Towards a Complete Tool Chain for Eco-Balancing Governmental Buildings

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Abstract

With the Assessment System for Sustainable Buildings for Federal Buildings (BNB), Germany is pioneering the implementation of certification systems for Sustainable Buildings in Europe. Using BNB methodology and tools, building products are not assessed as individual products, but looked at within the context of the entire building and its parts. The most important impacts of the building on the global environment (i.e. environmental burdens like ozone depletion or consumption of resources like energy and water) are assessed by means of Life Cycle Assessment (LCA) methodology and are calculated according to the Type III Environmental Product Declarations (EPD) standard for building products described in ISO 14025 and EN 15804.

This paper will describe the tool chain needed to first calculate EPD data sets in LCA tools, store them in a central repository, the ÖKOBAU.DAT, and how the EPD data sets can then be used in other tools for calculating the environmental footprint of an entire building.

1. Introduction

With the Assessment System for Sustainable Buildings for Federal Buildings (BNB) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), Germany is pioneering the implementation of certification systems for Sustainable Buildings in Europe. It is one of the few countries where the state requires a binding sustainability assessment for its federal construction projects. Most European Countries use such certification systems only on a voluntary basis, if at all.

Using BNB methodology and tools, building products are not assessed as individual products, but looked at within the context of the entire building and its parts. Particularly with respect to Ecological Quality, building materials form an essential part of the overall assessment. The most important impacts of the building on the global environment (i.e. environmental burdens like ozone depletion or consumption of resources like energy and water) are assessed by means of Life Cycle Assessment (LCA) methodology. In addition to the construction phase of the building materials and components, also their use phase and end of life aspects are taken into account in the process models which are used for the calculation of the needed assessment indicators. These calculations are performed according to the Type III Environmental Product Declarations (EPD) standard for building products described in ISO 14025 and EN 15804.

The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), a research institution under the portfolio of the BMUB, has initiated and is maintaining the ÖKOBAU.DAT - a database of life cycle assessment (LCA) data sets for generic and specific construction materials and components which provides the essential data sets needed for the

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assessment of buildings according to the Type III Environmental Product Declarations (EPD) standard for building products described in ISO 14025 and EN 15804. Both, the technical database system which is used to store the ÖKOBAU.DAT data sets, i.e. soda4LCA (service oriented data base system for LCA) [6], which is developed by the Institute of Applied Computer Science (IAI) of the Karlsruhe Institute of Technology (KIT), and the technical data format used for the EPD data sets have been described in a paper presented at the EnviroInfo 2013 conference in Hamburg [7].

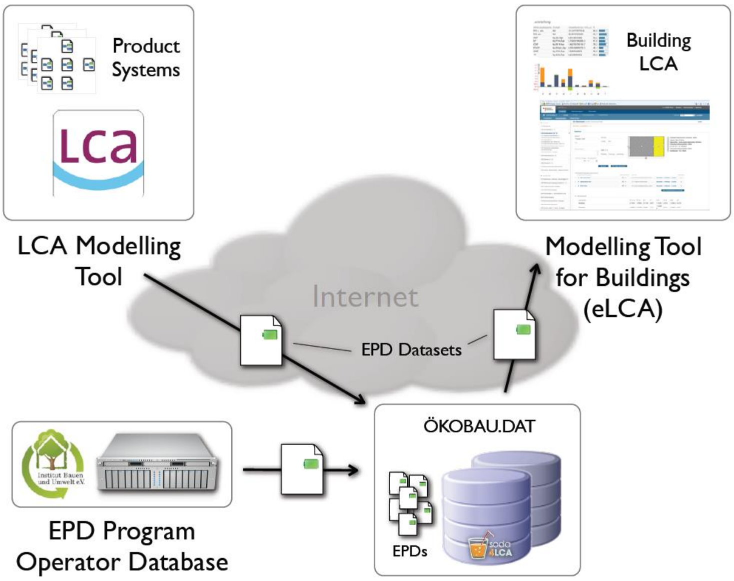

Figure 1: EPD data set tool chain

This paper will therefore not focus on the EPD format and EPD data storage itself, but rather on the complete tool chain (see Figure 1) needed to first calculate EPD data sets in a LCA modelling tool, then transfer and store them in the ÖKOBAU.DAT and finally access the data sets with another tool for calculating the environmental footprint of the entire building. In a project financed by BBSR and led by IAI called "ÖKOBAU.DAT Interfaces", this tool chain was explored in deeper detail to analyse deficiencies in the EPD data format, in the calculation of such data sets, in the service API for accessing and storing data sets in the ÖKOBAU.DAT, and to identify and eliminate issues which pose problems for the final calculation of the entire building footprint in the modelling tool used by the architects.

While the GaBi LCA tool by PE International AG was used for the calculation of most existing EPD data sets provided by the ÖKOBAU.DAT, it was decided within the mentioned project to enhance the open source LCA software tool openLCA [5] developed by GreenDelta GmbH, which at that time had no support for EPD calculation, to fully support the calculation of EPDs and use openLCA for analysing the EPD calculation process within the tool chain. This decision was made because in openLCA the required algorithms can be implemented as closely as possible according to the EPD standards and the open source nature of openLCA allows it to easily examine the implemented algorithms and can therefore provide guidelines and best practices for other vendors how to implement the EPD calculations within their own LCA tool. Furthermore, openLCA has already a very good integration with the soda4LCA database system used for the ÖKOBAU.DAT so that calculated EPD data sets can be directly stored within ÖKOBAU.DAT from the openLCA tool.

The eLCA tool implemented for the BBSR by beibob is a web based tool used by architects for the calculation of a BNB conform environmental footprint of governmental buildings. Prior to the "ÖKOBAU.DAT Interfaces" project, the eLCA tool already used EPD data sets for its calculations, but was based on a previous and not standard-conform format definition for EPD data sets. This led to many problems in eLCA which were addressed by the redesign of the format in the “Fortschreibung ÖKOBAU.DAT” project which is described in [7]. In the “ÖKOBAU.DAT Interfaces” project, eLCA was adapted to the new format and fully integrated with the ÖKOBAU.DAT using the REST-based service API of soda4LCA [2]. This led to a more consistent and easier use of the EPD data sets in eLCA and a much more flexible modelling approach for the complete building model.

In the following chapters the implementation and central concepts of EPD data set calculation in openLCA and the usage of EPD data sets in eLCA will be described in more detail. Also the interaction between openLCA, the ÖKOBAU.DAT and eLCA via the service API are explained. Finally, some lessons learnt and further work to be done will be discussed.

2. Implementing EPD calculation in LCA tools

openLCA [5] developed by GreenDelta GmbH is a freely available, open source LCA modelling tool for professional Life Cycle Assessment and footprint modelling which supports all common modelling options, such as parameterization and complex mathematical models for unit processes, describing complex process and product models graphically as connected process chains (see Figure 2), supporting different kind of allocations and system expansions and even uncertainty calculations. Calculation capabilities include LCI and LCIA result calculations for arbitrary common LCIA methods and visualization options of the results, like Sankey diagrams to visualize hotspots.

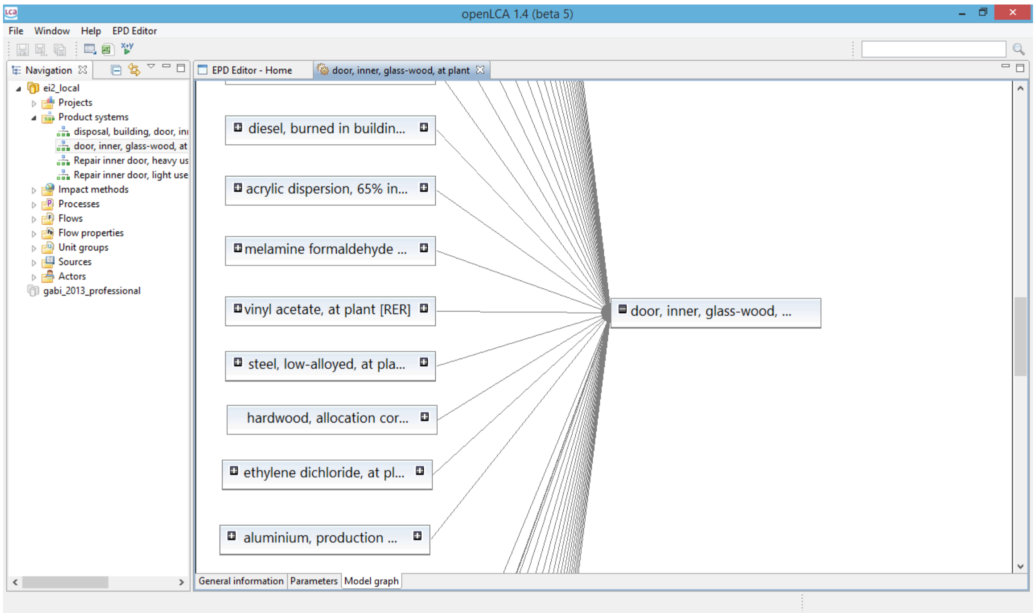

Figure 2: openLCA tool showing a process chain (product system) modelling the production life cycle phase of a typical inner house door made of glass and wood

Because openLCA is based on the Eclipse Rich Client (RCP) application platform, it can be easily extended by writing new Eclipse plugins for the platform [1]. Therefore, the EPD generation support was implemented in openLCA as an additional Eclipse plugin. The main home screen of this plugin in openLCA is shown in Figure 3. It provides controls for the creation of new EPDs, for configuring the connection to a soda4LCA server [2] (i.e. the ÖKOBAU.DAT) and searching for EPD datasets within the EPD repository. The plugin provides further functionality to change the configuration of indicators which should be calculated and for defining additional material properties which authors can use to attach such properties to EPD products for the later use by the building calculation tool.

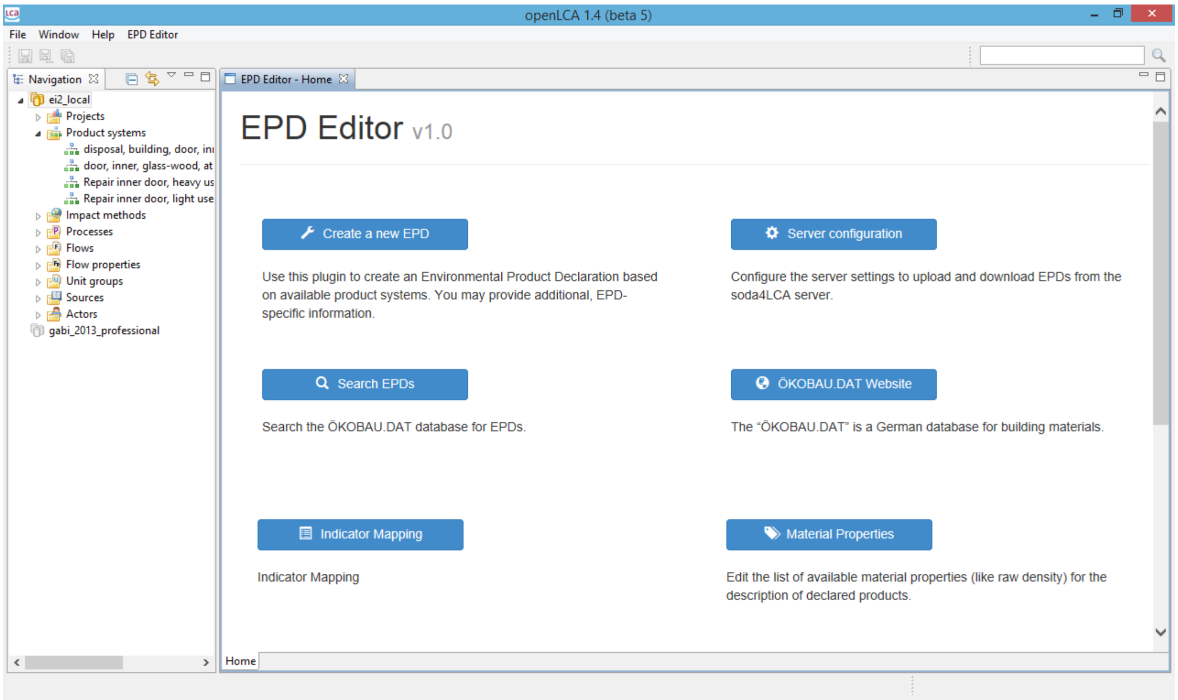

Figure 3: openLCA plugin providing support for EPD editing and calculation

Since the EPD format is based on the ILCD data format [4,8] and openLCA already supports the ILCD format as well as arbitrary LCI and LCIA result calculations based on ILCD method data sets which contain machine readable calculation procedures for LCI and LCIA indicators, EPD support can be easily implemented in openLCA.

The main addition which had to be implemented for openLCA was a new calculation project context which allows to group several product systems describing the process models of a construction material or component in the different life cycle phases (production of the material, installation, use phase, end of life) as well as rules for calculating the EPD LCI and LCIA indicators along the specified life cycle product chains into one calculation project context.

To create a new EPD calculation project, the process models (product systems) of the different life cycle stages (production phase, transport, use phase, disposal) have to be created first. Figures 2 and 3 show that product systems ("disposal, building door, inner, glass-wood" to model the disposal stage, "door, inner, glass-wood, at plant" for the production stage and two scenarios for the use stage "repair inner door, heavy usage", "repair inner door, light usage" for modelling heavy and light usage of the door) are already available for a generic construction product "door, inner, glass-wood, at plant", which is a door made out of glass and a wooden frame.

A new EPD project using these product systems can now be created by clicking on the "Create a new EPD" button at the home screen of the EPD plugin in openLCA (see Figure 3). The plugin will then show a creation wizard which asks for the name of the new EPD project, a description text and the reference product for the EPD. In our example, the reference product will be "door, inner, glass-wood, at plant".

After finishing the creation wizard, openLCA will show a screen which looks like that shown in Figure 4 but with empty upper and lower tables at the right part of the screen. The modeller will then define in the upper table of the screen which product systems will cover what kind of life cycle stage of the product (e.g. “A1-A3” for the production stage, “B3” for usage and “C4” for the disposal. In the case that several scenarios are modelled in different product systems, an identifier for the corresponding scenario should be attached to the product system entry as well.

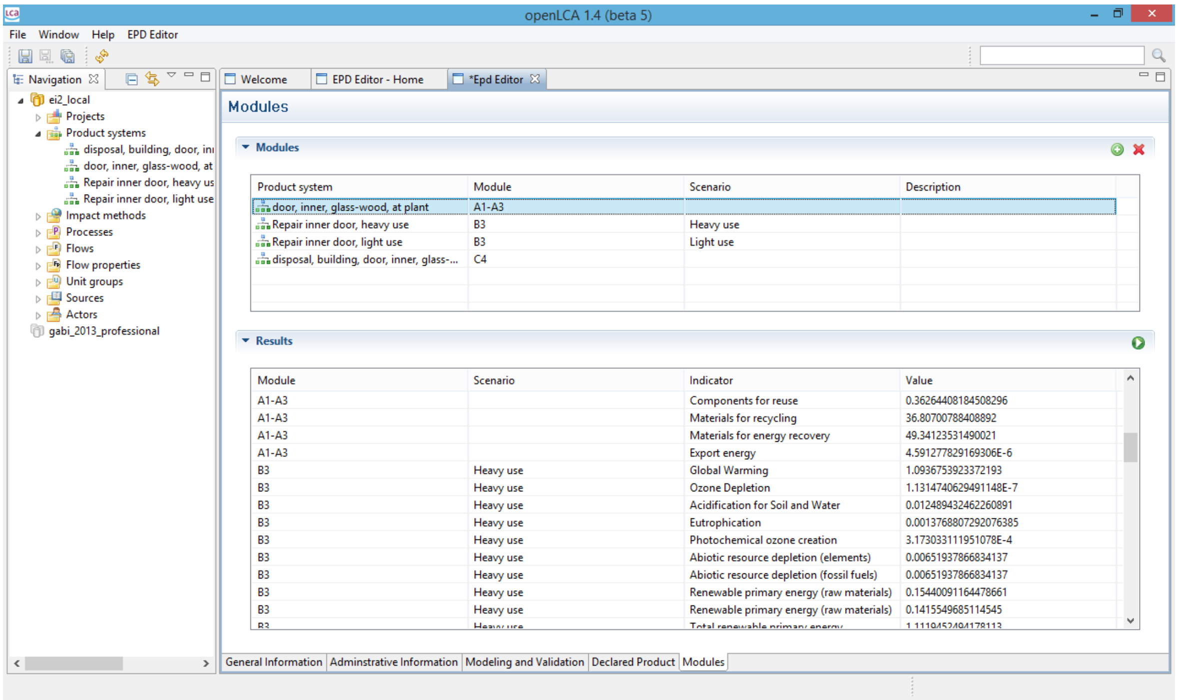

Figure 4: EPD calculation screen after calculation of the values

After defining in the upper table of Figure 4 which product systems should be used for calculating the indicators for the different life cycle stages, the calculations can be performed by pressing the calculation button.

The information which calculations have to be performed is stored in a calculation project profile which will be loaded when a modelling user creates a new EPD calculation project. The LCA tool can then access the calculation rules through corresponding LCIA method data sets and perform the calculations along the process chains attached to the calculation project by the modeller. The calculated results will then be shown in the lower table seen in Figure 4. As already described before, the calculation profiles can also be edited in openLCA. This can be used to create other forms of EPD calculations like those which are used in the construction sector.

Besides calculating the values of the indicators of an EPD based on available product systems modelled, the EPD editor of openLCA allows also the manual input and updating of result lines in the lower table of Figure 4. Thus, openLCA can be used as a simple EPD editor when the calculations are already performed with another tool and only an EPD conform dataset has to be created.

After calculation and quality control of the EPD dataset, it can be saved from within the openLCA directly into the ÖKOBAU.DAT EPD repository which is based on the soda4LCA software [6]. soda4LCA supports the creation of separated data stocks (storage container) in which datasets can be stored [3]. Normally, a LCA tool like openLCA should be configured to store new EPD datasets in ÖKOBAU.DAT in a data stock called “inbox”. The maintainer of ÖKOBAU.DAT can then first review the datasets when arriving in the inbox and perform quality control. If datasets are of sufficient quality they can then be moved to a certain production data stock (i.e. a special released version of the ÖKOBAU.DAT). Otherwise they are rejected and the submitter will be notified that certain aspects of the dataset have to be corrected.

Tools, that merely use EPD datasets, should only access data stocks in ÖKOBAU.DAT which contain released EPD datasets (i.e. they work with one of the released version of ÖKOBAU.DAT). One of these tools is eLCA, which will be described next.

3. eLCA – Using EPD data sets for assessing governmental buildings

A first step in using EPD datasets from ÖKOBAU.DAT in eLCA is the import of all EPD datasets of a certain version of ÖKOBAU.DAT into the internal database of the tool. In eLCA this import can be easily achieved because it uses the soda4LCA REST API to access the ÖKOBAU.DAT (see Figure 5). Via the API the user can first select a version of ÖKOBAU.DAT from the list of available release data stocks (e.g. in Figure 5 the data stock "ÖKOBAU.DAT 2014" was selected) and can then start the import process.

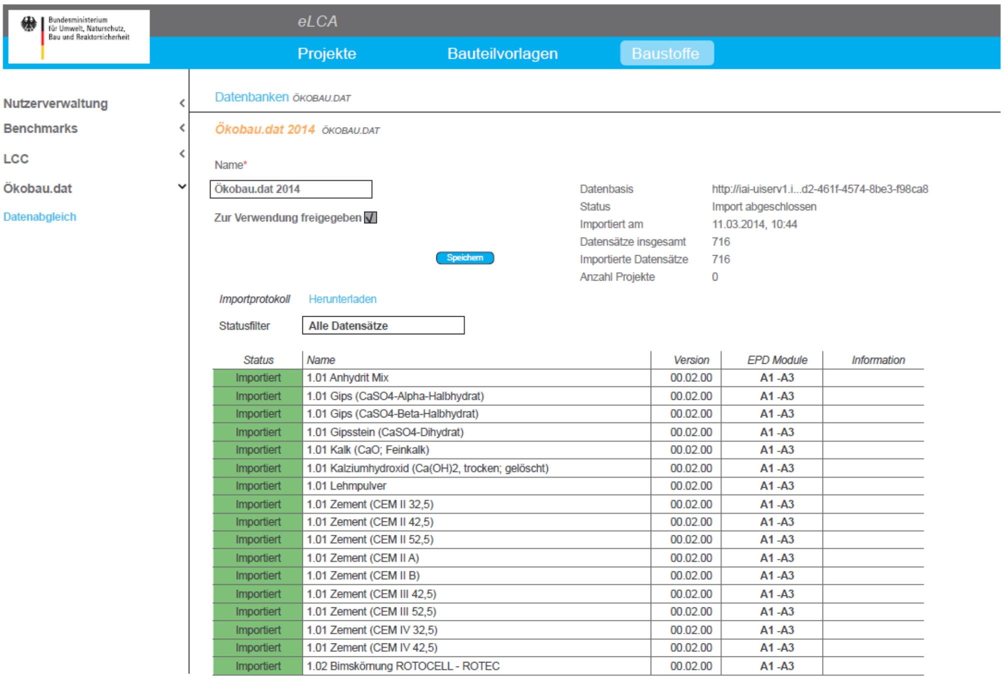

Figure 5: Import screen of eLCA

eLCA will then import all data sets from the given release data stock and will perform some comparison and sanity checks to make sure that the imported datasets will be of good enough quality as well as compatible and usable within the tool. The results of these checks will then be presented to the importing user (see Figure 5) who can then decide if the datasets should be made available for modelling.

To ease the modelling of buildings for assessing an entire building, the eLCA tool provides the architect with functionalities to build and use a modelling library of higher level compound construction components. For example, if the architect needs to specify the outside walls of the building, he would use a wall component which is a compound component modelling the complete outside wall, i.e. consisting of a brick of a certain type, insulating material, and finery and used glue materials (see Figure 6). If the architect needs to specify windows or doors, he uses compound objects consisting of a frame of a certain material, like wood, and a certain type of glass and corresponding fittings.

Figure 6 shows the compound component editor of eLCA. The compound component shown models an outer wall of a building as mentioned above. The graphic attached to the compound component model shows that the wall consists of seven subparts. Each subpart can be either another compound component or a basic construction material which is the reference product of an associated EPD dataset from the ÖKOBAU.DAT.

The higher level compound components allow the architect then to model the entire building by specifying a list of used compound parts and basic construction materials and their amount according to a reference unit like square meters.

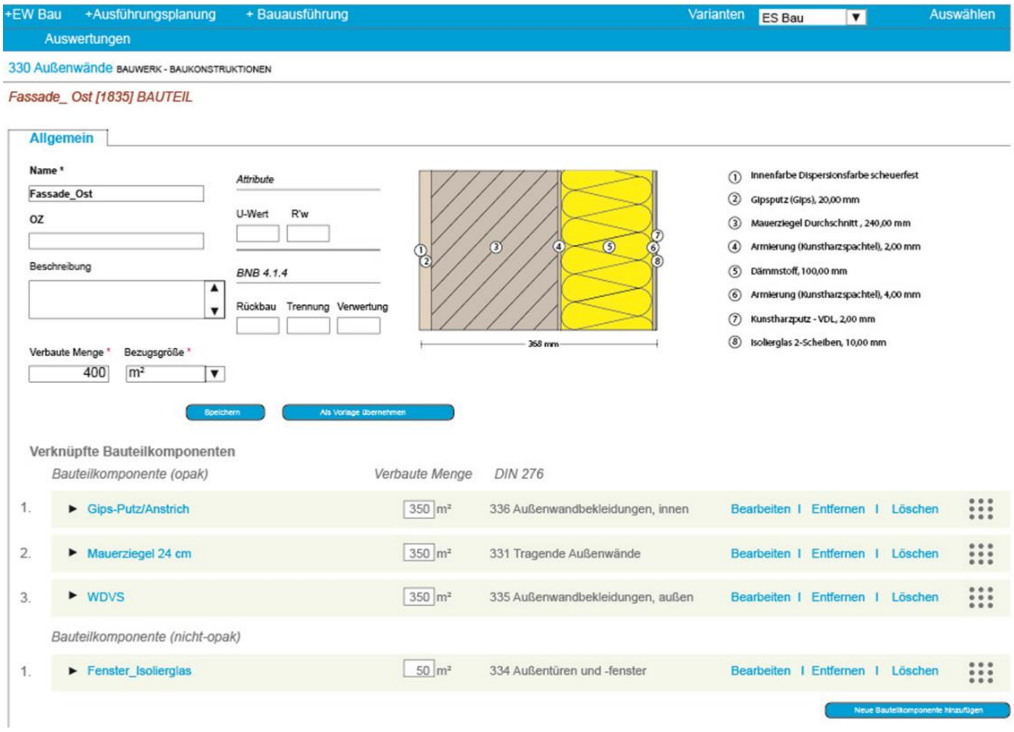

Figure 5: eLCA screen showing the model of a complex construction component (outer wall of a building) which is composed of several construction materials

To perform the assessment calculation, the eLCA tool has to analyse the internal composition of the compound object and then perform separated calculations for all sub materials which will then be summed up. Each base material used in a compound component has associated EPD data sets within the ÖKOBAU.DAT which can be used for the calculation of the indicator values contributed by this material. The indicator values in the EPD data set are normed to a certain amount of the material and have to be scaled by the total amount of this material contained within the entire building. This calculation has to be done with all materials contained in the compound components and after that the contribution of all materials has to be added to get the final values for the entire building.

4. Conclusions and Outlook

First results of the "ÖKOBAU.DAT Interfaces" project have shown that the described tool chain can be used to efficiently create and use EPD datasets for the assessment of buildings. The soda4LCA database software with its REST API [2] seamlessly integrates EPD calculation and building modeling tools as producers and consumers of EPD datasets with the central repository for EPD datasets, the ÖKOBAU.DAT. The EPD editor and calculation tool implemented for openLCA is easy to use and calculates all needed indicators for the different life cycle stages in one go and the compound component model of eLCA makes it easy for its users to build libraries of reusable building construction components so that models of complete buildings can be efficiently created.

The procedure can be streamlined and optimized by the integration of better quality control mechanisms and workflow like feedback mechanisms. For example, eLCA already checks in its import procedure if there are some quality problems in EPD datasets which hinder their usage in eLCA calculations. Currently, the results of this analysis have to be communicated back to the author of the corresponding EPD data set manually. In the future, the necessary quality control should already be performed within the ÖKOBAU.DAT when EPD datasets are uploaded to its "inbox". The maintainers of the ÖKOBAU.DAT should have the possibility to quality control all relevant aspects of incoming EPD datasets before they are moved into release data stocks. Furthermore, analysis results of rejected data sets should automatically be communicated back to the authors. This can be accomplished by enhancing the soda4LCA API to incorporate information that allows it to send emails to dataset authors or provide a message stream within the tools integrated with the soda4LCA software as feedback mechanism.

Another issue observed in the integration project is the necessity to have mechanisms to communicate extensions of different reference data back to tools using this data. E.g. for eLCA it's really important that the reference system of available construction products and the accompanying categorization of building construction materials in ÖKOBAU.DAT is synchronized with its internal notion of building construction materials. Currently, the mapping of ÖKOBAU.DAT and eLCA product notions is maintained manually in eLCA. As a result, every extension to the products and their categorization in ÖKOBAU.DAT has to be manually added to eLCA and vice versa. In the future one can imagine that products and categories will be maintained and extended in ÖKOBAU.DAT and automatically communicated back to tools via the soda4LCA service API.

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