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Product data and building assessment – flow of information

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Abstract. The design, realisation and operation of buildings should be based on the principles of sustainable development, and consequently on the goal to conserve natural resources as a critical aspect of it. To this end, improving the resource efficiency in all building-related activities – from design to end-of-life – is necessary. Yet, such an effort cannot be fully successful if not based on comprehensive information. On the architects' side, there is a need for information on construction products to be fed into the assessment of building design variants. The exchange of information between product and building level is a topic dealt with in European (CEN TC 350) and International (ISO TC59 SC17) standardization. However, the demand on product information goes beyond the content of an Environmental Product Declaration (EPD). It is therefore necessary to discuss what are the additional needs for product information and how to provide this information to be practical for a building assessment. Finally, it is necessary to discuss how buildings should be documented along their life cycle to provide useful information for third parties. Third parties are – among others - valuation professionals, facility managers or demolition/dismantling companies. An approach to building files/building information packs will be presented, where information on the physical composition of the building and its material flows in the life cycle (material inventory) becomes an integral part. With regard to standardization, how to determine and present a recycling potential of a building will be discussed. Current research projects in Germany will inform the discussion.

Keywords: Building file, construction product, flow of information, actors, assessment

1. Introduction

The careful use of resources – here in the sense of natural resources – is part of the management rules to support sustainable development [1]. The objective is to use renewable raw materials only within their regeneration capacity, to delay the depletion of non-renewable resources (such as fossil fuels and mineral raw materials), and to reduce the impacts on the environment caused by the extraction of raw materials, their processing and use, as well as their disposal. Various strategies have already been developed for this purpose [2], indicators have been introduced and applied [3] as well as research projects have been initiated [4-5]. Nevertheless, various obstacles arise. From the author's point of view, these



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include: (1) the absence of generally recognized principles for the determination, assessment and communication of material flows, (2) the absence of incentives for the determination and documentation of the material composition (material bills) of products and (3) a still underdeveloped problem perception.

In the past, the discussions about the use of natural resources were entirely focused on determining the timing of the running-out of reserves of fossil fuels (oil peak). Currently, policy-making and science are focusing on limiting climate change. It is only gradually becoming clear to the public that there is a shortage of other natural resources as well (in addition to fossil fuels). In the sustainability assessment, resource conservation and climate protection become protection goals of equal importance.

The manufacture of construction products consumes fossil fuels and other resources and contributes to the environmental pollution due to GHG emissions. There is a close relationship between the use of natural resources and the resulting environmental impacts. In addition to fossil energy sources, biomass, metals and non-metallic minerals should also be regarded as natural resources that need to be conserved.

The activities of manufacturing, construction, use and disposal of buildings and structures are not only associated with significant energy resource consumption and undesirable effects on the local and global environment, but also with substantial material flows. Approximately 40% of the global raw materials consumption can be attributed to the construction sector [6]. In this sense, focusing more intensively on the determination, assessment and targeted influencing of material flows associated with the construction and real estate sector now becomes a necessity.

2. Basic principles

2.1. Cumulative mass flow – pros and cons

To determine the consumption of fossil fuels, it is possible to convert them into oil equivalents via their caloric value or to aggregate them as cumulative energy consumption or abiotic depletion potential (ADP) fossil. So far, such an approach has failed to capture non fuel related material flows, although it is needed for indicators at national level, e.g. resource productivity. The development of an indicator for a “cumulative raw material flow” has not been successful so far; the indicator ADP elements is only conditionally suitable for the construction sector [7]. It gives a distorted picture in favor of rare substances.

From the author's point of view, it is not absolutely necessary to represent material flows over an aggregated value. In the interest of a resource management approach, it is rather advantageous to assign materials used in the construction sector to different resource groups: biomass, metal, non-metallic minerals and fossil fuels. In the case of fossil fuels, a separate presentation has already been introduced.

2.2. Life cycle models, actors and decision-making situations in the construction sector.

In research, the application of life cycle analysis is already widespread. For construction products, construction works and buildings, standardized models exist to describe their respective life cycles. Although these models are similar in their organization into phases and modules, they do not need to be identical. The service life/use phase of a construction product may differ significantly from the service life/use phase of a building.

The following groups of actors are of particular interest to the topic discussed here: (1) legislators; (2) building owners and developers; (3) designers/architects; (4) sustainability consultants/LCA specialists (5) companies in the construction product manufacturing industry; (6) companies in the field of deconstruction and waste disposal. In order to perform their duties and as part of their sense of responsibility towards the environment and society, these actors need information created, processed and interpreted by third parties as well as they need themselves to pass on information to third parties. The needs-based design of information flows along the value chain is a prerequisite for resource management in the interest of resource conservation.

Material flows in the construction sector are influenced, amongst others, by (1) legislative requirements, (2) requirements imposed by local authorities, (3) clients' specifications and decisions, (4) archi-

tect' proposals for construction products and structures, (4) manufacturing processes, products and services offered by the building product manufacturing industry, (5) services and service offers provided by the dismantling and recycling industry. Essential decision-making situations are (a) the design and realization of new buildings, (b) replacement of components during the building's life cycle and (c) design and implementation of refurbishment, conversion or reuse measures including decisions between refurbishment or dismantling and complete replacement of the existing building with a new one.

2.3. Job sharing between product and building level

The object of assessment here is the building. First of all, a building must fulfill all functional and technical requirements in the sense of the legally or normatively specified features or properties contractually agreed upon with the client. EN 15643-1: 2010 "Sustainability of construction works - Sustainability assessment of buildings - General framework" also specifies that requirements for environmental, economic and social performance shall be formulated in the client's brief. In this context, requirements can also be defined that directly or indirectly have consequences for the type and extent of resource utilization in the lifecycle. Direct possibilities are: (1) requirements for limiting primary energy consumption, non-renewable for production and operation (in terms of a budget); (2) requirements for a preferential use of products from renewable resources; (3) requirements for a preferential use of products with high recycled content. Indirect possibilities include (4) requirements for ensuring the durability of structures, (5) requirements for flexibility and adaptability of the building, (6) requirements for ease of maintenance, repair and replacement of building components, and (7) requirements for ease of deconstruction and recycling. Some sustainability assessment systems such as BNB [8] and DGNB [9] contain such requirements. Within the scope of the process quality as an additional part in the German sustainability assessment systems, a demand for a comprehensive object documentation requires the preparation of material listings/material inventories.

Buildings are made up of construction products. Construction products often transfer their characteristics and properties to the building structure. The selection of construction products is usually made on the basis of the knowledge of their place/position in the building, the way/type of installation in a structure, the type of stress, the intended service life and type of use of the structure, and is influenced by environmental (life cycle environmental impacts), economic (life cycle costs), social (health-related risks) and design considerations. The LCA data available in an Environmental Product Declaration (EPD) or a Product Environmental Footprint (PEF) are a prerequisite for the creation of building-level LCA data. Therefore, the description of the material composition of the building itself – in the form of bill of materials – is a requirement. However, a life cycle assessment is not enough to assess the environmental and health-related soundness of buildings. There is a need for additional information, e.g. with regard to the hazardous substances that released into the indoor air or into the soil and water around the property. As a result of CEN TC 351, there are now harmonized methods relating to the measurement of the release of regulated dangerous substances under the Construction Products Directive (CPD). The place and type of communication of such data are not conclusively clarified. From the author's point of view, EPD and PEF are suitable instruments for construction products. For years it has been discussed which data could be added as additional information in these instruments – in this sense, there would be room for information on risks to the health of process workers, building users and neighbours as well as the local environment.

In the area of sustainability assessment, a job sharing between the building and product levels is emerging. The building is the object of assessment, while data on construction products form a necessary basis for information. This raises the question of how appropriate information flows can be organized.

3. Structuring of interactions and information flows

In the following, interactions and information flows between actors and in particular between building and product levels are discussed using the example of designing a new building.

When formulating the project goals in the client's brief, the client can already formulate requirements for resource efficiency. This can be done in several ways, such as by demanding the use of sustainability

certification with related indicators, specifying a resource-saving and recycling-friendly construction method or specifying the use of specific recycled products (in Germany, the use of recycling concrete (RC) is sometimes required for public construction projects).

Using environmental product declarations (EPDs) and other sources of information (in Germany, for example, WECOBIS [10]), architects can select resource-efficient designs, construction methods and construction products and analyze the consequences of the selection and combination of available options during the design phase, using a life cycle assessment. A partial aspect is the determination and assessment of a recycling potential (module D) for buildings. For the environmental performance assessment of buildings designers can use EN 15643-2: 2011 “Sustainability of construction works - Assessment of buildings - Part 2: Framework for the assessment of environmental performance” and EN 15978: 2011 “Sustainability of construction works in assessing the environmental performance of the building - Assessment of environmental performance of buildings - Calculation method”.

The indicators described in the standards give rise to a need for information on LCA data on construction products. So far, these are made available via EPDs, but also databases. The content of EPDs is still based on the specifications provided by EN 15804: 2012 + A1:2013 “Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products”. However, both the type and number of indicators included in this standard are currently under revision. There is a lot of ongoing discussion about the implications of the European Commission's idea of introducing a PEF for influencing the future design of EPDs [11].

From the perspective of the author, it is important to design the information flows between product and building level on the basis of a life cycle assessment when assessing the environmental performance of the building. For this, the modules A-D are suitable for describing the life cycle of construction products and construction works/buildings. In addition to the functional and technical requirements to be met, the construction method and materials as well as the life cycle model are determined in agreement between the client and the architect at the level of the building. This also involves the establishment of scenarios for determining the maintenance and replacement cycles as well as for end-of life stages of the building, such as de-construction and disposal. The compilation of the building LCA already from the early design stages – and its update as the design evolves into its final state – is advisable in order to examine the impacts of the various design decisions on the environment. Designers are not required to perform an LCA in the traditional sense of the word; instead, they typically combine results from the quantity take-off with LCA data on construction products. The quantity determination of construction products and materials thus becomes an important task, resulting in a material bill as an essential document.

The lifecycle scenarios defined at building level give rise to the need for data on construction products. EPDs are needed which contain information for the individual information modules A - C and D with which several scenarios can be unfolded; this means that the further development of EPDs should consider the development of several case-based information packages for each module that describes downstream processes (A4-C4 & D) to allow the users of the information (i.e. designers and other stakeholders) to select which information package is more relevant to their building case – e.g. for C and D modules two different data packages can be included: data for the case of a demolition without further recycling and data for a selective deconstruction/disassembly with subsequent recycling. These provide the basis for determining values for modules C and D at the building level - see also Figure 1.

Figure 1 shows a possible procedure for organizing information flows. First, the designer selects a model to describe the future life cycle of the building – an orientation towards the internationally accepted modular approach to organizing the life cycle into modules A to C and D is recommended. Without a doubt, it goes without saying that the future life cycle is associated with uncertainties. In the case of the application of sustainability assessment systems deterministic models are therefore used on the basis of conventions. The system rules must clearly define these conventions – e.g. selective deconstruction with maximum degree of recycling. It is also possible to specify two alternative scenarios (demolition versus de-construction) to quantify the advantages of selective deconstruction. Outside the application of a sustainability assessment system, the probability of occurrence of individual scenarios must

first be discussed. This offers the analysis of alternatives, including an assessment of the effort and related impacts to improve the ease of deconstruction and recycling-friendliness. It should be noted that deconstruction and recycling occur not only at the end of the life cycle of the building, but also at the end of the life cycle of building components (e.g., windows). The scenario for deconstruction chosen for the building leads to a dataset which can be selected from the information on construction products in module C. However, it first has to be examined whether the constellation into which the product was built to form a building component makes it inseparable or separable.

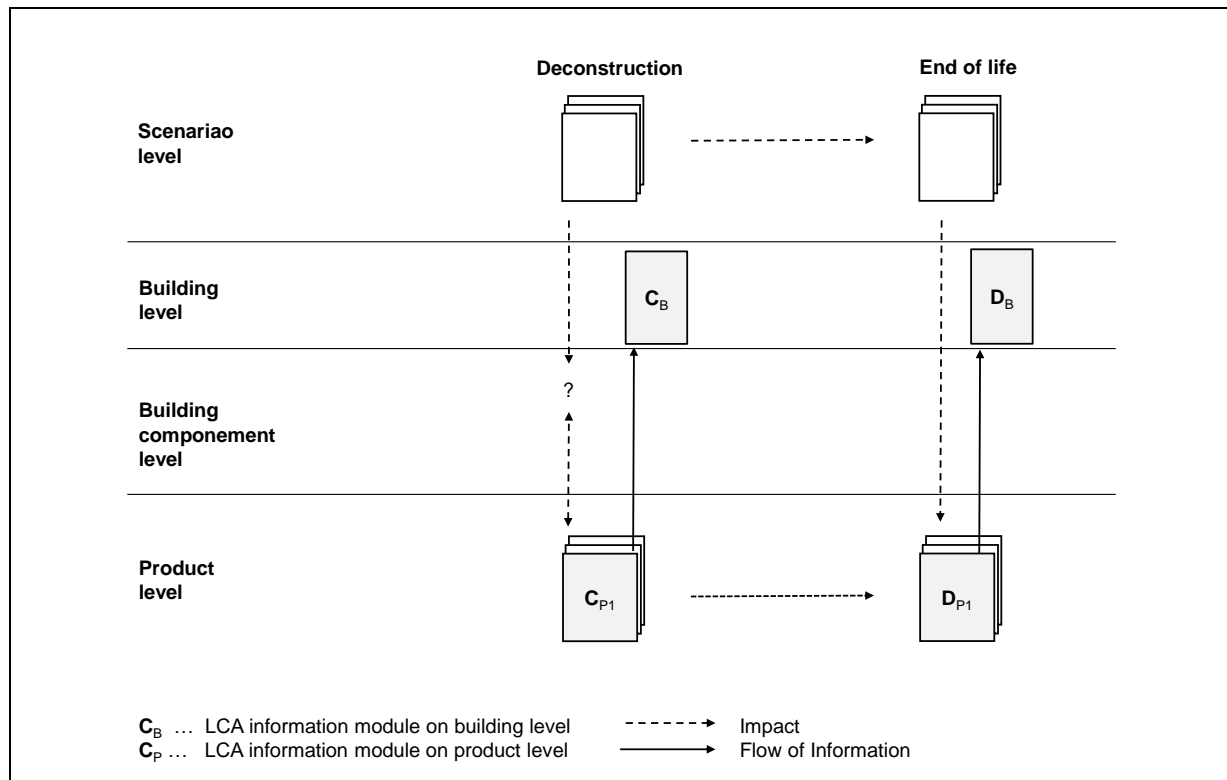


Figure 1. Relationships between building and product level (Source: Present author)

The module C at the building level is derived from the results of the module C on product level. Subsequently, when defining scenarios at building level, it is necessary to define what type and extent of recycling should be pursued. Once again, scenarios can be here specified.

Depending on the scenario selected at building level and the recycling options at the product level, a recycling potential D at building level can be determined. There is a close interdependency between the information provided by modules C and the information determined in module D at the product level. In particular, the status of a product after its separation from a building component with respect to whether it is mixed or unmixed or polluted or unpolluted affects the type and quality of recycling possibilities. Currently, according to standardization, the determination of recycling possibilities is based on current technologies and their relative distribution. Possibilities arise for manufacturers to express the effects of take-back guarantees by means of information on module D.

Once again, it becomes clear how close the connections between the building and the product level are. It is suggested that this should be emphasized even more in standardization.

4. Consequences for instruments and tools

4.1. Information on construction products

Today, environmental information on construction products is typically in the form of an EPD, in the future perhaps in the form of a PEF. As a result of the EU research project BAMB, additional material passports are being proposed, which include information on the suitability of materials for recovery and reuse should be included in other products and processes, among others [12]. From the author's point of view, the distribution of product-related information to different instruments and formats is not expedient. Rather, there is growing demand on as complete as possible information in a format that can be further processed in building information models (BIM). Such product information should include as a minimum: (1) technical and functional characteristics and properties under defined conditions of use; (2) technical service life; (3) maintenance and replacement cycles; (4) instructions for transport, storage; processing, dismantling and recycling according to different possibilities; (5) complete LCA; (6) outgassing and washing-out behavior under defined conditions; (7) behavior in special situations (fire, flood, explosion); (8) type and extent of take-back possibilities at the end of the product's service/useful life provided by the manufacturers; (9) all substances/ingredients (in relation to firefighters and allergy sufferers); (10) recipe related to the used resources. In relation to the latter, an assignment to the groups of biomass, metals, non-metallic minerals and fossil fuels is preferable to a fully aggregated indicator such as ADP elements. So far, EPD does not include this differentiation.

An extension of the content of the EPDs towards capturing the full lifecycle is needed. Mandatory information on modules C and D is the subject of standardization activities under CEN TC 350.

The processability of EPDs in BIM has already been the subject of international standardization - see, for example, ISO/WD 22057 [Under development] "Enabling the use of Environmental Product Declarations (EPD) at construction works level using building information modelling (BIM)".

4.2. Material inventory and building files

For some time now, under the names of resource passport or material passport instruments are promoted which contain a description of the material composition of the buildings. They correspond to a material inventory that has traditionally been created by designers. The author sees them as part of a lifecycle-related object documentation in the form of a building file or home information pack. At a minimum, a material inventory should contain information such as a list of the products used with regard to the resources used, on the one hand, and with reference to the product name, approval and the manufacturer, on the other hand. Desirable is an assignment of the installed products to the different building parts (foundation, load-bearing structure, interior construction, building services), information on the time and type of de-construction of components (replacement of components in replacement investments, dismantling of the building) as well as the expected waste category (waste code).

Initiatives on material passports or building files have so far been unsuccessful. From the perspective of the author, the demand for such information must first be strengthened. In connection with the planning of the maintenance budget, the valuation or the sustainability certification (including complete life cycle assessment, or determination of a PEF for building, or determination of a carbon footprint), there is currently an increasing interest in information on the material composition of buildings.

The current initiative of the European Commission to improve the information on the sustainability of buildings LEVELs [13] contains under point 2.1.1 requirements for a "bill of materials" in the sense of a material inventory. It remains to be seen whether and when this proposal will prevail.

4.3. LCA and sustainability assessment

In order to be able to evaluate the deconstructability and recyclability of designs/building concepts already in the design phase, there is an interest in the determination and evaluation of a recycling potential [14]. This "Module D" for buildings must not be offset against other partial results of the LCA on buildings, but must always be specified as additional information. The sustainability assessment systems BNB and DGNB used in Germany already contain indicators for describing the deconstructability and

recyclability, the type and place of consideration of a module D inside a sustainability assessment system is still being discussed.

5. Research activities in Germany

In Germany, several research projects funded by the Federal Environment Agency are being processed. On the one hand, the basic principles and prerequisites for an extension of the EPDs to modules C and D are currently worked out. On the other hand, it is discussed how the demand for material inventories can be strengthened, which actors have a particular interest in such information and on which occasions the provision of such information is necessary. The results of the projects are reported elsewhere (see www.umweltbundesamt.de/en).

6. Summary and recommendations for action

On the part of the author the following recommendations for action are given:

- The topic of scarcity of resources as well as strategies for the conservation of natural resources in the design, construction and operation of buildings must be brought into public discussion even more than before. Many initiatives by the European Commission and its member states are already moving in this direction.
- It is recommended that the topics of resource conservation and climate protection be better integrated. In addition to the fact that resource conservation can contribute to climate protection, measures to protect the climate can trigger additional material flows. Measures to protect the climate and conserve resources should therefore be analysed in terms of their environmental, economic and social impact, preferably in the form of a complex sustainability assessment.
- The presentation of resource use divided into the groups biomass, metals, non-metallic minerals and fossil fuels should be preferable to a fully aggregated presentation. Discussion is also necessary on how to deal with the use of drinking water and land/surface area in the future.
- The bill of materials in the form of a material inventory becomes a relevant document and forms the basis for life cycle assessment, life cycle costing, the evaluation of risks to health and the environment, and the development of concepts for deconstruction and recycling. Discussion is necessary on whether and how the material inventory can provide a reference to the resources used in the manufacturing of the construction products on the one hand, and to specific product and manufacturer information on the other hand.
- A material inventory does not automatically have to become a stand-alone and independent document. Rather, it is a useful component of a building passport/building file approach. The material inventory should be supplemented by a comprehensively formulated deconstruction and recycling concept. How this information can be kept up-to-date and updated over a lifespan of up to 100 years is still unclear. Further research is needed in this direction.
- Legal requirements for the description of the material composition of buildings are pending. An alternative way is to stimulate the demand for such information. Thus, today valuation professionals, insurers, facility managers, as well as companies specialising in deconstruction and recycling processes, have an interest in information on the material composition of buildings. It makes sense that they articulate and enforce this need for information.

The sustainable design, construction and operation of buildings, which should contribute to resource conservation and climate protection, can be supported by the application and further development of information management methods.

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