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To cite this article: D Rochlitzer and T Lützkendorf 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1078** 012104

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# Management and communication of HVAC-specific life cycle-related information - filling the gaps for sustainability assessment of buildings

D Rochlitzer<sup>1</sup> and T Lützkendorf<sup>1</sup>

<sup>1</sup> Karlsruhe Institute of Technology (KIT), Kaiserstraße 12, 76131 Karlsruhe, Germany

E-Mail: daniel.rochlitzer@kit.edu

**Abstract.** Assessing the contribution of buildings to sustainable development is no longer just a matter of scientific investigation. Increasingly, such considerations are becoming a prerequisite for the award of subsidies or the fulfillment of legal requirements. One aspect is the evaluation of the environmental performance, based on a life cycle assessment of the complete building in its life cycle. This requires corresponding data on all installed products (materials, components, systems) on a consistent methodological basis and suitable communication forms. To that, information is required on technical characteristics and the life cycle assessment results of construction products. Thereby the following problems are occurring: (1) there are not enough environmental product declarations according to EN 15804 A2 available in the field of building services systems (e.g. HVAC) and (2) the data contained in EPDs do not fully cover the information needs of designers and decision-makers. This complicates the work of involved actors and endangers the competitiveness of product suppliers. In response, a proposal for a product information system for building services is presented. It is adapted to the specifics of HVAC systems and the information needs of related actors. The background is the situation in Germany, but results can be transferred to other countries / markets.

**Keywords:** HVAC-systems, Information Management, Information System, EPD, DoP

## 1. Introduction

Buildings and constructed assets form the basis for the development of the economy and society. However, this development must take place within planetary boundaries. In weighing up the costs and benefits, it is necessary to collect, evaluate and specifically influence the energy and mass flows and impacts on the global and local environment associated with construction, operation, maintenance and end-of-life. Life cycle analysis is applied to record the complete building in its entire life cycle. Among other things, life cycle assessment (LCA) and life cycle costing (LCC) are utilized.

LCA has been used for issues in the construction and building sector since 1990 [1,2]. In 2006, standards for LCA (ISO 14040 and ISO 14044) and the declaration of environmental data (ISO 14025) were published for the first time at the international level and have since been further developed. For the specific concerns of the construction and building sector, including the selection and assessment of building products, these ISO standards have been supplemented by ISO TC 59 SC17 and CEN TC 350 with specific norms (ISO 21930, ISO21931, EN 15643, EN 15978, EN 15804). In particular, EN 15804



A2 in its current version, combined with EN 15949, now provides a consistent basis for the creation and communication of environmental information on construction products. This data makes up the basis for the LCA of buildings as part of environmental performance assessment. In this context, construction products include building materials (e.g. concrete, building components (e.g. windows) and technical systems (e.g. building services), and thus all types of products that are integrated into buildings [3]. The importance of LCA in the building and real estate sector has recently been underlined by the draft of the European performance of building directive (EPBD) and the EU taxonomy, which endorse an LCA for new buildings to provide information on life cycle-based greenhouse gas emissions [4,5]. Also, this leads to a growing demand for related product information in line with EN 15804.

At the time of the introduction of EN 15804, there were 340 Environmental Product Declarations (EPDs) from three EPD program holders in Europe. By the beginning of 2021, this number had grown to over 10.000 standard-compliant EPDs from 32 program holders [6]. Thereby a large amount of environmental information for building materials and components has been published over the past ten years and can be used as a database for environmental performance assessment of buildings. In contrast, a considerable data gap exists for Heating, Ventilation and Air Conditioning (HVAC) components and systems. This is difficult to understand, as the increasing demand for EPDs for this product group also became apparent at an early stage. Already in 2010, the final report "Low Carbon Construction - Innovation & Growth Team" called for EN 15804 to become the basis for consistent measuring of greenhouse gas emissions from construction products of all kinds [7]. Since 2011, the EU Construction Products Regulation (CPR) indicates that EPD's should be used for a selection of construction products [8]. The growing need for data on EPDs for construction products has been accelerated by the worldwide use of certification systems for buildings, such as BNB (Sustainable Building Assessment System), DGNB (German Sustainable Building Council), LEEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) among others. LCA data is also playing an increasingly important role in the course of Building information modelling (BIM). In response, the ISO 22057 standard is being developed to address BIM-suitable formats for EPDs. A trend towards legal requirements is emerging to meet the need for data and thus create a basis for LCA of buildings. In the summer of 2021, France passed the "Réglementation Environnementale 2020", which requires LCA for new buildings and EPDs for the included construction products from January 2022 [9]. By now in addition to the legal requirements, LCA requirements also play a more significant role in funding programs and customer requirements. In the design of e.g. climate-neutral buildings further ecological, technical, functional, economic and sociocultural information and assessment aspects must be taken into account. That creates new demands for product-related data in addition to the information contained in an EPDs.

The object of consideration should be the entire building. By this, design issues are included, which go beyond the concerns of the building envelope and contain the building service engineering. In this context, the CPR draft attempts to develop a framework for improving the performance of construction products based on defined basic requirements for construction works [10]. Also, the Commission will be empowered to establish a central EU construction product database to simplify access to product information. For energy-related construction products, priority for the setting of requirements is given to the Ecodesign for Sustainable Products Regulation [11].

In practice, it is apparent that despite the increasing demand for HVAC related product information, the database for HVACs has the most extensive data gaps among the construction products. Furthermore, the industry remains uncertain concerning the downstream players in the process chain as to which data is required and when. Also, in the majority of LCAs of buildings that have been published in the past, the environmental impacts of building services have hardly been taken into account or have only been considered as a lump sum [12,13]. This situation is unsatisfactory. With an increasing presence of technology in buildings and more building-integrated systems for the use of renewable energies, the problem of missing data grows larger. Studies that investigate the environmental impacts of HVAC mainly consider office and residential buildings. They estimate the environmental impact of building services as significant. Its share in the whole building life cycle assessment amounts to one-third of the

environmental impact caused, with 2 - 48 % tolerances occurring [14-16]. The GWP share amounts to 15-36 % of the total embodied carbon content of the building [13,17,18].

On the one hand, this must include the data requirements of designers and decision-makers and on the other hand, it must take into account the interests and possibilities for action of manufacturers, who for their part, depend on information from upstream and downstream processes along the value chains. This paper aims to present the main features of a comprehensive information system for HVAC products based on the data needs of the players involved in the design and realization of buildings. The approach describes the situation in Germany; however, the results presented can be transferred to other countries and or markets in Europe.

## 2. Requirements and basics for a product information system

A product information system is a collection of data on a product and forms the basis for modeling the building and its life cycle. The life cycle is shown in green in Figure 1 and is faced with the individual construction project phases of the Committee of the Associations and Chambers of Engineers and Architects for the Fee Regulations (AHO), the Fee Regulations for Architects and Engineers (HOAI) and the tasks of facility management. Likewise, on the right in Figure 1, the phases of EN 15643 are assigned to the building life cycle. This shows that the contents of the product information system must extend beyond the concerns of the construction project phases, facility management tasks and EN 15643. Since the HVAC products usually have a shorter use phase than the entire building, the aspects of circularity must be included in the solution approach. The circularity can be optimized by increasing the efficiency, reusability and service life of the products, their components and by improving recyclability.

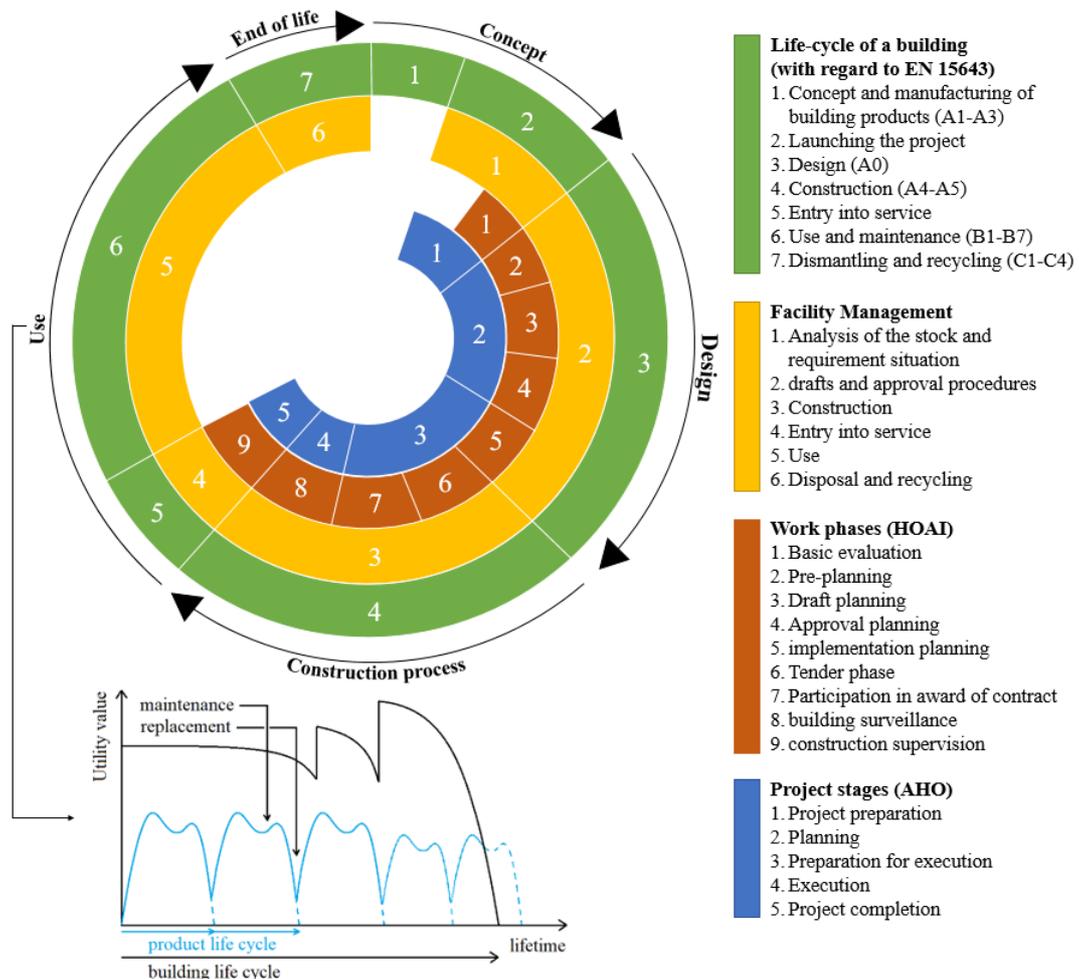


Figure 1. Phase model for the design process and life-cycle of a building, based on [19]

The product information system intends to support engineers and product manufactures, among others. Data needs can then be served from a central database and substantiate decisions with information. The initial point for the development of the product information system is the analysis of the building life cycle, the product life cycle, the design and decision-making processes, including the information needs of involved stakeholders.

### 2.1. *Life cycle of construction products*

A life cycle analysis assumes that an object of consideration (e.g. product, process or service) passes through several phases along its life cycle. The resulting energy and mass flows and environmental impacts can be precisely quantified, assigned to individual life cycle phases in accordance with EN 15804+A2 and finally displayed in suitable communication formats (here B2B) using LCA. They form the basis for an environmental performance assessment in accordance with EN 15643 and EN 15978.

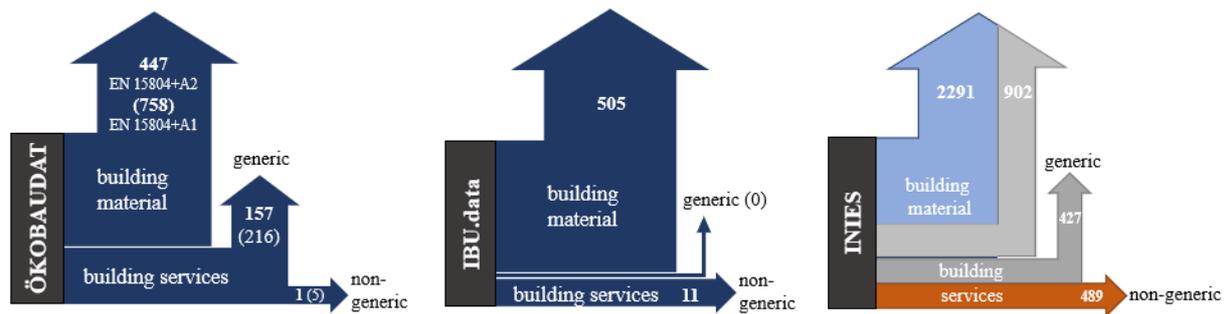
### 2.2. *Involved actors*

The clients and owners, designers and engineers, manufacturers, suppliers, craftsmen, demolition, disposal and recycling companies, and users directly influence the environmental impacts which are allocated to the construction and building sector, including the upstream and downstream industries. Their decisions and actions have a direct impact on building technology. In addition, funding agencies, banks, insurance companies and society have an indirect influence. Finally, politics, municipalities, and raw material manufacturers impact the product life cycle. These usually provide a cross-project framework for action in the construction industry, but they have no connection to a specific construction project or building product. In a product information system, the data needs of specific groups of actors with direct influence are to be considered first and foremost. On the one hand, their information needs also include other actors' interests (e.g. funding criteria), and on the other hand, the concept of a product information system can be extended with missing data.

### 2.3. *Initial situation in the HVAC sector*

Implementing an information management system for the creation, procurement, and administration of data is beneficial both for the companies themselves and the planners. On the one hand, a variety of formats with product information can be served from one source (safety data sheet, technical data sheet, EPD, Declaration of Performance - DoP, Product Environmental Footprint - PEF). On the other hand, designers and engineers have access to required specific information. HVAC design practice is still often hampered by time-consuming duplicate data entry processes, missing or non-transparent data, lack of information exchange or inaccurate product information. Data needs are increasing, especially for HVAC, including LCA data. Life cycle assessment data on building products are used to evaluate the environmental performance of buildings holistically. In Germany, however, building life cycle assessments have not been and are not yet being applied across the board and only rarely are the environmental impacts of HVAC systems considered. With the funding program from the Reconstruction Loan Corporation, calculation results for the Global Warming Potential (GWP) have become, in concerns of the proof for the Quality Seal for Sustainable Buildings (QNG), for the first time, a prerequisite for funding. The draft of the EU Energy Performance of Buildings Directive defines that LCA of GWP will be carried out in Europe from 2027. The EU Taxonomy already requires this for large buildings.

Such LCAs require the ISO type III environmental declaration, such as the EPD. Figure 2 shows the product-related availability of environmental information from the three largest European databases for building products. In February 2022, a total of only 12 non-generic (including specific) current data sets were available for the building services product portfolio in accordance with EN 15804+A2. In contrast, 584 generic HVAC datasets exist (according to EN 15804+A1). In a specific EPD, a company specifies the product-related environmental impacts. If no specific data is available, generic data is generally provided and used in databases. They are based on alternative accessible sources, such as technical literature. The uncertainties in the generic data are taken into account, with safety margins of up to 30% on the indicator values recorded [20].



**Figure 2.** Construction product datasets, based on ÖKOBAUDAT, IBU.data and INIES

Due to the current data basis, the environmental impacts of HVAC are usually not considered at all or only as a lump sum. For example, while the simplified procedure of the DGNB and the BNB consider the embodied impacts of building services as a lump sum, these are not considered in LEED [21] and in BREEAM [22].

The FDES (Fiche de Déclaration Environnementale et Sanitaire), DED (données environnementales par défaut), PEP (Product Environmental Profile) and the EPD offer standard-compliant environmental information and thus increase the data basis for the ecological assessment of buildings. In addition, an EPD also contains administrative and process-related information, which are listed in Table 1.

**Table 1.** Information content of an EPD

Process information	Administrative information	Environmental information
Geographical, temporal and technological representativeness	Client and owner	18 Indicators on the use of resources
Validity, scope	Registration detail	13 Core environmental impact indicators
Functional unit	Data creator and publisher	6 Optional environmental impact indicators to be specified
Data sources and data type	Identification number	
Conformity to standards and language	License, access and usage restrictions	

However, this does not entirely cover the environmental information needs of planners. Of course, an EPD is not the only source of information. However, from the authors' point of view, it makes sense to integrate EPDs into a superordinate system of product information.

Therefore, the proposal for a product information system for building technology considers further data for ecological assessment that are not required by the EN 15804+A2 standard. At the same time, it is proposed to provide adjustable EPDs for the development process for new products or product variants, which should be available when the products launch on the market.

Depending on the type of HVAC product, there are a number of laws (e.g. Product Safety Act and Product Liability Act), standards (e.g. DIN EN 82079-1 and DIN EN ISO 9241) and general as well as specific directives (e.g. Ecodesign Directive or EC Machinery Directive) that set minimum requirements for product characteristics and contents of technical documentation. For the harmonization and extension of such documentation for the purpose of improving the performance of construction products as well as the quality of product-related data, a framework is developed in the draft of the CPR. Annex I Part B lists requirements, which will not be relevant in their entirety for all HVAC products. The example of an air-handling system in Table 2 can demonstrate this. While all CPR requirements for active units, such as ventilators, are highly relevant, some requirements regarding the energy consumption,

software failures, electricity etc., are not applicable for passive components, such as a filter, sound absorber, air duct and (fire) dampers. Consequently, the generally formulated product requirements must be understood as the highest common denominator, which must be checked for applicability and concretized individual for the HVAC categories.

**Table 2.** Applicability of CPR requirements to different HVAC products (example air-handling unit)

		Air handling system	
		active units	passive units
<b>product safety requirements</b>	chemical risks due to leaking or leaching		
	risk of unbalanced composition of substances resulting in flawed, safety-relevant functioning		
	mechanical risks		
	mechanical failure		
	physical failure		
	risks of electric failure		
	risks linked to electricity supply breakdown		
	risks linked to unintended charge or discharge of electricity		
	risks linked to software failure		
	risks of software manipulation		
	risks of incompatibility of substances or materials		
	risks linked to the incompatibility of different items, at least one of them being a product		
	risk of not performing as intended, whilst the performance is safety relevant		
	risk of misunderstanding instructions for use in a field affecting health and safety		
	risk of unintended inappropriate installation or use		
	risk of intended inappropriate use		
<b>product environmental requirements</b>	durability requirements		
	minimising whole-life-cycle greenhouse gas emissions		
	maximising recycled content without safety loss or outweighing negative environmental		
	selection of safe, environmentally benign substances		
	energy use and energy efficiency		
	resource efficiency		
	identification which product or parts and in what quantity can be reused after de-installation		
	upgradability		
	reparability during the expected life span		
	possibility of maintenance and refurbishment during the expected life span		
	recyclability and the capability to be remanufactured		
	capability of different materials or substances to be separated and recovered		

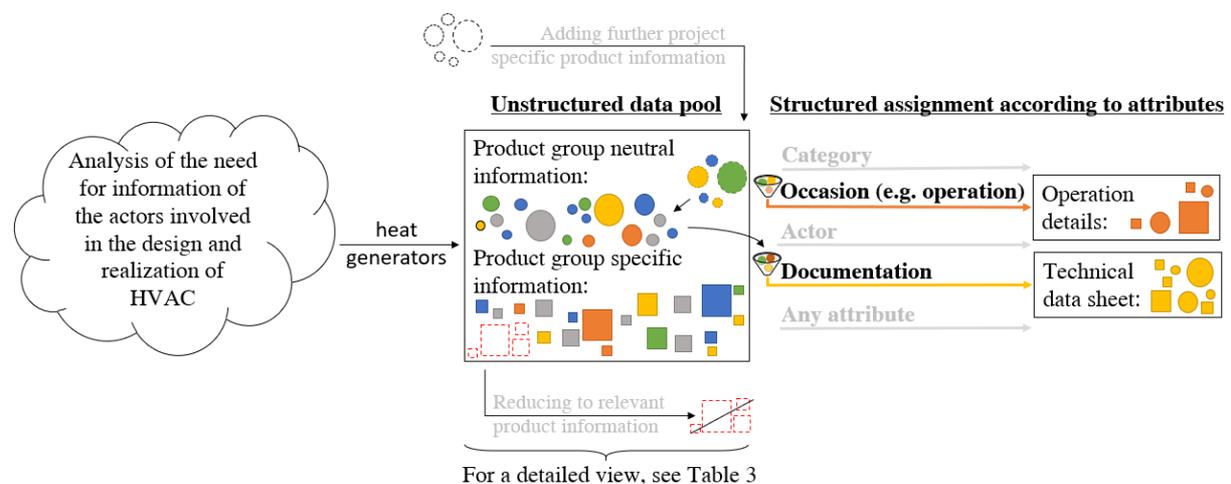
Additionally, it should be noted that the CPR and therefore these requirements do not apply (in the current draft) to lifts, escalators, boilers, pipes, tanks, systems treating wastewater, sanitary appliances, ancillaries and other products intended to be in contact with water for human consumption [23]. That will create data gaps for LCA of buildings and need rethinking.

Apart from these minimum requirements, manufacturers and other stakeholders can carry out the product-related documentation at their own discretion. Consequently, the documents on the market differ from each other in scope and content. Moreover, the efficiency details for equipment and systems are usually based on normative characteristic values, which can deviate significantly from actual values. This situation makes it difficult for planners to draw up comparisons of variants in consideration of sustainability aspects and to prepare LCAs.

The challenge with an equally crucial economic valuation is often the determination of current cost parameters. They involve greater uncertainties due to widely varying prices. Usually, reference projects, experience reports, standard specifications, market data and relevant technical literature are used to narrow down the range of possible costs. For this purpose, the product information system offers non-monetary information to support cost calculation. This includes information on working hours (e.g. assembly time) as well as repair and replacement cycles, which support life cycle costing (LCC).

### 3. Proposal for a structured product information system for building services engineering

The starting point for developing the product information system was an analysis of properties, characteristics and other relevant information for the design of HVAC as well as sustainability assessment of buildings. The list of required information generated from this does not claim to be complete. Rather, the example of heat generators (e.g. heat pump, oil, gas and pellet heating system) is used to explain how an information management system can be structured to serve corresponding information needs in a targeted manner. Table 3 schematically presents the structure of a product information system. According to the concept developed, it is initially placed on the manufacturer's side and can be used to serve the information needs of third parties consistently from a database. Manufacturers can thus generate documents of all kinds, including EPDs, PEFs, safety data sheets, and so on. At the same time, they can decide whether and to what extent they allow designers and others direct access to the system.



**Figure 3.** Development of the product information system

### 4. Unstructured versus structured data

Table 3 presents a systematic of information without interpreting it as a fixed shape. As illustrated in Figure 3, the first step is to obtain this data from third parties (e.g. upstream suppliers, service providers for LCA). The information requirements already existing in the information system can be adapted to individual problems in the product description by extending or reducing them. Basically, the data pool consists of product group-specific and product group-neutral information requirements. The latter can be adopted unchanged for other HVAC product groups deviating from heat generators. The data pool resulting from the information procurement can already provide the basis for an information system, as long as required data is held and suitable search functions are found. This search can be supported by an allocation with the help of order principles and attributes. Alternatively, these provide options for the transition to a structured system.

Using the attributes listed in Table 4, the data can be assigned to an information category or to occasions, actors and document types. Since identical content can often be allocated to multiple search terms, the authors believe the future for communication of HVAC related information lies in non-hierarchical management of data. Multiple attributes selections for further targeted product specifications are workable as desired. The order principles and attributes can be optionally extended.

**Table 3.** Structure of contents of a product information system (example heat generator)

<p><b>Product identification<sup>1</sup></b>  Product name  Product code  Product group  Year of manufacture</p> <p><b>Manufacturer identification<sup>2</sup></b>  Company name  Address  Website</p> <p><b>Documentation</b>  Technical Data Sheet  Declaration of performance  Safety Data Sheet  Maintenance and inspection guide  Environmental Product Declaration  Label</p> <p><b>Technical features and properties<sup>3</sup></b>  Requirements at the installation site  Weight, dimensions  Description of relevant components  Performance, consumption data<sup>4</sup> / efficiency class  Service / maintenance friendliness &amp; cycles  Fuel type and quality  Retrofitting capability<sup>5</sup>  Special features of storage, transport, installation  Special features of dismantling and utilization  Properties with regard to exceptional impact<sup>6</sup></p> <p><b>Delivery form and installation instructions</b>  Size and weight of the individual parts  Packing type  Installation requirements  Commissioning / Adjustment</p> <p><b>Social aspects</b>  Ergonomics  Operator friendliness  Product safety</p>	<p><b>Data for Facility Management / Operation<sup>3</sup></b>  Workload during usage  Safety<sup>7</sup> requirements / test specifications  Type and cycles of inspection and maintenance  Type and cycles of replacement of components  Possibility of remote diagnosis / maintenance  Functional scope for control  Equipment for monitoring</p> <p><b>Circular economy data on product &amp; packaging</b>  Friendliness of deconstruction / recycling  Utilization / reuse  Manufacturer incentives to return equipment  Inventory of materials<sup>8</sup></p> <p><b>Environmental data (excerpt from extended EPD<sup>9</sup>)</b>  Lifetime  Resource consumption  Effects on the global environment (LCA)<sup>10</sup>  Effects on local environment - emissions  Noise level</p> <p><b>Contractual matters</b>  Warranty period  Product liability and disclaimer  Possibilities for leasing  Possibility of (full) maintenance contract  Spare parts supply guarantee  Return condition and guarantee</p> <p><b>Corporate Environmental &amp; social responsibility</b>  Sustainability Report  Environmental management system  Participation in take-back &amp; collection systems  Compliance with environmental and social standards<sup>11</sup></p> <p><b>Service offers of the company</b>  Product consultation  Planning and dimensioning guides  Tender assistance  Training offers for craftsmen</p>
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<sup>1</sup> for the product system and individual components<sup>3</sup> Part of the data is the basis for costing<sup>5</sup> also in terms of the interchangeability of components<sup>7</sup> e.g. fire behavior, compressive strength, electrical safety<sup>9</sup> according to EN 15804 A2 and EN 15952<sup>10</sup> a.o. GWP<sup>2</sup> Importer, if applicable<sup>4</sup> Including demand for operating supplies<sup>6</sup> Fire, flood, mechanical destruction, earthquake<sup>8</sup> with information on pollutants, waste code, grade purity and end-of-life processes<sup>11</sup> incl. upstream chains

**Table 4.** Possibilities of structuring information

<b>Order principle</b>	Attributes
<b>Categories</b>	technical, ecological, economical, sociocultural, administrative, organizational, (contractual-)legal
<b>Occasions</b>	<b>Relation to life cycle:</b> storage, transport, installation/assembly, commissioning, operation, maintenance, repair, retrofitting/removal/conversion, dismantling, disposal/recycling <b>Relation to design:</b> dimensioning, consulting, tendering
<b>Actors</b>	Owner/investor, manufacturer, dealer, architect, specialist planner, contractor, operator/user, maintenance companies (heating engineers, chimney sweeps) Demolition and disposal companies, recyclers
<b>Documentation</b> (data for documents available from product information system)	<b>Plant documentation:</b> Technical datasheet, parts list of system components, safety data sheet, declaration of performance, environmental product declaration <b>Installation documentation:</b> Mounting instructions, delivery form <b>Operating documentation:</b> Operating instructions/manual, care, cleaning and maintenance instructions (inspection, maintenance, repair), accessories/spare parts catalogue <b>Deconstruction documentation:</b> Material data sheet, disassembly instructions
<b>Transformation</b>	product group-neutral, product group-specific

## 5. Excursus on the further development of environmentally relevant information

As a strategy for conserving resources, attention is currently growing on the topics of closed-loop recycling. Here, the question arises about how recycling-friendly HVAC systems and their components are developed. As a result, the need for information on recycling potential is increasing.

At the same time, there is growing interest in evaluating the use of primary raw materials as part of natural resources. The ADP<sub>element</sub> indicator used so far is not well suited for this purpose. What is needed in terms of resource management is a detailed description of the product's material composition and its components. Mineral raw materials and ores are of particular interest in assessing the cumulative raw material input. Just as a building has a different life cycle than its individual parts, so do HVAC systems and their components. Modules B4 and B5 in a LCA of technical systems should therefore be interpreted as replacement or modernization of components. In this respect, the components' replacement cycles should be indicated and the possibilities of their (later) upgrade or modernization.

## 6. Discussion

The product information list has so far only been developed for heat pumps, oil, gas and pellet heating systems concerning the information needs of actors with direct influence. For the evaluation of less widely used heat generators, such as fuel cells, as well as for the consideration of further actors, the information system may need to be expanded to include additional types of characteristics. Furthermore, the application of the production information system must be transferred to other product groups. The proposal has not yet been coordinated with industry representatives; this will be done next.

Moreover, it is recommended to extend the research of the available Type III environmental information for HVAC beyond the scope of Figure 2. So far, the question remains unanswered how extensive the database of European environmental declarations is, in general for HVAC and in detail for their product groups. In this sense, it would be of further interest to determine whether practice proved product categorization rules for the creation of environmental declarations for HVAC are already available

abroad, which could serve as a template for the German market. For the cross-national use of standard-compliant EPDs, it should be clarified how the representativeness of the data can be proven for the respective application. Available environmental data are based, among others, on regionally different resource flows (e.g. energy mix electricity production). Equally crucial is the question of whether B2B communication formats for EPDs should be adapted to the special features of HVAC and whether considerations presented in section 5 should be incorporated into standardization.

## 7. Conclusion and outlook

This contribution shows an unmet information need for the HVAC systems and that a requirement-oriented design would have great potential for system and product selection improvement, when sustainability considerations are included. Central information management and an understanding of sustainability extended to the complete product life cycle can help exploit this potential. For this purpose, this contribution proposes the main features of a comprehensive product information system, particularly for the companies involved in building services engineering, to help them quickly close existing information gaps. Both is in their interest (e.g. product optimization) and in the interest of all those who need the data to fulfill their tasks. Regarding environmental information for HVAC, the data foundation has been lacking for more than a decade. With the increasing mechanization of buildings and building services the need for data continues to grow. The preparation of environmental data over the complete product life cycle through the application of LCA is standardized by EN 15804 A2 and EN 15949. Nevertheless, too few EPD's exist, so the environmental impact of HVAC can hardly be determined. The solution approach integrates the EPD into a superordinate system of product information. It proposes additional information not required by EN 15804 A2 or the CPR for developing building services related data to adapt the EPD's to HVAC specifics.

The challenge in the implementation of the information system is to analyze the data needs and decision-making situations of the actors, to identify missing data bases and to compile relevant available information comprehensively. Subsequently, this information is then provided with attributes to classify it according to concrete questions. This ongoing process can be pursued for the group of heat generation systems and - based on this example – be implemented for other product groups.

The presented information system improves the flow of information along the value chain by enabling product manufacturers to orientate their product design towards the information needs and wishes of the downstream actors in the process chain.

Product-related documentation in HVAC development is project-neutral to a certain extent and goes beyond the provision of product information. For the management and communication of life cycle-related information for product optimization, additional tools such as C2C or B2C standardized document templates (e.g. DoP, tender boilerplates etc.) adapted to the product information system should therefore be contemplated. With this, the exchange of information between the building level (requirement / demand side) and the product level (offer/ supply side) can be improved along the value chain.

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