bewertungssystem/bnb-buerogebaeude/bnb-bn-2015/kriterien-bnb-buero-und-verwaltungsgebaeude-neubau.html, see Arbeitshilfe 4.1.4

[18] CEN 2010 *EN 15643-1:2010 Sustainability of construction works – Sustainability assessment of buildings – general framework* (Brussels: CEN)

[19] iiSBE. CO2 & built environment [Internet]. 2017 [cited 20 October 2018] Available at: http://www.buildingscarbonbudget.org/

[20] Schweizer Ingenieur–und Architekten-Verein. SNARC [Internet]. 2004 [cited 20 October 2018] Available at: https://www.eco-bau.ch/resources/uploads/SNARCD.pdf

[21] Schweizer Ingenieur–und Architekten-Verein. SIA Effizienzpfad Energie [Internet]. 2011 [cited 20 October 2018]. Available at: http://www.sia.ch/fileadmin/content/download/sia-norm/kommissionen/SIA_Faltblatt_Effizienzpfad_A4.pdf

[22] Hollberg A, Vogel P and Habert G 2018 LCA benchmarks for decision makers adapted to the early design stages of new buildings *Proc. Sixth Int. Symposium on Life-Cycle Civil Engineering* (IALCCE 2018) (Ghent: CRC Press LLC)

[23] CEN 2015 *CEN/TR 16797-1:2015 Construction products: Assessment of release of dangerous substances – Guidance on the statistical assessment of declared values – Part 1: Principles and rules of application* (Brussels: CEN)

[24] BAMB 2020. Materials passports [Internet]. 2016 [cited 20 October 2018]. Available at: https://www.bamb2020.eu/topics/materials-passports/

[25] Leibniz Institute of Ecological Urban and Regional Development. KartAL IV: Mapping the anthropogenic material stock IV [Internet]. 2018 [cited 20 October 2018]. Available at: https://www.ioer.de/1/projekte/kartal-iv/

[26] Thiel D and Riedel D 2011 *Typisierte Bauteilaufbauten-Präzisierung der Pauschalwerte für Wärmedurchgangskoeffizienten aus der Bekanntmachung der Regeln der Datenaufnahme im Nichtwohngebäudebestand* Final Report (Stuttgart: Fraunhofer IRB Verlag)

[27] Böhmer H Fanslau-Görlitz D Zedler J 2005 *U-Werte alter Bauteile: Arbeitsunterlagen zur Rationalisierung wärmeschutztechnischer Berechnungen bei der Modernisierung* (Stuttgart: Fraunhofer IRB Verlag)