Importance of building services in ecological building assessments

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Abstract. The new Energy Performance of Buildings Directive (EPBD) 2018 and the GebäudeEnergieGesetz (GEG) tightened the requirements for energy efficiency and the use of renewable energy sources in buildings at EU and national levels. Environmental impacts from manufacturing, dismantling and recycling of buildings are not taken into account. Green Building Certification Systems, such as the DGNB or BNB systems, are therefore the only ones that (voluntarily) set holistic, ecological requirements for buildings. Based on a Whole-Building Life Cycle Assessment, the entire building life cycle and its environmental effects are evaluated. While building services in this context are usually only included in such a simplified approach, the full scope of the produced environmental impacts are underestimated and misjudged for the reduction of emissions and other environmental impacts. This publication uses the results of a life cycle assessment of a typical office building (in Germany) to show the amount of influence building services have on environmental impacts of buildings. Furthermore the study shows an approach how the very high procurement and calculation effort of LCA can be reduced by linking the Building Information Modelling (BIM) Method and LCA models to enable a significantly more efficient and easier calculation process, especially for building services.

1 Introduction

Particularly in the construction sector, as one of the key sectors for achieving national, European and international climate protection goals, intensive measures to reduce emissions and environmental impacts are required in view of economic growth, demographic change and increasing comfort requirements.

The newly revised Directive on the Energy Performance of Buildings (EU) 2018/844 [1], which came into force on 9 July 2018, requires EU countries to transpose the new requirements into national law within 20 months. At the same time, the Federal Government of Germany is continuing to work on the "GebäudeEnergieGesetz" (GEG), which will replace the Energieeinsparungsgesetz (EnEG), the Energieeinsparungsverordnung (EnEV) and the Erneuerbare-Energien-Wärmegesetz (EEWärmeG) [2]. A first draft shows that, similar to the new EU directive, ambitious measures are being sought in the areas of building renovation and new building construction, but the environmental compatibility of products and their effects on the climate are largely ignored.

Energy efficiency and the use of renewable energy sources have been at the forefront of the planning and design of buildings in recent years. The aim was to achieve the lowest possible energy consumption during the use phase and so more and more energy-efficient building standards have been developed. With the reduction of environmental pollution in the use phase, the relevance of the production and disposal phase has increased relatively [3]. The environmental impact of the construction and disposal phase of a building is becoming increasingly important, especially in the case of passive houses and energy plus standards, the main characteristics of which are very low primary and final energy requirements.

From the point of view of the environment and climate, the requirement for buildings is to consider the conservation of resources in all life cycle phases and to plan and build buildings accordingly. Particularly green building certificates anchor this strategy in the sustainability assessment of a building. In addition to topics such as energy, water, economic efficiency and society, high demands are placed on climate and environmental protection. The Life Cycle Assessment (LCA) is an essential instrument in this context. The Green Building Certification System of the German Sustainable Building Council (DGNB) and the Assessment System for Sustainable Building (BNB), for example, call for a Whole-Building Life Cycle Assessment (WBLCA) to be used to examine the environmental impacts of building construction and building services in a building, to present them transparently and finally to optimize them. Other green building labels such as the U.S. LEED (Leadership in Energy and Environmental Design) or the UK-based BREEAM (Building Research Establishment Environmental Assessment Method) also include LCAs in their assessment system. However, they weight them lower and also require a smaller scope of accounting. Only the building materials

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are accounted for here. Technical building equipment is not considered.

In the context of this publication, the results of a WBLCA of an office building typical for Germany are used to illustrate the share of building services in the environmental impact of a building. Based on the calculation method of the DGNB or BNB system, the building services systems and all associated components in addition to the structural design were recorded and calculated as comprehensively as possible.

The aim was to use real planning data to illustrate the proportion of building services in a WBLCA and to determine its significance for environmental impacts. This also had to be considered against the background that building services in the DGNB and BNB system can initially be represented within a simplified procedure (VeV) with a 10 % surcharge and in the currently valid version with a 20 % surcharge.

In order to illustrate the effort and the difficulties of the complete coverage of building services with this procedure and make it more comprehensible, the calculation tools and aids used were consciously chosen from practical experience. Own solutions (Excel tools or similar) or fee-based databases were not used.

After an introduction to the topic, section 2 of the publication presents the underlying standards, the LCA- software and the various databases relevant to the German market. Section 3 describes the procedure, the anonymized reference project, the system boundaries and all assumptions made. Section 4 shows and analyses the results. The results are discussed in section 5. Approaches to solutions are presented using the Building Information Modeling (BIM) method. Section 6 concludes the publication with a conclusion and outlook.

2 Theoretical background

In the following, the norms and standards, which form the basis of a WBLCA for the calculation of the environmental impacts of building construction and building services, are briefly explained.

2.1 Series of standards ISO 14000

An LCA describes a method. The purpose of this method is to provide information on how a product or process affects the environment throughout its life cycle. This makes it possible to measure and compare environmental impacts in the various phases of a life cycle. Within the ISO 14000 series, two standards standardize the general life cycle assessment methodology: ISO 14040 describes the most important principles and structure for carrying out a life cycle assessment [4]. ISO 14044 defines details and recommendations on how the procedure for assessing a life cycle assessment should be carried out [5].

2.2 DIN EN 15978 and 15804

DIN EN 15978 [6] and DIN EN 15804 [7] are part of a series of standards that standardize the assessment of the holistic performance of buildings over their life cycle. All these standards are the responsibility of the Technical Committee CEN / TC 350 Sustainability of construction works. While DIN EN 15978 forms the basis of WBLCA, DIN EN 15804 defines product category rules for the environmental product declarations of building products.

An Environmental Product Declaration (EPD) contains information on the use of energy and resources in the production of the construction product as well as information on its technical and functional properties. EPDs therefore also serve as a product-specific basis for LCA of buildings and for the comparison of functionally equivalent construction products. In addition, an EPD also contains information on the technical characteristics required to assess the construction product for the whole building. These include, for example, service life, heat and sound insulation properties and the influence on the quality of the indoor air.

Specifically, DIN EN 15804 standardizes which types of environmental impacts must be made available in which stages of a life cycle. A total of 24 different impact indicators are defined, which are used in the different life cycle stages: Product stage (A1-A3), Construction stage (A4-5), Use Stage (B1-7) and end of life stage (C1-4). The stages are supplemented by Module D, which balances information on reuse, recovery or recycling outside the life cycle and system boundaries (from cradle to grave). Only the declaration of modules A1-A3 (Figure 1) is mandatory for the manufacturers of the products or the creators of an EPD. The declaration of all other environmental impacts in the remaining life cycle phases is a voluntary choice of the manufacturer [7]. For example, only environmental impacts from the product stage are available for many data sets.

2.3 Whole-Building Life Cycle Assessment according to DGNB/BNB-system

DGNB certification (current version 2018) requires the calculation of a WBLCA and weights this with 9.5 % of the overall rating. The procedure is described in the corresponding criteria profile ENV 1.1 "Life cycle assessment of a building" [8].

According to the DGNB requirements, the life cycle modules A1-A3, B4, B6 and C3-C4 as well as module D have to be calculated. ÖKOBAUDAT version 2016-I or newer is specified as the data basis. Within the WBLCA of the DGNB system, building services can be calculated using two different calculation methods: the simplified procedure (VeV) or the complete procedure (VoV). While the VoV basically stipulates a complete inclusion of all components of the German cost groups (KG) 300: building - building constructions and 400 building – building services according to DIN 276 [9], the VeV allows a limitation to eight essential component groups of the building constructions and building services. Specifically, VeV stipulates that the heating and cooling systems as well as the central ventilation systems must be included in the building model. Pipes, lines, ducts and other technical building equipment systems are not to be included in the building model. To compensate for this simplification, the result of the environmental impacts in the individual life cycle phases must be "worsened" by a factor of 1.2, i.e. multiplied by a 20% surcharge. The BNB system requires in its criteria, a very similar calculation of the WBLCA without taking module D into account.

2.4 LCA-Software

In practice, WBLCA are usually calculated either with self-created Microsoft Excel solutions or with one of the existing diverse software solutions. Since the input of life cycle assessments is usually based on freely programmable material and energy flows and processes in common LCA software, such as Simapro, OpenLCA or GaBi, these are largely unsuitable or impracticable for use in the planning process for a building [10].
In addition to these general LCA software solutions, a (small) number of life cycle assessment software solutions that focus on the construction industry and the building sector have arisen over the past few years. These are primarily used to support LCA calculations within Green Building Certification Systems [11]. For the German market these are: CAALA, eLCA, LEGEP, One Click LCA, Ökobilanz-bau and SBS Building Sustainability. These software systems work according to a similar principle: The individual environmentally relevant data of a product are further processed by the software in projections into processes that correlate with each other via material and energy flows. Among other things, quantities, masses, areas and volumes are used as further input parameters for the calculation. These are linked and multiplied with standardized life cycle assessment data and environmental product declarations, taking into account specified service life.

2.5 LCA databases

In Germany, freely accessible life cycle assessment data sets are available via the databases ÖKOBAUDAT and IBU.data. The ÖKOBAUDAT platform is made available by the Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (BMUB) as a standardized database for ecological assessments of buildings and is required as a data basis in the DGNB and BNB systems. In September 2013, ÖKOBAUDAT became the first life cycle assessment database to fully comply with the DIN EN 15804 standard [12]. A total of around 1,200 building materials, construction and transport processes are currently described in terms of their ecological impact. Depending on the origin of the data records, the following four data record types are distinguished:

- Generic: data set collected from different sources with an additionally added charge
- Representative: average data set of selected manufacturers
- Average: average data set of an entire manufacturer group
- Specific: data set of a single manufacturer (EPD according to DIN 15804)

The ÖKOBAUDAT database consists of generic data sets to a large extent. In Germany, the IBU (Institut für Bauen und Umwelt - Institute for Building and Environment) is making intensive efforts to provide more product-specific data sets for construction products in the form of standardized EPDs. This has been done since 2017 via the digital database IBU.data. The IBU is one of the leading international program operators for EPDs in the construction industry and the first organization in Germany to implement the European harmonized standardization for environmental product declarations on sustainability in the construction industry [13]. In January 2017, there were over 3,600 EPDs for construction products tested worldwide in accordance with DIN EN 15804. More than 1,500 of these were published by the IBU and are mostly available in the IBU.data [14]. In the current ÖKOBAUDAT 2017 database, about one third of the 1,200 data sets are EPDs.

Data from the BNB-System [15] are used to determine the service life of the building or building structure (KG 300),. Values for the service life for building services (KG 400) are taken from VDI 2067 [16].

3 Method

The following section gives an overview of the selected reference office building, the procedure, including a description of the anonymized example project, the system boundaries, and the assumptions made.

3.1 Description of the reference office building

As a reference for a typical German office and administration building, an office building was chosen which, in terms of size, structure and geometry, is comparable to the reference model office of the study "Development of a database with model buildings for energy-related investigations, in particular economic efficiency" by the Zentrum für Umweltbewusstes Bauen [17].
Furthermore, the project was planned according to the current state of the art. The year of completion was 2018. Important parameters of the building and its technical equipment are briefly described in Table 1.

3.2 Description of calculation tools, system boundaries and assumptions

The freely accessible software eLCA was used for the WBLCA, the development of which was commissioned by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). eLCA offers the calculation of modules A1-A3, B6 and C3 and C4. Optionally, the life cycle assessment can be calculated by including module D. As eLCA has not yet integrated ÖKOBAUDAT 2017, ÖKOBAUDAT 2016-I is used in this study. It should be noted that ÖKOBAUDAT 2016 contains fewer data sets, especially for building services. This made it more difficult to model the building realistically in an LCA model. An individual input option for LCA data, e.g. in the form of EPDs from IBU.data, is not possible, like many other WBLCA software solutions does not allow, too [18]. The software eLCA uses the cost group structure of DIN 276.

Table 1. Description of the reference office building

Building structure	Reinforced concrete supporting structure, exterior walls made of mineral material with ETICS and plaster as well as aluminium curtain walls (mullioned facade). The windows are made of aluminium and triple glazed. The reinforced concrete flat roof with waterproofing is partially greened.
Type of use	Office and administration
A/V ratio and window ratio	0.28 1/m and 47.5 %
Number of floors	6 + underground parking (U1, U2)
Gross floor area	BGF= 11.300 m²
Net floor area	NGF = 9.605 m²
Volume	V = 37.643 m³
Energetic standard	Compliance with German Energy Conservation Ordinance (EnEV 2016)
Building Services	Hot water preparation: Decentralized water heating with the aid of instantaneous water heaters
	Heating: Heat supply: district heating ; Heat consumers: Static radiators, Thermally activated building systems (TABS), ventilation and air-conditioning
	Ventilation : Central ventilation system with heat recovery (cross-flow heat exchanger); Pressure ventilation system for smoke extraction
	Cooling: Refrigeration: compression refrigerating machine; Delivery: Thermally activated building systems (TABS), ventilation and air conditioning system
	Other technical equipment: 4 elevators, LED lighting, oil tank for emergency power supply

Especially the second and third level of the cost group structure allows a meaningful and detailed subdivision. The building is calculated in terms of the VoV (complete procedure) with the boundary conditions according to DGNB Version 2018, i.e., from the lower edge of the floor slab or foundation including the building services and the fixed installations. Furniture, outdoor facilities and development are not considered. Furthermore, the VoV procedure stipulates that all materials representing more than 1% of the total mass of the building must be included in the VoV.

Since the aim of this work was to calculate the environmental impacts of building services as accurately as possible with the freely accessible database in Germany, supposedly small material or component groups below the 1% threshold were also taken into account. For example, in addition to pipe and air-duct networks, fire dampers, lighting tubes and sockets were also included using available data sets.

3.3 Preparation and processing of relevant information

Many pieces of different information from various project participants are necessary to calculate the WBLCA. This information is not always available in the service phase according to the German HOAI[1] or in the quality or desired level of detail required for a life cycle assessment of the building with the possibility of optimization.

While the German EnEV verification and building physics component catalogue are usually only available in phases 4 or 5, ground plans, sections, views and area calculations are already available earlier. Pipe and air duct networks calculations as well as sufficiently detailed building services planning are also only completed in phase 5. Depending on whether building services and the associated masses are determined from plan drawings or a detailed mass determination, which already exists, the effort for preparation can vary greatly. In addition, the mass and quantity parameters must first be determined in such a way that they correspond to the reference values of the LCA data sets. The eLCA online tool offers a conversion function for this purpose, with which conversions can be carried out automatically using stored gross densities.

4 Results of the evaluation

A total of 305 data sets were used to calculate the WBLCA of the example project in order to model components of the KG 300 and 400 including the distribution and supply systems. 269 of these are for building construction and 36 for technical building components.

4.1 Overall results (A1-A3, B6, C3-C4, maintenance/replacement)

To increase transparency, the absolute WBLCA results are listed in Table 3 below. Since the presentation and communication of the results is difficult due to the very different value ranges, the absolute result values were given as relative proportions in the following figures. The results refer to the life cycle modules A1-A3, B6, C3-C4 as well as maintenance and replacement after the service life has expired. Module D is not included in this calculation. For a condensed presentation of the results in figure 2, the new result values of the relevant nine impact indicators were summarized by calculating the sum and then the mean value of the nine required impact indicators in the DGNB/BNB system.

[1] Note: the total performance or output of an architect or engineer is divided into nine service phases in Germany according to the fee structure for architect and engineer services (HOAI). Phases 1 through 3 are usually grouped as design phase, while phase 4 and show a much more detailed design.

Table 2. Absolute, annual WBLCA results of the total result, indicated per square meter net floor area

Indicator	Unit	Production	Maintenance	Use	End of Life	Total
GWP, Global Warming Potential,	kg CO_2-Eqv.	8.497	2.157	38.511	1.130	50.294
ODP, Ozone Layer Depletion Potential	kg R11-Eqv.	8.37E-08	2.04E-07	2.21E-09	1.80E-11	2.90E-07
POCP, Photochemical Ozone Creation Potential	kg Ethene-Eqv.	0.0027	0.0012	0.0048	0.0001	0.0087
AP, Acidification Potential	kg SO_2-Eqv.	0.0185	0.0054	0.0560	0.0008	0.0807
EP, Eutrophication Potential	kg PO4-Eqv.	0.0023	0.0007	0.0077	0.0001	0.0108
PEges, Sum of total use of non-renewable primary energy resources and total use of renewable primary energy resources (PEnrt + PErt = PEges)	MJ	97.617	33.140	592.275	1.564	724.596
PEnrt, Total use of non-renewable primary energy resources	MJ	86.731	30.391	491.126	1.403	609.651
PErt, Total use of renewable primary energy resources	MJ	10.887	2.750	101.148	0.161	114.945
ADPelements, Abiotic depletion potential for non- fossil resources	kg Sb-Eqv.	7.43E-05	0.00012	6.46E-06	3.22E-07	0.00020

In a second step, the relative proportions of operating energy (life cycle module B6) and building construction (life cycle modules A1-A3, C3-C4 plus maintenance) were presented. The building construction will continue to be broken down into KG 300 and KG 400. In this context, it is important to interpret the results of a life cycle assessment in connection with the respective database used.

While the building construction accounts for around 41.6% of the overall result, the share of operating energy predominates at 58.4%. This means that the environmental impacts of building products and technical building equipment in the stages of production, maintenance and end of life are considerably high in the context of this example office building. The building construction (KG 300) is responsible for about 18.5 % of the environmental impacts, building services (KG 400) for 23.1 %. This is an important finding with regard to the relevance of technical building equipment to the overall result, particularly in view of the fact that the KG 400 with 0.5 % has an extremely low mass fraction of substances compared to 99.5 % of the KG 300. Since technical building equipment and its supply networks consist of material components such as metals and plastics to a large extent, these often have a higher environmental impact per kilogram of material used. For example, the mass of m = 1 kg of a PE-X-Alu pipe shows a four times higher global warming potential in the production stage than m = 1 kg of EPS rigid foam insulation for walls and roofs. Also it shows a global warming potential around 80 times higher than the mass of m = 1 kg of structural concrete of compressive strength class C 35/45.

A detailed examination of the nine relevant impact indicators in Figure 1 provides information on how the environmental impacts arise. Figure 1 shows how the mean value of the sum of the nine impact indicators for operating energy, KG 300 and KG 400, shown in Figure 2 is determined.

Although the environmental impacts of the KG 300 in seven of nine impact indicators are significantly higher than those of the KG 400, ODP and ADPe are almost completely influenced by the KG 400.

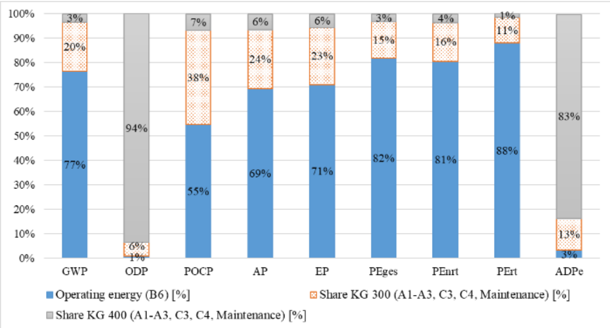

Figure 1. Relative shares differentiated by operational energy consumption and cost groups 300 and 400 in the nine impact indicators relevant according to the DGNB/BNB system

KG 300 and in particular operating energy play almost no role in these two impact indicators. These two indicators are mainly influenced by the material groups metal and plastic. As a rule, these are the main components of building services and their supply systems.

4.2 Building construction (A1-A3, C3-C4, Maintenance/Replacement)

In order to analyze the environmental impact of building services in comparison to the structural building components, the following subsection only considers the building construction without the operating energy in the utilization phase. Figure 4 shows the respective ratios of the environmental impacts of building construction (KG 300) and building services (KG400) for the various impact indicators. If the mean value of the nine impact indicators is calculated, building services has an average of just under 33% of the environmental impacts.

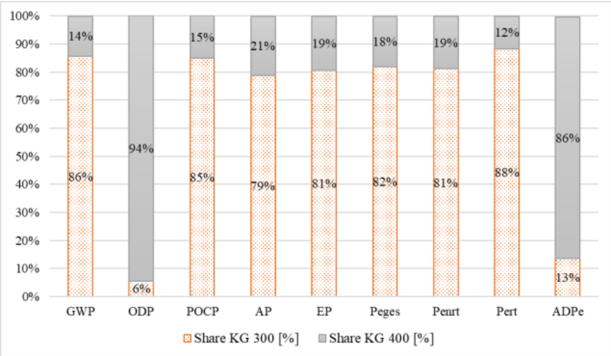

Figure 2. Share of cost groups 300 and 400 differentiated according to the nine impact indicators relevant according to the DGNB/BNB system

If module D (credits from recycling, etc.) is taken into account, the building services' share of the overall result is reduced by around 7 percentage points due to credits for pipe and air duct networks resulting primarily from the recycling process of metals. In seven of the nine impact indicators, the proportion of environmental impacts from building construction is considerably higher than that from building services. For the other two indicators, ODP and ADPe, the KG 400 determines the environmental impacts almost completely. In order to carry out an even more detailed analysis, a further breakdown of the nine impact indicators into the life cycle stages production, end of life and maintenance/replacement is necessary.

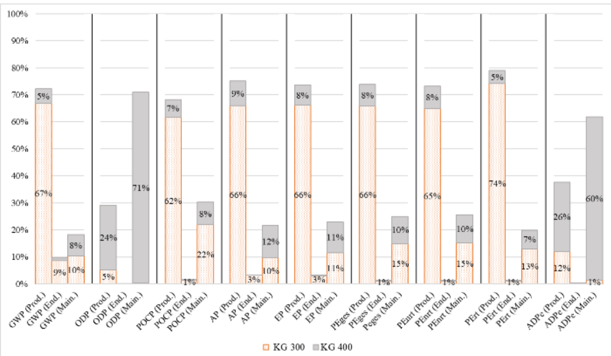

Figure 3. Share of cost groups 300 and 400 in the environmental impacts in the nine impact indicators relevant according to the DGNB/BNB system in the product, end of life and maintenance/replacement stage

On the basis of this presentation of the results, it can be clearly seen that the major part of the environmental impacts caused by the building services are caused in the maintenance/replacement stage. In each of the nine impact indicators, these phases account for the largest share of the KG 400. The reason for this is the relatively short service life of the technical building components. Replacement cycles in the maintenance phase of, for example, 10 years for pumps, 15 years for lifts or 30 years for ventilation ducts [16] cause high environmental impacts. If components from measurement and control technology or building automation, which could not previously be represented by a data set, could be included, the environmental impacts would increase further, as components of these trades usually have service lives of less than 10 years. The end of life stage for KG 400 is usually less than 1 % and has only a small share.

4.3 Impact of the different building services systems

There is a clear correlation between the masses of substances and the environmental impacts. The ventilation systems (KG 430) with the largest mass of substances are also responsible for the majority of the environmental impacts of the KG 400. Supply (pipes and air ducts) have the largest share of both mass and environmental impact. While the heat supply systems (KG 420) account for 22.1 % of the environmental impacts, the conveyor systems (KG 460) for 5 % and the waste water, water and gas systems (KG 410) for 2.8 %, the high-voltage systems (KG 440) do not have a significant influence on the environmental impacts with only 0.2 %. This is mainly explained by the incomplete illustration of KG 440 based on the planning documents.

5 Discussion

Following the presentation and interpretation of the results, the following section discusses not only the relationship between the environmental impacts of KG 300 and KG 400, but also the amount of work required for implementation and practicability.

5.1 Problematic: Scope of work in procurement, preparation and calculation

The effort for procuring and processing the information required for the WBLCA, such as material and quantity data, taking into account the technical building equipment, is very high. This has also become clear in the context of this study. On the one hand, the cooperation of different project participants is necessary and on the other hand the mass determination for building materials and building services components from floor plans, pipe and air duct networks calculations means a high expenditure. It is therefore understandable that despite the malus factor in the context of DGNB/BNB certifications and despite a lack of knowledge about the full effects on results, only the VeV has been applied in practice with very few exceptions [19]. The high expenditure of time and money that has to be invested by the VoV including the modeling of building services for the WBLCA, as well as the lack of practicability, does not make the VoV worthwhile for the user or client. A further complicating factor is that the VoV does not lead to precise results either. Thus, there is no incentive to incur the large additional expense for a supposedly detailed WBLCA including comprehensive building services modeling [19].

Another challenge is the requirements of the VoV, all components or materials that represent more than 1% of the total mass of the building must be taken into account. Conversely, this means that both the total mass of the building and any group of materials that could theoretically have such a mass fraction would have to be relatively precisely known. This aspect means a considerable additional effort for the preparation of the WBLCA.

5.2 Data availability and representation in the LCA model

The lack of basic data is often already a problem during the modeling of the building construction. Many assumptions and compromises have to be made to find alternative data sets.

Compared to the ÖKOBAUDAT version of 2009, almost twice as many data records were made available (approx. 1,200). However, there are still gaps, especially for building services. Components from metering and control technology or building automation cannot be mapped. Studies from 2010 and 2014 already identified these gaps in the database for building services [3], [19].

The use of IBU.data is not possible within eLCA, as is the case for most other German WBLCA software. It is not possible to integrate individual EPDs manually. Thus data sets from IBU.data, which could close gaps in ÖKOBAUDAT due to their clear product affiliation, cannot be used. This concerns, for example, (LED) lighting and pipe or duct insulation as well as volume flow controllers. Therefore either an own calculation solution must be developed, e.g. with the help of Microsoft Excel, or a similarly applicable data set must be used. The necessary assumptions, estimates and compromises then reduce the significance of the LCA model.

5.3 Building Information Modeling (BIM)-Method as a solution

The digitization of the building and construction industry is summarized under the term BIM. In addition to the entire 3D project management, BIM methodology is also a great added value for many of the criteria required for sustainability certification. For example, with the help of BIM as a holistic and cooperative working methodology, which represents the digitization of the entire structure from "cradle to grave" and a cross-sectional discipline of all specialist areas in planning and construction, the process of WBLCA can be made significantly more efficient. By making information for the calculation of the WBLCA earlier, more structured and more easily accessible, an almost fully automated WBLCA would be possible according to the evaluation systems of the various green building certification systems of buildings [20].

The BIM method, which requires a technological architecture such as the modeling program Autodesk Revit, requires the enrichment of various information or data on building physics and building services of the various project participants in the BIM model. The information thus stored in the 3D model by the architects and specialist planners later serves as the basis for the WBLCA. The project-specific quantities, masses or areas can be used to determine the total environmental impact of the building, for example, according to an extended cost group structure. For this purpose, reference life cycle assessment data sets (e.g. ÖKOBAUDAT) are used which show the environmental impacts for a reference unit such as kg, m3, m2, m, number of units. By multiplication with the project-specific variables known from the BIM model, environmental impacts can be fully automatically calculated, evaluated and visually displayed.

The first software solutions that link BIM and WBLCA models are the Revit plug-ins from Tally or One Click LCA. However, these do not allow real-time display and calculation of the LCA or fully automated calculation of the WBLCA and do not yet provide faultless compatibility and communications between the BIM and WBLCA model. For the time being, therefore, these solutions are still associated with a high degree of manual improvements [21].

A slightly different approach, which is currently being developed, envisages the use of the information management software DESITE-MD from CEAPOINT. This additional software solution is not a Revit plug-in or online tool, but an analysis and information system that can facilitate the use of digital building models in a variety of ways. In the case of the WBLCA, the aim is to use the BIM model to access the data of building physics or building services with the aid of so-called modules and domains within DESITE and to extract individual information programmatically from the model. Then these pieces of information are linked with LCA data sets and EPDs from IBU.data and are further used for the calculation and visualization of the WBLCA results directly in real time.

Thus, the very high effort for the quantity and mass determination of pipe, cable and air duct systems in buildings can be greatly reduced. An evaluation of the 1,500 pages for pipe and air duct network calculation in this example project would be many times faster. The accuracy of the calculation can also be significantly improved in this way.

The motivation for the preparation of a WBLCA can thus be considerably increased. In this way, the LCA can be helped to achieve a meaningful depth of detail. If, in future, the database is expanded, especially in the area of technical building equipment, and the creation or integration of product-specific EPDs is promoted, this will greatly promote the use of the WBLCA as an early and iterative planning instrument. In particular, the expense of a WBLCA within the framework of a Green Building Certification could be significantly reduced and the attractiveness of the certificate positively influenced.

6 Conclusion and outlook

Building services accounts for one third of the environmental impact of the building (excluding operating energy) on average of all impact indicators in this project. In some indicators, even more than 80 % is reached (for ODP and ADPe). Considered in terms of life cycle modules, the KG 300 usually has a significantly higher share in the product stage (A1-A3), but the importance of building services in the maintenance/replacement stage predominates, especially due to the relatively short replacement cycles. In this attempt to model the building services as comprehensively as possible using existing data sets, it was possible to calculate the most important building services systems such as heating, cooling, ventilation and sanitation and to demonstrate their influence on the WBLCA, but it was still not possible to fully capture the entire scope of building services.

In view of the fact that many areas of building services could not be represented due to missing data records or due to a lack of precise planning documents, an even larger share of building services in the building construction than 33 % can be assumed in reality. In particular, the components of measurement and control technology such as cable lines, sensors, (thermostatic) valves, etc. contribute to the fact that building services accounts for an even larger share of the environmental impact of buildings.

This short study confirms the already known challenges in the calculation of a WBLCA and points out additional difficulties that are often not considered or known in the WBLCA process.

The inclusion of module D into the calculation has a major impact on the determination of how high the building services share of the environmental impacts is. Various credits of the material group metals, which can mainly be found in the supply systems, reduce the share of building services in the reference building presented by approx. 7 percentage points (without consideration of operating energy).

A further finding is that the DGNB and the BNB certification system are the only drivers requiring the calculation of building services within the framework of a WBLCA. However, the surcharge of a factor of 20 % for building services seems to be rather small when the simplified procedure is applied and does not really constitute a motivation to calculate in detail. The results of this short study show that this surcharge should perhaps be higher.

A particularly useful approach is to expand the available data basis, e.g. ÖKOBAUDAT by including additional EPDs from the IBU.data database. A higher motivation of the manufacturers to have EPDs of their technical building equipment products created is also desirable, because a broad, detailed database is necessary in order to comprehensively model buildings in a WBLCA.

To this end, the linking of BIM and WBLCA models is regarded as groundbreaking (and necessary) in order to enable a significantly more efficient and easier calculation process. This increases the chance that the sensible method of WBLCA can be used for optimization during planning.

The aim should be to ensure that the WBLCA is not only drawn up once as part of a certification process in order to reflect the building that has been realized. It should serve as an iterative planning instrument for optimization in all planning phases. From the point of view of building services, there is a desire to expand the still small number of data sets and to make simple calculation processes possible.

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