BIM as a tool for Green Building Certifications: an evaluation of the energy category of LEED, BREEAM and DGNB

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Abstract. The Architecture, Engineering, and Construction (AEC) industry faces essential challenges related to the three sustainable pillars (social, economic and environmental). For instance, to decrease the carbon emissions, the consumption of energy and raw materials, to design sustainable cities and to improve the methodologies and technologies used to minimize cost and environmental problems. One alternative to overcome these challenges is the Green Building Certifications (GBCs), as for example Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Methodology (BREEAM), and German Sustainable Building Council (DGNB), and the new tools to support their process of implementation, for instance Building Information Modelling (BIM). The main objective of this paper is to study the viability of using BIM in the process of certification of energy category of LEED, BREEAM and DGNB for new projects using as a case study the building EUREF HAUS 12 – 13 located in Berlin - Germany. The methodology established is descriptive-exploratory and considers four research techniques, bibliography review, semi-structured interviews, BIM case study analysis, and work meetings with a BIM expert. The results illustrate that BIM can support all the energy requirements of LEED, BREEAM and DGNB and that despite the challenges that represent the implementation of BIM in GBCs, the advantages of it increases the efficiency of this process significantly.

1. Introduction

In 2050 it is expected that the 68% of the world population will live in urban areas [1]. This fact represents an essential challenge to the AEC industry, because it requires a new approach to design and develop cities. From the point of view of the three pillar of sustainability: social, economic and environmental, the focus is on the design of sustainable spaces and houses for people, on the innovation of technologies and procedures to decrease cost and environmental problems and on the reduction of carbon emission and resources used (energy, water and raw materials), since nowadays the buildings are one of the biggest producers and consumers of them [2].

There are several alternatives to achieve sustainable development and to overcome the current and future challenges of the AEC industry. Nowadays, one of these alternatives is the certification of the buildings according to sustainable standards. There are several GBCs available in the market, for example, LEED, BREEAM, Energy start, Green Globes and DGNB.

The GBCs besides contributing to reducing the consumption of energy, carbon and water, and the production of waste [3,4], also verify the level of sustainability that a project achieves according to the guidelines defined for each standard [3]. Currently, the accelerated growth of the technology used in...
the AEC industry is continuously developing new tools to support the process of evaluation of the GBCs. One example of that is the approach of BIM as an alternative to “the accomplishment of established sustainability goals” [5].

The report of EUBIM of 2019 finds BIM as the “most impactful technological development in the construction sector” [6], since it is thought its use is expected to have saved between 15-25% in the global infrastructure market by 2025 [6]. If it is only considered 10% of these saving in the European construction sector, the quantity is €1.3 trillion. In addition to this economic advantage, it is also recognised the potential social and environmental benefits such as climate protection and resource efficiency [7].

Considering the described context in the AEC industry, this research is focused on to analyse the viability of using BIM in the process of certification of energy category of LEED, BREEAM and DGNB for new projects using as a case study the project EUREF HAUS 12 – 13. The focus on the energy category is because it has the most significant weight of all the requirements evaluated in each certification. In the case of LEED, the energy requirements represent 30% of the total weight of the nine assessed areas, in BREEAM 23% of the ten categories defined, and in DGNB 22.1% of the six fields analysed (see Figure 1).

Figure 1. Energy requirements weight of LEED, BREEAM and DGNB. Own elaboration based on [8, 9, 10].

2. GBCs and BIM: Description and analysis

Before to analyse if it is possible to use BIM in the three GBCs selected, it is relevant to describe and understand the structure of these certifications and the tools and procedures available in the market to integrate BIM in the process of certification.

2.1. Energy category of LEED, BREEAM and DGNB

LEED, BREEAM and DGNB have a similar structure, which considers different levels of information. To organise these levels and define a common criterion to analyse the three GBCs mentioned a Work Breakdown Structure (WBS) was chosen.

Each GBC has five levels. The names defined by the different GBCs for each level is not the same, but to homogenise them, this research defines standard terms. Level 0 is related to the name of the certification (LEED, BREEAM and DGNB). Level 01 is the category (in this case, the energy is the focus). Level 02 is the credit names, which are the lists of themes considered in the level 01. Level 03 is the requirements related to each credit name. And level 04 are the documents asked to proof the requirements were achieved (see Figure 2).
2.2. Integrating BIM and GBCs: Feasibility

2.2.1. Current energy criteria supported by BIM

Many of the available BIM software, plugins and other third-party applications for the analysis and simulation of buildings in the market, can also be used as tools to assist the process of GBCs. Some of these tools, like ArchiCAD, Revit, Vectorworks, Ecotect, Hourly Analysis Program (HAP), Integrated Environmental Solutions (IES-VE) or Green Building Studio (GBS), can be used across different certification types (and schemes), including the ones in which this research focuses, LEED v4 (2016), BREEAM (2016) and DGNB (2018).

Considering these three GBCs with their schemes and analysing them supported by research material and other sources [11], it is possible to quantify and compare the impact of using BIM in the process of certification. The results show that BIM can assist 100% of DGNB's energy-related criteria, 60% in the case of BREEAM and dropping to 55% for LEED certification (see Figure 3).

![Figure 2. GBCs structure. Own elaboration based on [8, 9, 10].](image)

![Figure 3. BIM supporting LEED, BREEAM and DGNB energy criteria [12, 13, 14, 15, 16].](image)
2.2.2. Phases to implement BIM in GBCs

The academic articles reviewed illustrate that it is feasible to implement BIM in GBCs through the development of different phases of work [17, 18, 19, 20, 21, 22]. There are 13 phases identified (see Table 1), which, according to the authors, have different advantages and disadvantages.

- Disadvantages: high cost, lack of BIM parameters for GBCs (not all requirements can be considered in BIM), high time consuming and low interoperability.
- Advantages: documentation (level 04) generated automatically, efficient collaboration and information exchange between teamwork and precise definition of the GBC from the design stage.

The phases 2, 5, 6 and 11 are repeated in at least 4 of the 6 documents analysed, and the disadvantages are concentrated in phase 5 and 6, but at the same time in the phase 5 is recognised that it offers an “efficient collaboration and information exchange between teamwork” (see Table 1).

Table 1. Phases to implement BIM in GBCs. Own elaboration [17, 18, 19, 20, 21, 22].

| Phases                                                                 | GBC in general | LEED | BREEAM | DGNB |
|------------------------------------------------------------------------|----------------|------|--------|------|
| 1. Develop an external data base with all the information required     |                | x    |        |      |
| 2. Define the type of project, the scope and the requirements of the different phases |                | x    | x      | x    |
| 3. Collect all the data for the BIM model (information and guidelines)  |                |      |        |      |
| 4. Transform the data according to the BIM language                     | x              |      |        |      |
| 5. Creation of the model in a BIM platform (considering all the parameters required) | x              |      |        |      |
| 6. Develop the simulation (different software involved)                 |                | x    | x      | x    |
| 7. Develop a green building certification module (plug-in developed for some of the GBC) | x              |      |        |      |
| 8. Develop a map of the relationship between BIM analysis methods and the GBC requirements |                | x    |        |      |
| 9. Design the neighbourhood modulation (BIM/GIS)                        |                |      |        |      |
| 10. Establish the method to aggregate the results from different software|                |      |        |      |
| 11. Evaluate the GBC requirements achieved                              | x              | x    | x      | x    |
| 12. Calculation of the GBC costs                                       | x              |      |        |      |
| 13. Report the results according to the GBC requirements                |                |      |        |      |

3. Methods

This study is descriptive-exploratory and considers four research techniques:

- Literature review of primary and secondary literature related to the fundamental concepts of this study: there are two criteria to choose the literature. First, the year of the publication, since considering the accelerating growth in AEC technology, it is relevant to focus on the newest investigations (from 2015 to 2019). Second, the quality of the information. For example, the material reviewed is obtained only from official sources.

- Semi-structured interviews to three experts about the three GBCs analysed: the goal of this technique is to understand the relationship between two variables, the first is the objective of the energy requirements of LEED, BREEAM and DGNB and the second is the process of certification. These types of interviews are non-standardised since contemplates the definition of a list of topics and questions, which can be modified during the interview.

- BIM case study analysis of the project EUREF HAUS 12 – 13: there are three reasons for the selection of this case. First, the quantity of the information available since the Research campus Mobility2Grid has a complete BIM model and previous research of it [23]. Second, the
possibility to have advice from a BIM expert of this research team. Third, the current certification LEED platinum that this project has (see Figure 4 and Table 2).

Figure 4. EUREF HAUS 12-13 Revit model 3D view [24].

Table 2. Euref Haus 12 -13 – General information [16].

| General information EUREF HAUS 12-13 |
|--------------------------------------|
| Address                              | Torgauer Str.12-15, 10829 Berlin |
| Use                                  | Office building                  |
| Year of construction                 | 2013                              |
| GBC awarded                          | LEED Platinum 2014                |
| Investment costs                     | €6,500,000 approx.                |
| Gross floor area (GFA)               | 19,900 m2                         |
| GFA above ground                     | 15,250 m2 (ten stories)           |
| GFA below ground                     | 4,650 m2 (two stories)            |
| Building height                      | 46,65 m                           |

- Work meetings with a BIM expert of the Research campus Mobility2Grid: supervision of the academic methodology used in this study and the research related to the viability of integrating BIM and GBCs in the EUREF HAUS 12 -13.

4. Results: Integrating BIM and Energy category of GBCs: Euref Haus 12 -13

4.1. Steps of Implementation

There are three relevant topics regarding the methodology of integrating BIM and the energy criteria of LEED, BREEAM and DGNB in the EUREF HAUS 12 – 13, the first involves the selection of the phases, the second considers the selection of the credit names (level 02) and the third contemplates the selection of the requirements and documentation (level 03 and 04).

4.1.1. Selection of the phases:

There are thirteen phases to implement BIM in GBCs (see Table 1), from these five phases are implemented in the case study. The selection criteria are two. First, the phases that are most repeated in the articles reviewed (phases 2, 5, 6 and 11). And second, the coherence and logic sequence of procedures between them, it means that no step can be skipped (phase 4). The phases selected are:

- Phase 1: Define the type of project, the scope and the requirements of the different phases
- Phase 2: Transform the data according to the BIM language
- Phase 3: Creation of the model in a BIM platform (considering all the parameters required)
- Phase 4: Develop the simulation (different software involved)
- Phase 5: Evaluate the GBC requirements achieved
4.1.2. Selection of the credit names (level 02):
According to the section 2.2.1, 45% (LEED), 40% (BREEAM) and 0% (LEED) of the credit names of the energy criteria of the GBCs studied are currently not supported by BIM (see Figure 3). This study is focused on them since for the credit names that have a BIM tool which supports the certification process; there is already evidence that illustrates that its use is feasible. Considering this, only LEED and BREEAM are analysed because BIM supports the 100% of the DGNB credit names of energy category.

4.1.3. Selection of the requirements and documentation (level 03 and 04):
In phase 2 named “Transform the data according to the BIM language”, all the documentation of the credit names indicated above is analysed according to the BIM parameters and the Structured Query Language (SQL). From the six SQL data type, four are present in the documentation of the energy criteria of the 3 GBCs, these are: Character and String Data Types, Numeric, Date and Time Data Types and Binary Data Types.

From each one of the 4 SQL data type, one example is chosen to explore alternatives to their implementation. The EUREF HAUS 12 – 13 is already built, for this reason in the explanation of the phases some steps are considered done and others are complemented with new ones proposed to be implemented.

4.2. Development of the 5 phases selected
4.2.1. Phase 1:
Define the type of project, the scope and the requirements of the different phases: in the case of the EUREF HAUS 12 – 13, the type of project is office, the scope was LEED platinum, and the requirements were defined according to the scheme "Building Design and Construction - Core and Shell Development" of LEED v4. In this phase, the communication strategy has an important role, since all the participants must know the requirements of the GBC selected.

4.2.2. Phase 2:
Transform the data according to the BIM language: this phase is divided into two steps, data collection and data interpretation.

Step 1: The data collection considers two processes. The revision of the manuals of LEED, BREEAM and DGNB and the systematisation of all the requirements (level 03) and the documentation (level 04) of the credit names (level 02) that are currently not supported by BIM. This process is developed following the structure of Table 3.

Table 3. Data collection and interpretation format. Own elaboration.

| Green Building Certification | Level 01: Energy Points | Weight % | Goal | Level 03: Requirements | Level 04: documentation | BIM parameter | SQL data type | Additional information description |
|-----------------------------|-------------------------|----------|------|------------------------|------------------------|--------------|--------------|----------------------------------|
| LEED – BREEAM - DGNB       | 33                      | 30       | Goal |                        |                        |              |              | Yes | No | Additional information description |

Step 2: The data interpretation contemplates two processes. The first is the categorisation of the data collected to a type of information that can be read by BIM (BIM parameters and SQL data type). The BIM parameters “store and communicate information about all elements in a model” [25]. There are fifteen types of parameters, Text, Integer, Number, Length, Area, Volume, Angle, Slope, Currency, Mass Density, URL, Material, Yes/No, Imagen and Family type.

The SQL “is an attribute that specifies the type of data that the object can hold” [26]. This type of data is an essential piece of information, and the combination of them define the structure of a database. There are six types of SQL, Character and String Data Types, Numeric, Date and Time Data Types, Binary Data Types, Unicode Character and String und Miscellaneous Data Types.

The outcome of this study reflects that in the case of LEED, five credit names are not supported by BIM, which have ten requirements and 30 documentation and that for BREEAM, there are three credit
names that are not supported by BIM, which have eight requirements and seventeen documentation. Regarding the SQL, the Character and String and Numeric are the Data Types more present in the credit names of LEED (57% and 33%) and BREEAM (53% and 35%) (see Figure 5).

![Figure 5. SQL Data Type available in LEED and BREEAM. Own elaboration based on [13, 14, 16, 17].](image)

The relevance of transforming the data collected to a type of information that can be read by BIM (BIM parameters and SQL data type) is that the result of this process allows the GBC consultant to discuss with the IT professional or BIM expert having the same language. This situation improves the certification process and increases the number of credit names that can be supported by BIM.

After the transformation of the data collected to a type of information that can be read by BIM, it is developed the second process. It is the identification and description of the additional data required. For example, a letter from the manufacturer.

The challenges faced in phase two are the no standardisation between the LEED, BREEAM and DGNB documentation is possible, because all of them require different types of evidence and the large amount of information to be processed.

### 4.2.3. Phase 3

Creation of the model in a BIM platform (considering all the parameters required): a reference Revit model was developed by the Project Team of EUREF HAUS 12 – 13. To implement all the parameters required for the GBCs two steps are defined, the creation of a family with the credit names and points available of the energy criteria of the three GBCs and the implementation of the fourth types of documentation according to the SQL data type analysed above.

**Step 1:** The creation of a family with the credit names and points available of the energy criteria of the three GBCs considers two processes. The first is the generation of a family inside of the “Annotation Symbols” type with all the credit names of the energy category indicated in the manuals of LEED, BREEAM and DGNB and then import them to a “Sheet”. In addition six other parameters are created, five are numbers: Points, Yes, Maybe Yes, Maybe No and No and one is a formula to calculate the total Point achieved, which sums the point of the column Yes ([1]) and Maybe yes ([2]) (formula: [1] + [2]) (see Figure 6).

The meaning of these parameters is: Yes (the point/s is/are achieved), Maybe Yes (the point/s can be achieved, but there are not achieved yet), Maybe Not (the point/s can be not achieved, or it is difficult to achieve them) and Not (the point/s are not achieved).
Figure 6. Formula to obtain the points achieved. Own elaboration.

The second is the creation of a schedule for each GBCs with the parameters defined in the step above (see Figure 7). This research is focused on the energy criteria, but this method can be applied to other criteria.

Figure 7. Energy category schedule of LEED. Own elaboration.

Step 2: The implementation of four types of documentation according to the SQL data type analysed (see Table 10) considers three processes. The first process is to identify which parameters are relevant for each of the four examples defined. It is developed considering the information generated in phase 2, step 2 (see above). The second process is the creation and organisation of them in the Revit reference model of EUREF HAUS 12 -13. And the Third process is to apply this method of work to a credit name that is already supported by BIM. The justification of this process is that during the interviews, one of the challenges identified was the lack of BIM parameters available in the reference model for GBCs.

The credit name selected is L02: “Hea 02 Indoor air quality” belongs to the L01: Health and wellbeing of BREEAM, because the author of this study developed it without a BIM reference model for other project and know the quantity of time required to its implementation using the traditional method.

As a result, all the parameters were implemented successfully in the BIM reference model, but some challenges were faced:

- Several numbers of subprocess to insert the information (new family, new schedule, new parameters)
- Incompatibility between the old and new version of the same software. For example, a Revit doc 2018 cannot be open in Revit doc 2019 and vice versa
- A large amount of information to be processed
- PDF format it is not importable to Revit
- The type of parameter cannot be modified after its definition. If it necessary to change the typology a new parameter must be created
In the case of procedure 3, the traditional and BIM method are compared. The traditional method takes less time, at the beginning, to be implemented, but this quantity of time is required every time that this credit name is evaluated. In the case of BIM method, the initial quantity of time is more significant than in the traditional method, but when all the parameters are implemented in the BIM model, the process is automatized, and it is not necessary to expend more time in it. The automatization and the reduction of work is an important advantage of the BIM method.

## Figure 8.

Traditional v/s BIM method results of the implementation of Hea 02 of BREEAM. Own elaboration.

### 4.2.4. Phase 4

Develop the simulation (different software involved); this phase is not settled in this study because the energy simulation already has a BIM tool which supports their process of certification.

### 4.2.5. Phase 5

Evaluate points achieved of the GBCs requirements achieved is not possible because only four documentation types are analysed in this study. However, the method applied offers a strategy to continue implementing the other documentation in BIM to achieve a full integration of BIM and GBCs.

To have a successful implementation between BIM and GBCs is relevant to identify all the professionals involved in each of the five phases described since each of them have specific responsibilities and roles in the process of certification.

## 5. Discussion

The discussion is addressed considering two topics.

### 5.1. Phases:

From the 13 phases identified in the literature review related to the integration of BIM and the GBCs, five are implemented in the case study. These represent a methodology of work, which can be applied to the other criteria (level 01) of the GBCs. The phases also contribute to control the process of integration between BIM and GBCs since these offers to the GBC consultant an organised description of all the necessary steps and procedures.

### 5.2. Challenges and advantages:

During the implementation of the 5 phases, different challenges were identified. Despite that, the automatization of the phases and the GBCs requirements in a BIM tool (in this case Revit) is a significant advantage. Only for the energy criteria, there are 131 types of documentation (level 04) required to prove that the requirements (level 03) are fulfilled (see Figure 2). It nowadays represents a considerable quantity of time and work, which need to be repeated for each project. BIM offers an alternative to improve this process and reduce the time invested, a situation that is significant in countries as Germany because the man work hour is expensive in comparison to other countries.

## 6. Conclusions

The rise of buildings and infrastructure product of the increment of the percentage of people living in cities represents a significant challenge to the AEC industry because these consume a significant quantity of energy and raw material and produces large carbon emissions. As it was presented in this study, there are several alternatives to achieve sustainable development and to overcome the current
and future challenges of the AEC industry. One of these alternatives is the GBCs and the new tools to support their process of implementation, as BIM.

The viability of using BIM in the process of certification of LEED, BREEAM and DGNB for new projects was analysed, and the conclusion is that BIM can support all the GBCs requirements. It does not mean that the process does not have constraints and challenges (time, cost, quantity of information and software restrictions), but the advantages of the automatization after the implementation of all the parameters increase significantly the efficiency of this process and the recollection of the documentation (level 04) required for each certification. Considering the advantages and constraints identified, each AEC industry has to analyse if the use of BIM is feasible considering its requirements and current situation.

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