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greenBIM, a BIM-based LCA integration using a circular approach based on the example of the Swiss sustainability standard Minergie-ECO

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Abstract. There exist hundreds of sustainability certifications for the built environment. The number is expected to rise as the focus on environmental issues increases. However, these certificates are usually carried further through linear-based approaches in a late building phase. They are disconnected from the design practice, while, as shown by the 'MacLeamy Curve', design decisions made earlier in the building process strongly affect positive outcomes. As a result, decision-making metrics are limited and the related improvements of the building concepts are minimized. There is an opportunity to bring forward sustainability certifications metrics and benchmarks in a digital built environment. Here, a proof-of-concept of such a circular approach is presented, using the Swiss sustainability standard Minergie-ECO as an example. Life-Cycle Assessment (LCA) calculations are implemented in a digital form, namely Building Information Modelling (BIM). The BIM-LCA integration demonstrates that current prevalent linear approaches can be further refined and turned into circular ones. Hence, the time and effort for their implementation are reduced, and decision-making information is brought in a structured and visual form. Moreover, architects and planners are enabled to apply sustainability metrics in their processes.

1 Motivation and Theoretical background

The Architecture, Engineering, Construction, and Operations (AECO) industry is one of the main industries contributing to greenhouse gas (GHG) emissions and, respectively, climate change. There is a clear reduction of GHG emissions due to operational energy in new buildings. However, embodied emissions in such buildings tend to rise [1]. One way to account for the issue is Life Cycle Assessment (LCA), typically applied through sustainability standards in industry practice.

There are many sustainability metrics and regulations developed to bring a shift towards a net-positive building environment [2]. However, conventionally, their implementation is for certification after the design phase of a building is finalised. Moreover, the practice usually involves sustainability specialists for their execution, rather than planners and architects,

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creating silos of expertise. In that sense, the metrics are disconnected from the design process, minimising the potential refinements.

The application of sustainability objectives to the built environment requires a dedicated framework, which involves the various AECO industry stakeholders [3]. One way to engage them and materialize project opportunities is by applying digitalisation techniques. Building Information Modelling (BIM) is a 3D model-based process and technology by which a structure of information obtained by different stakeholders is created and a multidisciplinary collaboration amongst them is achieved [4].

Therefore, there is an opportunity to bring forward sustainability certification-related building improvements in a digital built environment.

2 Objectives and Methodology

The main objective of this study was to achieve a BIM-based LCA integration using a circular approach, based on the example of existing sustainability standards in Switzerland. Furthermore, the study aimed to define a methodology for digital integration of these certificates, covering additional aspects of sustainability in AECO, while increasing the focus of sustainability metrics and benchmarks as the main incentive for the design and building process. In that sense, to make sustainability certificates more understandable to non-sustainability experts, e.g. architects and planners, enabling them to consider environmental characteristics in their projects.

To achieve this, the potential for integration of established LCA standards is analysed and related workflows in the BIM practice in the Swiss AECO industry are evaluated. The existing practice for the application of the Swiss sustainability certificate Minergie-ECO is considered and a BIM plug-in based on it is created. The development is later tested by diverse stakeholders in Switzerland, considering key aspects and further opportunities.

3 Results

Linear and circular LCA approaches are acknowledged to achieve BIM-LCA integration (Figure 1).

The linear approach represents the current practice adopted by AECO practitioners. The approach is based on a separated building model and analysis tool. Because of that, the workflow is disconnected and linear, resulting in no direct feedback possible. The quantity take-off is manual and there is potential for errors. The data complexity require specified LCA skills and result in a time-consuming method with difficult decision-making.

The circular approach integrates a BIM model and a parametric tool. Therefore, there is circular information flow and direct feedback. The quantity take-off is automated, the data complexity is simplified, and hence, the approach gives acceleration bases and enables decision-making.

The main characteristic of the linear approach is that different information silos, part of it, are disconnected. On the contrary, the circular approach links and analyses the information throughout its implementation. In that sense, the circular approach allows planners and architects to analyse additional aspects in the design processes they are acknowledging, visually enabling sustainability metrics.

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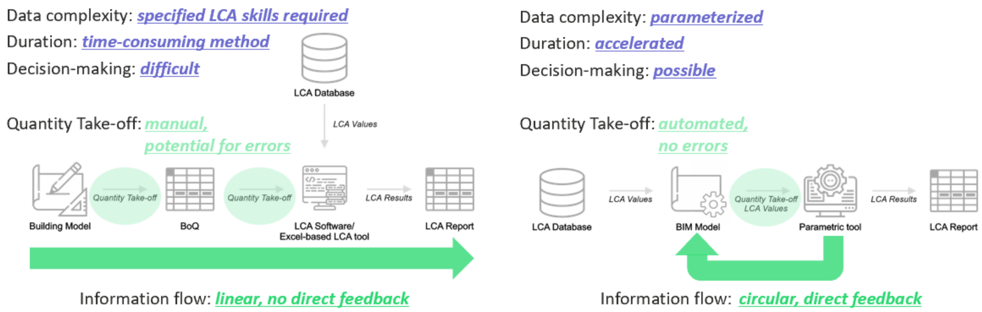

Fig. 1. Linear and circular approaches

Furthermore, the building process in Switzerland [5] is considered. Aspects, related to Level of Information Need (LOIN), namely Level of Development (LOD), Level of Information (LOI) and Level of Geometry (LOG) are taken into account and associated with building phases [6]. In Figure 2 the different information complexity, required for LCA, is related to the building model creation in different building phases.

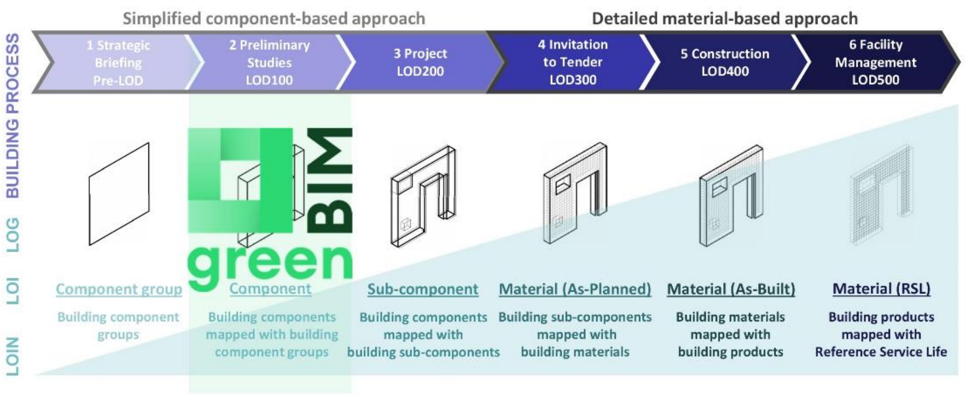

Fig. 2. Building process differentiation in Switzerland, LOIN (LOD, LOI and LOG), and LCA data

The circular approach and the building process differentiation are further implemented in a BIM tool, called greenBIM (Figure 3). The tool is developed as a plug-in for the BIM software programme Revit, following the regulations and benchmarks of the Swiss sustainability standards Minergie-ECO. The focus of the current version is on new buildings, whereby integration of the methodology for the evaluation of existing buildings is also taken into account. After the Revit version and acknowledging the usage of different BIM software types, an ArchiCAD version is developed as well.

The tool implements information related to the building function, excavation work, floor area and building technologies in the analysed model. It also uses an integrated database with building components from bauteilkatalog.ch, Lignum, SIA 2032 and KBOB leaflet. The database provides information about grey energy (kWh/m².a) and GHG emissions (kg CO_2-eq/m².a). Both aspects are calculated, based on different building materials, part of the building components. This information is then assigned to the existing model's geometry and, respectively, the components part of it. Since greenBIM adds additional parameters to the building components the model's geometry can be designed both in a simplified and in a detailed way.

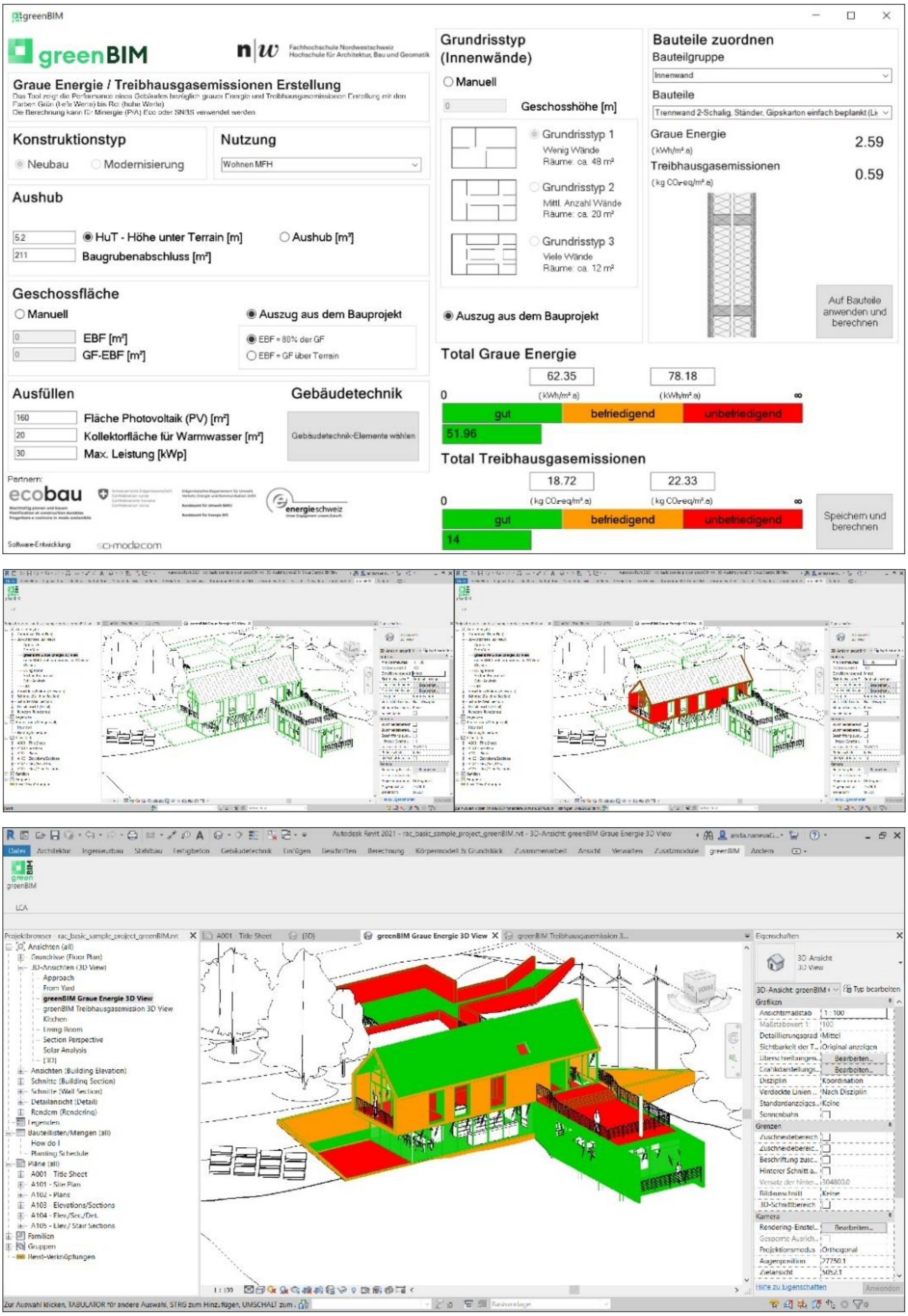

Fig. 3. greenBIM (Translation of the main menus: "Graue Energie / Treibhausgasemissionen Erstellung" – Grey energy / Greenhouse gas (GHG) emissions Creation; "Konstruktionstyp" – Construction type; "Nutzung" – Use; "Aushub" – Excavation; "Geschossfläche" – Floor area; "Ausfüllen" – Fill; "Gebäudetechnik" – Building services; "Grundrisstyp (Innenwände)" – Floor plan type (interior walls); "Bauteile zuordnen" – Assign building components; "Total Graue Energie" – Total grey energy; "Total Treibhausgasemissionen" – Total greenhouse gas (GHG) emissions.)

Once the information is part of the model, it is compared to benchmarks on element and building level and the model is coloured for better decision-making.
greenBIM has been tested by different stakeholders, part of the Swiss AECO industry. As a result, the tool is now available with free access upon request over [7].

4 Future potential

There is future potential in developing a circular design platform (Figure 4). A circular design platform could work both with new and existing buildings. Information Exchange Requirements (IER) are applied for efficient and transparent creation of an Industry Foundation Classes (IFC) open source-based digital twin [8]. A common data structure is used for creating the digital twin and a database. The database provides information about different analytical use cases, e.g. embodied and operational energy, and material recyclability. The circular design platform brings together the digital twin and the database and analyses the information according to different requirements and sustainability standards. Based on that the analysis criteria are covered and materials are reused or recycled. Furthermore, processes, part of the life-cycle of the building, are analysed.

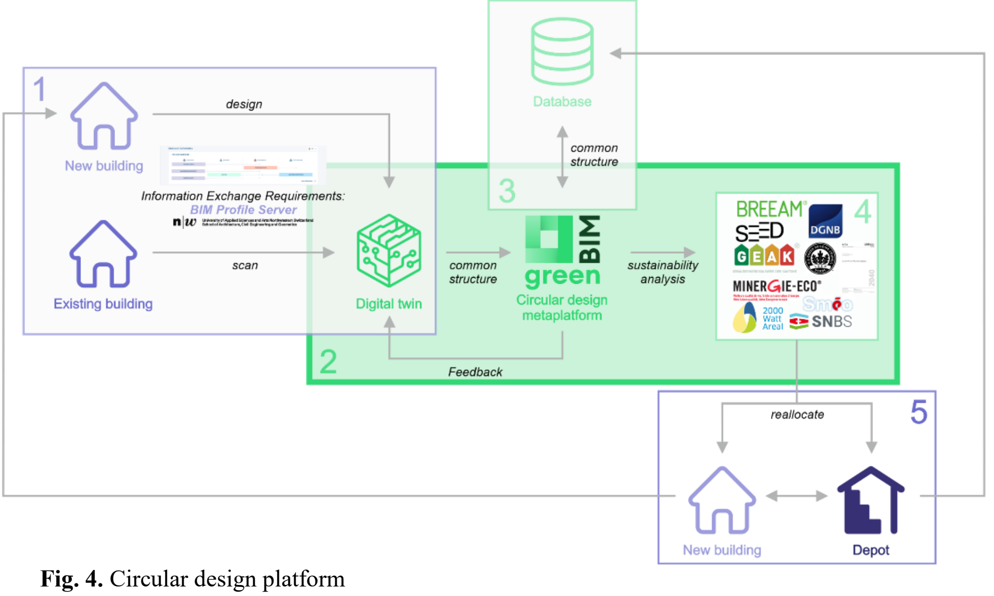

Fig. 4. Circular design platform

5 Conclusion

Through the development of this study, a BIM-LCA integration using a circular approach based on the example of the Swiss sustainability standard Minergie-ECO is achieved. Moreover, a BIM plug-in, called greenBIM, is created. The integration implements sustainability-related calculations in BIM while providing decision-making metrics through the design process. Benchmarks on an element and building levels, serving for optimisation, time-saving, reliability and visualisation, are implemented. The methodology applied for the creation of greenBIM serves as a basis for implementing additional sustainability aspects. The focus of sustainability metrics and benchmarks as the main incentive for the design and building process is increased and sustainability certificates are made more understandable. Therefore, architects and planners are given more incentives for implementing sustainability metrics.

Abbreviations

AECO - The Architecture, Engineering, Construction, and Operations
BIM - Building Information Modelling
GHG emissions - greenhouse gas emissions
IER - Information Exchange Requirements
IFC - Industry Foundation Classes
LCA - Life-Cycle Assessment
LOD - Level of Development
LOG - Level of Geometry
LOI - Level of Information
LOIN - Level of Information Need

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