Master's Thesis

Toward BIM-based ESG Assessment

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List of Abbreviations

A

AEC	Architectural, Engineering, and Construction
API	Application Programming Interface
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
B	
BBP	Better Building Partnership
BBSR	Bundesinstitut für Bau-, Stadt- und Raumforschung
BEAM	Building Environmental Assessment Method
BEP	Building Execution Plan
BIM	Building Information Modelling
BOQ	BILL of Quantities
BPS	Building Performance Simulation
BREEM	Building Research Establishment Environmental Assessment Method
BSA	Building Sustainability Assessment
C	
CAD	Computer-Aided Design
CDE	Common Data Environment
CFD	Computational Fluid Dynamics
CityGML	City Geographical Markup Language
CO_2	Carbon Dioxide
COBie	Construction Operations Building Information Exchange
CSR	Corporate Social Responsibility
D	
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
DIN	Deutsches Institut für Normung
E	
EC	Embodied Carbon
EIR	Employer Information Requirement
EL	Entity Level
EN	European Standard
EPD	Environmental Product Declaration
ESG	Environmental, Social, and Governance
EUI	Energy Use Intensity
G	
GAV	Gross Annual Value
GBI	Green Building Index
GBS	Green Building Studio
gbXML	Green Building eXtensible Markup Language
GRESB	Global Real Estate Sustainability Benchmark
GRI	Global Reporting Initiative
H	
HVAC	Heating Ventilation Air-conditioning and Cooling
I	
IEA	International Energy Agency

IES-VE	Integrated Environmental Sollussion – Virtual Environment
IFC	Industrial Foundation Classes
ISO	International Standard Organisation
L	
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
LOD	Level of Development
LOG	Level of Geometry
LOI	Level of Information
M	
MC	Model Checking
MSCI	Morgan Stanley Capital International
MVD	Model View Definitions
O	
OM	Operation Measures
P	
PPD	Predicted Percentage of Dissatisfaction
PPM	Predicted Mean Vote
PRI	Principle of Responsible Investment
Q	
QTO	Quantity Take-off
R	
REITs	Real Estate Investment Trusts
S	
S&P	Standard & Poor
SBTool	Sustainable Building Tool
SRI	Social Responsible Investment
STEP	Standard for the Exchange of Product Data
T	
TCFD	Task Force on Climate-Related Financial Disclosures
TM	Technical Measures
TR	Technical Requirement
U	
UK	United Kingdom
UN	United Nation
US	United States
V	
VE	Virtual Environment

Abstract

The growing importance of ESG consideration in the real estate sector has underlined the need for efficient data collection, validation and quality assurance. The complexity of ESG assessment is driven by the nature of the data required for accurate reporting. This study employs the BIM methodology to streamline and enhance ESG assessment in the real estate sector, aiming to promote credibility in ESG assessments of development projects.

The primary objective of this thesis is to present a BIM-based ESG assessment workflow that enhances the understanding of how BIM can be integrated with ESG matrices in development projects. This involves identifying the potential applications of BIM in facilitating ESG indicator assessments, defining the necessary information requirements (both geometric and semantic), identifying suitable software tools that can aid the assessment process, determining the appropriate BIM implementation (Open BIM or Closed BIM), and interoperability. This thesis is based on the theory that combining BIM and ESG assessment can result in more precise and reliable evaluations of ESG indicators for development projects.

A multifaceted methodology is employed, which involves a systematic review and analysis and the execution of qualitative interviews. The systematic review and analysis consist of studying the current BIM implementation for sustainability evaluation and analysing the GRESB development indicators to determine the potential assessment of the indicators within the BIM framework. On the other hand, the qualitative approach involves interviews with ESG analysts from real estate companies to understand their ESG assessment methodologies and challenges, and with building planners and consultants to explore their BIM workflows for sustainability evaluations.

Findings from the analysis of GRESB development indicators revealed that BIM can support the assessment of 11 out of 21 indicators. A potential GRESB score of 28.50 out of 70 can be achieved, which equates to a 40.71% fulfilment rate of the total GRESB development component. The interviews with building planners highlight their diverse approaches to sustainability evaluation. Their presented workflow was analysed for potential assessment of the GRESB development indicators. The findings revealed the assessment of 6 indicators with a GRESB score of 17.25, reflecting a 24.64% fulfilment rate of the GRESB development component. This highlights a potential gap in fully harnessing BIM's capabilities for broader sustainability criteria.

This research validates the theory that BIM can enhance the assessment of specific ESG indicators in real estate development. By focusing on GRESB indicators and integrating BIM workflows, this research offers a pathway to improve the efficiency of ESG assessments in a BIM workflow, contributing to a deeper understanding of how BIM can be leveraged for ESG assessments.

1 Introduction

The global concern surrounding climate change and its environmental impact has propelled the importance of addressing sustainable practices in the real estate sector. According to the 2022 global carbon emission report by the International Energy Agency (IEA), the building sector is responsible for about 39% of the global annual greenhouse gas emissions (GHG).[1] Emphasis on environmental protection and resource conservation has led to the implementation of numerous sustainability action plans. International organisations have developed several frameworks for ethical and sustainability initiatives, such as socially responsible investment (SRI), corporate social responsibility (CSR), and environmental social and governance (ESG), among others. While each of these frameworks may have distinct focuses and scopes, they all contribute to a broader vision of creating a more sustainable and equitable environment for current and future generations.

The principle behind ESG has existed since the 1960s as Socially Responsible Investment (SRI).[2] However, it was not until 2004 that the term “ESG” was first introduced in a report by the United Nations (UN) titled “Who Cares Wins” aimed at promoting its adoption by businesses and increasing awareness of its significance in the financial market.[3] ESG has persistently evolved over the years to include various aspects of sustainability and ethics. Initiatives, such as the Paris Agreement, aiming to foster climate neutrality and overall sustainable development have driven the adaptation of ESG issues among stakeholders. These developments have made the concept an essential consideration for businesses and investment, providing a comprehensive framework for assessing a company’s ethical and sustainability practices.[4]

The increasing emphasis on corporations to disclose their environmental, social, and governance (ESG) impacts has prompted inquiries about ensuring transparency. ESG reporting is important due to its significant effects on investors. However, inconsistencies and a lack of standardised criteria hinder the lack of interpretation and comparison of ESG data. Investors usually demand high-quality, precise, and consistently disclosed ESG information for making financial decisions.[5]

The fundamental basis for incorporating ESG „starts with data“.[6] Effective ESG integration requires transparent methodologies for collecting, assessing, and aggregating ESG factors based on reporting standards to ensure accuracy and comparability.[7] Given the growing popularity of ESG and its integration into investment decisions, ensuring data integrity and reliability is of utmost importance. It is essential to thoroughly examine key factors in measuring and analysing

[1] Cf. IEA, Buildings - Energy System - IEA. Internet source.
[2] Cf. Morgan Stanley Capital International, The Evolution of ESG Investing. Internet source.
[3] Cf. UN Global Compact, Who Cares Wins – Connecting Financial Markets to a Changing World (United Nations, 10/13/2023).
[4] Cf. Kempeneer, Shirley; Peeters, Michaël; Compernolle, Tine: Bringing the User Back in the Building: An Analysis of ESG in Real Estate and a Behavioral Framework to Guide Future Research. In: Sustainability Issue 6-2021, pp.1–2.
[5] Cf. Lokuwaduge, Chitra; Silva, Keshara de: Emerging Corporate Disclosure of Environmental Social and Governance (ESG) Risks: An Australian Study. In: Australasian Accounting, Business and Finance Journal Issue 2-2020, p. 36.
[6] Cf. Jennifer, et al.: A Blueprint for Integrating ESG into Equity Portfolios. In: Journal Of Investment Management-2018, p. 45.
[7] Cf. Cort, Todd; Esty, Daniel: ESG Standards: Looming Challenges and Pathways Forward. In: Organization & Environment Issue 4-2020, p. 491.

ESG performance to address concerns and guarantee the accuracy and dependability of ESG data.[8] In the real estate sector, ESG matrices such as energy, water, material, CO_2 emissions, waste management, and health and well-being, among others, evaluate the overall sustainability performance of real estate properties and development.

Building Information Modelling (BIM) holds significant potential to foster the assessment, validation, and collection of high-quality ESG data related to real estate development projects and building operations. In a study conducted by Svetlana (2021), the author demonstrated a methodology for integrating Corporate Social Responsibility (CSR) indicators using information modelling within the energy sector. The author concluded the findings with the saying, "(...) BIM is the most effective tool for introducing the ESG concept into investment practice in the energy sector".[9] However, the BIM functionalities extend beyond the energy aspect. These functionalities will be discussed in the following chapter.

This thesis primarily centres on the comprehensive ESG assessment of real estate assets, specifically focusing on development projects (planning, design, and construction). In the study, the Global Real Estate Sustainability Benchmark (GRESB) is employed as the fundamental standard for assessing ESG indicators for potential BIM integration. GRESB has emerged as a widely recognised and industry-leading framework that provides a comprehensive set of ESG indicators and metrics tailored to the real estate sector.[10,11] These indicators encompass diverse aspects, including energy and water efficiency, carbon emissions, building material, occupant satisfaction, and community engagement. Integrating GRESB's indicators with BIM workflow is a pivotal focus of this study, as it seeks to enhance the accuracy and efficiency of ESG data collection and assessment within the real estate development context. By exploring the synergy between these two concepts, this research aims to identify a solution for seamless integration, thereby fostering the development of environmentally friendly and ethically sound buildings.

1.1 Motivation and Contribution

This thesis is driven by the importance of tackling the complex challenges surrounding ESG data collection, validation, and quality assurance within the context of real estate development. As highlighted in the previous section, ESG assessment is marred by the complexity of gathering accurate and reliable data. As businesses and organisations increasingly recognise the significance of ESG considerations, there is a pressing need to streamline and simplify the ESG reporting process. In the realm of real estate, where the impact on the environment and communities is substantial, the incorporation of ESG principles becomes even more crucial. This study aims to improve the efficiency of ESG assessment and data collection, as well as enhance the accuracy and quality of ESG reporting in the real estate sector. By leveraging the BIM

[8] Cf. Sakis, Kotsantonis; George, Serafeim: Four Things No One Will Tell You About ESG Data. In: Journal of Applied Corporate Finance Issue 2-2019, p. 50.
[9] Cf. Svetlana, I. Kodaneva: Efficiency Improving Methodology for Corporate Social Responsibility Indicators in Order to Ensure the Energy Transition Using Information Modeling Tools. In: Journal of Contemporary Issues in Business and Government Issue 02-2021, p. 6.
[10] Cf. Devine, Avis; Sanderford, Andrew; Wang, Chongyu: Sustainability and Private Equity Real Estate Returns. In: The Journal of Real Estate Finance and Economics-2022, p. 5.
[11] Cf. Newell, Graeme; Nanda, Anupam; Moss, Alex: Improving the Benchmarking of ESG in Real Estate Investment. In: Journal of Property Investment & Finance-2023, p. 6.

methodology, the study seeks to introduce an innovative approach towards sustainable practices, thereby promoting greater credibility in ESG assessments.

This approach not only aligns with the increasing demand for transparent and accurate ESG evaluations but also positions real estate projects to meet the evolving expectations of investors who consider ESG performance for investment decisions. This study will lay the groundwork for a future where ESG assessment becomes integral to the built environment, fostering sustainable, resilient, and socially inclusive real estate assets.

1.2 Goal and Objective

The primary goal of this thesis is to develop a BIM-based ESG assessment workflow and advance the understanding of how BIM can be integrated with ESG matrices. By harnessing the functionalities of BIM as a transformative digital workflow and aligning it with the multifaceted dimensions of ESG, this thesis seeks to establish a systematic approach to enhance ESG assessment processes in real estate development projects.

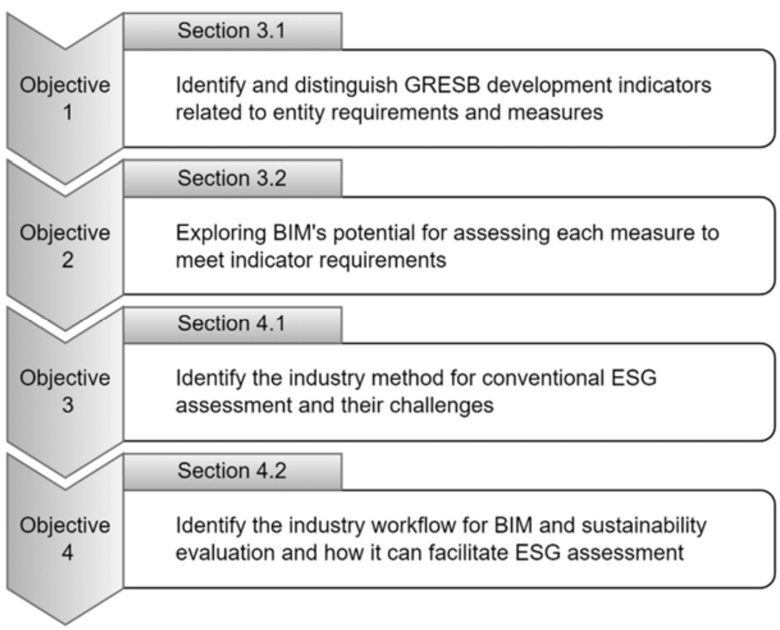

Figure 1: Research objective

The goal encompasses four key objectives: first, to identify and differentiate the GRESB development ESG indicators that assess an entity's requirements and measure, further distinguishing them into qualitative and quantitative categories. This objective lays the foundation for a precise integration of ESG assessment within the BIM framework.

The second objective delves into exploring BIM functionalities that can be leveraged to assess each specific measure to meet the requirements of the identified GRESB development indicators. This objective seeks to verify the extent to which BIM can effectively be utilised to address the ESG matrices, ensuring accurate evaluation. A BIM workflow will be presented outlining the geometric and semantic information required in the BIM model, data exchange and interoperability, possible BIM-based software tools, assessment process and output.

Furthermore, this objective involves identifying the key challenges and opportunities that emerge from integrating BIM and ESG assessments.

The third objective involves a qualitative interview with ESG analysts from different real estate companies to identify their methodology for ESG assessment of development projects and the challenges they face during data collection and evaluation. This objective will support understanding how BIM can be leveraged to mitigate the challenges faced during ESG assessment and data collection.

The fourth objective is also achieved through a qualitative interview with building planners and consultants who utilise BIM workflow for sustainability evaluation. The aim of this objective is to identify the extent to which industry BIM workflow for sustainability evaluation can facilitate the assessment of ESG indicators. These interviews will provide real-world insights into the opportunities and limitations of implementing such an approach.

1.3 Research Question

Given the background information provided, this research aims to explore and address several fundamental questions, which include:

1. Which of the GRESB ESG Indicators and sub-options would be feasible for integration within the BIM workflow?

2. What geometric and semantic information is necessary for analysing a model based on the indicators and sub-options with potential BIM application?

3. What BIM workflow (Open BIM and Closed BIM), Interoperability and software tools could be utilised to assess the GRESB indicators and sub-options with potential BIM applications?

4. To what extent could the BIM methodology assess and evaluate GRESB ESG indicators within the BIM workflow?

5. What methodology do real estate companies employ for ESG assessment and data collection, and what challenges do they face in the process?

6. What BIM workflow do building planners and consultants follow for sustainability evaluation, and to what extent could the identified workflow support the evaluation of GRESB indicators?

1.4 Outline and Structure

The subsequent chapters of the thesis are organised as follows:

Chapter 2: State of Art: This chapter engages in an in-depth literature review, delving into the existing body of knowledge surrounding both BIM and ESG. It will establish a solid foundation by exploring BIM's current state and usage for sustainability practices.

Chapter 3: BIM-based ESG Assessment: This chapter involves analyses of GRESB development indicators and their potential integration based on a systematic review of the existing BIM workflow for sustainability assessment. The chapter advances the study by presenting a workflow that integrates BIM with ESG indicators. Furthermore, it will calculate the percentage fulfilment of the GRESB indicators that can be supported by the BIM workflow using the GRESB scoring methodology.

Chapter 4: Proof of Concept: This chapter involves the execution of qualitative interviews with different stakeholders, including ESG analysts and building planners. By engaging these experts, the chapter seeks to identify the methodology employed by real estate companies, ESG assessment, and the BIM workflow followed by building planners for sustainability evaluation. Furthermore, it will evaluate the extent to which the employed workflow by the building planners can facilitate the assessment of the GRESB ESG indicators.

Chapter 5: Discussion: This chapter provides a comprehensive overview of the research findings and discusses implications in terms of contributions. Furthermore, it will provide an overview of the research journey and how the findings answer the research questions.

Chapter 6: Conclusion: This chapter concludes the thesis by summarising the key findings and outlining avenues for future research in BIM-based ESG assessment.

2 State of Art

The following chapter introduces the concept of ESG in real estate, discussing its role in promoting sustainability and the challenges it poses. It will then provide a detailed review of current ESG ratings and benchmarking within the real estate sector while shedding light on the GRESB ESG assessment. Furthermore, the BIM Methodology will be introduced as a potential solution to these challenges and a practical approach for implementing ESG practices in real estate projects. Lastly, a review of relevant research studies pertaining to BIM and building sustainability assessment will be presented to guide the framework formulated within this thesis.

2.1 ESG Strategy In Real Estate

The real estate sector has recognised the significance of ESG concepts as it strives to enhance its focus on sustainability. Today, considering environmental, social, and governance issues in financial decision-making has become more than just a moral obligation. ESG has become an essential component in business practice. The concept of ESG has undergone significant evolution, encompassing diverse goals and aspirations. This has led to the emergence of multiple strategies aimed at integrating these concepts into business practices.[12]

The environmental dimension has gained the most attention among the three dimensions of ESG.[13,14] These can be attributed to its contribution toward addressing global issues relating to the environment, such as natural resource depletion, clean energy, pollution, waste management, climate change mitigation and reducing emissions across industries, which have become paramount. Consequently, the environmental dimension assesses an organisation's impact on the natural environment and the environmental risks it might face.[15] The environmental dimension of ESG in real estate includes using eco-friendly construction methods, implementing energy-efficient building designs, and integrating renewable energy sources. It also involves reducing water consumption, minimising waste generation, and other measures to mitigate the environmental risks associated with climate change and extreme weather events. Additionally, this dimension encompasses initiatives to enhance biodiversity conservation and promote responsible land use.[16]

The social dimension is also an essential component of ESG, as it pertains to an organisation's impact on society and communities. However, it has not gotten as much attention as the environmental aspect.[17] Nevertheless, there is a growing interest in the social dimension, with rating agencies increasing focus beyond fundamental social rights to include well-being,

[12] Cf. Brounen, Dirk; Marcato, Gianluca; Op 't Veld, Hans: Pricing ESG Equity Ratings and Underlying Data in Listed Real Estate Securities. In: Sustainability Issue 4-2021, p. 3.
[13] Cf. ibid., p. 4
[14] Cf. Newell, Graeme: Real Estate Insights: The Increasing Importance of the "S" Dimension in ESG. In: Journal of Property Investment & Finance-2023, p. 2.
[15] Cf. Zhang, Qingquan T. et al., Environmental, Social Responsibility, and Corporate Governance (ESG) Factors of Corporations Alternative data and artificial intelligence techniques: Applications in investment and risk management, ed. Zhang, Qingquan T; Li, Beibei; Xie, Danxia, Palgrave Studies in Risk and Insurance Basingstoke 2022, pp. 142–143.
[16] Cf. Brounen, Dirk; Marcato, Gianluca; Op 't Veld, Hans: Pricing ESG Equity Ratings and Underlying Data in Listed Real Estate Securities, p. 5.
[17] Cf. Kempeneer, Shirley; Peeters, Michaël; Compernolle, Tine: Bringing the User Back in the Building, p. 5.

satisfaction and indicators related to environmental justice, such as affordability and accessibility of energy-efficient buildings.[18] At the property level, the social dimension is attributed to matrices related to the user's comfort and well-being, such as indoor environmental quality, housing affordability, tenant satisfaction, and construction safety, whereas, at the corporate level, the social matrices encompass broader sustainability and ethical considered which are beyond the specific attributes for individual assets such as diversity and inclusion, employee health and well-being.[19]

The government dimension pertains to the company's internal management practices and policies. These encompass the set of controls, procedures, and practices an organisation implements to comply with legal requirements and address external stakeholder expectations. The efficacy of a company's governance is assessed by how well it adheres to these standards.[20]

2.1.1 The Benefit of ESG in Real Estate

The financial implications of incorporating ESG factors into the investment process remain debated among academics. While many view ESG as a significant value driver, its financial impact remains uncertain. Some works of literature are contradictory and present mixed findings, suggesting that enhancing ESG practices may not always result in automatic increases in investment value.[21] Nevertheless, Some research shows that companies with excellent ESG ratings demonstrate superior operational performance and are also perceived as having lower levels of risk. A study by Aroul et al. (2022) examined the correlation between ESG and operational efficiency in Real Estate Investment Trusts (REITs) using S&P Global to analyse publicly-traded REITs in the United States. The result revealed that higher ESG scores positively impact REIT performance. The authors found that ESG scores positively correlate with the increased operational efficiency of REITs. This research underscores the importance of ESG practices in real estate investment for enhanced performance.[22]

Liu and Jin (2023) have conducted a study to investigate the connection between ESG performance and financial irregularities in Chinese real estate firms listed on the stock exchange. The research findings indicate a negative correlation between the ESG performance level and corporate financial irregularities. The study suggests that companies with better ESG performance are less likely to experience financial irregularities.[23] This implies that prioritising and improving ESG practices can contribute to mitigating financial risks within companies.

Another study by Feng and Wu (2021) delves into an in-depth analysis of the relationship between ESG disclosure, firm debt, and firm value for REITs. The study considers the GRESB ESG public disclosure data, specifically on REITs. The findings presented compelling evidence of an inverse correlation between REIT's debt cost and ESG disclosure level. The study shows a positive

[18] Cf. ibid., pp.5–6.
[19] Cf. Zhang, Qingquan T. et al.: Environmental, Social Responsibility, and Corporate Governance (ESG) Factors of Corporations Alternative data and artificial intelligence techniques, p. 143.
[20] Cf. ibid., p. 144.
[21] Cf. Kempeneer, Shirley; Peeters, Michaël; Compernolle, Tine: Bringing the User Back in the Building, p. 2.
[22] Cf. Aroul, Ramya Rajajagadeesan; Sabherwal, Sanjiv; Villupuram, Sriram V.: ESG, Operational Efficiency and Operational Performance: Evidence from Real Estate Investment Trusts. In: Managerial Finance Issue 8-2022, pp. 1206–1220.
[23] Cf. Liu, Dingru; Shanyue, Jin: How Does Corporate ESG Performance Affect Financial Irregularities? In: Sustainability Issue 13-2023, pp. 1–16.

relationship where increased levels of ESG disclosure among REITs result in enhanced financial flexibility and higher market valuation. Furthermore, they assessed the impact of COVID-19 and discovered that REITs with better ESG performance prior to the pandemic exhibit a higher firm value during the pandemic, which demonstrates that investors place a high value on REITs that prioritise ESG practice.[24]

2.1.2 ESG Challenges

Challenges regarding the implementation and reporting of ESG practices are complex and vary. Organisations face difficulties in managing ESG criteria due to inconsistencies. The increasing number of rating agencies tends to result in a higher variation in ESG assessment, further complicating the process. The lack of standardisation within the rating industry exacerbates these challenges as different raters may have different views on a specific company's ESG performance across various categories.[25] Berg et al. (2019) studied these inconsistencies within ESG rating agencies. They studied the divergence between six rating agencies and documented their primary source of inconsistencies, which are scope (different sets of attributes), measurement (same attribute with varied indicators), and weight (different levels of importance or weight to the same attributes). The findings revealed a 36% divergence in scope, 56% in measurements and 6% in weight.[26] These inconsistencies and diverse methods used by rating agencies may cause confusion and misinterpretation for investors and other interested parties who depend on these ratings to make informed decisions. These discrepancies can lead to conflicting evaluations, making it more challenging to understand a company's practices.

Another challenge in ESG reporting is collecting and maintaining quality data from reporting organisations. Inaccuracies in ESG reporting often arise from confusion and difficulty in assessing the requirements for preparing comprehensive reports. This is due to the lack of clarity in standards definitions and intent, leading to incomplete and potentially inaccurate information reporting.[27] Kotsantonis and Serafeim's (2019) research revealed that companies use over 20 methods to report Employee Health and Safety data. These methods use different terminology and employ varying units of measurement.[28] This variation poses a significant challenge for organisations comparing their ESG performance with industry peers utilising different standards. Furthermore, this challenge could mislead investors who look into ESG data for investment performance.

2.1.3 ESG Rating and Benchmarking In Real Estate

Real estate ESG benchmarking evaluates properties based on environmental, social, and governance criteria to identify areas for improvement and best practices. Rating agencies provide a principal guideline for quantifying ESG matrics of real estate assets and providing property scoring methods. The rating agencies offer investors a way to assess a company’s ESG performance and identify potential risks and opportunities for making investment decisions.[29]

[24] Cf. Feng, Zifeng; Wu, Zhonghua: ESG Disclosure, REIT Debt Financing and Firm Value. In: The Journal of Real Estate Finance and Economics-2021, pp. 1–35.
[25] Cf. Kempeneer, Shirley; Peeters, Michaël; Compernolle, Tine: Bringing the User Back in the Building, p. 3.
[26] Cf. Berg, Florian et al., Aggregate Confusion: The Divergence of ESG Ratings (University of Zurich, 2022), pp. 1315–1344.
[27] Cf. Jonsdottir, Bjorg, et al.: Barriers to Using ESG Data for Investment Decisions. In: Sustainability Issue 9-2022, p. 4.
[28] Cf. Sakis, Kotsantonis; George, Serafeim: Four Things No One Will Tell You About ESG Data, p. 51.
[29] Cf. Berg; Kölbel; Rigobon: Aggregate Confusion: The Divergence of ESG Ratings, p. 6.

Nevertheless, there is a lack of commonly agreed-upon criteria for ESG rating since most rating agencies are not specific to sectors. The absence of conceptual rating criteria and aggregation methods causes discrepancies, as it is not clearly understood which criterion can benefit ESG performance and to what extent, making it difficult for investors to choose a particular rating standard. This has led to a demand for greater conceptual clarity on ESG standards.[30] The rating agencies have constantly emerged, improving their standards and methodology to include a broader range of ESG matrices and ensure a more accurate and comprehensive assessment of ESG performance.[31]

Newell et al. (2023) have categorised the real estate ESG benchmark into four different categories, i.e., benchmarks at the real estate fund/asset level, the listed real estate level, the real estate property delivery level, and the real estate reporting level. The following table presents each level based on Newell et al.'s (2023) benchmarking categories.

Table 1: ESG Benchmarking levels.[32]

Benchmarking level	Reporting standards	Discription
Real estate fund/asset level benchmarks	Global Real Estate Sustainability Benchmark (GRESB)	Assess the sustainability performance of real estate investment funds and individual
Listed real estate property-level benchmarks	Standard & Poor (S&P)	Assess the ESG performance of publicly listed real estate funds.
	Morgan Stanley Capital International (MSCI)	
Reporting level benchmarks	Task Force on Climate-Related Financial Disclosures (TCFD),	Assess the degree of transparency and completeness in reporting and disclosing ESG practices of real estate companies regarding their ESG performance.
	Principle of Responsible Investment (PRI)	
	Global Reporting Initiative (GRI)	
Property delivery level benchmarks	Leadership in Energy and Environmental Design (LEED)	Asses the sustainability performance such as energy, water, waste and CO2 emissions of individual real estate projects during their development
	Building Research Establishment Environmental Assessment Method (BREEAM)	
	Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB)	
	EnergyStar	

However, some ESG benchmarking, such as GRESB, provide multiple benchmarking levels for listed and non-listed real estate assets and use the standardised methodology consistent with the reporting level benchmarks such as PRI, TCFD and GRI.[33] Furthermore, Newell et al. (2023) interviewed 60 real estate stakeholders, revealing that GRESB was frequently cited as the

[30] Cf. Kempeneer, Shirley; Peeters, Michaël; Compernolle, Tine: Bringing the User Back in the Building, pp.2–3.
[31] Cf. Zhang, Qingquan T. et al.: Environmental, Social Responsibility, and Corporate Governance (ESG) Factors of Corporations Alternative data and artificial intelligence techniques, p. 155.
[32] Cf. Newell, Graeme; Nanda, Anupam; Moss, Alex: Improving the benchmarking of ESG in real estate investment, pp. 5–12.
[33] Cf. Global Real Estate Sustainability Benchmark, GRESB Documents: Real Estate Standard and Reference Guide. Internet source.

primary benchmarking standard.[34] However, MSCI, Sustainalytics,[35] and S&P,[36,] have also been listed as some of the significant benchmarking providers on listed real estate funds.

This thesis primarily focuses on the GRESB standard for analysis. The following section provides an insight into the GRESB methodology.

2.1.4 Global Real Estate Sustainability Benchmark (GRESB)

The Global Real Estate Sustainability Benchmark (GRESB) is a global standard for reporting and evaluating a company's ESG performance in real estate and infrastructure. The GRESB real estate assessment standard is defined explicitly for the real estate sector and was first introduced in 2009.[37] GRESB is Widely recognised as a key driver in assessing and promoting ESG practices through a comprehensive benchmarking framework and has become an essential standard for advancing sustainability specific to the real estate sector.[38,39]

According to the GRESB document (2023), The evaluation of ESG performance is based on three primary ESG components: Management, performance, and development. GRESB use a standardised methodology that is consistent with globally recognised frameworks such as TCFD, GRI, and PRI, irrespective of property type. The GRESB real estate benchmark report evaluates the ESG performance of a property company, fund, or developer participating in the GRESB assessments. GRESB has two benchmark reporting methods: the benchmark for standing investment and the development benchmark. The standing investment benchmark involves the reporting of management and performance components. On the other hand, the GRESB development benchmark requires the reporting of the management and development components. The allocation of Environmental, Social, and Government indicators is distributed among these three benchmarking components, as illustrated in Table 2.

Table 2: ESG dimensions score attributed to each component.[40]

Component	Evironmental (G)	Social (S)	Government (G)
Management	0%	35%	65%
Performance	89%	11%	0%
Development	73%	21%	6%

Table 3 presents the different aspects of each component of the GRESB standard. The GRESB management component evaluates real estate entity's strategies and policies set to manage their ESG performance. It examines how sustainability is integrated into their business operations and decision-making processes, including goal-setting, stakeholder engagement, risk management procedures, and the existence of sustainability-focused teams and leadership.

[34] Cf. Newell, Graeme; Nanda, Anupam; Moss, Alex: Improving the benchmarking of ESG in real estate investment, pp.10–11.
[35] Cf. ibid., p. 6.
[36] Cf. Nanda, Anupam, ESG in Real Estate Investment The Palgrave Encyclopedia of Urban and Regional Futures, ed. Robert, Brears [S.l.] 2022, p. 3.
[37] Cf. Devine, Avis; Sanderford, Andrew; Wang, Chongyu: Sustainability and Private Equity Real Estate Returns, p. 4.
[38] Cf. ibid., p. 5.
[39] Cf. Newell, Graeme; Nanda, Anupam; Moss, Alex: Improving the benchmarking of ESG in real estate investment, p. 6.
[40] Cf. Global Real Estate Sustainability Benchmark: GRESB Documents. Internet source.

The performance component assesses real estate portfolio sustainability outcomes by examining quantitative and qualitative data. This process involves examining different environmental metrics, such as energy and water usage, waste management techniques, and monitoring of greenhouse gas emissions, along with assessing social aspects like tenant comfort, community engagement, and diversity and inclusivity initiatives. This approach provides a tangible depiction of how effectively a real estate organisation is putting its sustainability objectives into practice.

The development component focuses on incorporating sustainable practices in the planning, design, and construction phases of new development and heavy renovation. This combines many factors, including using environmentally friendly building materials, ensuring energy efficiency, water conservation, and waste management. Additionally, it considers social factors such as indoor environmental quality, community engagement, and construction safety. This component underscores the importance of sustainable practices right from the inception of a project, ensuring that the impact on the environment and society is minimised throughout the property's lifecycle.[41]

Table 3: GRESB component weight and aspects.[42]

Component	Aspect	Number of ESG Indicators	Weight (%)
Management	Leadership	6	30
	Policy	3	
	Reporting	3	
	Risk Management	10	
	Stakeholders Engagement	11	
Performance	Reporting Characteristics	2	70
	Risk Assessments	5	
	Target	2	
	Tenants & Community	9	
	Energy	1	
	GHG	1	
	Water	1	
	Waste	1	
	Data Monitoring & Review	4	
	Building Certification	3	
Development	Reporting Characteristics	2	70
	ESG Requirements	3	
	Materials	3	
	Building Certifications	2	
	Energy	3	
	Water	1	
	Waste	1	
	Stakeholder Engagement	8	

[41] Cf. ibid. Internet source.
[42] Cf. ibid. Internet source.

2.1.5 GRESB Development Component

This study focuses on projects during the planning, design, and construction phases. The development component covers aspects of building planning, design and construction process, ensuring that new construction projects (ongoing and completed) and redevelopment projects align with sustainable practices. According to the GRESB document (2023), the component comprises seven aspects and twenty-one indicators covering all three ESG dimensions. The E-dimension consists of twelve indicators focusing on efficiency measures taken to decrease environmental impact, such as energy efficiency, water conservation, waste management, and sustainable building material sourcing. On the other hand, the S-dimension consists of eight indicators that evaluate the social impact on an entity's activities, such as health and well-being initiatives for occupants, construction site safety practices, and the development impact on local communities. Moreover, the G-dimension consists of one indicator specifically defined to assess the effectiveness of an ESG strategy in planning and executing a development project at the entity level. Each aspect within these indicators encompasses specific requirements that assess the entity's strategy, policy, and standard followed for the development project and common measures incorporated into the entity's requirements.

Table 4: GRESB Development Component Indicators.[43]

Aspect	Indicator Code	Indicator	Dimension	Score
ESG Requirements	DRE1	ESG strategy during development	G	4.00
	DRE2	Site selection requirements	E	4.00
	DRE3	Site design and development requirements	E	4.00
Material	DMA1	Materials selection requirements	E	6.00
	DMA2.1	Life cycle assessments	E	Not scored
	DMA2.2	Embodied carbon	E	Not scored
Energy	DEN1	Energy efficiency requirements	E	6.00
	DEN2.1	On-site renewable energy and low carbon technologies	E	6.00
	DEN2.2	Net zero carbon design and standards	E	2.00
Water	DWT1	Water conservation strategy	E	5.00
Waste	DWS1	Waste management strategy	E	5.00
Building Certification	DBC1.1	Green building standard requirements	E	4.00
	DBC1.2	Green building certifications	E	9.00
Stakeholder Engagement	DSE1	Health & Well-being	S	2.00
	DSE2.1	On-site safety	S	1.50
	DSE2.2	Safety metrics	S	1.50
	DSE3.1	Contractor ESG requirements	S	2.00
	DSE3.2	Contractor monitoring methods	S	2.00
	DSE4	Community engagement program	S	2.00
	DSE5.1	Community impact assessment	S	2.00
	DSE5.2	Community impact monitoring	S	2.00

[43] Cf. ibid. Internet source.

The indicators are weighted based on their relevance and importance. In this case, the E-dimension is assigned a higher weightage compared to the S-dimension and G-dimension. Specifically, the E-dimension is given a percentage weight of 73%, indicating its significant contribution towards sustainability performance assessment. On the other hand, the S-dimension is allocated a score of 21%, while the G-dimension has a much lower allocation, with only 6%. The emphasis placed on each dimension reflects their significance in evaluating overall sustainability.[44]

2.1.6 GRESB Reporting and Benchmarking

The GRESB benchmarking has been seeing steady growth, with an average increase of 2% annually, as shown in Figure 2. The GRESB 2022 real estate benchmark is a testament to the institution's vast influence and reach within the real estate sector. It covers an extensive spectrum, evaluating 1,820 funds and firms across various sectors, including health care, office, residential, retail, and more. Even more remarkable is that these evaluations span a Gross Annual Value (GAV) of $6.9 trillion across 74 countries, encompassing a significant portion of the global real estate market.[45]

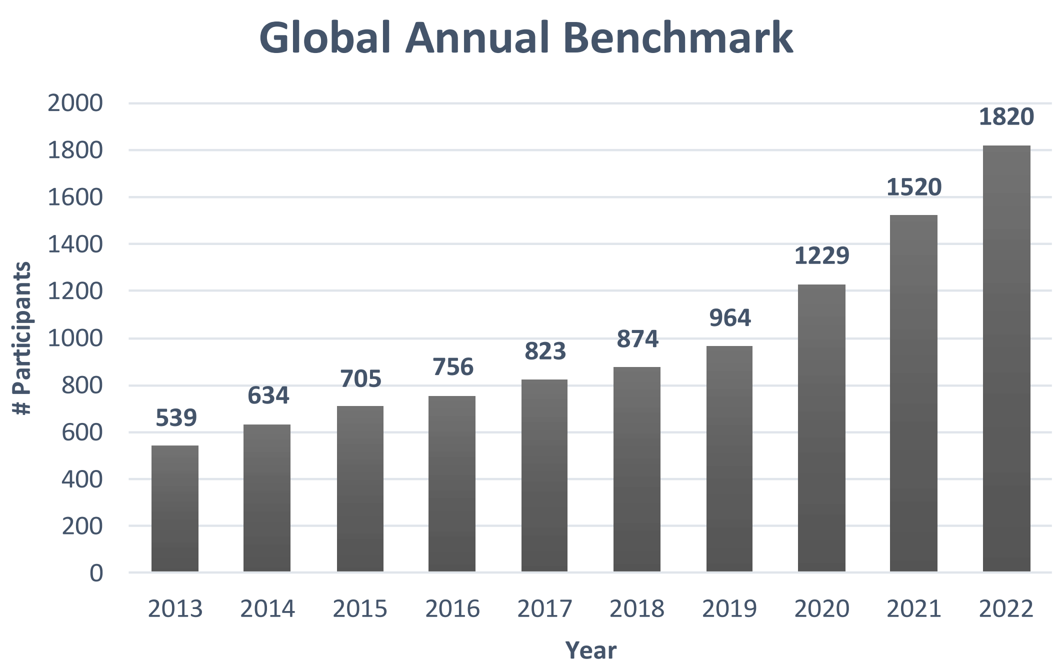

Figure 2: Annual participation in the GRASB assessment.[46]

The graph illustrates the annual participation in the GRASB assessment by firms/funds for the real estate standing investment and development benchmark. The number of participants combines both the listed and non-listed firms/funds.

[44] Cf. ibid. Internet source.
[45] Cf. GRESB, 2022 Real Estate Assessment Results - GRESB. Internet source.
[46] Cf. ibid. Internet source.

2.1.7 GRESB Reporting Approach

To better understand the criteria, indicators, and scoring methodology of each assessment type, GRESB offers comprehensive reference guides. These guides are valuable for participants seeking accurate information and ensuring their organisation is evaluated fairly. During the assessment process, participants collect data related to their organisation's ESG implementation, such as energy consumption, water usage, waste management, tenant engagement initiatives, diversity and inclusion policies, and governance structures. Using the reporting tool in the GRESB portal, participants complete the survey based on the reference guides, including uploading evidence documents and asset-level data for the performance component. Supportive evidence is required for selected indicators and is manually evaluated and scored based on fulfilment. In order to maintain a high level of accuracy and credibility, all participant submissions are subjected to a response check. This process is carried out by a third-party SRI organisation, which carefully evaluates each assessment and identifies any inconsistencies or errors in the report. The process helps to minimise errors and enables participants to review and revise their responses with guidance on unclear indicators or incorrect answers.

After the complete submission, each reported component is scored following the GRESB scoring methodology. The GRESB scoring methodology uses a schema that assesses each component based on the indicator and sub-option selected. The scoring process is automated and requires manual intervention for validating evidence-based indicators. The standing investment reporting is assigned 30% weightage to the management component and 70% to the performance component, while development reporting is assigned 30% weightage to the management component and 70% to the development component.

Rating is done based on the assessment score, and companies are assigned a rating star, with top performance having a GRESB 5-star rating and bottom performance having a GRESB 1-star rating. Entities that score at least 15 points in management and 35 points in either Performance or Development are awarded a green star as a symbol of their exceptional performance.

Next, each participating organisation is categorised and allocated a peer group. The categorisation considers factors such as Gross Average Value (GAV) and geographical location. To meet the GAV factor, at least 75% of the participant's portfolio must consist of a single property type. Participating entities that did not meet this requirement will be categorised as having a diversified property type. However, at least 75% of their portfolio must consist of two property types. A threshold of 60% GAV is set in order to assign a geographical category. The categories are country, sub-region, and region. If a participant does not meet the threshold for any of these categories, they are assigned to a globally diversified category. Following this process, peers are identified and allocated to each participating organisation in the GRESB assessment. This helps organisations that share similar characteristics to gain an understanding of their relative position, recognise their strengths and weaknesses, and establish objectives for improvement.[47]

[47] Cf. Global Real Estate Sustainability Benchmark: GRESB Documents. Internet source.

2.2 BIM Methodology

Building Information Modelling (BIM) is a collaborative process in the planning, design, construction and operation of a built facility that leverages digital tools and technologies to enhance project coordination, communication, and efficiency throughout the life cycle of a facility. This innovative approach enables team members to collaborate with enhanced efficiency compared to conventional methods. The fundamental principles underlying BIM are effective communication and seamless collaboration among project stakeholders.[48] The development of BIM dates back to the 1970s, with advancements in computer-aided design technology. Eastman et al. (1974) demonstrated using a computer database to describe buildings with detailed construction information. They showed how a computer-based building description could replicate or improve the strengths of drawings as a medium for building design, construction, and operation while eliminating most of their weaknesses.[49] However, it was not until 1992 that van Nederveen and Tolman introduced the term Building Information Model in their research paper.[50] This marked an important milestone in the evolution of BIM in the AEC industry. Over time, numerous software products with BIM functionalities have been introduced by various software vendors such as Autodesk, Graphisoft and Vectorworks, among others, leading to increased adoption within the AEC industry.

There are multiple definitions of the acronym BIM. However, according to the National BIM Standards (NBIMS) US;

Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition. A basic premise of BIM is a collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder.[51]

The utilisation of BIM encompasses a wide range of features that enable the comprehensive modelling and management of a building's lifecycle, fostering an integrated approach to design and construction. BIM is the foundation for innovative design and construction processes, resulting in superior-quality buildings at reduced costs with shorter project durations. Additionally, BIM has the potential to enhance facility management processes and facilitate future modifications to the structure.[52]

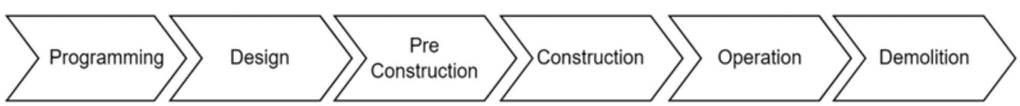

Figure 3: BIM process.[53]

[48] Cf. Azhar, Salman; Khalfan, Malik; Maqsood, Tayyab: Building Information Modeling (BIM): Now and Beyond. In: The Australasian Journal of Construction Economics and Building Issue 4-2012, p. 17.
[49] Cf. Eastman, Charles; et al.: An Outline of the Building Description System.-1974, pp. 2–23.
[50] Cf. van Nederveen, G. A; Tolman, F. P.: Modelling Multiple Views on Buildings. In: Automation in Construction Issue 3-1992, p. 215.
[51] Cf. NBIMS, National Building Information Model Standard Project Committee. Internet source.
[52] Cf. Eastman, Charles M. et al., BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, 3rd ed. Hoboken, New Jersey 2018, p. 1.
[53] Cf. Azhar, Salman; Khalfan, Malik; Maqsood, Tayyab: Building Information Modeling (BIM): Now and beyond, p. 16.

One of the fundamental characteristics of a BIM is its capability to convey both geometry and semantics. Objects in the model can be represented digitally in 2D and 3D with accurate measurements, shapes, and forms, as well as possess meaning with additional descriptive properties and their relationships to other elements. Object-based modelling is essential for analysis, such as structural analysis, building performance simulations or quantity take-off, and for deriving technical drawings directly from the model.[54]

2.2.1 BIM Level of Development (LOD)

The Level of Development (LOD) specifies the level of geometric detail (LOG) and level of alphanumeric information content (LOI) required. It indicates model maturity and progression of a model element depending on the specific needs and requirements for each phase of the design process, from conception to completion.[55]

The American Institute of Architects (AIA) developed an LOD schema to convey the reliability of BIM elements at different stages of development and use in the design and construction process through definitions and illustrations. BIM Forum published an extension of the AIA’s schema, which provides a specification guide for LODs, categorising them into six standards based on hierarchy (LOD-100, LOD-200, LOD-300, LOD-350, LOD-400, and LOD-500). At each LOD level, the geometrical and non-geometrical information of the model elements increases, reflecting the progression of the project and the amount of detailed information available. This guide illustrates the LOI and LOG at different stages.[56]

LOD-100: This is a basic level commonly utilised in project conception. The model element is usually depicted through a symbol or generic representation.

LOD-200: A visual representation of the model is depicted as a generic element with a rough estimate of its dimensions, form, position, and orientation.

LOD-300: The representation of the model element is manifested in the model as a specific system, object, or assembly with considerations for its dimension, size, shape, location, and orientation.

LOD-350: The representation of the model element in the model is conveyed through a specific system, object, or assembly, taking into account its dimension, size, shape, location, orientation, and its interactions with other building systems.

LOD-400: The model element is depicted with its specific dimension, shape, location, quantity, and orientation. Additionally, it includes information on detailing, fabrication, assembly, and installation to ensure accurate representation.

[54] Cf. Borrmann, André et al., Building Information Modeling: Technology Foundations and Industry Practice Cham, Switzerland 2018, pp. 5–6.
[55] Cf. ibid., pp. 10–11.
[56] Cf. BIM Forum, Level of Development Specification. Internet source.

LOD-500: The model element is a field-verified representation of size, shape, location, quantity, and orientation. The LOD 500 does not indicate progression to a higher level of geometry or information.

2.2.2 BIM Implementation and Interoperability

The BIM workflow revolves around utilising a building model as the fundamental basis for all information exchange. This collaboration involves integrating various software applications and platforms to enable efficient data exchange between stakeholders throughout the project's life cycle. The level of BIM implementation can be classified into two categories: Big BIM and Little BIM.[57] BIM in its complete application, is known as "Big BIM" and involves constant collaboration among different stakeholders and integrates multiple disciplines throughout the project's life cycle. Conversely, "Little BIM" pertains to the usage of BIM for a single subject or field. The little BIM implementation is centred on a specific discipline rather than across multiple disciplines throughout the project's life cycle. Both BIM implementations require integration with another software in addition to the modelling software (also called BIM authoring software). However, this requires data exchange between multiple BIM software or platforms.[58]

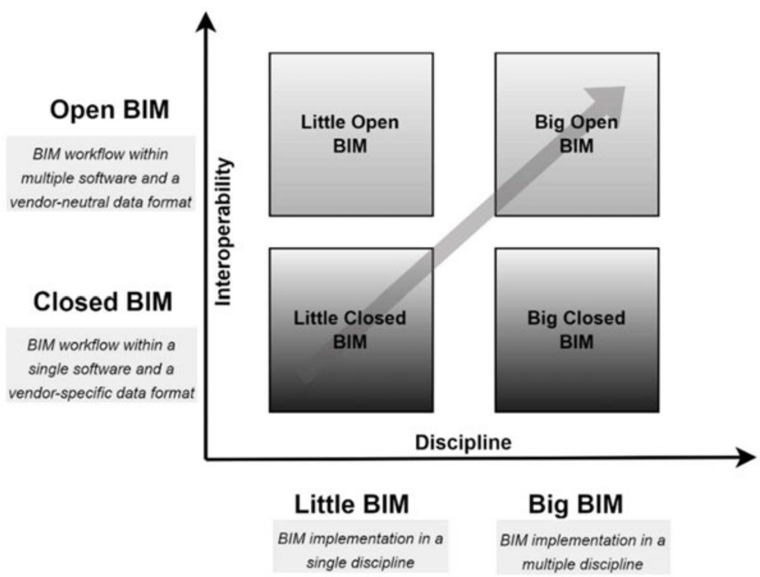

Figure 4: BIM implementation (Little and Big BIM) and interoperability (Open and Closed BIM).[59]

Data exchange and interoperability between different BIM platforms and software applications can be achieved using two approaches, namely, Closed BIM and Open BIM. The "Closed BIM" is a restrictive workflow where information exchange is within a specific software vendor's platform. In contrast, the "Open BIM" uses a neutral data format to share information and facilitate collaboration independent of the vendor.[60]

[57] Cf. Jernigan, Finith E., Big BIM, Little Bim: The Practical Approach to Building Information Modeling : Integrated Practice Done the Right Way!, 2nd ed. Salisbury, MD 2008.
[58] Cf. Borrmann et al., Building information modeling, p. 11
[59] Cf. Thomas, Liebich et al., Die Auswirkungen Von Building Information Modeling (BIM) Auf Die Leistungsbilder Und Vergütungsstruktur Für Architekten Und Ingenieure Sowie Auf Die Vertragsgestaltung: Forschungsvorhaben | Zukunft Bau | BIM-HOAI (Bundesamt für Bauwesen und Raumentwicklung (BBR)).
[60] Cf. Borrmann et al., Building information modeling, p. 11.

The closed BIM workflow has limited interoperability with other software as it relies on vendor-specific data formats.[61] Examples of closed vendor-specific file formats include RVT for Autodesk Revit, PLN for Graphisoft ArchiCAD, and NWD for Navisworks. These file formats can only be opened and edited effectively within their software applications.

The Open BIM concept is promoted by buildingSMART International organisation. They support the Industry Foundation Classes (IFC) standard, which plays a key role in the Big Open BIM approach.[62] Other Open BIM data formats include BIM Collaboration Format (BCF), City Geography Markup Language (CityGML), Green Building eXtensible Markup Language (gbXML), and Construction Operations Building Information Exchange (COBie).[63] The following section provides some commonly utilised data exchange formats during the design phase of a BIM workflow.

2.2.2.1 Industry Foundation Classes (IFC)

The Industry Foundation Classes (IFC) is an International Organization for Standardisation (ISO) schema (ISO 16739) developed and maintained by buildingSMART, which employs ISO-STEP EXPRESS modelling language. The IFC is a comprehensive scheme designed to manage all information pertaining to a building from its initial planning stages to the end of its lifecycle. IFC facilitates open BIM interoperability, making collaboration and exchange of information between different AEC software applications. It is versatile enough to be used for almost any data exchange throughout the entire life cycle.[64] The IFC schema is a highly sophisticated and complex data model that describes a hierarchical structure and adopts an object-oriented approach to depict a building model's physical geometry and semantics structure. In response to the complexity of the IFC data model, buildingSMART introduced the concept of Model View Definitions (MVDs) to specify which subsets of the data model are required for a given data exchange.[65] Over the years, various versions of the IFC schema have emerged, with IFC2X3 being the most commonly used.[66] The current latest release of the IFC schema is the IFC4.3 (as of 01.07.2023).[67]

2.2.2.2 Green Building XML (gbXML)

The Green Building XML schema is an XML-based schema for information between various BIM software tools used for Building Performance Simulation (BPS) and analysis.[68] It is a favoured standard for energy analysis in building design as it enables simple import and export of building information such as the building envelope, zones and systems.[69] The gbXML standard has gained extensive adoption within the AEC industry, as it is supported by over 50 BIM authoring, CAD, and analysis tools. The XML file contains over 500 elements and attributes that comprehensively describe a building's geometry, material properties, thermal zones, HVAC systems, and other relevant data for energy analysis.[70] Interoperability for building energy simulation relies on data

[61] Cf. ibid., p. 273.
[62] Cf. ibid., p. 124.
[63] Cf. buildingSMART International, Open BIM Definition. Internet source.
[64] Cf. Eastman et al., BIM handbook, p. 100.
[65] Cf. Borrmann et al., Building information modeling, pp. 80–85.
[66] Cf. ibid., p. 86.
[67] Cf. buildingSMART International, IFC Schema Specifications - BuildingSMART Technical. Internet source.
[68] Cf. Borrmann et al., Building information modeling, p. 205.
[69] Cf. Eastman et al., BIM handbook, p. 110.
[70] Cf. Green Building XML, About GbXML Green Building XML Schema. Internet source.

gbXML and IFC files format to exchange data between programs.[71] gbXML is increasingly recognised as a standard format for energy analysis due to its streamlined approach, adaptability, and reduced complexity compared to IFC, making It a highly suitable web-based tool for efficient data processing and interconnectivity within this domain.[72] As previously mentioned, gbXML also facilitates open BIM interoperability between different software, encouraging smooth collaboration among team members in designing sustainable buildings.

2.2.2.3 Direct Link

Information exchange between two independent software tools can be facilitated through direct linking with add-ons. This method enables real-time data synchronisation or temporary file communication, allowing changes made in one tool to reflect in the other. Direct link connections are often established via APIs or integrated features within the software itself. Examples of such APIs include Revit API, ArchiCAD GDL, and Bentley MDL, which offer direct linkage capabilities using programming interfaces like C++, C#, or Visual Basic. Most vendors have their own interface, which enhances the limitations of the native BIM software and expands its functionalities.[73]

2.2.2.4 Proprietary File Format

Proprietary data exchange formats are specific file formats created by software vendors. These formats lack standardised openness and interoperability with other software.[74] They contain detailed project information such as geometry, attributes, and configurations designed to work efficiently within a particular software ecosystem. Some common examples of proprietary file formats include Autodesk Revit.RVT format, Graphisoft ArchiCAD.PLN format, and Bentley System.DGN format.[75] Though proprietary formats support data exchange within their respective software environments, they limit the sharing and utilisation of data across different tools.[76]

2.3 BIM & Sustainability

BIM has emerged as a key driver in shaping the integration of sustainability principles into building design, construction, and operation. BIM enables collaboration among stakeholders across a project's lifecycle, allowing them to exchange data and information that contributes to achieving sustainable buildings. This alignment between BIM and sustainability promotes efficient architectural, engineering and construction processes prioritising environmental preservation.[77] The BIM process facilitates the simulation and analysis of a facility throughout its lifecycle, allowing stakeholders to evaluate the potential environmental impact of the development project. This information allows developers to make informed decisions to mitigate negative effects, ultimately leading to sustainable building practices.

[71] Cf. Clayton Miller et al., BIM-Extracted Energyplus Model Calibration for Retrofit Analysis of a Historically Listed Building in Switzerland (2014), p. 2.
[72] Cf. Vanda, et al.: BIM Enabled Building Energy Modelling: Development and Verification of a IM Enabled Building Energy Modelling.-2019, pp.1–2.
[73] Cf. Eastman et al., BIM handbook, p. 91.
[74] Cf. Borrmann et al., Building information modeling, p. 263.
[75] Cf. Eastman et al., BIM handbook, p. 92.
[76] Cf. Borrmann et al., Building information modeling, p. 273.
[77] Cf. Carvalho, José Pedro; Bragança, Luís; Mateus, Ricardo: A Systematic Review of the Role of BIM in Building Sustainability Assessment Method. In: Applied Sciences Issue 13-2020, p. 2.

The use of BIM for sustainable practices has led to the concept referred to as "Green BIM".[78] Green BIM involves integrating sustainable practices into BIM workflows by leveraging data-rich models to evaluate various sustainability measures such as energy efficiency, renewable energy potential, water resource conservation, materials and resources efficiency, and indoor environmental quality in the design and construction of buildings.[79] Implementing BIM in the context of sustainable design requires an integrated design process that incorporates different areas of expertise from the early design stage to all phases of the project. This approach involves a diverse project team collaborating through interoperable means to address the challenges and opportunities for developing a high-performance project and achieving sustainability objectives.[80]

2.3.1 Building Performance Simulation (BPS)

The BIM process enhances building performance in various areas such as energy analysis, which evaluates energy consumption and efficiency, daylight and solar studies to optimise natural lighting and heating, and thermal simulations throughout the project's lifecycle. These simulations can provide valuable insights into a building's energy consumption, thermal performance, daylighting, and even occupant comfort.[81]

Abanda et al. (2016) investigated the impact of different building orientations on energy consumption using Green Building Studio for simulation. The findings revealed that a well-oriented building can lead to effective energy saving throughout the building life cycle.[82] This shows the importance of early-stage performance evaluation, simulating different scenarios and design options to make informed decisions regarding design choices.

Vincent et al. (2019) Presented a BIM framework for addressing the impact of natural ventilation on indoor thermal comfort and energy consumption. The framework demonstrates how BIM can support maintaining a comfortable environment while reducing energy consumption.[83]

Another study by Anju and Abhaykumar (20019) incorporates various sustainability parameters to evaluate the sustainability of a green office building and a conventional building. The results showed significant energy savings, water usage savings, and carbon reductions for the office building.[84]

Various BPS software tools include IES-Virtual Environment (VE), SimPro, Green Building Studio, Design-Builder, and Graphisoft-Eco-Design.[85] Data exchange and interoperability between BIM

[78] Cf. McGraw-Hill Construction, Green BIM. SmartMarket Report. How Building Information Modeling Is Contributing to Green Design and Construction. Association Partners (2010).

[79] Cf. Wu, Wei; Issa, Raja R. A.: BIM Execution Planning in Green Building Projects: LEED as a Use Case. In: Journal of Management in Engineering-2015, pp. 1–4.

[80] Cf. Glema, Adam; Dummenahally, Nuthan, Green BIM - Eco Friendly Sustainable Design with Building Information Modeling BIM in Civil Engineering - Open Data Standards in Civil Engineering (pp.29-36), ed. Jan; Karlshoj 2016, p. 1.

[81] Cf. Jin, Ruoyu, et al.: Integrating BIM with Building Performance Analysis in Project Life-Cycle. In: Automation in Construction-2019, p. 4.

[82] Cf. F.H. Abanda; L. Byers: An Investigation of the Impact of Building Orientation on Energy Consumption in a Domestic Building Using Emerging BIM (Building Information Modelling). In: Energy-2016.

[83] Cf. Vincent J.L. Gan, et al.: BIM-Based Framework to Analyze the Effect of Natural Ventilation on Thermal Comfort and Energy Performance in Buildings. In: Energy Procedia-2019.

[84] Cf. Anju; Ebrahim, Abhaykumar S; Wayal: Bim-Based-Building-Performance-Analysis-of-a-Green-Office-Building. In: International journal of science and technology Issue 8-2019.

[85] Cf. Jin, Ruoyu, et al.: Integrating BIM with building performance analysis in project life-cycle, p. 7.

authoring tools and building performance simulation tools are mostly established in an open BIM format using IFC and gbXML. gbXML is considered the most adapted standard format for exporting building-relevant data for energy simulation.[86] There are also closed BIM building performance simulation tools such as Autodesk Insight, which is directly integrated with Autodesk Revit to create energy models automatically using its simulation engine.[87]

2.3.2 Life Cycle Assessment (LCA)

Integrating BIM with Life Cycle Assessment (LCA) provides benefits in managing digital information and streamlining data collection throughout a building's life cycle. This approach gained popularity in the academic literature, enabling rapid estimation of environmental impacts and continuous improvement of building specifications during project development.[88] LCA can be conducted at different stages to analyse the material's embodied carbon footprint and operational emissions using product-specific EPD from the manufacturer or generic datasets from Ökobaudat and e Institut Bauen und Umwelt (IBU).[89] A whole building LCA requires a substantial amount of data for assessment. Data is required across four stages: product (extraction and assembly), construction (energy and construction process), operation (energy and water use, maintenance, repair, replacement and refurbishment), and end-of-life (deconstruction, transportation, waste processing and disposal).[90] There are different methods for utilising BIM information for LCA. These approaches are more distinguished between data enrichment and interoperability. Wastiels and Decuypere (2019) distinguish the BIM-based LCA workflow into the following five strategies.[91]

LCA enriched BIM object: This strategy adds LCA info to BIM objects used in the model, making LCA profiles directly associated with the geometric and material data in the BIM environment. The workflow can be followed by calculating and analysing with a plugin or exporting to a dedicated LCA software. However, Wastiels and Decuypere (2019) highlighted that this approach has not yet been achieved due to limited available BIM objects with Life cycle information and a lack of standardised data structure for the LCA data.

IFC import of qualities: This strategy entails importing volumes from the BIM model to LCA software, usually using an Open BIM format like IFC. The LCA requires linking building components to LCA profiles for calculation and analysis within LCA software. Workflow that adheres to the open BIM approach would be better suited for a detailed LCA of the building.[92]

Bill of quantities (BOQ) export: This strategy involves extracting a bill of quantities from the BIM model, usually in the form of a spreadsheet, and importing it into LCA software to calculate the

[86] Cf. Borrmann et al., Building information modeling, p. 189.
[87] Cf. Autodesk, Insight | Building Performance Analysis Software. Internet source.
[88] Cf. Tam, Vivian W. Y. et al., State-of-the-Art of BIM-Based LCA in the Building Sector Proceedings of the 25th International Symposium on Advancement of Construction Management and Real Estate, ed. Peng, Yi et al. Singapore 2021, p. 54
[89] Cf. Bartels, Niels et al., Application of the BIM Method in Sustainable Construction: Status Quo of Potential Applications in Practice, 1st ed., Springer essentials Cham 2023.
[90] Cf. Potrč Obrecht, Tajda, et al.: BIM and LCA Integration: A Systematic Literature Review. In: Sustainability Issue 5534-2020, p. 10.
[91] Cf. Wastiels, L; Decuypere, R.: Identification and Comparison of LCA-BIM Integration Strategies. In: IOP Conference Series: Earth and Environmental Science-2019, p. 3.
[92] Cf. Bartels et al., Application of the BIM Method in Sustainable Construction, p. 36.

environmental impact. The components are then linked with LCA profiles for calculation and analyses within the software.

BIM viewer for Linking LCA profiles: In this approach, a BIM Viewer is used to attribute LCA profiles in an intermediate step. The BIM model is exported using an IFC file to the BIM viewer for the LCA profile linking to the building components. The data is then sent to the dedicated LCA software for calculation and analysis. Common BIM Viewers include “eveBIM-viewer”, Solibri, and DESITE BIM. Utilising the LCA plug-in can offer a valuable advantage in performing a preliminary assessment of design variations.[93]

LCA plug-in: This approach utilises LCA plugins in the BIM environment. The plug-in assigns LCA profiles and does all calculations within the authoring tool. No dedicated LCA software is needed. LCA results can be shown in the geometric model. Common plug-ins include Autodesk Insight Tech, CAALA, Tally, and One-click LCA.

A review conducted by Tejda et al. (2020) found that Information exchange between BIM and LCA tools is often facilitated manually using BOQ. The BOQ collected from the BIM model is transferred into an LCA tool, which is not an automated approach and is prone to errors.[94]

2.3.3 BIM-based Building Sustainability Assessment (BSA)

The Building Sustainability Assessment (BSA) method is a comprehensive evaluation process used to measure and assess the sustainability performance of a building. The primary objective of the BSA is to assess the environmental, societal, and economic impacts of a construction project. The BSA method provides critical information that supports decision-making during various stages of building design, construction, and operation. There are various sustainability assessment systems, like LEED in the US, DGNB in Germany, and BREEM in the UK, used to evaluate building performance and life cycle assessment. These systems rate the sustainability performance of buildings and provide certifications. They are designed to accommodate different scales of analysis, ensuring that buildings are thoroughly evaluated for sustainability.[95]

In recent years, there has been a growing interest among researchers in the application of BIM to enhance the practical implementation of Building Sustainability Assessment methods.[96] Today, various criteria from the BSA method have already been assessed using the BIM methodology. Wong and Kuan (2014) proposed a BIM-based method for assessing building sustainability levels by obtaining the necessary parameters from a BIM model. They analysed BEAM Plus standards through relevant literature and survey studies with BIM experts and professionals in sustainable building design. The analysis indicated that 26 out of 80 BEAM Plus criteria could be assessed by utilising the BIM process. However, the criteria being assessed were mainly related to the building materials and geometries.[97]

[93] Cf. ibid., p. 36.
[94] Cf. Potrč Obrecht, Tajda, et al.: BIM and LCA Integration: A Systematic Literature Review.
[95] Cf. Bragança, Luís; Mateus, Ricardo; Koukkari, Heli: Building Sustainability Assessment. In: Sustainability Issue 7-2010, pp.2011–2012.
[96] Cf. Yujie Lu, et al.: Building Information Modeling (BIM) for Green Buildings: A Critical Review and Future Directions. In: Automation in Construction-2017.
[97] Cf. Wong, Johnny Kwok-Wai; Kuan, Ka-Lin: Implementing ‘BEAM Plus’ for BIM-Based Sustainability Analysis. In: Automation in Construction-2014, pp. 163–175.

Akhanova et al. (2021) conducted a comprehensive analysis of the BIM-based assessment of the Kazakhstan Building Sustainability Assessment Framework (KBSAF) through a literature review. They developed a systematic framework to guide the assessment process and validated its applicability through a three-round survey. One of their findings indicates that BIM can facilitate the assessment of 24 out of 46 KBSAF indicators.[98]

Carvalho et al. (2019) demonstrate an approach to automate SBToolPT-H Building Sustainability Assessment using BIM methodology. They found that 15 of the 25 SBToolPT-H sustainability criteria can be fully assessed with BIM, while 9 others can be partially assessed. The authors suggested a structured framework based on these findings and recommended further development of SBToolBIM end-user application connected to Autodesk Revit API to extract data from the model in relation to SBToolPT-H criteria.[99]

The integration of the BIM method within the realm of design compliance with green building standards presents a transformative pathway toward embracing the assessment of ESG standards in the context of real estate development.

[98] Cf. Akhanova, Gulzhanat, et al.: Building Information Modeling Based Building Sustainability Assessment Framework for Kazakhstan. In: Buildings Issue 9-2021.

[99] Cf. Carvalho, José Pedro; Bragança, Luís; Mateus, Ricardo: Optimising Building Sustainability Assessment Using BIM. In: Automation in Construction-2019, pp. 170–182.

3 BIM-based ESG Assessment

This section will provide an analysis of GRESB ESG indicators based on potential integration and assessment using the BIM method and functionalities. As demonstrated in the previous chapter, BIM plays a crucial role in providing tools and techniques to evaluate the sustainability criteria of a development project. The scope of this thesis is restricted to new development projects during the planning, design, and construction phases. The ESG indicators of the GRESB development component are utilised for the potential BIM integration and assessment. These specific components of the GRESB schema provide various indicators directly linked to the sustainable design construction of buildings.

The analysis was conducted in two distinct phases, aiming to enhance the simplicity and efficiency of the process. The initial phase, known as “ESG indicator analysis,” focused on examining the ESG indicators in detail. It involved a comprehensive review of their intents and terminology as outlined in the GRESB development standard. This thorough evaluation served as a basis for establishing designated standards and supportive guidelines, which were subsequently categorised into qualitative and quantitative components for assessment. A distinction was made between criteria that assess an entity's standards and requirements for planning and design and measures defined for implementation in the development process.

The second phase is the “BIM integration assessment”. It involves evaluating the GRESB development indicators based on potential integration and assessment using the BIM methodology. A systematic workflow is maintained for each indicator, considering factors such as the geometric and semantic information within the BIM model, data exchange interoperability, and possible software tools and outputs. By synthesising the strengths of BIM methodology and ESG principles, this process aims to provide a structured approach for conducting an ESG assessment of a development project.

Furthermore, the potential GRESB development indicator’s score will be calculated according to the GRESB scoring methodology to identify the potential weight of the GRESB development indicators that can be achieved using BIM methodology. This scoring analysis will provide a quantitative measure of the extent to which BIM can contribute to ESG assessment in alignment with the GRESB development framework.

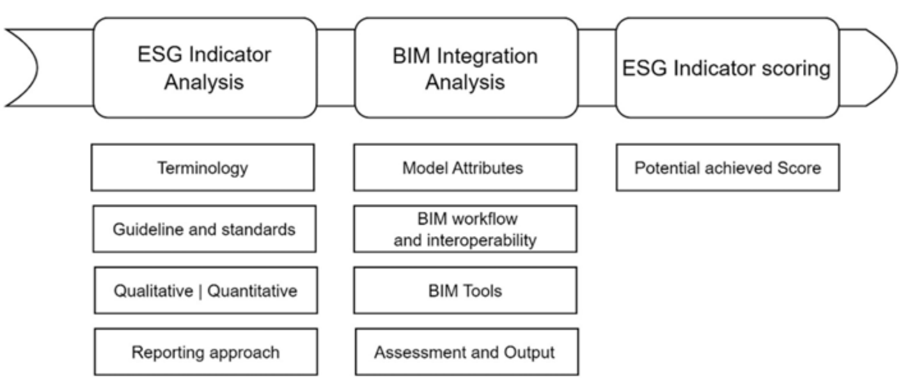

Figure 5: BIM-based ESG assessment process

3.1 ESG Indicator Analysis

The ESG indicator analysis is conducted to narrow down the scope of the thesis and determine which specific indicator would be relevant for the subsequent analysis and what data would be collected (qualitative/quantitative). GRESB provide detailed guidance and documentation to clarify the terminology of the criteria used in their assessment process. These documents help understand the indicators, intent, and definition of sub-options. Each criterion was first defined its terminology to understand what is being measured and reported.

Moreover, the GRESB development standard does not explicitly provide building design codes and standards that should be followed in the project planning, design and construction process. In many instances, the standards utilised by the entity are reported for each aspect. Aspects of the GRESB schema are divided into two sections: the requirements and the measures. The requirements are the policies that must be followed, such as planning obligations, standards, and building codes. The measures are the specific project activities that are implemented for improved efficiency within a particular aspect.[100] For example, in the energy aspect, the “DEN1 Energy efficiency requirements” indicator includes a “Requirement for planning and design” section. This is followed by the “Energy efficiency measures” section, as shown in Table 5. Therefore, it is vital to establish specific supportive guidelines, standards and recommendations for integrating ESG attributes into development projects. These involve studying each indicator's general definition and intent, including its respective sub-options. The recommendations specified in the GRESB under some indicator terminology were considered. In certain instances where no recommendation was provided, the DGNB standard code recommendations for new construction were considered. Following the GRESB recommendation and the DGNB recommended building design guidelines, each indicator’s sub-option was categorised as either quantitative or qualitative based on data collected from its assessment process. This approach ensures a robust evaluation of the environmental and social attributes.

Furthermore, the indicator’s sub-options were categorised into three categories based on the reporting approach: the technical requirements and technical measures. As previously mentioned, entity-level indicators are governance initiatives and policies that govern the environmental and social dimensions. The technical requirement pertains to the specific standards, guidelines, or strategy that an entity commits to in its sustainable development projects. These include setting energy efficiency requirements such as adhering to energy codes and standards and defining energy use intensity (EUI). On the other hand, the technical measures are the tangible actions and quantifiable data that an entity employs to fulfil the identified requirements. These are the measures taken to achieve the sustainability goals set out in the technical requirements.

Lastly, the governance indicator, which outlines ESG policies at the entity level, and measures defined to be implemented in the building operation were excluded from the subsequent analysis as this thesis is limited to the development stages in the planning, design and construction process. Appendix A for a detailed analysis, including all indicators and associated sub-options.

[100] Cf. Global Real Estate Sustainability Benchmark: GRESB Documents. Internet source.

Table 6 shows a fragment of the analysis of the energy aspect. The standards and guidelines were defined for the requirements. The first requirement, which is “1.1 development and implementation of a commissioning plan”, assesses the entity’s structured and systematic approach used in development projects to ensure that all systems and components of a building or facility are designed, installed, tested, and operated according to the intended function. The GRESB schema did not suggest any guidelines for the commissioning process. Therefore, the DGNB systematic commissioning methods are utilised. These include developing a monitoring concept, performing a preliminary function test, training and creating a commissioning report.[101]

Table 5: Excerpt of the ESG Indicator Analysis

Indicator Code	Indicator | Sub-options	Category	Score	Terminology	Standard | Guidline	Qualitative | Quantitative	Reporting approach
				Energy Aspect			
DEN1	**Energy efficiency requirements**	E	6.00				
	1. Requirements for planning and design						
	1.1. Development and implementation of a commissioning plan			Plan to review and verify design and construction phase, to ensure that the performance of faci ities, systems and assemblies meet defined objectives during the operational phase.	DGNB Methods: - Monitoring concept - Preliminary functional testing - Functional testing and training - Commissioning final report	Qualitative	Technical requirements
	1.2. Integrative design process			A design process that considers and involve multiple aspects, stakeholders and functions.	- Preliminary analysis - Designn and construction by analysing unique opportunities and constraints of the building site - building performance measurement and stakeholder feedback	Qualitative	Technical requirements
	1.3. To exceed relevant energy codes or standards			Energy requirements set by building codes and standards - US energy efficiency standard - International energy conservation code (2012)	- US energy efficiency standard - International energy conservation code (2012) DGNB Standard: - DIN 18599 - EN ISO 52000 - ASHRAE 90.1	Qualitative	Technical requirements
	1.4. Maximum energy use intensity post-occupancy			Requirement for a building to achieve a predetermined energy use intensity once in operation	EnEV / GEG - Minimum EUI (kWh/m2/a)	Qualitative	Technical requirements
	2. Common energy efficiency measure						
	2.1. Air conditioning			Energy-efficient air-conditioning units, such as those rated with a high energy efficiency rating, and secondary measures to promote efficiencies, such as strategic location and integration into building functionality design.	Energy-efficient air-conditioning units Design strategies: - Building orientation - Thermal gain Air-conditioned ventilation System (DGNB) - supply-air fan: PSFP = 1.5 kW/(m3/s) - exhaust-air fan: PSFP = 1.0 kW/(m3/s)	Quantitative	Technical measures
	2.2. Commissioning			Quality-orientated review and verification process during the design and construction phase, to ensure that the performance of fac lities, systems and assemblies meet defined objectives during the operational phase.	N/A	Quantitative	Technical measures

The second requirement, “1.2. Integrative design process”, assesses the entity’s collaborative approach to development that facilitates various sustainability factors. GRESB provided some examples, such as preliminary analysis and consideration of site opportunities, such as weather conditions and site-specific characteristics, to optimise the building performance.

The third requirement, “1.3. to exceed relevant energy code and standards”, assesses the entity’s energy efficiency design codes, also known as energy codes or building energy standards, followed in the development project. GRESB gave an option of the United States (US) energy efficiency standard and the International Energy Conservation Code (2002). However, it is not limited to the mentioned standards only. Therefore, more standards are listed to include local energy efficiency codes. Here, the DGNB energy standard code was considered, which recommends national and international standards for integrating energy efficiency measures in development.

[101] Cf. DGNB system, DGNB-Criteria-Set-New-Construction-Buildings-Version-2020-International. Internet source.

The last requirement, “1.4. Maximum energy use intensity post-occupancy”, assesses the entity’s energy use target for development projects to achieve during building operation. The approach for maximising energy use intensity depends on the entity’s regulatory requirements and goals. The GRESB standard did not define a guideline for integrating this requirement into the development project. However, This requirement is set for an entity to achieve a predetermined energy use intensity of a development project.

The second section provides a comprehensive list of energy efficiency measures. These measures are accompanied by detailed guidelines that have been formulated to facilitate their assessment. It is important to note that this robust process was utilised to evaluate all other aspects encompassed in the GRESB development schema. Colour codes were employed to enhance clarity and categorisation within the reporting approach. Table 5 demonstrates how these colours effectively distinguish between various sub-options included in the analysis. Notably, indicators marked with red signify those sub-options that fall outside the purview of subsequent analyses due to their focus on entity-level or operational measures, which is outside the scope of this study. On the other hand, yellow highlights denote technical requirements associated with project developments, while green indicates technical measures integrated into the planning design and construction process.

The following table (Table 7) provides a result of the ESG indicator Analysis. It highlights each indicator along with any associated sections. The “TM” column refers to technical measures in the reporting approach. The analysis revealed that technical measures have a higher proportion of 62.86% within the GRESB development schema. These measures will undergo a thorough evaluation in the subsequent BIM integration analysis. The technical requirement is denoted by “TR” and comprises 27.50% of the GRESB development schema. The “EL” and “OM” columns refer to the entity level and operational measures that are not considered in the subsequent analysis. The combined entity level and operational measures account for 9.64% of the GRESB development schema's weight.

Upon thorough analysis of all the indicators and sub-options in the GRESB development standard, it becomes evident that the BIM integration analysis might encounter certain challenges. Notably, the current findings highlight that a potential obstacle from 9.64% of the GRESB development indicator weights are government and operational measures, which are not considered in the subsequent BIM integration analysis. Furthermore, it is essential to recognise that not all requirements can be addressed through standardised approaches as they may vary depending on entity regulations, best practices, and organisational objectives and goals.

Table 6: ESG indicator analysis result

Aspect	Indicator Code	Indicator | Section	Reporting approach		
			TM	TR	EL | OM
ESG Requirements	DRE1	ESG strategy during development			x
	DRE2	Site selection requirements		x	
	DRE3	Site design and development requirements		x	
Material	DMA1	Materials selection requirements			
		1. Requirement for disclosure on environmental & health attribute of building material		x	
		2. Material characteristics specifications	x		
	DMA2.1	Life cycle assessments	x	x	
	DMA2.2	Embodied carbon	x	x	x
Energy	DEN1	Energy efficiency requirements			
		1. Requirements for planning and design		x	
		2. Common energy efficiency measure	x		
		3. Operational energy efficiency monitoring			x
	DEN2.1	On-site renewable energy and low carbon technologies	x		
	DEN2.2	Net zero carbon design and standards			
		1. Net zero carbon	x		
		2. Net zero carbon code/standard		x	
Water	DWT1	Water conservation strategy			
		1. Requirements for planning and design		x	
		2. Common water efficiency measures	x		
		3. Operational water efficiency monitoring			x
Waste	DWS1	Waste management strategy	x		
Building Certification	DBC1.1	Green building standard requirements		x	
	DBC1.2	Green building certifications	x		
Stakeholder Engagement	DSE1	Health & Well-being			
		1. Requirements for planning and design		x	
		2. Common occupant health and well-being measures	x		
		3. Provisions to verify health and well-being performance			x
	DSE2.1	On-site safety	x		
	DSE2.2	Safety metrics	x		
	DSE3.1	Contractor ESG requirements		x	
	DSE3.2	Contractor monitoring methods	x		
	DSE4	Community engagement program	x		
	DSE5.1	Community impact assessment	x		
	DSE5.2	Community impact monitoring	x		

3.2 BIM-ESG Integration Analysis

Having conducted the ESG indicator analysis, this section presents the core research methodology, which involves examining the feasibility and effectiveness of assessing various ESG indicators by utilising BIM workflow. The ultimate goal is to identify the GRESB development indicators and sub-options that can be integrated and assessed using the BIM process. In this section, each key component of the analysis will be explained.

The analysis process is initiated by evaluating the potential application of BIM for each technical measure (highlighted in green in Table 7). This involves conducting a comprehensive study of the existing research and practical applications that have explored the integration of BIM with sustainability assessment. It will identify the methods, tools, and techniques employed to link the BIM process with sustainability indicators. For the technical requirements (highlighted in yellow in Table 7), a review of building design codes, standards, and guidelines that can be fulfilled within a specific BIM workflow was conducted to identify BIM's alignment with ESG requirements.

Following the potential BIM application analysis, information requirements relating to each indicator's measures are listed to identify the information necessary for the analysis and simulation. This includes geometric and semantic information as defined by LODs. This ensures that the model created in a BIM authoring tool (such as Revit and ArchiCAD) can be imported into a simulation tool with accurate information for the analysis.

The next step in the analysis process involves establishing a comprehensive BIM workflow that promotes seamless information exchange between the BIM authoring tool and the dedicated BIM analysis and simulation software. The information considers both 'open BIM' and "closed BIM" workflow (open BIM and closed BIM are explained in Chapter 2). The data exchange format and how interoperability is realised are defined for each technical measure that can be assessed within the BIM workflow. Furthermore, BIM tools that can be utilised to assess each indicator's sub-option were defined. The study also presents the "assessment and output", mentioning the specific use cases where BIM can facilitate the ESG assessment process and stakeholder's expected outcomes or results.

Table 7: BIM-ESG integration analysis excerpt

Indicator code	Indicator | Sub-options	Potential BIM application	Information requirement	Interoperability	BIM BPS tools	Assessment and output
			Energy Aspect			
DEN1	**Energy efficiency requirements**					
	1. Requirements for planning and design					
	1.1. Development and implementation of a commissioning plan	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	—	—	—	N/A
	1.2. Integrative design process	Collaboration and communication among different stakeholders during the initial project stages to optimise design is one of the key attributes of BIM.	—	—	—	- Preliminary analysis - Energy analysis - Lightning analysis
	1.3. To exceed relevant energy codes or standards	BIM-based energy analysis software is used to analyse the total energy consumption of a facility according to various standard requirements.	—	—	—	- International Energy Conservation Code (2012) - DIN 18599 - ASHRAE 90.1 - ANSI/ASHRAE 140
	1.4. Maximum energy-use intensity post-occupancy	Energy analysis using simulation tools can provide results regarding the energy use intensity (EUI) of a facility, given the total annual energy consumption per area	—	—	—	Regulatory requirement on minimum EUI (kWh/m2/a)
	2. Common energy efficiency measure					
	2.1. Air conditioning	The potential energy load for heating and cooling can be analysed using BIM-BPS tools. Energy simulation tools contain different HVAC system options, each with its own efficiency ratings and specifications.	- Location (weather data) - Building orientation - Building envelope - Fenestration - Material thermal properties - Thermal zones - Systems (HVAC) - System efficiency - Operational Schedule	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- Energyplus - ES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - HVAC systems (energy consumption) (kWh)
	2.2. Commissioning	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	2.3. Energy modeling	BIM model can be simulated to analyse the total energy consumption considering all mechanical and electrical systems and building properties.	- Location (weather data) - Building orientation - Building envelope - Fenestration - Material thermal properties - Thermal zones - Systems (HVAC, lightning) - Operational Schedule	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- ES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - EUI (MJ/m2/a)

Table 7 provides a fragment of the entire process, offering valuable insight into the energy aspects. A colour-coded system is applied to categorise the results effectively. In this scheme, red is used to denote sub-options that cannot be assessed using the BIM process. The yellow signifies technical requirements that can be met by employing a BIM workflow. On the other hand, green indicates technical measures that can be assessed and evaluated within a BIM workflow. As mentioned in the previous analysis chapter, aspects of the GRESB schema are categorised into two sections: the requirements and the measures. Measures are typically tied to specific requirements that entities intend to meet to demonstrate their sustainability efforts.

3.2.1 BIM-ESG Integration Analysis Result

The analysis indicates the feasibility of assessing various ESG measures and fulfilling the requirements of the indicators defined in the GRESB development standard. The findings revealed that BIM workflow can support assessments for 11 of 21 indicators. Eight of these primarily focus on the environmental dimension within the aspect of materials, energy, water, and waste. The remaining three pertain to the social dimension and include health and well-being, onsite safety and safety matrices.

The remaining ten indicators were found not to be supported by the BIM workflow. These highlight potential gaps where conventional approaches or supplementary methods might be required for their assessment. Most of these indicators are related to the social dimension, as they evaluate measures outside the building design and construction process. These indicators include community impact monitoring, community engagement programs, and contractor ESG monitoring, which require a more traditional approach, like surveys, for data collection.

Environmental indicators that were not assessed within the BIM process fall under the ESG requirements and building certification aspects. In the ESG requirements, two indicators were not assessed, which include the site selection and site development. The site selection requirement indicator consists of criteria for sustainable site selection, such as preserving aquatic ecosystems, transforming existing areas, and safeguarding historical heritage sites. Similarly, the site development requirement indicator consists of criteria for minimising the negative impact of the construction site, such as protecting air quality, minimising noise pollution, and diverting construction waste from disposal. These two indicators are currently not considered assessable within an existing BIM framework.

In addition, the building certification indicators evaluate an entity's adherence to green building standards and require reporting on whether the project is certified or is registered for certification within a designated green building certification system. This indicator focuses on the entity's alignment with the green building certification system and cannot be supported by BIM workflow.

Although BIM methodology can assist in assessing specific indicators, there may be certain areas where conventional approaches or supplementary methods are still necessary. In the following section, a review of each aspect of the GRESB development standard that has the potential to be integrated and assessed within a BIM workflow is conducted.

Table 8: BIM integration assessment result

Aspect	Indicator Code	Indicator	Dimension	Supported by BIM	
				Yes	No
ESG Requirements	DRE1	ESG strategy during development	G		x
	DRE2	Site selection requirements	E		x
	DRE3	Site design and development requirements	E		x
Material	DMA1	Materials selection requirements	E	x	
	DMA2.1	Life cycle assessments	E	x	
	DMA2.2	Embodied carbon	E	x	
Energy	DEN1	Energy efficiency requirements	E	x	
	DEN2.1	On-site renewable energy and low carbon technologies	E	x	
	DEN2.2	Net zero carbon design and standards	E	x	
Water	DWT1	Water conservation strategy	E	x	
Waste	DWS1	Waste management strategy	E	x	
Building Certification	DBC1.1	Green building standard requirements	E		x
	DBC1.2	Green building certifications	E		x
Stakeholder Engagement	DSE1	Health & Well-being	S	x	
	DSE2.1	On-site safety	S	x	
	DSE2.2	Safety metrics	S	x	
	DSE3.1	Contractor ESG requirements	S		x
	DSE3.2	Contractor monitoring methods	S		x
	DSE4	Community engagement program	S		x
	DSE5.1	Community impact assessment	S		x
	DSE5.2	Community impact monitoring	S		x

3.2.2 BIM Integration Analysis Result Discussion

3.2.2.1 GRESB Development Material Aspect

The material aspect of the GRESB development standard focuses on the sustainable sourcing and assessment of the environmental and health impact of construction materials. The aspect consists of three indicators that evaluate the entity’s strategy for sustainable material selection, building life cycle assessment and assessing the building's embodied carbon emissions at different stages.

Table 9: Overview of the material aspect analysis

Requirements met	Measures assessed	Assessment	LOD	Information requirement
DMA1. Materials selection requirements				
1.1. Environmental Product Declarations	2.1. Locally extracted or recovered materials	Life Cycle Assessment - EPD-Product stage (A1-A3)	-	- Building envelop (walls, roof, floor, ceiling, column) - Material properties (type, quantity)
	2.2. Low embodied carbon materials 2.5. Material environmental impact	- Embodied carbon (A1-A3, A4, A5, C2-C4)		
	2.7. Rapidly renewable materials and recycled content materials	Beyond Life cycle - D (cradle-to-cradle)		
DMA2.1. Life cycle assessments				
	1.1. Cradle-to-gate 1.2. Cradle-to-practical completion/handover 1.3. Use stage 1.4. End-of-life stage 1.5. Cradle-to-grave 1.6. Whole life	Life Cycle Assessment - Embodied carbon emissions - Operational emissions	LOD200/300	- Material properties (type, quantity) - Generic datasets - Building systems load
			LOD 300/350	- specific LOD300 - Specific EPDs / Generic datasets
			LOD400	- Exact LOD350 - Product-specific EPDs - Product specification
DMA2.2. Embodied carbon				
	1.1. A1-A3 1.2. A1-A3, A4 1.3. A1-A3, A4, A5 1.4. A1-A3, A4, A5, C2-C4	Life Cycle Assessment - Embodied carbon emissions	See LCA	- Material properties (type, quantity, mass) - Generic datasets

DMA1 Material Selection Requirements

The first indicator describes strategies to manage environmental and health impacts associated with the building material supply chain. The indicator is categorised into two sections: the requirements for disclosure of environmental and health attributes and the material characteristic's specification preference.

The requirement for disclosure of environmental and health attributes of building materials focuses on the entity's guidelines for considering environmental and health attributes in building material selection. The first option, "1.1. Environmental Product Declarations (EPDs)", requires an entity to report their consideration of sustainable materials with available life cycle information. The EPDs must align with specific standards defined by GRESB. These standards include ISO 14025, 14040, 14044, EN 15804, and ISO 21931. Material and component EPDs contain information regarding the environmental impact of materials, covering the production phase from the extraction of the raw materials to the factory gates (modules A1 to A3).[102] The BIM process for LCA is integrated with product-specific EPDs to obtain LCA results. However, in areas where EPDs are not available, LCA inventories such as Ökobaudat and IBU.data provide generic datasets with material environmental impact in accordance with the DIN EN 15804.[103] The

[102] Cf. Shadram, Farshid, et al.: An Integrated BIM-Based Framework for Minimizing Embodied Energy During Building Design. In: Energy and Buildings-2016, p. 594.
[103] Cf. Bartels et al., Application of the BIM Method in Sustainable Construction.

different approaches for integrating environmental impact datasets in a BIM workflow have been explained in Chapter 2.

The material characteristics and specification section focuses on entity guidelines for selecting materials based on characteristics and specifications. Four material characteristics were found to be integrated and assessed in a BIM-LCA workflow to support the selection of materials with sustainable life cycle impact. These included material extraction, low embodied carbon material, environmental impact and low recycled content material. The material extraction is considered in the LCA product stage and included in the materials EPD. The low embodied carbon content and environmental impact of materials are assessed across all LCA stages with the exclusion of the operational stage. In contrast, the recycled content material can be assessed beyond the life cycle stage to identify the potential for recycling and reuse of the material.[104]

Although GRESB defines this indicator to assess an entity's sustainability consideration in the selection of building material across the supply chain, some criteria were deemed assessable in a BIM workflow for LCA. This process can support selecting materials with low environmental impacts in cases where EPDs are unavailable.

DMA2.1 Life Cycle Assessments and DMA2.2 Embodied Caborn

The following indicators, DMA2.1 Life Cycle Assessments (LCA) and DMA2.2 Embodied Caborn (EC) are not weighed but remain a GRESB requirement. The embodied carbon emission falls under the broader category of LCA and is evaluated using the same methodology as LCA. As highlighted in the previous chapter, a BIM-based LCA is carried out using different approaches, and the data required for a whole LCA across all stages are substantial.

Nonetheless, the accuracy of geometric and non-geometric information required for Life Cycle Assessment varies depending on the project phase.[105] As the project progresses, there is an improvement in the precision and accuracy of material information. The geometric and semantic information is defined based on increasing LODs. The commonly considered LODs for LCA are LOD200 and LOD300 due to their ability to provide generic and specific quantities with dimensions, sizes, and shapes for assessments.[106] However, the majority of the building elements can be assessed with higher accuracy at LOD350. Building components are fixed at this stage and contain the specific information for conducting a comprehensive LCA. At this stage, generic data can still be utilised when EPDs are unavailable or the use of conservative EPDs that reflect the actual product.[107] At LOD400, BIM models are exceptionally detailed, with product-specific data. Specific material and product environmental impacts, as described by EPDs, are represented with complete information.[108]

The various BIM-based software tools utilised for LCA are outlined in Appendix B. The most adaptable data exchange between the BIM authoring and LCA tools is by generating a schedule BOQ from the BIM model with material quantity and type information and then manually importing

[104] Cf. Potrč Obrecht, Tajda, et al.: BIM and LCA Integration: A Systematic Literature Review, p. 10.
[105] Cf. ibid., p. 14.
[106] Cf. Tam, Vivian W. Y. et al.: State-of-the-Art of BIM-Based LCA in the Building Sector Proceedings of the 25th International Symposium on Advancement of Construction Management and Real Estate, pp. 58–59.
[107] Cf. Nilsen, M; Bohne, R. A.: Evaluation of BIM Based LCA in Early Design Phase (Low LOD) of Buildings. In: IOP Conf. Series: Earth and Environmental Science-2019, p. 8.
[108] Cf. ibid., p. 7.

it into the LCA software.[109] Interoperability is also facilitated using the IFC file format to transfer geometric and non-geometric building information for LCA. In addition, direct links between BIM and LCA software applications can be facilitated, adding LCA functionalities to the BIM authoring software.[110] Furthermore, In the early stages of design, the gbXML format is employed for LCA, particularly when utilising LCA software such as CAALA. This approach considers both embodied and operational emissions to gain a basic understanding of environmental impact.[111]

3.2.2.2 GRESB Development Energy Aspect

The energy aspect of the GRESB development standard assesses the energy efficiency and sustainability design and construction to minimise energy consumption and greenhouse gas emissions. It evaluates an entity's strategy for integrating energy efficiency measures, renewable energy generation and approach toward net-zero carbon emissions in operation and construction activities.

Table 10: Overview of the energy aspect analysis

Requirements met	Measures supported	Assessment	LOD	Information requirement
DEN1. Energy efficiency requirements				
1.2. Integrative design process 1.3. To exceed relevant energy codes or standards 1.4. Maximum energy-use intensity post-occupancy	2.1. Air conditioning 2.3. Energy modeling 2.4. High-efficiency equipment and appliances 2.5. Lighting 2.6. Occupant controls 2.7. Passive design 2.8. Space heating 2.9. Ventilation 2.10. Water heating	- Energy load analysis - Sun and Shadow analysis - Daylighting analysis	LOD100	- Building envelope - Location - Orientation
		- Energy use analysis - HVAC analysis - Lightning and daylight analysis - Air flow analysis	LOD200	- Generic LOD100 - Fenestration - HVAC
		- Detailed energy use analysis - GHG emmission	LOD300	- Specific LOD200 - Lightning - Occupancy - Thermal properties - Operation schedule - Thermal zones
DEN1.1. On-site renewable energy and low carbon technologies				
	1.4. Solar/photovoltaic	- Solar analysis	LOD100	- Building exterior - Location - Orientation
		- PV energy potential	LOD200/300	- LOD100 - System efficiency - Covered area
	1.5. Wind	- Wind energy potential	LOD100	- Location
DEN2.2. Net zero carbon design and standards				
2.1. National/local green building council standard 2.2. National/local government standard 2.3. International	1.1. Net zero carbon - construction	See material aspect	See material aspect	See material aspect
	1.2. Net zero carbon - operational energy	See energy aspect	See energy aspect	See energy aspect

[109] Cf. Potrč Obrecht, Tajda, et al.: BIM and LCA Integration: A Systematic Literature Review, p. 5.
[110] Cf. Wastiels, L; Decuypere, R.: Identification and comparison of LCA-BIM integration strategies, pp. 2–5.
[111] Cf. Kasimir et al., Calculation of Embodied GHG Emissions in Early Building Design Stages Using BIM and NLP-Based Semantic Model Healing (Technical University of Munich: Chair of Computational Modelling and Simulation, 2023), p. 6.

DEN1. Energy Efficiency Requirements

The first indicator describes different strategies to integrate energy efficiency measures in the design and construction activities. The indicator is categorised into two sections: The requirement for planning and design and common energy efficiency measures. The requirement for planning and design consists of four sub-options focusing on guidelines such as planning obligations, standards, and building codes for integrating energy efficiency measures in the design and construction process. Each sub-option was evaluated based on its potential fulfilment within a BIM workflow.

The first option, “1.1. Development and implementation of a commissioning plan", cannot be assessed using the BIM methodology. Wong et al. (2014)[112] and Akhanova et al. (2021)[113] highlighted that building commission could not be achieved within the BIM process. Wu and ISa (2012) demonstrated a BIM process for building commissioning. BIM was found to streamline the documentation of the commissioning process for handover. However, the process still requires field testing and manual documentation of functionality tests.[114]

The second option, "1.2. integrative design processes", is considered one of the characteristics of BIM. BIM's implementation enables the coordination of various project stakeholders and data sources, leading to optimised building performance.[115] BIM enables stakeholders to simulate building performance seamlessly throughout various project stages.[116] GRESB highlighted some examples of integrative consideration during different design stages, which include preliminary analysis and collaboration. The BIM process fosters the initial assessment of a model by using simulations and analysis to evaluate a building's performance. This helps to consider different design alternatives, such as building orientation and materials, to meet the desired building functionality, sustainability and other requirements.[117] Furthermore, The BIM process provides multiple mediums for collaboration and communication of project information among stakeholders. Effective collaboration among project stakeholders is seen as one of the fundamental principles of BIM.[118] Collaboration is achieved through interoperable means using a data exchange file format or a Common Data Environment (CDE), enabling efficient data exchange among stakeholders.[119]

The requirement option “1.3. To exceed the maximum energy efficiency standard” evaluates an entity's compliance with energy efficiency standards and building codes. A BIM-based Building Performance Simulation (BPS) can effectively fulfil this requirement. Energy analysis is conducted using multiple simulation tools and engines that accurately assess the energy performance of buildings while adhering to energy codes and standards like DIN 18599 and ASHRAE (American

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[112] Cf. Wong, Johnny Kwok-Wai; Kuan, Ka-Lin: Implementing ‘BEAM Plus’ for BIM-based sustainability analysis, p. 165.

[113] Cf. Akhanova, Gulzhanat, et al.: Building Information Modeling Based Building Sustainability Assessment Framework for Kazakhstan, p. 12.

[114] Cf. Wu, W; Issa, R. R. A., BIM-Enabled Building Commissioning and Handover Computing in civil engineering*:* Proceedings of the 2012 ASCE International Conference on Computing in Civil Engineering, June 17-20, 2012, Clearwater Beach, Florida, ed. Flood, Ian; Issa, Raymond Reston, Va. 2012, p. 237.

[115] Cf. Eastman et al., BIM handbook, p. 1.

[116] Cf. Glema, Adam; Dummenahally, Nuthan: Green BIM - Eco Friendly Sustainable Design with Building Information Modeling BIM in Civil Engineering - Open Data Standards in Civil Engineering (pp.29-36), p. 29.

[117] Cf. Eastman et al., BIM handbook, p. 21.

[118] Cf. Azhar, Salman; Khalfan, Malik; Maqsood, Tayyab: Building Information Modeling (BIM): Now and beyond, p. 17.

[119] Cf. Eastman et al., BIM handbook, p. 85.

Society of Heating, Refrigerating and Air-Conditioning Engineers).[120] By adhering to these standards, simulation tools ensure that their calculations and predictions are consistent with industry norms, enabling decisions that meet regulatory requirements and sustainability goals.

Similarly, the last requirement option, “1.4. To maximise energy used intensity”, can be fulfilled using simulation tools. BPS tools calculate the potential annual energy use of a building, considering various aspects of the building envelope and systems.[121] These calculations can be compared to the energy requirements set by an entity, and an iterative approach can be employed using different design alternatives until the requirements are fulfilled.

The second section, “2. Common energy efficiency measure,“ presents a list of 10 energy efficiency considerations recommended for implementation. Some of the measures include energy-efficient systems like space heating, ventilation, air conditioning, lighting, and occupancy control. These measures have been carefully evaluated based on their potential integration and assessment within the BIM framework. Different simulation tools for energy analysis provide a variety of design strategies for energy efficiency, such as energy-efficient HVAC systems, lighting efficiency, control methods and operational schedules.[122] Furthermore, various efficiency options and passive design strategies, such as natural ventilation and daylighting, can also be analysed to improve the energy consumption of the building.[123] An overview of the common energy efficiency measures that can be assessed using BIM and BPS is presented in Table 10. The complete evaluation of all ten common energy efficiency measures is provided in Appendix B.

The information needed for energy simulation and analysis depends on the project stage. The building envelope and fenestration of a building are the important factors that contribute significantly to energy use.[124] Jin et al. (2019) categorise different LODs for BPS. In the concept stage, at LOD100, the model contains basic information about the building envelope (levels, shape, and area), location, and orientation, which can analysed to get a general perspective of the site’s condition, energy load, and potential design opportunities. In the preliminary stage, LOD200 contains generic information regarding the building envelope and system, such as fenestration and HVAC, which can be used to obtain more information on the building energy profile, such as HVAC load. A more detailed analysis is conducted at LOD300 and higher using specific data regarding the building systems, building zone, materials, and thermal properties such as U-value and R-value. At this stage, a more thorough energy use analysis can be conducted.[125]

As discussed in the previous chapter, data exchange and interoperability between BIM authoring tools and BPS software tools is facilitated using IFC and gbXML file format or direct link with BIM software tools. A list of BPS software tools used for energy analysis is provided in Appendix B.

[120] Cf. Bartels et al., Application of the BIM Method in Sustainable Construction, p. 21.
[121] Cf. Mahiwal, Sharda G; Bhoi, Manas Kumar; Bhatt, Naimish: Evaluation of Energy Use Intensity (EUI) and Energy Cost of Commercial Building in India Using BIM Technology. In: Asian Journal of Civil Engineering Issue 5-2021, p. 877.
[122] Cf. ibid., p. 885.
[123] Cf. Akhanova, Gulzhanat, et al.: Building Information Modeling Based Building Sustainability Assessment Framework for Kazakhstan, p. 8.
[124] Cf. Shahryar, Habibi: Role of BIM and Energy Simulation Tools in Designing Zero-Net Energy Homes. In: Construction Innovation Issue 1-2022, p. 110.
[125] Cf. Jin, Ruoyu, et al.: Integrating BIM with building performance analysis in project life-cycle, pp. 2–4.

DEN2.1 On-site renewable energy and low carbon technologies

The second indicator focuses on an entity's consideration of renewable energy generation and low-carbon technologies to reduce the environmental and economic impact associated with the use of fossil fuels. The indicator requires the percentage of energy demand that, by design, can be supplemented with the use of on-site renewable energy and low-carbon technology. GRESB provided a list of five renewable energy and low-carbon technologies that can be implemented during development. However, only two were deemed feasible for integration within the BIM workflow, including wind and solar energy generation. BIM BPS tools can be utilised to calculate the potential on-site solar energy generation by conducting a solar radiation analysis.[126] BPS tools such as GBS (Green Building Studio) can calculate the potential energy demand of solar photovoltaic and wind turbines.[127] With this approach, it becomes feasible to compare the percentage of energy demand that can be covered by renewables (such as wind and solar) with the total energy consumption of a building.

Solar analysis can be conducted during the conceptual phase by taking into account factors such as the building envelope, location, and orientation.[128] A more comprehensive assessment of PV systems requires specific information on panel efficiency and covered area. Wind energy analysis in GBS only considers the location's weather data. The software tool assumes the dimension and velocity of a single wind turbine to calculate the potential energy production.[129]

DEN2.2 Net Zero Carbon Design and Standards

The last indicator focuses on the design approach to achieve a net zero carbon performance. The first measure, “1.1. Net zero carbon construction”, requires the carbon emission associated with building material and construction stage up to the practical completion to be zero or negative. The BIM process can support the analysis of a building's carbon footprint from the product stage to the construction stage (A1 - A3, A4 - A5). This process has been explained in the previous section (Material aspect). Carbon emissions obtained from LCA results can be used to define net zero carbon emission strategies based on standard guidelines. Several carbon-reducing measures can be taken into account during the design phase, such as considering local materials, low embodied carbon and re-use of materials.

The second measure, “1.2. Net zero carbon operation”, requires carbon emission associated with the building operation to be zero or negative through on-site and off-site renewable energy supply. The role of BIM in energy efficient design and renewable energy supply has been presented in the previous paragraphs. BIM can support the achievement of net-zero strategies through energy-efficient design processes and optimisation of building performance. A detailed simulation of the building and considering energy-saving strategies and an efficient system can support the net zero strategies through the reduction of energy consumption. Furthermore, the integration of on-site renewable energy systems can provide potential energy production from renewable energy systems to support the net zero carbon strategy. Shahryar (2022) demonstrated a study leveraging the BIM process for energy-efficient decisions and integration of renewable energy to

[126] Cf. ibid., p. 2.
[127] Cf. Akhanova, Gulzhanat, et al.: Building Information Modeling Based Building Sustainability Assessment Framework for Kazakhstan, p. 13.
[128] Cf. Jin, Ruoyu, et al.: Integrating BIM with building performance analysis in project life-cycle, p. 2.
[129] Cf. Green Building Studio, Building Performance Simulation. Internet source.

balance the building's energy consumption. The study achieved a negative energy use using PV systems for energy generation.[130]

LCA tools, like One Click LCA, can evaluate carbon emissions and reduction options to define the Net Zero Carbon target while ensuring compliance with local net-zero carbon standards. The tool calculates carbon-reducing options such as material reuse, energy export, and biogenic carbon storage and determines the need for offsetting after other carbon-reducing measures have been exhausted.[131]

3.2.2.3 GRESB Development Water Aspect

The water aspect evaluates the different strategies for integrating water conservation measures in a development project. It describes various water-saving requirements and measures for promoting indoor and outdoor water efficiency. This aspect consists of one indicator focusing on water conservation.

Table 11: Overview of the water aspect analysis

Requirements met	Measures supported	Assessment	LOD	Information requirement
DEN1. Energy efficiency requirements				
1.2. Integrative design for water conservation 1.3. Requirements for indoor water efficiency 1.4. Requirements for outdoor water efficiency	2.2. Drip/smart irrigation 2.3. Drought tolerant/low-water landscaping 2.4. High-efficiency/dry fixtures 2.8. Reuse of stormwater and greywater for non-potable applications	Water use analysis Water Usage - Indoor (l/yr) - Outdoor (l/yr) Efficiency saving - Water saving (l/yr)	-	- Building type - Number of occupancy - Operation schedule Others information are added in the BPS tool - Plumbing fixtures efficiency - Vegetation type - Rain water catchment area

DWT1 Water Conservation Strategy

The indicator focuses on an entity's strategy in implementing water efficiency measures in the design and construction process. Similar to the DEN1 Energy Efficiency Requirements, this indicator is also categorised into two sections: the requirement for planning and design and the common water efficiency measure. The first section, “1. Requirement for planning and design”, evaluates the entity’s technical guidelines for implementing water efficiency. These guidelines contain the entity’s design obligations for water supply and usage (indoor and outdoor). Sub-options include a commissioning plan, integrative design, minimum water use intensity, indoor and outdoor water efficiency, and process water efficiency.

BIM’s ability for an integrative design process and non-fulfilment of a commissioning process have been explained in the DEN1 Energy Efficiency Requirements. The requirement for water use intensity, indoor and outdoor, can be achieved using the BIM process. BIM can be used to analyse the total water consumption of a building considering various factors such as building type, occupancy and plumbing fixtures. Furthermore, various water-saving measures can be integrated to reduce the overall water consumption of the indoor and outdoor environment.[132]

[130] Cf. Shahryar, Habibi: Role of BIM and energy simulation tools in designing zero-net energy homes, p. 115.
[131] Cf. One Click LCA, Net Zero Carbon Buildings. Internet source.
[132] Cf. Anju; Ebrahim, Abhaykumar S; Wayal: Bim-Based-Building-Performance-Analysis-Of-A-Green-Office-Building, p. 569.

The second section, “2. Common water efficiency measures”, consists of a list of water efficiency measures. These measures were carefully analysed in terms of their potential integration within the BIM framework for water use analysis. Anju et al. (2019) conducted a study on BIM-based building performance analysis using Green Building Studio to assess the water consumption of a green office building. They incorporated various water conservation measures such as rainwater harvesting, greywater reuse, native vegetation landscaping, and efficient water fixtures to estimate the total water consumption. Information regarding efficiency measures is added within the simulation tool's domain.[133]

3.2.2.4 Waste Aspect

The waste aspect evaluates an entity’s strategies for efficient on-site construction waste management and monitoring. It covers waste management practices for construction and demolition disposal in landfills, reusing, recovering and recycling.

Table 12: Overview of the waste aspect analysis

Requirements met	Measures supported	Assessment	LOD	Information requirement
DWS1. Waste management strategy				
	1.7. Waste separation facilities 2.1. Hazardous waste monitoring 2.2. Non-hazardous waste monitoring	- Construction site utilisation - Quantity take-off (QTO) - 4D Simulation - Phase planning	LOD350	- Material properties (quantities) - Waste seperation category (hazardeous/non-hazardeous) - waste index

DWS1 Waster Management Strategy

The indicator describes measures for waste management in construction practices and on-site waste monitoring. Several BIM use cases have been identified to contribute towards efficient waste management and reduction in the construction industry. These include 4D simulation for phase planning, quantity take-off, design review, planning for site utilisation, and 3D coordination.[134] Given the potential opportunities of BIM efficient waste management and reduction, various studies have proposed a BIM approach for construction waste management. Quiñones et al. (2022) conducted a study proposing a method to measure construction waste during the design phase. The authors created an Add-in using the Revit API (Application Programming Interface) to automate the process. This tool provides information on the types and quantities of construction waste generated by the design decisions made. However, the tool has certain limitations, as it can only be applied to specific building typologies. Additionally, it requires enriched BIM object libraries to estimate construction waste accurately.[135] A framework proposed by Handayani et al. (2022) provides an approach to implementing circular economy principles in construction and demolition waste management by leveraging BIM capabilities such as 3D BIM modelling, 4D simulation, and quantity take-off for direct construction waste estimation. It also addresses waste sorting, disposal methods, and associated cost estimates.[136]

[133] Cf. ibid.

[134] Cf. Won, Jongsung; Cheng, Jack C.P.: Identifying Potential Opportunities of Building Information Modeling for Construction and Demolition Waste Management and Minimization. In: Automation in Construction-2017, p. 8.

[135] Cf. Quiñones, Rocío, et al.: Quantification of Construction Waste in Early Design Stages Using Bim-Based Tool. In: Recycling Issue 5-2022, pp. 1–17.

[136] Cf. Handayani, Tantri N., et al.: The Building Information Modeling (BIM)-Based System Framework to Implement Circular Economy in Construction Waste Management. In: Journal of the Civil Engineering Forum Issue 8-2022, pp. 31–44.

BIM can support some of the measures defined by GRESB, such as waste separation facilities and waste monitoring. BIM use in site utilisation planning facilitates the creation of site layouts for different construction phase transitions and allows for efficient resource allocation and logistics. This can be achieved through 4D simulation and phase planning. Furthermore, 4D phase planning can support on-site waste monitoring during various construction phases, providing essential information such as waste index, material specification, hazard classification, and disposal methods.[137] Based on these functionalities, it was concluded that BIM could support this indicator in terms of on-site waste monitoring and waste separation facilities. The waste aspect only relates to the building material during construction, and information requirement is considered at an LOD level where the model is ready for construction (LOD350).[138]

3.2.2.5 Stakeholder Engagement Aspect

The stakeholder engagement aspects encompass the social-related indicators, which focus on designing and constructing buildings by prioritising occupant health, well-being and safety during construction. In addition, it involves engaging with contractors and the local community in the development area.

Table 13: Overview of the stakeholder engagement aspect analysis

Requirements met	Measures supported	Assessment	LOD	Information requirement
DSE1. Health & Well-being				
1.1. Health Impact Assessment	2.5. Daylight	Daylighting analysis - Daylight factor/glazing factor	LOD300	- Building envelope - Location (temperature, wind, humidity) - Orientation - Fenestration - HVAC (cooling/heating capacity, airflow, control) - Lightning - Thermal properties - Operation schedule - Building form and zones
	2.7. Humidity	Weather data - Relative/absolute humidity		
	2.8. Illumination	Lightning analysis - Illuminance (lux)		
1.2. Integrated planning process	2.10. Indoor air quality	Air flow analysis - Air exchange rate		
	2.11. Natural ventilation	Air flow analysis - Air exchange rate		
	2.14. Thermal comfort	Thermal comfort analysis - PMV-Index		
DSE2.1 On-site safety				
	1.2. Communicating safety information 1.6. Managing safety risks 1.9. Promoting design for safety 1.10. Training curriculum	Visualisation - Site layout - 4D simulation Rule-based model checking - Checking for safety regulation	LOD350	Building model ready for construction - Building envelope - Systems - Component properties
DSE2.1. Safety metrics				
	1.1. Injury rate 1.5. Severity rate 1.2. Fatalities 1.3. Near misses 1.4. Lost day rate	Cloud-based collaboration - Daily insident report	-	-

[137] Cf. Won, Jongsung; Cheng, Jack C.P.: Identifying potential opportunities of building information modeling for construction and demolition waste management and minimization, pp. 7–10.
[138] Cf. Virtual Building Studio, BIM Level of Development. Internet source.

DSE1 Health and Well-being

This indicator assesses an entity's strategy to promote occupant's health and well-being during the design and construction process. The indicator consists of two sections: The requirement for planning and design and the common occupant health and well-being measures.

The first section, “1. Requirement for the planning and design”, evaluates an entity’s guidelines for incorporating user comfort into development projects. GRESB provided options such as health impact assessment and integrative design strategy. The health impact assessment requires reporting an entity’s means of assessing the health impact of its own policies. This requirement cannot be fulfilled within a BIM workflow. However, the integrative design process can be facilitated in a BIM workflow.

The second section consists of a list of common occupant health and well-being measures that assess various comfort factors of the indoor environment, such as acoustics, air quality, lighting conditions, and thermal comfort. These measures were evaluated based on their potential integration and assessment within the BIM workflow. BIM-based BPS involves a multidisciplinary process that considers indoor environmental quality. For instance, factors such as daylighting, lighting, heating, cooling, and ventilation are integrated into the assessment of building energy performance. This shows an interdependent relationship between energy use and comfort levels. Overall, evaluating a building's performance requires a holistic approach that takes into consideration both energy efficiency and indoor environmental quality.[139]

Daylight and lightning analysis can provide valuable information regarding the light levels in indoor environments. This information can be used to optimise the design of a building's lighting system, ensuring visual comfort for the occupants. BPS tools simulate various parameters, such as daylight factor and illuminance level, determining the amount of natural and artificial light in the building's interior spaces.[140] Daylight and lightning analysis are integral measures in designing energy-efficient buildings while considering indoor occupant’s visual comfort.

Thermal comfort and indoor air quality using mechanical and natural ventilation can be assessed within the BIM framework. Computational Fluid Dynamics (CFD) is the common approach for airflow simulation of a naturally ventilated environment.[141] BIM provides building geometric and semantic information utilised in the CFD domain to simulate the airflow and air exchange rate by natural ventilation,[142] which can then be used to evaluate the indoor temperature for thermal comfort conditions related to the predicted mean vote (PMV) and the percentage of people dissatisfied (PPD) index.[143]

For a mechanically ventilated building, HVAC systems are utilised for thermal comfort by regulating the relevant airflow rate and supplied temperature (heating and cooling) within the

[139] Cf. Duygu Utkucu; Hatice Sözer: Interoperability and Data Exchange Within BIM Platform to Evaluate Building Energy Performance and Indoor Comfort. In: Automation in Construction Issue 116-2020, p. 1.
[140] Cf. Jin, Ruoyu, et al.: Integrating BIM with building performance analysis in project life-cycle, pp. 2–4.
[141] Cf. Vincent J.L. Gan, et al.: BIM-based framework to analyze the effect of natural ventilation on thermal comfort and energy performance in buildings, p. 3320.
[142] Cf. ibid., p. 3324.
[143] Cf. Duygu Utkucu; Hatice Sözer: Interoperability and data exchange within BIM platform to evaluate building energy performance and indoor comfort, p. 5.

comfort levels while taking into account the outdoor environment (temperature and humidity) in estimating the overall energy consumption.[144]

Due to the interdependencies between comfort analysis and energy analysis, the geometric and semantic information for a detailed energy analysis is required for comfort analysis. A thorough comfort analysis is conducted at LOD300 when the model contains detailed space, components, and systems information. However, other factors, such as daylight and airflow, can be evaluated in a preliminary stage.[145] Information from BIM authoring tools is exchanged with BPS and CFD tools using IFC, gbXML direct link and other interoperable means with CAD file formats. Natural ventilation and thermal comfort are simulated in CFD tools like Autodesk CFD, which exchange information directly with Revit,[146] while others, such as SimScale, facilitate the import of CAD files exported from a BIM authoring tool.[147]

DEN2.1 On-site safety and DEN2.2 Safety Metrics

The second indicator, onsite safety and safety metrics, focuses on practical ways to promote and monitor safety measures during construction activities. For the on-site safety indicator, GRESB provides a list of options for promoting on-site safety. Among the measures include the availability of safety personnel on-site, safety communication, managing safety risk, training and promoting design for safety. Certain safety measures can be facilitated through the use of BIM methodology. One such measure includes effective communication. Poor communication with construction workers is one of the significant factors behind the incidence on site.[148] The BIM process can enhance construction safety by improving communication with workers through visualised site plans and layouts. Moreover, incorporating a 4D simulation of construction activities and scheduling can help identify potential hazards that might occur during construction activities. This visualisation of the construction process can further facilitate effective communication and manage safety risks.[149] Furthermore, a rule-based checking can be employed in the design stage to ensure that the developed building model meets all the safety requirements. This process promotes the design for construction safety.[150]

Other research has investigated the use of 4D simulation with Virtual Reality (VR) for construction safety training. Azhar (2017) conducted a study on the impact of visualisation on safety planning and management. The study utilised BIM 4D simulation and virtual reality to demonstrate the effectiveness of visualisation in safety education, training, and hazard detection. The study found that visualisation helps simulate the actual site conditions, making it easier to identify potential hazards and improve safety measures.[151]

[144] Cf. Mahiwal, Sharda G; Bhoi, Manas Kumar; Bhatt, Naimish: Evaluation of energy use intensity (EUI) and energy cost of commercial building in India using BIM technology, p. 891.
[145] Cf. Jin, Ruoyu, et al.: Integrating BIM with building performance analysis in project life-cycle, p. 2.
[146] Cf. Duygu Utkucu; Hatice Sözer: Interoperability and data exchange within BIM platform to evaluate building energy performance and indoor comfort, p. 7.
[147] Cf. SimScale, Simulation Software. Internet source.
[148] Cf. Akram, Ramsha, et al.: Exploring the Role of Building Information Modeling in Construction Safety Through Science Mapping. In: Safety Science-2019, p. 467.
[149] Cf. Sijie Zhang, et al.: BIM-Based Fall Hazard Identification and Prevention in Construction Safety Planning. In: Safety Science-2015, p. 43.
[150] Cf. ibid., p. 44.
[151] Cf. Salman Azhar: Role of Visualization Technologies in Safety Planning and Management at Construction Jobsites. In: Procedia Engineering-2017.

The safety matrix indicator assesses how safety issues are monitored and reported during construction. This includes keeping a record of on-site incidents, such as fertility, injuries, and near misses. BIM platforms for construction management, such as Autodesk Construction Cloud, offer a cloud-based solution for effective project management, including the capability to create custom attributes for daily reports of construction activities. This platform lets construction teams easily record and report daily incidents in a centralised platform, getting real-time insights and keeping track of incident occurrences at the construction site.[152]

3.2.3 ESG Indicator Scoring

The GRESB development indicators were scored following the result of the BIM-ESG analysis. The scoring was conducted following the GRESB scoring methodology. GRESB has a publicly available scoring document that provides each indicator's score and the fraction attributed to all sub-options. The indicators with multiple sections are scored based on the sub-option in each section, and the sum of the scores from all sections is then aggregated against their respective indicator weights to calculate the achieved score. The GRESB standard does not require the fulfilment of all sub-options to achieve a maximum score. However, the maximum achievable score for all sub-options is 1, even when all measures are fulfilled. For example, suppose a fraction of one-fourth (¼) is given to all sub-options. In that case, participants only need to fulfil four of these options to achieve the maximum score.[153] The formula used to calculate each indicator score is highlighted below.

$$w = b * \sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{ai} \leq 1$$

w	Potential score
b	Indicator weight
a	Sub-option weight with BIM integration potential

Formula 1: Scoring formula for indicators without section based on the GRESB scoring method.[154]

$$w = b * \left(c_1 * \sum_{i=1}^{n} a_1 i \leq 1 + c_2 * \sum_{i=1}^{n} a_2 i \leq 1 + c_3 * \sum_{i=1}^{n} a_3 i \leq 1 \ldots + c_n * \sum_{i=1}^{n} a_n i \leq 1 \right)$$

w	Potential score
b	Indicator weight
c	Section weight
a	Sub-option weight with BIM integration potential

Formula 2: Scoring formula for indicators with a section based on the GRESB scoring method.[155]

During the scoring process, certain assumptions were made, particularly for the indicators that require evidence for their validation. GRESB reviews these evidence-based indicators manually to verify whether the reported requirements and measures are fulfilled. Each reviewed indicator is awarded a validation score multiplier ranging from 0 to 1. In this context, a score multiplier of 0 indicates that the provided evidence does not meet the indicator requirements. A score multiplier

[152] Cf. Autodesk Construction Cloud, Construction Safety Management Software. Internet source.
[153] Cf. GRESB, Real Estate Scoring Document. Internet source.
[154] Cf. ibid. Internet source.
[155] Cf. ibid. Internet source.

of 0.5 suggests partial acceptance, where some aspects meet requirements but others fall short. Finally, a maximum score multiplier value of 1 signifies full acceptance, indicating that all required evidence has been successfully demonstrated. This evidence consists mainly of documented policies that outline the entity's overarching commitment to ESG considerations during development. Therefore, a maximum score multiplier of 1 was considered for the evidence-based indicators.

The assessment is conducted considering a single asset; therefore, indicators requiring the percentage of portfolio coverage are assumed to be 100%. This is because, in some indicators, the percentage of portfolio cover is considered a score multiplier to determine the assigned score. This approach allows for a comprehensive evaluation of individual assets and their performance in relation to the ESG objectives.

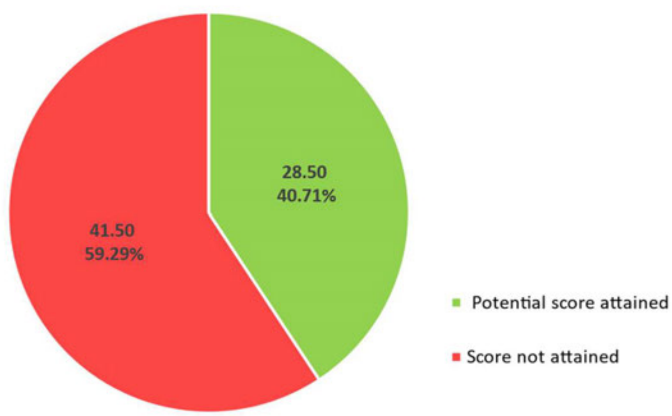

Figure 6: Potential score attained and percentage fulfilment of the GRESB development component

All 11 indicators that can be supported using the BIM process were scored based on sub-options, sections and indicator weight. The GRESB development component has a total score of 70 points, which indicates the overall performance of the real estate development portfolio. The result shows that utilising the BIM process for assessing sustainability criteria during the planning design and construction process can foster the attainment of 28.50 points of the GRESB development component. This equates to a 40.71% fulfilment rate of the development criteria, as shown in Figure 6.

Four indicators were found to attain a maximum point, including on-site renewable energy and low carbon technology, net-zero design and construction, on-site safety, and safety measures. This means that the number of sub-options that can be supported with the BIM workflow meets the defined minimum requirements by GRESB. As previously mentioned, GRESB does not require the implementation of all sub-options to attain maximum points for the indicators. Other indications were scored to varying extents. However, although the BIM workflow can support Life Cycle Assessment and Embodied Carbon, they do not account for any portion of the GRESB development component. Table 15 presents the List of all indicators and potential scores attained.

Table 14: ESG indicator score

Aspect	Code	Indicator	Indicator Weight	Category	Potential score attained	% of Indicator attained
ESG Requirements	DRE1	ESG strategy during development	4.00	G	0.00	0%
	DRE2	Site selection requirements	4.00	E	0.00	0%
	DRE3	Site design and development requirements	4.00	E	0.00	0%
Material	DMA1	Materials selection requirements	6.00	E	5.00	83%
	DMA2.1	Life cycle assessments	Not scored	E	0.00	-
	DMA2.2	Embodied carbon	Not scored	E	0.00	-
Energy	DEN1	Energy efficiency requirements	6.00	E	5.00	83%
	DEN2.1	On-site renewable energy and low carbon technologies	6.00	E	6.00	100%
	DEN2.2	Net zero carbon design and standards	2.00	E	2.00	100%
Water	DWT1	Water conservation strategy	5.00	E	3.75	75%
Waste	DWS1	Waste management strategy	5.00	E	2.50	50%
Building Certification	DBC1.1	Green building standard requirements	4.00	E	0.00	0%
	DBC1.2	Green building certifications	9.00	E	0.00	0%
Stakeholder Engagement	DSE1	Health & Well-being	2.00	S	1.25	63%
	DSE2.1	On-site safety	1.50	S	1.50	100%
	DSE2.2	Safety metrics	1.50	S	1.50	100%
	DSE3.1	Contractor ESG requirements	2.00	S	0.00	0%
	DSE3.2	Contractor monitoring methods	2.00	S	0.00	0%
	DSE4	Community engagement program	2.00	S	0.00	0%
	DSE5.1	Community impact assessment	2.00	S	0.00	0%
	DSE5.2	Community impact monitoring	2.00	S	0.00	0%

3.2.4 Challenges and Limitation

In the attempt to achieve a seamless integration between BIM and ESG assessment, several challenges and limitations arose. This section addresses the challenges and limitations related to the BIM-ESG integration.

While BIM is effective in modelling and simulating various building-related indicators, its capabilities are limited when dealing with ESG attributes that go beyond the boundaries of the building structure. Factors like social and governance aspects, such as indicators related to community engagement or community impact assessment, are outside the building's digital representation. Assessing such measures may require a conventional or supplementary approach for data collection outside the BIM workflow.

Another challenge encountered is related to how each measure is defined within the GRESB schema. GRESB generally provides information on each indicator's intent and explains the terminology meant by the sub-option. However, it does not define a quantifiable scale that will lead to complete compliance, making the assessment challenging to choose from various interrelated factors. Without a standardised and measurable framework, the assessment process becomes subjective and prone to inconsistencies. Clear and concise information requirements are paramount for collecting data from simulations and analyses within the BIM workflow. This reason led to the consideration of the DGNB standard recommendation for sustainable building design to break down these measures into actionable components while retaining their holistic essence, which could enhance the practicality and effectiveness of BIM integration.

Another challenge arises from the holistic nature of some GRESB measures. Measures that are supposed to be quantifiable in nature are still described holistically, making it complex to define the specific BIM intervention for data collection. A good example is a passive design, which is listed as one of the energy efficiency measures. Passive design is an energy-efficient approach, but its implementation relies on the integration of various passive strategies, such as natural ventilation and lightning. The minimum intervention that can satisfy this measure is not clearly understood. Another example is the is the On-site Safety Indicator, which has several sub-options listed, but non was defined a terminolofy by GRESB. This makes it difficult to understand what measures should be implemented. For instance, the sub-option of continuously improving safety performance is quite general and does not specify clear measures that should be implemented.

4 Stakeholder Interview

This chapter presents the conventional ESG assessment and industrial application of BIM in sustainability evaluation through qualitative interviews with different stakeholders. Nine participants from 8 different organisations participated in this study. The following table presents the list of interview sessions and the roles of participants and organisations.

The first section of this chapter presents the result of the interview with ESG analysts from different real estate companies. The objective of the interview is to get insight into how real estate companies conduct an ESG assessment in terms of data collection and the challenges they face in the process. The second session presents the interview with planners and consultants who utilise the BIM process for sustainability evaluation in the planning phase of a development project. The objective is to identify the industry workflow for sustainability evaluation and how it could support the assessment of the GRESB ESG indicators for development projects.

Table 15: List of interviewees with roles and organisations

Interview session	No of Stakeholders	Experties	Positions	Organisation
A	1	ESG	Senior Associate ESG Manager	PATRIZIA
B	1	ESG	Sustainability Specialist	LaSalle Investment Management
C	1	ESG	Project Manager Sustainability	Vasakronan AB
D	1	ESG	Sustainability Manager	ACCUMULATA Group GmbH
E	1	BIM & Sustainablity	Head of Green Tech	EPEA GmbH – Part of Drees & Sommer
F	1	BIM & Sustainablity	Sustainable Construction Analyst	LIST Eco GmbH
G	1	BIM & Sustainablity	Project Manager and Technical Planner	Averdung Ingenieure & Berater GmbH
H	2	BIM & Sustainablity	Energy and Sustainability Consultants	ATP sustain GmbH

4.1 Stakeholder Perspectives in ESG Assessment

The stakeholder interview highlighted a varying adherence to various standards and guidelines, reflecting the diverse nature of sustainability in the real estate sector. A recurring theme of the interview is the adherence to local and regional regulatory standards, incorporation of green building certification systems (such as DGNB, LEED and BREEM), and GRESB standing investment benchmarking. Regulatory requirements are underscored as significant drivers, with stakeholders highlighting the necessity of adhering to specific energy efficiency standards in various regions as different regions impose unique energy efficiency requirements. They also note that certain restrictions exist for renting and leasing new buildings. Some countries have restrictions on increasing rent or leasing buildings that do not meet a specific Energy Performance Certificate (EPC) class. The EU Taxonomy framework played a complementary role, guiding stakeholders in establishing sustainability requirements for new development projects and renovations, mirroring the industry's adaptability to evolving regulatory frameworks.

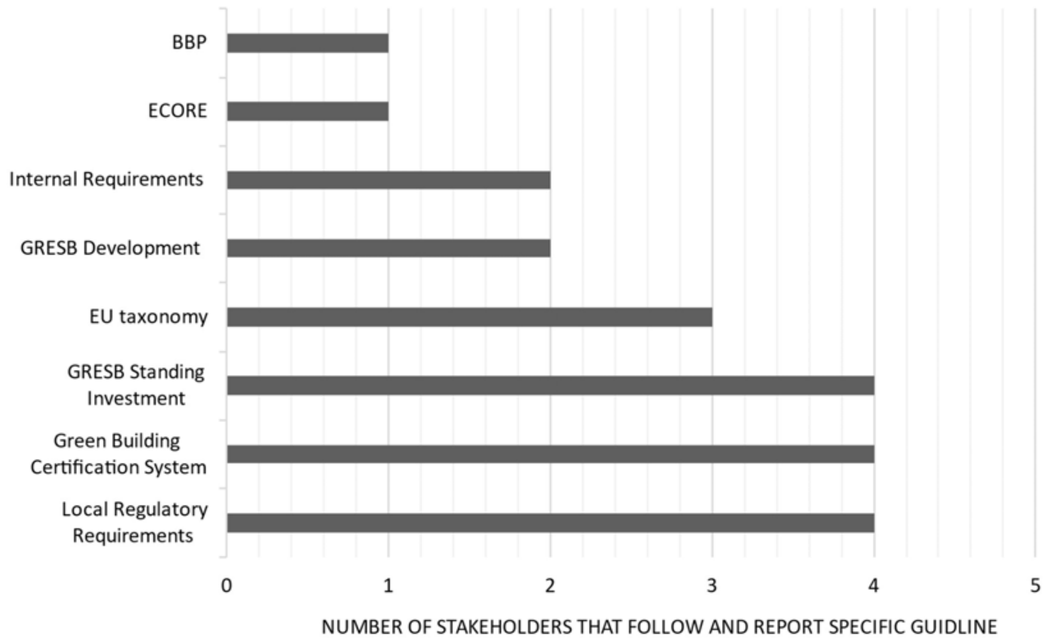

Figure 7: Stakeholder's Industry standards and guidelines

Furthermore, the GRESB development and performance framework is reported for assets and funds. Stakeholders mainly rely on GRESB to evaluate and disclose their portfolio's ESG performance. Nevertheless, the reporting of GRESB benchmarking is limited to only selected assets and funds, as mentioned by all interviewees. The Better Building Partnership (BBP) guideline is also referenced by interviewee B as a guideline for developing an internal framework for development projects. The BBP is a collaborative initiative in the UK that works to improve the sustainability practice of commercial real estate. It brings property owners, investors, and other stakeholders together to achieve shared objectives and sustainability practices.[156] Affiliation with the ESG-Circle of Real Estate (ECORE) initiative was also mentioned by interviewee D, although it was perceived as less relevant to investors with international portfolios as the initiative is more focused on the German market. The ECORE initiative provides a framework for ESG scoring and benchmarking for the real estate sectors, focusing on governance, consumption, emissions, and asset checks.[157] Some organisations develop internal ESG requirements, illustrating a proactive approach to customising ESG assessment according to their specific objectives. This variety of standards and guidelines highlights the diverse nature of ESG assessment in the real estate sector. Stakeholders represented by interview A emphasised the influence of investors in shaping ESG assessment practices. Investors are increasingly imposing specific requirements and

[156] Cf. BBP, Better Buildings Partnership. Internet source.
[157] Cf. ECORE, ESG-Circle of Real Estate. Internet source.

standards on real estate projects to align them with sustainability goals. The important requirements mentioned are the Carbon Risk Real Estate Monitor (CREEM) tool, EU Taxonomy and regulatory requirements. These enable real estate developers and managers to set targets for energy efficiency and carbon emissions. The stakeholders also emphasised compliance with regulatory requirements in various regions, further underscoring the investor-driven nature of these standards, as non-compliance can have legal and financial repercussions, such as restrictions to rent out buildings or increase rents. These investor-driven requirements reflect a shift in the real estate industry, where sustainability is no longer an optional consideration but a critical factor shaping real estate development.

4.1.1 ESG Data Collection and Benchmarking

Building Material's Embodied Carbon Emission Benchmarking

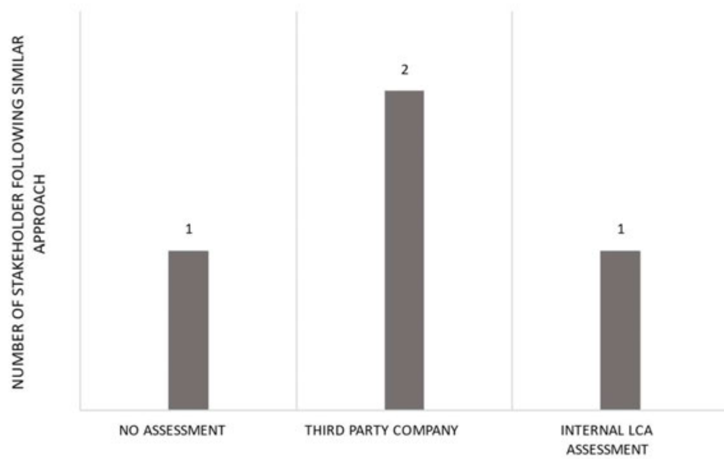

Figure 8: Number of stakeholders following a similar approach

This section delves into the methods employed by stakeholders within the real estate industry for collecting data pertaining to the embodied carbon emissions of construction materials. Embodied carbon emissions represent a critical criterion of the GRESB development standards and account for all carbon emissions throughout the life cycle of a building with the exclusion of operational emissions.

Data collection and benchmarking of embodied carbon emissions in construction, different stakeholders have their own practices with minor variations. The stakeholder, represented by Interview A, expressed the challenges associated with accurately quantifying the embodied carbon emissions, highlighting the complexity, particularly in building elements with multiple materials like façade, comprising components such as glass, steel, and insulation. The stakeholder underscored the non-viable task of tracing the origins of each material and assigning precise embodied carbon values, implying that such granular assessments may not be practically feasible. Such assessment is not considered in their development projects. Accurately quantifying the environmental impact and embodied carbon emission of material is a significant challenge due to the uncertainties and assumptions involved in the process. Determining the precise carbon footprint of a building project can be complex as it relies on various data sources and calculation methods that may not always be entirely accurate.[158]

In contrast, Interviewee C provided a more proactive approach to embodied carbon assessment. The organisation engages with consultants who conduct embodied carbon emissions calculations using the building model and software tools such as One Click LCA or a Swedish tool. The stakeholder highlighted their commitment toward carbon neutrality of the embodied carbon emissions by 2030, introducing circularity measures, setting a threshold for maximum CO2 emissions per project and using Biogenic construction materials.

Interviewee D outlined a comprehensive strategy for evaluating embodied carbon emissions. Their approach involves conducting life cycle assessments at different stages, following a green building certification system. They collaborate with external planners to evaluate the overall carbon footprint of the building, aligning with the requirements of a green building certification system. Moreover, they also conduct an internal sensitivity analysis to see how the embodied carbon emissions would react to potential changes in building material. Notably, the stakeholder underscores the preference for using Excel for calculations due to having more flexibility and control in the assessment process.

Energy Use Intensity (EUI) and Carbon Emission Benchmarking

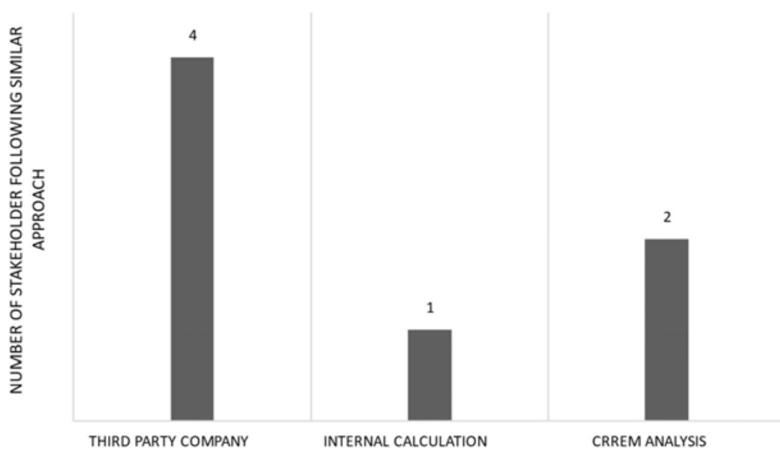

Figure 9: Percentage number of stakeholders following a similar approach

Stakeholder perspectives on data collection regarding potential energy use and CO_2 emission diverge across practices and contexts. This section explores the methods employed by stakeholders within the real estate industry to collect data on the potential energy use of buildings and CO_2 emissions. The stakeholder highlighted their energy-related data collection and assessment methods in both development projects and existing structures.

Interviewee A outlined data collection processes in the context of real estate development projects. It involves calculations performed by either an auditor or the construction company

[158] Cf. Eirik Resch, et al.: An Analytical Method for Evaluating and Visualizing Embodied Carbon Emissions of Buildings. In: Building and Environment Issue 168-2020, p. 10.

responsible for the development. These calculations rely on established standards, such as those from the International Energy Agency (IEA) and the Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) table, to estimate potential energy consumption and CO_2 emissions while also considering energy and emissions reduction measures. Moreover, the stakeholder acknowledges the CRREM tool as a valuable resource for setting energy and CO_2 benchmarks that align with the industry's commitment and compliance with the 2040 net-zero target primarily focused on operational emissions. In the case of existing buildings, challenges arise from tenant's non-obligatory contribution of energy data. To address this, a green lease requirement for energy consumption reporting is implemented to encourage tenants to provide energy consumption data periodically. Green leases, which aim to promote sustainable energy management in rental properties, play a significant role in outlining the sustainability responsibilities of both tenants and landlords, including providing consumption data for reporting purposes.[159] Additionally, they install smart metering technology to ensure accurate measurement and collection of operational energy consumption.

Interviewee B highlights their commitment to achieving net-zero carbon emissions by 2050 and has implemented a Net Zero Carbon program that covers the entire lifecycle of their assets. The organisation adopts a collaborative approach to data collection, relying on third-party providers for data collection and analysis based on regulatory and internal requirements. During the development phase, third parties simulate and assess the potential energy consumption of the development project. Property managers are tasked with data collection in operational assets. Furthermore, they have an ongoing effort to enhance data collection through the implementation of smart meters, allowing for real-time and automated data aggregation.

Interviewee C highlighted their engagement with consultants for energy calculation aligning with Swedish regulations that establish maximum energy use intensity requirements. The organisation is committed to reducing energy consumption below national regulations by implementing proactive energy-efficient measures. They aspire to achieve carbon neutrality across all stages by 2030. This goal extends beyond operational emissions and encompasses a holistic approach, considering both direct and indirect emissions. While the stakeholder acknowledges that they have achieved net-zero carbon in their operational activities, they also recognise the challenge posed by indirect emissions, particularly those arising from tenant electricity purchases from non-renewable sources. This highlights the desire to address emissions comprehensively.

Interviewee D highlights a vast data collection process. Building planners employ dynamic energy simulations based on German regulatory standards like the Gebäudeenergiegesetz (GEG) to establish base loads. However, these analyses do not encompass tenant consumption patterns. To address this gap, an internal analysis is conducted to predict tenant consumption patterns by assuming various tenant scenarios, providing a holistic view of energy consumption based on different types of tenants. CRREM analysis is then conducted based on energy consumption and carbon emission benchmarks in alignment with the CRREM pathway for net-zero targets. Additionally, smart metering and other smart infrastructure are also installed to monitor operational energy consumption, demonstrating a commitment to real-time data collection for reporting purposes.

[159] Cf. Hedemann, Konrad et al., More Than a Green Certificate: Green Leases and Investment Return in Commercial Real Estate 2023, p. 2.

4.1.2 Challenges in ESG Assessment

This section presents the challenges stakeholders face in ESG assessment. Challenges were divided into two categories: the assessment process-related challenge and the standard-related challenge. Figures 10 and 11 highlight the common theme in each category based on the stakeholders' responses.

Assessment process challenges

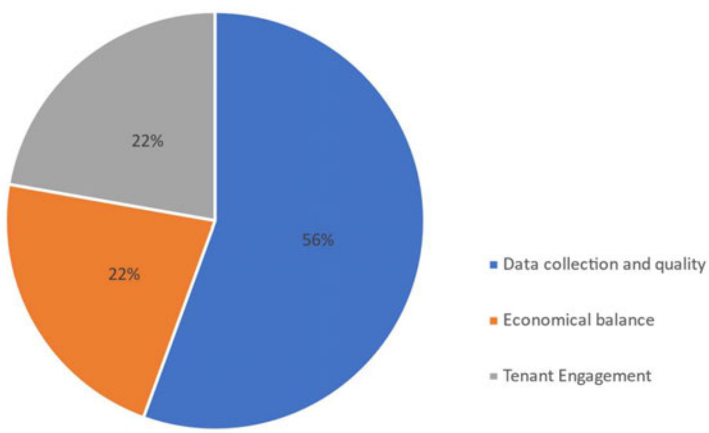

Figure 10: Frequency of stakeholders mentioning a challenging theme related to assessment and data collection

One of the foremost challenges stakeholders have identified is the issue of data collection and quality, which relates to the completeness of ESG-related data for conducting an analysis and the accuracy of the results. Of particular relevance is the challenge of assessing embodied carbon emissions. One of the stakeholders expressed concerns regarding the need for more high-quality material information for accurate embodied carbon assessment, further emphasising the difficulties in tracing the origins of materials used in construction. The assessment of material impact faces several challenges, including the lack of quality due to uncertainties and estimations of EPDs, a lack of common data sources, scarcity of EPDs, and a degree of reliance on generic datasets, which can cause inaccurate results.[160]

Another aspect of data quality relates to the operational phase of buildings. Two stakeholders reported significant discrepancies between the energy consumption levels calculated by energy planners during the design phase and the actual energy usage by tenants in the operational phase. This disparity has profound implications, not only for the accurate assessment of carbon emissions but also for the overall energy efficiency of the building. One stakeholder highlighted their use of different tenant patterns for internal analysis. However, the stakeholder mentioned the need for the calculation of realistic building performance, considering the various types of tenants for more accurate analysis. Moreover, during the operational phase, a stakeholder pointed out that the reluctance of tenants to share their energy consumption data, coupled with the absence of legal requirements for tenants to report such data, poses a challenge in conducting

[160] Cf. Waldman, Brook; Huang, Monica; Simonen, Kathrina: Embodied Carbon in Construction Materials: A Framework for Quantifying Data Quality in EPDs. In: Buildings and Cities Issue 1-2020, p. 628.

an effective ESG assessment. This also makes it difficult to implement strategies for reducing energy consumption and carbon emissions to meet their net zero target.

Furthermore, a stakeholder has highlighted the difficulty in defining Key Performance Indicators (KPIs) for measuring various ESG factors. While the environmental aspect, which includes calculating energy consumption and CO_2 emissions, can be measured through quantifiable metrics, the social aspect poses challenges because it relies on qualitative indicators. Collecting data on tenant‘s comfort, health, and well-being, which are important ESG indicators, presents difficulties in terms of relevant interventions for collecting high-quality and reliable data.

The stakeholders have also raised concerns about the economic challenges that arise when integrating ESG measures into development projects. The correlation between ESG and financial performance is a subject of debate in academic circles. Findings of various studies on this topic vary, with some research indicating a lack of correlation between ESG and financial performance. In contrast, others suggest mixed results or even an inverse relationship, with some studies suggesting a positive relationship between ESG and financial performance, particularly over the long term.[161] However, stakeholders highlighted the challenge of the increasing intensity of the standards, which set new maximum values and requirements. This has made it difficult for real estate investors and developers to comply with the evolving regulations. Meeting these standards often requires significant investments, which may not be economically viable from the investor's perspective. Therefore, balancing ESG measures and economic feasibility remains a significant challenge. Another stakeholder highlighted that the intensification of regulation has a positive impact as it prevents "Greenwashing". Furthermore, some ESG measures, such as the reuse of greywater and rainwater collection for non-potable use, were mentioned to be capital-intensive and demand substantial investments. Stakeholders have raised concerns about the economic viability of such sustainable measures, as they may not always yield a clear financial benefit.

Moreover, stakeholders underscore tenant engagement as crucial in achieving net-zero targets and enhancing ESG performance. The relationship between tenants and landlords plays a crucial role in driving successful energy efficiency measures.[162] However, two stakeholders have acknowledged the difficulties in engaging tenants to collaborate on sustainability measures and encouraged them to take ownership of their role in sustainability-related activities. Conducive tenant engagement brings numerous benefits, as highlighted by GRESB. These benefits encompass both tangible and intangible factors. Tangible advantages include decreased water and energy usage and reduced utility expenses. On the other hand, intangible benefits include increased environmental awareness, improved communication and collaboration between landlords and tenants, a more favourable occupancy environment, and better occupant health and well-being.[163] One important issue raised by a stakeholder is the disparity in sustainability requirements between landlords and tenants. The existing legal and regulatory framework mandates property owners to implement sustainability measures, putting them responsible for adopting sustainability strategies. However, tenants are not subject to any similar requirements

[161] Cf. Kempeneer, Shirley; Peeters, Michaël; Compernolle, Tine: Bringing the User Back in the Building, p. 2.
[162] Cf. Hedemann; Zhu; Lang, More than a Green Certificate: Green Leases and Investment Return in Commercial Real Estate, p. 3.
[163] Cf. GRESB, Tenant Engagement–The Road to Corporate Sustainability. Internet source.

despite being significant contributors to the consumption of resources and the creation of environmental impacts.

Standards and Guidelines Related challenges

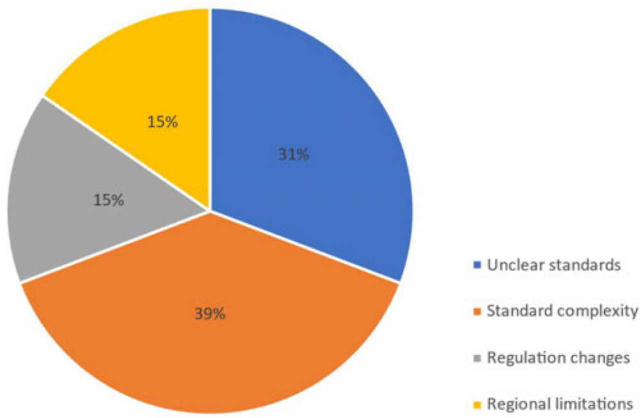

Figure 11: Frequency of stakeholders mentioning a challenging theme related to standards and guidelines

Stakeholders have noted several challenges regarding the standards and guidelines, encompassing issues related to clarity, complexity, constant changes, and regional limitations. One notable challenge is the ambiguity surrounding ESG standards and regulations. Currently, there is no standardised framework for assessing ESG matrices. As a result, various metrics, rating agencies, and reporting standards are being used. This has led to ambiguity and imprecise definitions of ESG criteria. Although there have been some advancements in developing ESG frameworks and guidelines, the absence of a unified and globally recognised standard remains a significant challenge.[164] Stakeholders highlighted the existence of fragmentation of various standards and regulations. The lack of harmonisation in standards makes it challenging for them to capture and implement all necessary requirements. Two stakeholders mentioned the EU taxonomy to be imprecise. The example of EU taxonomy was mentioned to require the integration of an energy monitoring system but lacks specification, leading to uncertainty regarding the specific actions required for compliance.

Another theme in the interview is the complexity of standards and regulations. Stakeholders mentioned that regulations are becoming more rigorous and setting new maximum values that are difficult to attain. As regulations become more strict, the assessment process becomes increasingly demanding. A stakeholder gave an example of the new legal requirement in the UK to achieve a minimum 10% biodiversity net gain. Such assessment was highlighted as complex and requires the involvement of certified ecologists in evaluating various habitats and tracking seasonality. The complexity of standards is not limited to specific regulations but extends to the criteria documentation associated with widely recognised standards like GRESB and DGNB. While the comprehensive nature of these systems is a good resource for clarity, stakeholders find the initial volume of information overwhelming. Simplifying and efficiently filtering essential requirements from supplementary details would facilitate a smoother adherence process.

[164] Cf. Li, Ting-Ting, et al.: ESG: Research Progress and Future Prospects. In: Sustainability Issue 13-2021, p. 24.

However, another stakeholder emphasises that complexity is essential for maintaining the virtue of the ESG assessment.

Furthermore, the dynamic nature of ESG regulations presents a challenge for stakeholders. Requirements are constantly changing, requiring organisations to observe a proactive approach to keep up with evolving standards. Sustainability regulations are regularly modified to address global sustainability goals and environmental concerns. However, stakeholders have also pointed out that the standards themselves are evolving and establishing new priorities. Staying updated with these changing regulations requires allocating resources and personnel to monitor and integrate the changes within their assessment framework.

Finally, one of the stakeholders recognised the regional limitations in applying ESG standards. These limitations apply to globally recognised standards, which developed a uniform approach to ESG assessment. The stakeholder noted the GRESB standard to be holistic and aiming to encompass the wide-ranging aspects of sustainability assessment applicable to every country. However, the reality is far more complex, as the legality of data collection can vary from one region to another. An example given is that GRESB requires the collection of tenant consumption data as a vital component of its ESG reporting. Stakeholders in countries like Germany encounter legal restrictions due to data privacy regulations, making compliance challenging. Furthermore, the stakeholder also highlighted that the EU is regulating the EPC (Energy Performance Certificate) class for new developments across all EU member states without considering variations in calculation methodologies across different countries. This creates a challenge in meeting requirements in one region compared to another.

Table 16: Challenges in ESG assessment

Theme	Comment
Data Quality	• Difficulty in accurately assessing material embodied carbon due to the complex nature of material supply chains. (A) • Variations between energy consumption as projected by auditors and actual tenant consumption. (A), (D) • Complexity in defining and measuring qualitative indicators for social aspects of ESG assessment. (B) • Lack of legal obligation for accessing tenant's energy consumption data. (A)
Economical Balance	• Challenges in keeping up with regulations and standards while ensuring economic viability. (A), (C)
Tenant Engagement	• Active tenant engagement in achieving net-zero targets and enhancing overall ESG performance. (A), (C)
Unclear Standards	• Lack of precise definitions in regulations, resulting in uncertainty regarding compliance. (A), (C) • Fragmentation of various standards and regulations, requiring improved standardisation and clarity. (B)
Standard Complexity	• Regulations are getting intense and setting new maximum value challenges for organisations aiming to meet them. (A), (B) • Complexity in defining methods and assessment for biodiversity criteria. (B) • The overwhelming nature of comprehensive ESG assessment documents suggests the need for streamlined data. (D) • Balancing the multifaceted aspects of ESG, given differing stakeholder priorities and criteria. (D)
Regulation Changes	• The rapid evolution of ESG regulations, necessitating continuous adaptation. (A), (B)
Regional Limitations	• Variability in data collection capabilities and legal restrictions across different countries. (A) • Differences in calculation methodologies and regulatory harmonisation challenges, as seen with EPC classes. (A)

4.2 Stakeholder Perspectives in BIM and Sustainability Evaluation

This section delves into the methodologies employed by building planners and consultants in utilising BIM for sustainability evaluation. Their insights provide valuable perspectives on how BIM is practically employed in various aspects of sustainability, including energy modelling, lifecycle and embodied carbon assessment and indoor environmental quality assessment.

The stakeholders demonstrated their lack of limitation when it comes to sustainability standards, as the choice of specific standards and frameworks often depends on the client's preferences and requirements. Several green building certification systems, including DGNB, BREEM, LEED, WELL, and Qualitätssiegel Nachhaltiges Gebäude (QNG), were mentioned to have been utilised. Furthermore, the stakeholders also conduct checks for compliance with the EU taxonomy requirements.

4.2.1 BIM Workflow for Sustainability Evaluation

Material Environmental Impact and Life Cycle Assessment

Stakeholders highlighted multiple approaches for material impact assessment within the context of LCA and circular economy. While BIM was utilised for data extraction, stakeholders noted that the depth of information required for LCA often exceeded what BIM models are providing. Materials quantities were mentioned to be extracted from the BIM model. Product-specific EPDs and generic ökobaudat datasets were mentioned to be utilised for LCA, and Stakeholders often created tools tailored to life cycle assessment requirements. ökobaudat provides both generic datasets and EPDs from diverse manufacturers in compliance with EN 15804.[165]

The stakeholder represented by interview E describes a structured workflow for LCA and embodied carbon assessment using BIM viewer for material classification. They have developed an internal tool to foster their focus on circularity. Importantly, their approach involves thorough data collection, classification, and assessment within their BIM process. Building materials are exported from the BIM model in an IFC format and then imported into Solibri for classification into material groups. Material information take-off is done from Solibri to an internal tool for LCA and circularity assessment. Additionally, the ability to update classifications at different IFC levels ensures that the process remains dynamic and adaptable to changes. Reports from the process include the material embodied carbon emissions, circularity, and material certificate.

Interviewee F highlights the integration of BIM in assessing material circularity and conducting life cycle assessments. The stakeholders highlighted the use of BIM workflow to demonstrate compliance with EU taxonomy based on the DGNB checklist for EU taxonomy. They utilised their BIM workflow for LCA and circularity. Their workflow combines the use of commercial tools, including DESITE BIM viewer, CAALA, Concular and Madaster. The stakeholder introduced their LCA and circularity assessment workflow using Desite and Madaster. The model was developed following Madaster IFC guidelines for platform compliance to ensure the workflow can be automated. Material classification and LCA are done using their developed program in DESITE BIM, and they regularly update datasets from ökobaudat. The circularity assessment is done by importing the IFC model into Madaster software tools. Reports on the embodied carbon

[165] Cf. ÖKOBAUDAT, Sustainable construction information portal. Internet source.

emissions, circularity index, and building resource passport are generated. Furthermore, the stakeholder mentioned the possible use of Concular for circularity assessment.

The Stakeholder represented by interviewee G adopted a rather systematic strategy for the material impact assessment. Their workflow reflects an effort to minimise the environmental burden, particularly the "embodied energy" associated with construction materials and technical systems. They utilise the ökobaudat dataset to calculate the grey energy and CO2e of material. Their use of BIM is mainly for documenting material post-usage information concerning detachability, recyclability, reuse and generating a Building resource passport.

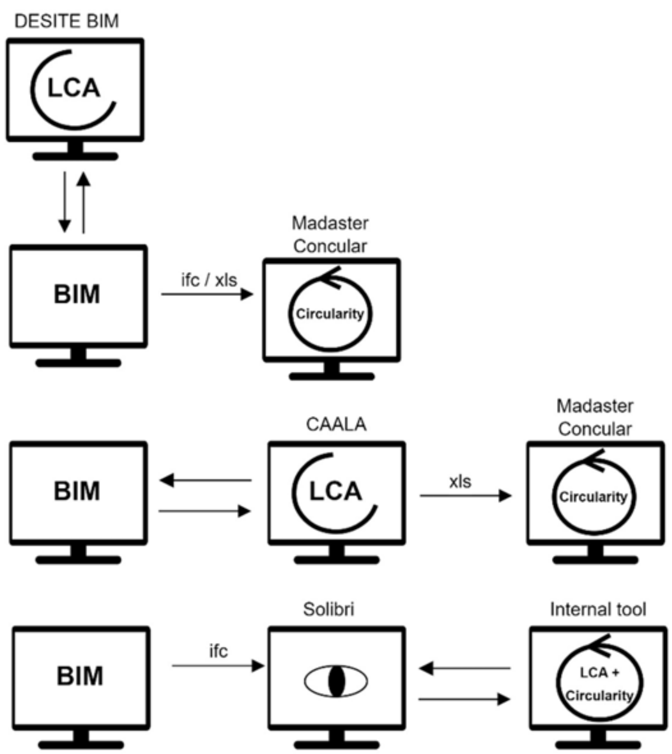

Figure 12: Stakeholder‘s workflow for LCA and circularity assessment according to interviews E[166] and F[167].

Stakeholders also highlighted some challenges associated with the BIM workflow. One of the challenges mentioned is the loss of data during mass export. Building components were sometimes missing when quantities were exported from the BIM model. Another challenge mentioned is the varying calculation rules for LCA, as well as the need to integrate datasets into the internal program for LCA. Stakeholders explained that datasets are updated regularly, and they have to update their software tool to the latest version. In addition, stakeholders also mentioned the lack of datasets, especially when it comes to composite structures. This necessitates modifications and customisation of the datasets, which can be prone to inaccuracy.

[166] Pascal Keppler, EPEA GmbH – Part of Drees & Sommer: Interviewd on 26/08/2023.
[167] Karina and Große Lögten, LIST Eco GmbH & Co. KG: Interviewd on 27/08/2023.

Energy Efficiency and Indoor Environmental Assessment

Interviewee E employs IES-Virtual Environment (VE) as their primary tool for energy analysis within the BIM framework. The IES-VE is a building performance simulation software tool that offers a wide range of functionalities for evaluating and optimising various aspects of building performance. These tools facilitate the analysis of HVAC load, environmental impact assessment, daylight and artificial lighting simulations, thermal comfort modelling and more. One of its key features is the ability to conduct energy modelling considering various energy efficiency measures and support compliance with various international building performance standards such as the International Energy Conservation Code (IECC) 2012 and ASHRAE 90.1. Furthermore, IES VE enables seamless data exchange and supports interoperability in an open BIM workflow using IFC, gbXML, and a direct link with BIM software tools.[168]

Interviewee D demonstrates the usage of solar computer building services and energy calculation software. The software covers a wide range of areas, including energy, building physics, heating, air conditioning, ventilation, building and system simulation. The energy calculation process integrates energy efficiency measures in conformity with the German Building Energy Act "Gebäudeenergiegesetz (GEG)" and DIN 18599 while facilitating data exchange and interoperability through IFC files and direct links with Revit.[169]

Regarding indoor environmental quality, Interviewee A highlights their consideration of measures such as visual comfort, thermal comfort, and occupant control within their indoor environmental quality assessment for development projects. They simulate thermal comfort using tools like IES VE and TRNSYS. IES VE can be used for airflow analysis using Computational Fluid Dynamics (CFD) to assess the performance level in terms of indoor comfort.[170] TRNSYS, on the other hand, despite not being primarily a BIM-based software, is a simulation software used for energy modelling and analysing the performance of HVAC systems, renewable energy systems, thermal/airflow modelling, and other related building simulations.[171]

Water conservation and Weste management

Stakeholders did not consider water resource conservation and waste management in a BIM workflow. Interviewee F mentioned their reliance on product sheets to determine flow rates for water fixtures. On the other hand, Interviewee H demonstrates a more proactive approach to water use calculation. They focus on DGNB benchmarks, integrate the different flow rates in their internal tool for the planning process and calculate the total water consumption. Furthermore, they consider water conservation measures such as the use of greywater and rainwater collection, although they acknowledged the inherent complexities of such systems, particularly concerning installation. Rainwater collection for gardening and irrigation was another strategy employed to reduce reliance on conventional water sources. The response regarding waste management ranges from not being considered due to its extension beyond the planning phase to being handled by a third-party waste collection company. This highlights a potential gap in their BIM process, which is not being integrated with water conservation and waste management strategies.

[168] Cf. IES Virtual Environment (VE), Integrated Environmental Solutions | IES. Internet source.
[169] Cf. Solar-Computer, Software for Technical Building Equipment. Internet source.
[170] Cf. IES Virtual Environment (VE): Integrated Environmental Solutions | IES. Internet source.
[171] Cf. TRNSYS, Transient System Simulation Tool. Internet source.

4.3 Analysis of Stakeholder's BIM Workflows for Enhanced GRESB Assessment with

This section delves into the correlation between stakeholder's BIM workflow for sustainability evaluation and the GRESB ESG indicators for development projects. It will evaluate the portion of the GRESB development indicators that can be assessed within the existing industry workflow for sustainability evaluation using the stakeholder's BIM methodology. Software tools and techniques mentioned by stakeholders were studied to identify their correlation with the GRESB indicators. The table below highlights the analysis process, shining light on the energy aspect. The energy simulation tools mentioned to be utilised by stakeholders were investigated based on their functionaries and use that can facilitate the assessment of each sub-option defined in the GRESB development standard.

Table 17: Excerpt analysis of the energy aspect based on stakeholder's BIM workflow

Energy Aspect			
Indicator Code	Indicator | Sub-options	BIM Tools and application	
		IES- Virtual Environment	Solar Computer
		Open BIM - IFC - gbXML Closed BIM - Direct link	Open BIM - IFC Closed BIM - Direct link
DEN1	Energy efficiency requirements		
	1. Requirements for planning and design		
	1.1. Development and implementation of a commissioning plan	Not applicable	Not applicable
	1.2. Integrative design process	Facilitates integrative design by allowing the analysis of various building components and systems while considering location strategies and building physics for energy efficiency.	Facilitates integrative design by allowing the analysis of various building components and systems while considering location strategies and building physics for energy efficiency.
	1.3. To exceed relevant energy codes or standards	Provides the ability to model energy performance and assess compliance with energy codes and standards such as ASHRAE 90.1	Model energy performance and assess compliance with German Buidling Energy act (Gebäudeenergiegesetz, GEG) and DIN V 18600
	1.4. Maximum energy-use intensity post-occupancy	Can simulate and predict post-occupancy energy usage for building designs.	Can simulate the annual primaty energy demand of the building
	2. Common energy efficiency measure		
	2.1. Air conditioning	Support the modeling and optimisation of space cooling/air conditioning systems.	Calculate cooling load and allow for system modelling and optimisation
	2.2. Commissioning	Not applicable	Not applicable
	2.3. Energy modeling	Conduct comprehensive energy modeling and analysis of building	Conduct comprehensive energy modeling and analysis of building

The analysis results show that the presented workflow can support the assessment of 6 out of 21 indicators related to energy, material and stakeholder engagement aspects to a varying degree. The indicators include:

1. DMA1. Material selection requirement
2. DMA2.1. Life cycle assessment
3. DMA2.2. Embodied carbon
4. DEN1. Energy efficiency requirement
5. DEN2.1. Onsite Renewable and low-carbon technologies
6. DSE1. Health and Well-being

4.3.1 Analysis Discussion

Material Aspect

Table 18: Material indicators assessed following stakeholder's BIM workflow

Material selection requirements met	Material characteristics assessed	Data exchange and interoperability	BIM tools	Assessment
DMA1. Materials selection requirements				
1.1. Environmental Product Declarations	2.1. Locally extracted or recovered materials 2.2. Low embodied carbon materials 2.5. Materials environmental impacts 2.7. Rapidly renewable materials and recycled content materials	Open BIM - IFC - gbXML Closed BIM - Direct link	Internal tool, Desite, CAALA, Madaster, Concula	-Life Cycle assessment - Circularity assessment
DMA2.1. Life cycle assessments				
	1.1. Cradle-to-gate	Open BIM - IFC - gbXML Closed BIM - Direct link	Internal tool, Desite, CAALA	- Life Cycle assessment
	1.2. Cradle-to-practical completion/handover			
	1.3. Use stage			
	1.4. End-of-life stage			
	1.5. Cradle-to-grave			
	1.6. Whole life			
DMA2.2. Embodied carbon				
	1.1. A1-A3 (Cradle-to-gate)	Open BIM - IFC - gbXML Closed BIM - Direct link	Internal tool, Desite, CAALA, Madaster, Concula	-Life Cycle assessment - Circularity assessment
	1.2. A1-A3, A4 (Cradle-site)			
	1.3. A1-A3, A4, A5 (Cradle-to-practical completion)			
	1.4. A1-A3, A4, A5, C2-C4 (Cradle-to-practical completion and end of-life)			

The GRESB ESG indicator related to materials addresses the responsible procurement and use of materials in real estate projects. Regarding BIM workflows, Interviewees from diverse organisations have shown varying levels of alignment with this indicator. Stakeholders utilised industry-developed and commercial software such as Desite BIM, CAALA, Madaster, and Concula. These demonstrate a commitment to sustainability through efficient material utilisation, recycling, and circular economy practices. CAALA is a software tool designed to assess the environmental impact of a building throughout its entire life cycle stages. This tool helps users understand the building's potential energy demand in operation and carbon emissions across the building's whole life cycle. The software facilitated information exchange through direct links with other software tools and gbXML file format.[172] DESITE BIM, on the other hand, streamlines coordination and the model-checking process, thus providing easy access to model information. The software offers a comprehensive overview of all the data contained within the model through its open interface. This feature allows for personalized data analysis and facilitates expanding and assessing models imported in IFC format using customised checking rules. Additionally, DESITE BIM offers integration of external databases such as ökobaudat and IBU.data for

[172] Cf. CAALA, Unlocking Sustainability. Internet source.

building-related EPDs and also provides an API that allows users to create new programs within the software.[173]

The stakeholder's workflows involve tracking the life cycle of materials, assessing embodied carbon emissions, and evaluating material circularity. These are in accordance with multiple GRESB indicators related to the material aspect. Table 17 presents the GRESB indicators and sub-options that are assessed using the workflow presented by the stakeholders. Three of the GRESB development indicators related to the material aspect can be assessed using the presented workflow, including material selection requirement, LCA and embodied carbon.

Energy Aspect

Table 19: Energy indicators assessed following stakeholder's BIM workflow

Energy efficiency requirements met	Energy efficiency measures assessed	Data exchange and interoparability	BIM tools	Assessment
DEN1. Energy efficiency requirements				
1.2. Integrative design process 1.3. To exceed relevant energy codes or standards 1.4. Maximum energy-use intensity post-occupancy	2.1. Air conditioning 2.3. Energy modeling 2.4. High-efficiency equipment and appliances 2.5. Lighting 2.6. Occupant controls 2.7. Passive design 2.8. Space heating 2.9. Ventilation 2.10. Water heating	Open BIM - IFC - gbXML Closed BIM - Direct link	IES-Virtual Environment, Solar Computer	Energy analysis
DEN1.1. On-site renewable energy and low carbon technologies				
1.1. Percentage of energy demand that by design will be coverd by on-site renewable energy and low carbon technologies	1.4. Solar/photovoltaic	Open BIM - IFC - gbXML Closed BIM - Direct link	IES-Virtual Environment, Solar Computer	Solar analysis potential
	1.5. Wind	Open BIM - IFC - gbXML Closed BIM - Direct link	IES-Virtual Environment	Wind energy potential

The GRESB development indicators related to energy encompass energy efficiency, integration of renewable energy sources, and net zero carbon strategy. Stakeholders employ simulation tools such as IES-VE and Solar Computer for energy-efficient design. As presented in the previous section, these tools facilitate integrative design processes that consider multiple energy modelling and efficiency factors based on standards such as ASHRAE and DIN 18599. These tools prove valuable in addressing GRESB indicators relating to the energy aspect by analysing the building's energy performance, considering energy efficiency measures and assessing the viability of integrating renewable energy systems. Two indicators related to the GRESB development energy

[173] Cf. Theißen, Sebastian, et al.: Using Open BIM and IFC to Enable a Comprehensive Consideration of Building Services Within a Whole-Building LCA. In: Sustainability Issue 14-2020, p. 10.

aspect can be supported, including energy efficiency requirement and onsite renewable energy and low carbon technologies.

Stakeholder's Engagement Aspect

The Health and Well-being indicator is a subset of the GRESB developments stakeholder engagement aspect that aims to create indoor environments that are safe, healthy, and comfortable for the occupants. The stakeholders highlighted the relationship between energy simulation and indoor environmental quality, which are interdependent in their assessment. Simulation software such as IES-VE and TRNSYS were mentioned to be utilised by stakeholders to assess how design decisions impact the indoor environment, particularly regarding indoor air quality, thermal comfort, and visual comfort. The IES-VE software tool provides multiple simulation modules for indoor environment daylight, thermal comfort, illuminance level, and CFD to evaluate factors like indoor air quality and natural ventilation.[174] This helps promote sustainable design by enabling the assessment of various design alternatives and enhancing a building's energy efficiency, environmental impact, and overall occupant well-being. TRNSYS is software used for energy simulation and building analysis. It calculates indoor thermal comfort levels by considering factors such as air temperature, average elevated air speed, mean radiant temperature, relative humidity, metabolic rate, and clothing factor. TRNSYS also calculates daylight-related outputs, including Daylight Factor, Daylight Autonomy, and illuminance levels.[175] This aligns with GRESB's objective of promoting social criteria in development projects that enhance the well-being of building occupants.

Table 20: Health & well-being indicator assessed following stakeholder's BIM workflow

Health & Well-being equirements met	Health & Well-being measures assessed	Data exchange and interoparability	BIM tools	Assessment
DSE1. Health & Well-being				
1.1. Health Impact Assessment	2.5. Daylight	Open BIM - IFC - gbXML Closed BIM - Direct link (Sketchup pligin)	IES-Virtual Environment, TRNSYS	Daylighting analysis
	2.7. Humidity		IES-Virtual Environment, TRNSYS	Humidity level/control
	2.8. Illumination		IES-Virtual Environment, TRNSYS	Lightning analysis
1.2. Integrated planning process	2.10. Indoor air quality		IES-Virtual Environment	Air flow analysis
	2.11. Natural ventilation		IES-Virtual Environment	Air flow analysis
	2.14. Thermal comfort		IES-Virtual Environment, TRNSYS	Thermal comfort

174 Cf. IES Virtual Environment (VE): Integrated Environmental Solutions | IES. Internet source.
175 Cf. TRNSYS, Transient System Simulation Program: TRNSYS 18 Updated Version. Internet source.

4.3.2 Indicator Scoring

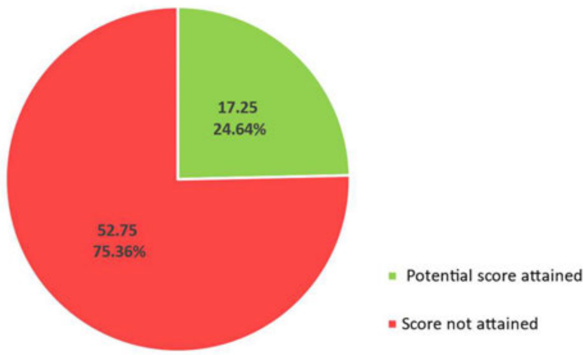

Figure 13: Scoring of the indicators based on the GRESB scoring workflow

The stakeholder interviews have provided valuable insights into the BIM workflow employed by planners and consultants for sustainability evaluation. The 6 identified indicators that can be supported using the BIM methodology, including Material Selection Requirements, LCA, Embodied Carbon, Energy Efficiency Requirements, On-site Renewable Energy, and Health and Well-being, are subject to GRESB scoring. This section presents the scoring of the indicators with potential integration and assessment using the stakeholder's BIM workflow. Similar to the previous BIM integration assessment, the GRESB scoring methodology is employed to quantify each indicator and its sub-options potential score. The findings of this chapter reveal that following the BIM workflow presented by stakeholders, a total of 17.25 score points can be achieved out of the 70 points within the GRESB development component. This represents a 24.65% fulfilment of the total GRESB scores for development benchmarking.

5 Discussion and Limitation

The analysis of the GRESB development indicators based on potential integration within the BIM framework provides proof of the feasibility and limitations of using BIM for ESG assessment, highlighting specific indicators where BIM can support their assessment in real estate development. Based on the analysis of GRESB development indicators, it was found that the BIM methodology could assist in assessing 11 out of the 21 indicators to varying degrees of applicability. These 11 indicators pertain to different aspects of the GRESB development schema, such as material, energy, water, and stakeholder engagement, thereby answering the first research question of the study. In the analysis process, Information requirements, interoperability within the BIM workflow (Open and Closed BIM), and BIM software tools that can be utilised for assessment were all defined in an effort to answer the second and third research questions. However, the Open BIM workflow was found to be implemented in assessing all criteria which require information exchange between platforms using IFC and gbXML file formats. The study also calculated the potential score based on the indicators that can be supported using the BIM process by adapting the GRESB scoring methodology. The findings revealed the potential achievement of 28.50 score points out of a total of 70 in the development component of the GRESB standard using BIM methodology. This equates to a 40.71% completion rate towards meeting all development requirements, thereby answering the fourth research question.

While BIM has proven valuable in assessing several sustainable ESG indicators, it is limited in dealing with ESG attributes beyond the building structure, such as social indicators related to the development community and environmental indicators related to due diligence for sustainable site acquisition aspects. Assessing such measures may require a conventional or supplementary approach outside the BIM workflow.

Interview conducted with ESG analyst in real estate companies presented their approach to ESG assessment. It become evident real estate companies are integrating various sustainability standards and guidelines to assess their development and operational assets. One reason is due to the consistent demand from investors to incorporate different guidelines. Major standards and guidelines for development projects include regulatory requirements, EU taxonomy, and the CRREM tool. For operational assets, the GRESB standing investment Benchmarking was mentioned to be reported by all stakeholders. However, some companies also report the GRESB development Benchmarking for development assets. The common method employed by stakeholders for ESG data collection is through third-party providers (auditors, consultants, and planners), with some organisations also conducting internal assessments. Stakeholders face various challenges in ESG assessment, including data collection and quality, balancing requirements and financing, active tenant engagement, and standard-related challenges. Various of the mentioned challenges correlate with the literature. Challenges such as the lack of information on material environmental impacts also correspond with the challenge mentioned in the interview with building planners and consultants.

In the interview with building planners and consultants, questions were asked regarding their workflow for sustainability evaluation using the BIM process, particularly related to building materials, energy, water waste, and indoor environmental quality. Stakeholders highlighted varying approaches for evaluating sustainability criteria for development projects using BIM. A stakeholder identified the use of BIM workflow for LCA and circularity to prove the EU taxonomy checklist. This identified a practical application of BIM in assessing EU taxonomy criteria. Their BIM approach for sustainability evaluation was found to support the assessment of 6 GRESB indicators related to material, energy, and stakeholder engagement aspects. Furthermore, the 6 indicators score based on the GRESB scoring method revealed the potential achievement of 17.25 out of the 70 scores of the GRESB development component. These relate to 24.64% fulfilment of the GREB development component, thereby answering the last research question.

The stakeholder interview presents a limitation with only 6 indicators supported using their presented BIM workflow, compared to the 11 indicators analysed in a systematic review of BIM and sustainability assessment. Although the stakeholders have demonstrated a commendable commitment to integrating numerous sustainability indicators into their BIM workflows, these results present a gap in fully harnessing BIM's capabilities to address broader sustainability criteria. GRESB indicators such as water conservation have been considered to be assessed using BIM workflow in previous studies, as presented in Chapters 2 and 3. However, stakeholders do not integrate such indicators into a BIM framework.

Nevertheless, it is important to recognise certain limitations of the stakeholder interview with building planners and consultants. GRESB indicators, including waste management during construction and construction safety, have a broader scope that extends beyond the planning phase and may not be directly integrated into the initial stages of development projects.

The findings of this study align with and extend previous research on the integration of BIM and sustainability assessment. Previous studies have generally acknowledged the potential of BIM to support sustainability evaluations of green building standards such as LEED, BREEM and SBTool. Furthermore, this study delves deeper into the integration of specific ESG indicators, providing a more targeted and comprehensive assessment within the BIM workflow by presenting the information requirement and data exchange. Overall, the findings contribute to a better understanding of how BIM can be potentially leveraged in ESG assessments.

6 Conclusion

This study contributes to the new body of knowledge on integrating ESG assessment of development projects into a BIM workflow. It indicated a clear opportunity for utilising the BIM process for assessing ESG indicators. The creation of a clear distinction between the indicator's technical requirements and technical measures indicates that the BIM process can support the assessment of various measures while adhering to standard definitions within the requirements. Moreover, the integration of DGNB standard recommendations for certain requirements with limited guidelines in the GREDB standard presents a clear correlation between ESG standards and the Green Building Certification System. The research findings reveal that BIM methodology exhibits a varying degree of applicability in supporting 11 out of 21 key indicators specified in the GRESB development standard. Furthermore, the study presents a calculated potential score, revealing that the adoption of BIM methodologies could potentially achieve 40.71% of the GRESB development benchmarking, equivalent to a 28.50 score. The study has not only identified these indicators but also shed light on the information requirements, interoperability within the BIM workflow (Open and Closed BIM), and the BIM software tools that can be employed for assessment. The findings demonstrate that an Open BIM workflow can be implemented for information exchange between different software tools.

Interviews with ESG analysts within the real estate industry identified the various methods and challenges faced regarding ESG assessment for development and operational assets. This practical perspective is valuable for understanding the real-world dynamics of ESG assessment and can guide efforts to improve sustainability practices in the sector.

The interview with the building planners and consultants revealed the practical application of BIM in sustainability evaluation and the integration of EU taxonomy checks within the BIM workflow. This highlights the practical application of BIM functionalities for ESG assessment. The industry experts have assessed various sustainability criteria using BIM, which correlates with some of the GRESB indicators for development projects. Their BIM workflow supports six GRESB indicators, which can achieve a GRESB score of 17.25, corresponding to a 24.65% fulfilment of the GRESB development component.

Finally, this thesis presents the viability of integrating BIM workflow with ESG assessment. The study contributes to the broader academic on BIM and sustainability, advancing the understanding of how these two domains can synergise effectively. To explore this potential further, a future study could employ the presented BIM-based ESG assessment workflow to assess an actual GRESB report submitted by an entity, following their exact standards and guidelines for each requirement and measure. This practical application would provide valuable insights into the feasibility and effectiveness of integrating BIM and ESG.

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Appendix A ESG Indicator Analysis

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
				ESG Requirements Aspect			
DRE1	**ESG strategy during development**	**G**	**4.00**	**Entity's ESG Strategy in place for development projects and elements addressed**			
	1. Elements addressed in the strategy						
	1.1. Biodiversity and habitat			Variety of plant and animal species and the natural environment they live and function	- Wildlife - Endangered species - Ecosystem services - Habitat management	Qualitative	Entity level
	1.2. Building safety			Environmental issues with the potential to create or exacerbate risks to human safety. Such as fire safety, structural safety, and electrical and gas safety during development.	- Site inspection at key milestone - Recording building safety observations - Designated personnel to oversee building safety compliance during development.	Qualitative	Entity level
	1.3. Climate/climate change adaptation			Preparation for long-term change in climatic conditions or climate-related events.	- Building flood defences - Xeriscaping - Tree species resistant to storms and fires - Adapting building codes to extreme weather events.	Qualitative	Entity level
	1.4. Energy consumption			The use of energy by the entity	N/A	Qualitative	Entity level
	1.5. Green building certifications			Recognition that a project has satisfied the requirements of a green building rating system.	N/A	Qualitative	Entity level
	1.6. Health and well-being			Conditions in which people are born, grow, work, live and age, and the broader set of forces and systems shaping the conditions of daily life." These are the conditions that enable or discourage healthy living	- Physical activity - Healthy eating - Reduction in toxic exposures - Equitable workplaces - Maternity and paternity leave - Access to healthcare	Qualitative	Entity level
	1.7. Indoor environmental quality			The conditions inside the building.	- Air quality - Access to daylight and views - Pleasant acoustic conditions - Occupant control over lighting - Thermal comfort	Qualitative	Entity level
	1.8. Life-cycle assessments/embodied carbon			Compilation and evaluation of the potential emissions and environmental impacts of materials and components that make up a structure, from raw material acquisition or generation from natural resources to final disposal.	N/A	Qualitative	Entity level
	1.9. Location and transportation			Location of a building in relation to the surrounding area.	- Mass transit network - Active transportation - Amenities	Qualitative	Entity level
	1.10. Material sourcing			Responsible sourcing of materials considers the environmental, social and economic impacts of the procurement and production of products and materials.	N/A	Qualitative	Entity level
	1.11. Net-zero/carbon neutral design			Reduce the carbon emissions associated with all aspects of the project.	- Operational energy - Construction material - Additional carbon from residential use	Qualitative	Entity level
	1.12. Pollution prevention			Any practice that reduces, eliminates, or prevents pollution	- Air pollution - Noise pollution - Light pollution - Thermal pollution - Land/soil pollution - Water/marine pollution	Qualitative	Entity level
	1.13. Renewable energy			Any source of energy that can be used without depleting its reserves, including sun, wind, water, biomass or Earth s core, using on-site technologies.	- Photovoltaic panels - Wind turbines - Transpired solar collectors/solar hot water heaters/solar thermal energy - Small-scale hydroelectric power plants - Geothermal energy, landfill gas.	Qualitative	Entity level
	1.14. Resilience to catastrophe/disaster			Preparedness of the built environment towards existing and future threats of natural disaster.	- Management policies - Informational technologies - Educating tenants. Communities, suppliers - Physical measures at the asset level.	Qualitative	Entity level
	1.15. Site selection and land use			Encourage the use of previously occupied or contaminated land. Encourage development on land that already has limited value to wildlife and to protect existing ecological features from substantial damage during site preparation and completion of construction works.	N/A	Qualitative	Entity level

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
	1.16. Sustainable procurement			Encourage, facilitate or require the reduction of consumption of goods within the building or premises and/or the sourcing of sustainable or ethical goods.	- Reduction of paper consumption - Supply of biodegradable materials - Use of recycled paper and building materials	Qualitative	Entity level
	1.17. Waste management			Issues associated with hazardous and non-hazardous waste generation, reuse, recycling, composting, recovery, incineration, landfill and on-site storage.	N/A	Qualitative	Entity level
	1.18. Water consumption			The use of water resources by the entity.	N/A	Qualitative	Entity level
	2. Availability of the strategy						
	2.1. Publicly available			N/A	N/A	Qualitative	Entity level
	2.2. Not publicly available			N/A	N/A	Qualitative	Entity level
DRE2	**Site selection requirements**	**E**	**4.00**				
	1.1. Connect to multi-modal transit networks			Pedestrian, bicycle, and mass-transit networks.	N/A	Qualitative	Technical requirements
	1.2. Locate projects within existing developed areas			Development projects are prioritized in areas that have existing infrastructure, development, and urban infill as opposed to greenfield development.	N/A	Qualitative	Technical requirements
	1.3. Protect, restore, and conserve aquatic ecosystems			Ecosystems such as coastal and riparian areas, wetlands and deepwater habitats that provide critical ecosystem functions for aquatic organisms, other wildlife and people.	N/A	Qualitative	Technical requirements
	1.4. Protect, restore, and conserve farmland			Agricultural land, designated as such by a national, local, or intergovernmental authority	N/A	Qualitative	Technical requirements
	1.5. Protect, restore, and conserve floodplain functions			Land area adjecent to waterways	N/A	Qualitative	Technical requirements
	1.6. Protect, restore, and conserve habitats for native, threatened and endangered species			Land areas that contain habitat for plant and animal species identified as threatened or endangered by a national or intergovernmental authority	N/A	Qualitative	Technical requirements
	1.7. Protect, restore, and conserve historical and heritage sites			Preservation of buildings or land which are of as historical, heritage, or cultural significance.	N/A	Qualitative	Technical requirements
	1.8. Redevelop brownfield sites			Areas of land or premises that have been previously used, but have subsequently become vacant, derelict or contaminated	N/A	Qualitative	Technical requirements
DRE3	**Site design and development requirements**	**E**	**4.00**	**Sustainable site design/construction criteria for development projects**			
	1.1. Manage waste by diverting construction and demolition materials from disposal			Support a low-waste construction site and minimise the down-cycling of materials.	- Diverting construction and demolition materials - Reusing materials - Recycling materials	Qualitative	Technical requirements
	1.2. Manage waste by diverting reusable vegetation, rocks, and soil from disposal			Minimize the disposal of reusable vegetation, minerals, rocks and soil.	- Use of materials as resources in site design - Use of materials to produce compost	Qualitative	Technical requirements
	1.3. Minimize light pollution to the surrounding community			Minimize the effects of light pollution caused by construction lighting and other human-made sources to the surrounding areas of the development sites.	N/A	Qualitative	Technical requirements
	1.4. Minimize noise pollution to the surrounding community			Minimize the effects of noise pollution caused by construction activities to the surrounding areas of the development sites.	N/A	Qualitative	Technical requirements
	1.5. Perform environmental site assessment			An assessment during the due diligence process that ensures the environmental implications of the site are taken into account	- Site contamination - Site potential environmental hazard - Human health hazard arising from the site	Qualitative	Technical requirements
	1.6. Protect air quality during construction			Protect air quality and reduce pollution by using construction equipment that reduces emissions of localized air pollutants and greenhouse gasses.	N/A	Qualitative	Technical requirements
	1.7. Protect and restore habitat and soils disturbed during construction and/or during previous development			Support healthy plants, biological communities, water storage, and infiltration with actions such as the protection of on-site habitat, restoring disturbed soils, and supporting off-site land conservation.	- On-site habitat - Restoring disturbed soils - Supporting off-site land conservation	Qualitative	Technical requirements
	1.8. Protect surface water and aquatic ecosystems by controlling and retaining construction pollutants			Protect receiving waters (including surface water, groundwater, and combined sewers or stormwater systems)	- Creation and implementation of a stormwater pollution prevention plan - Erosion and sedimentation control plan	Qualitative	Technical requirements

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
				Material Aspect			
DMA1	**Materials selection requirements**	**E**	**6.00**				
	1. Requirement for disclosure on environmental & health attribute of building material						
	1.1. Environmental Product Declarations			Products and materials for which life-cycle information is publicly available and which have positive, sustainable, life-cycle impacts.	EPD should confirm with: - ISO 14025 - ISO 14040 - ISO 14044 - EN 15804 - ISO 21931	Qualitative	Technical requirements
	1.2. Health Product Declarations			Products and materials for which the inventory of all ingredients used is publicly available, with a full disclosure of all known hazards and associated effects.	- MSD Sheets	Qualitative	Technical requirements
	2. Materia characteristics specifications						
	2.1. Locally extracted or recovered materials			Materials that are extracted, harvested or recovered within a specified distance from the construction site.	-	Qualitative	Technical measures
	2.2. Low embodied carbon materials			Embodied carbon is the sum of all the carbon required to produce materials, considered as if that carbon was incorporated or embodied in the product itself.	-	Quantitative	Technical measures
	2.3. Low-emitting VOC materials			Materials that have reduced concentrations of chemical contaminants (volatile organic compounds or VOC) that can damage air quality, human health, productivity, and the environment.	-	Quantitative	Technical measures
	2.4. Materials and packaging that can easily be recycled			Materials and packaging that make are composed of elements that can be easily recycled in waste management systems.	-	Qualitative	Technical measures
	2.5. Materials that disclose environmental impacts			Materials made from agricultural products that are typically harvested within a 10-year or shorter cycle	-	Qualitative	Technical measures
	2.6. Materials that disclose potential health hazards			Fully disclosed and publicly available information about the human health and environmental impacts or characteristics of the products or materials used.	-	Qualitative	Technical measures
	2.7. Rapidly renewable materials and recycled content materials			Products made from pre-consumer and/or post-consumer material diverted from the waste stream bamboo, wool, cotton insulation, agrifiber, linoleum, wheatboard, strawboard and cork.	-	Quantitative	Technical measures
	2.8. “Red list” of prohibited materials or ingredients that should not be used on the basis of their human and/or environmental impacts			Contains the worst in class materials prevalent in the building industry as published by the International Living Future Institute	-	Quantitative	Technical measures
	2.9. Third-party certified wood-based materials and products			Certification that encourages responsible and sustainable forest management	Certification bodies include, but are not limited to: - Forest Stewardship Council (FSC); - Programme for the Endorsement of Forest Certification (PEFC); - Sustainable Forestry Initiative (SFI).	Quantitative	Technical measures
DMA2.1	**Life cycle assessments**	**E**	**-**				
	1.1 Assessment			Quantitative assessment Qualitative assessment	BBCA Label (Bâtiment Bas Carbone) E+C- Label (Énergie Positive & Réduction Carbone) Embodied Carbon in Construction Calculator (EC3) Tool GHG Protocol - Product Life Cycle Accounting and Reporting Standard One Click LCA The Carbon Smart Materials Palette Whole life carbon assessment for the built environment, RICS EN 15978, EN 15804, ISO 14040/44, ISO 14025	Quantitative	Technical measures
	1.2. Boundaries of the calculation			Cradle-to-gate Cradle-to-practical completion/handover Use stage End-of-life stage Cradle-to-grave Whole life			

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
DMA2.2	**Embodied carbon**	**E**	**-**				
	1.1. Embodied carbon intensity for new construction projects:			A1-A3 (Cradle to gate) A1-A3, A4 (Cradle to site) A1-A3, A4, A5 (Cradle to practical completion)	-	Quantitative	Technical measures
	1.2. Embodied carbon intensity for major renovation projects:			A1-A3 (Cradle to gate) A1-A3, A4 (Cradle to site) A1-A3, A4, A5 (Cradle to practical completion) A1-A3, A4, A5,C2,C3,C4 (Cradle to practical completion and end of life stage)			
	1.3. Building layers included in the scope			Substructure Superstructure Finishes Fixed FF&E Building services (MEP) Furniture and appliances			
	1.4. Carborn emission disclosure:			Information or data readily accessible and available to all interested individuals and institutions.	- Publicly available - Not publicly available	Qualitative	
				Energy Aspect			
DEN1	**Energy efficiency requirements**	**E**	**6.00**				
	1. Requirements for planning and design						
	1.1. Development and implementation of a commissioning plan			Plan to review and verify design and construction phase, to ensure that the performance of facilities, systems and assemblies meet defined objectives during the operational phase.	DGNB Methods: - Monitoring concept - Preliminary functional testing - Functional testing and training - Commissioning final report	Qualitative	Technical requirements
	1.2. Integrative design process			A design process that considers and involve multiple aspects, stakeholders and functions.	- Preliminary analysis - Design and construction by analysing unique opportunities and constraints of the building site - building performance measurement and stakeholder feedback	Qualitative	Technical requirements
	1.3. To exceed relevant energy codes or standards			Energy requirements set by building codes and standards	- US energy efficiency standard - International energy conservation code (2012) DGNB Standard: - DIN 18599 - The local Standard - EN ISO 52000 - ASHRAE 90.1	Qualitative	Technical requirements
	1.4. Maximum energy use intensity post-occupancy			Requirement for a building to achieve a predetermined energy use intensity one in operation	EnEV - Minimum EUI (kWh/m2/a)	Qualitative	Technical requirements
	2. Common energy efficiency measure						
	2.1. Air conditioning			Energy-efficient air-conditioning units, such as those rated with a high energy efficiency rating, and secondary measures to promote efficiencies, such as strategic location and integration into building functionality design.	Energy-efficient air-conditioning units Design strategies: - Building orientation - Thermal gain Air-conditioned ventilation System (DGNB) - supply-air fan: PSFP = 1.5 kW/(m3/s) - exhaust-air fan: PSFP = 1.0 kW/(m3/s)	Quantitative	Technical measures
	2.2. Commissioning			Quality-orientated review and verification process during the design and construction phase, to ensure that the performance of facilities, systems and assemblies meet defined objectives during the operational phase.	N/A	Quantitative	Technical measures
	2.3. Energy modeling			A virtual or computerised simulation of a building that can be used to estimate the energy use of a building and evaluate its energy efficiency.	DGNB Standard: - DIN 18599 - The local Standard - EN ISO 52000 - ASHRAE 90.1	Quantitative	Technical measures
	2.4. High-efficiency equipment and appliances			Specification and purchase of electrical equipment and appliances that minimize the building s energy needs.	N/A	Quantitative	Technical measures

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
	2.5. Lighting			Natural daylight to reduce light energy consumption and energy efficient lighting units, Sensors and timers	Building design: - Angle of orientation - number and window sizing - Material (translucent, reflective coating) Daylight factor DGNB (DIN1034): min 1.0%, recommended 2.0% - Daylight autonomy (DGNB) ▪ min 45%, recommended 75% Efficient lightning units: - LEDs - CFLs - Halogen incandescent	Quantitative	Technical measures
	2.6. Occupant controls			Individual controls for heating, cooling and lightning building systems.	- User control (DGNB) ▪ Systems can be controlled individually for a particular room or by the users/user groups	Quantitative	Technical measures
	2.7. Passive design			Passive design uses layout, fabric and form to reduce or remove mechanical cooling, heating, ventilation and lighting demand.	- Natural ventilation - Daylight - Efficient heating - Efficient cooling	Quantitative	Technical measures
	2.8. Space heating			Energy efficient space heating systems for internal spaces within a building such as energy efficient mechanical systems, and maximizing the maintenance of internal heating via insulation, seals and windows and doors	- Energy-efficient systems (Solar thermal collector, radiators, Hot-air heating) - Design strategies (building orientation, Building envelope, thermal gain, etc.)	Quantitative	Technical measures
	2.9. Ventilation			Use of natural ventilation to reduse energy consumption and Use of energy-efficient mechanical ventilation systems to supply and remove air through an indoor space	Design strategies Energy-efficient mechanical ventilation Non-conditioned/heated air System (DGNB) - supply-air fan: PSFP = 1.5 kW/(m3/s) - exhaust-air fan: PSFP = 1.0 kW/(m3/s)	Quantitative	Technical measures
	2.10. Water heating			Energy efficient water heating systems such as those with a high-energy efficiency rating, including those which are demand-based, that do not lose energy on stand-by heating. Also includes efficient hot water distribution systems to reduce energy losses throughout the building.	- Standard (DGNB) ▪ Solar collector, according to DIN V 18599-8, Section 6.4.1,	Quantitative	Technical measures
	3. Operational energy efficiency monitoring						
	3.1. Building energy management systems			Computer-based automated systems that monitor and control all energy-related systems, including all mechanical and electrical equipment in buildings.	N/A	Quantitative	Technical measures
	3.2. Energy use analytics			Analysis of energy use to determine discrepancies between baseline and actual energy use.	N/A	Quantitative	Technical measures
	3.3. Post-construction energy monitoring			Monitoring of energy consumption during the operational phase of the building, to identify that energy use objectives are being met.	N/A	Quantitative	Technical measures
	3.4. Sub-meter			A system that allows the measurement of utility use by an individual occupant within a multi-tenant property, such as individual electricity meters.	N/A	Quantitative	Technical measures
DEN2.1	**On-site renewable energy and low carbon technologies**	**E**	**6.00**				
	1.1. Biofuels			Liquid of gaseous fuels, such as bioethanol and biodiesel, that are made from biomass.	- % of energy demand that by design should be covered by renewable system	Quantitative	Technical measures
	1.2. Geothermal			Electricity generated from subterranean steam or heat generated from subterranean stems or hot water.	- % of energy demand that by design should be covered by renewable system	Quantitative	Technical measures
	1.3. Hydro			Energy generated by the gravitational force of falling or flowing water.	- % of energy demand that by design should be covered by renewable system	Quantitative	Technical measures
	1.4. Solar/photovoltaic			Energy generated from solar heat and/or radiant light.	- % of energy demand that by design should be covered by renewable system	Quantitative	Technical measures
	1.5. Wind			Energy generated from solar heat and/or radiant light.	- % of energy demand that by design should be covered by renewable system	Quantitative	Technical measures
DEN2.2	**Net zero carbon design and standards**	**E**	**2.00**				
	1. Net zero carbon						
	1.1. Net zero carbon - construction			When the amount of carbon emissions associated with a building s product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy.	- Net-Zero carbon building products - Net-zero carbon construction	Quantitative	Technical measures

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
	1.2. Net zero carbon - operational energy			When the amount of carbon emissions associated with the building s operational energy on an annual basis is zero or negative through the use of offsets or the net export of on-site renewable energy. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset.	- Net-zero carbon operation	Quantitative	Technical measures
	2. Net zero carbon code/standard						
	2.1. National/local green building council standard			specify:standard	N/A	Qualitative	Technical requirements
	2.2. National/local government standard			specify:standard	N/A	Qualitative	Technical requirements
	2.3. International standard, specify			specify:standard	N/A	Qualitative	Technical requirements
				Water Aspect			
DWT1	**Water conservation strategy**						
	1. Requirements for planning and design	E	5.00%				
	1.1. Development and implementation of a commissioning plan			Plan to review and verify design and construction phase, to ensure that the performance of facilities, systems and assemblies meet defined objectives during the operational phase.	N/A	Qualitative	Technical requirements
	1.2. Integrative design for water conservation			A design process that considers and involve multiple aspects, stakeholders and functions.	- Preliminary analysis - Designn and construction by analysing unique opportunities and constraints of the building site - building performance measurement and stakeholder feedback	Qualitative	Technical requirements
	1.3. Requirements for indoor water efficiency			Requirement such as planning oblication, building codes and standards to reduse water consumption and improve efficiet use of water	- Indoor water use - Efficient water use	Qualitative	Technical requirements
	1.4. Requirements for outdoor water efficiency			Requirement for water use outside the building structure	- Outdoor water use - Efficient water use	Qualitative	Technical requirements
	1.5. Requirements for process water efficiency			Requirement to reuse water use for building systems such as boilers, and chillers as well as operational processes such as dishwashing	N/A	Qualitative	Technical requirements
	1.6. Requirements for water supply			Provission of surface water, ground water, rain water, external waste water, munincipal water or other water utilities usually via pipe and pumps	N/A	Qualitative	Technical requirements
	1.7. Requirements for minimum water use intensity post-occupancy			Requirement for building to achieve a predetermined water use intensity once building is fully operational	- Water use intensity (L/m2/yr)	Qualitative	Technical requirements
	2. Common water efficiency measures include						
	2.1. Commissioning of water systems			Quality-orientated review and verification process during the design and construction phase, to ensure that the performance of facilities, systems and assemblies meet defined objectives during the operational phase.	N/A	Qualitative	Technical measures
	2.2. Drip/smart irrigation			Drip irrigation systems save water by irrigating, fertilising and aerating trees, shrubs, plants and bushes directly at the roots. Smart irrigation systems save water by adjusting the watering schedule	- Irrigating directly from root - Sheduled irrigation	Quantitative	Technical measures
	2.3. Drought tolerant/low-water landscaping			Reduction of water use through landscaping characteristics considering Less or no irrigation.	N/A	Quantitative	Technical measures
	2.4. High-efficiency/dry fixtures			Fixtures that do not require the use of water such as: - Composting toilet systems - Waterless urinals	N/A	Quantitative	Technical measures
	2.5. Leak detection system			Systems that detect water leaks such as: - Condensate water overflow - Chiller water leaks - Plumbing line cracks - Heating/cooling piping leaks - Outside seepage.	N/A	Quantitative	Technical measures

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
	2.6. Occupant sensors			Motion sensor devices that turn water fixtures on (or off) in response to the presence (or absence) of people.	N/A	Quantitative	Technical measures
	2.7. On-site wastewater treatment			Process of water decontamination as a consequence of any anthropogenic, industrial or commercial use, before the water is released again into the environment or is reused.	N/A	Quantitative	Technical measures
	2.8. Reuse of stormwater and greywater for non-potable applications			Reuse of water that collects during precipitation and Wastewater generated from hand basins, showers and other water-using devices and equipment.	- Storm water collection - Grey water reuse	Quantitative	Technical measures
	3. Operational water efficiency monitoring						
	3.1. Post-construction water monitoring			Monitoring of water consumption during the operational phase of the building, to identify that water conservation objectives are being met.	N/A	Quantitative	Operational measures
	3.2. Sub-meter			A system that allows the measurement of utility use by an individual occupant within a multi-tenant property	N/A	Quantitative	Operational measures
	3.3. Water use analytics			Analysis of water use to determine discrepancies between baseline and actual water use	N/A	Quantitative	Operational measures
				Waste Aspect			
DWS1	**Waste management strategy**	**E**	**5.00%**				
	1. Management and construction practices						
	1.1. Construction waste signage			Visible signage that clearly indicates the process of properly dealing with the waste generated during construction	N/A	Qualitative	Technical measures
	1.2. Diversion rate requirements			Requirements to meet a specified diversion rate which are materials diverted from landfill, incineration (WTE), and the environment / total generation.	N/A	Quantitative	Technical measures
	1.3. Education of employees/contractors on waste management			Educating employees, contractors and crews on materials recovery techniques and procedures, such as sorting and storage methods, recoverable materials and removal techniques.	N/A	Qualitative	Technical measures
	1.4. Incentives for contractors for recovering, reusing and recycling building materials			Incentives, for example, allow contractors and crews to retain a portion of revenues and/or savings from materials recovery and sales	N/A	Qualitative	Technical measures
	1.5. Targets for waste stream recovery, reuse and recycling			The complete flow of waste from generation to the final disposal through building material waste from landfill by recovery of the material from the site to be recycled or sent to an energy recovery facility.	N/A	Qualitative	Technical measures
	1.6. Waste management plans			Plan that addresses the collection and disposal of waste generated during construction or renovation, usually including the collection, transfer, treatment and disposal of a variety of waste types.	N/A	Qualitative	Technical measures
	1.7. Waste separation facilities			A designated facility where waste is separated into different elements to be correctly disposed of, recycled, or otherwise managed.	N/A	Qualitative	Technical measures
	2. On-site waste monitoring						
	2.1. Hazardous waste monitoring			A solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical/chemical/infectious characteristics, may either cause or significantly contribute to an increase in mortality/serious irreversible illness	N/A	Qualitative	Technical measures
	2.2. Non-hazardous waste monitoring			Waste that does not have the potential to cause harm to humans, animals or the environment.	N/A	Qualitative	Technical measures
				Building Certification Aspect			
DBC1.1	**Green building standard requirements**	**E**	**4.00%**				
	1.1. The entity requires projects to align with requirements of a third-party green building rating system but does not require certification			N/A	- Green building rating system - potfolio covered	Qualitative	Technical requirements
	1.2. The entity requires projects to achieve certification with a green building rating system but does not require a specific level of certification			N/A	- Green building rating system - potfolio covered	Qualitative	Technical requirements

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
	1.3. The entity requires projects to achieve a specific (above the minimum) level of certification			N/A	- Green building rating system - potfolio covered	Qualitative	Technical requirements
DBC1.2	**Green building certifications**	E	9.00%				
	1.1. Projects registered to obtain a green building certificate at the end of reporting year			N/A	- Green building rating system - Area coverd - % coverd - Number of assets - % of GAV coverd	Qualitative	Technical measures
	1.2. Projects that obtained a green building certificate or official pre-certification			N/A	- Green building rating system - Area certified - % certified - Number of assets - % of GAV certified	Qualitative	Technical measures
				Stakeholder Engagement			
DSE1	**Health & Well-being**	S	2.00%				
	1. Requirements for planning and design						
	1.1. Health Impact Assessment			Means of assessing the health impacts of policies, plans and projects using quantitative, qualitative and participatory techniques.	N/A	Qualitative	Technical requirements
	1.2. Integrated planning process			A design process that considers and involve multiple aspects, stakeholders and functions.	- Preliminary analysis - Designn and construction by analysing unique opportunities and constraints of the building site - building performance measurement and stakeholder feedback	Qualitative	Technical requirements
	2. Common occupant health and well-being measures						
	2.1. Acoustic comfort			Minimizing sound to promote mental well-being and in some instances, physical ear health	Promoting used acoustic comfort through design and material selection. Requirement for reverberation time (DGNB) - Compliance with DIN 18041:2016-03 Efforts to protect the ears of construction workers and surrounding communities in both construction and operation	Quantitative	Technical measures
	2.2. Active design features			Design features specifically aimed to positively contribute towards occupant health and well-being	- Centrally located staircases	Qualitative	Technical measures
	2.3. Biophilic design			Design that draws upon the innate connection between humans and nature.	- Connections with nature - Access to views - Place-based design - Interior design that includes plants, water and/or symbolic connections to nature through images, colours, and shapes.	Qualitative	Technical measures
	2.4. Commissioning			Quality-orientated review and verification process during the design and construction phase, to ensure that the performance of facilities, systems and assemblies meet defined objectives during the operational phase.	N/A	Qualitative	Technical measures
	2.5. Daylight			The capacity of a building to provide maximum daylight exposure to occupants via building design.	- Design (Angle of orientation, number and window sizing) - Material (translucent, reflective coating) - Daylight factor (DGNB) ▪ min 1.0%, max 2.0% - Daylight autonomy (DGNB) ▪ min 45%, max 75%	Quantitative	Technical measures
	2.6. Ergonomic workplace			Aims to increase efficiency and productivity and reduce discomfort in the workplace.	N/A	Qualitative	Technical measures
	2.7. Humidity			A measure of the concentration of water vapour present in the air	N/A	Quantitative	Technical measures
	2.8. Illumination			Light falling on a surface per unit area, measured in lux.	- Illumination recommendation (DGNB) ▪ Single cluster office 500 lux ▪ Open space office 500 lux	Quantitative	Technical measures
	2.9. Inclusive design			Design that accommodates individuals of different religions, genders and gender identities, ages, ethnicities and ability levels.	N/A	Qualitative	Technical measures
	2.10. Indoor air quality			The physical or biological characteristics of air within buildings. Indoor air quality (IAQ) is typically the product of outdoor quality mediated by the design and operation of building systems.	- Indoor air quality (DGNB) ▪ VOC concentration ▪ Air exchange rate category I and II of EN 15251 or DIN EN 16798-1	Quantitative	Technical measures

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
	2.11. Natural ventilation			Supplying and removing air through an indoor space without using mechanical systems, such as wind-driven and buoyancy-driven ventilation	- Max depth for natural ventilation through opening windows with minimum air exchange (DGNB) ▪ Max depth for I-sided ventilation= 2.5*h. ▪ II-sided ventilation = 5*h	Quantitative	Technical measures
	2.12. Occupant controls			Individual controls of building systems.	- Ventilation control - Heating/cooling control - Shading/glare protection control - Artificial light control	Qualitative	Technical measures
	2.13. Physical activity			Promotion of health-focused physical activity events and access to spaces designated for recreation, such as:	- Green spaces - Picnic areas - Sport facilities - Children s playgrounds etc	Qualitative	Technical measures
	2.14. Thermal comfort			The indoor thermal environment that contributes to employee productivity and well-being.	- Air temperature - Air velocity - Humidity DGNB (office) - Compliance with DIN EN 15251 ▪ Heating (19°C-25°C) ▪ Cooling (23°C-27°C)	Quantitative	Technical measures
	2.15. Water quality			Reduction of water contamination risk and provision of clean fresh sources of water.	N/A	Qualitative	Technical measures
	3. Provisions to verify health and well-being performance						
	3.1. Occupant education			Education and training of building occupants to increase knowledge on sustainability principles and the benefits to their health and well-being,	N/A	Qualitative	Operational measures
	3.2. Post-construction health and well-being monitoring (eg. occupant comfort and satisfaction)			A structured approach towards measuring and managing the health and well-being of occupants, such as occupant comfort and satisfaction.	N/A	Quantitative	Operational measures
DSE2.1	**On-site safety**	**S**	**1.50%**				
	1.1. Availability of medical personnel			N/A	N/A	Qualitative	Technical measures
	1.2. Communicating safety information			N/A	N/A	Qualitative	Technical measures
	1.3. Continuously improving safety performance			N/A	N/A	Qualitative	Technical measures
	1.4. Demonstrating safety leadership			N/A	N/A	Qualitative	Technical measures
	1.5. Entrenching safety practices			N/A	N/A	Qualitative	Technical measures
	1.6. Managing safety risks			N/A	N/A	Qualitative	Technical measures
	1.7. On-site health and safety professional (coordinator)			N/A	N/A	Qualitative	Technical measures
	1.8. Personal Protective and Life Saving Equipment			N/A	N/A	Qualitative	Technical measures
	1.9. Promoting design for safety			N/A	N/A	Qualitative	Technical measures
	1.10. Training curriculum			N/A	N/A	Qualitative	Technical measures
DSE2.2	**Safety metrics**	**S**	**1.50%**				
	1.1. Injury rate			Monitoring and reporting on-site health and safety by keeping records of the number of incidents over time.	N/A	Quantitative	Technical measures
	1.2. Fatalities						
	1.3. Near misses						
	1.4. Lost day rate						
	1.5. Severity rate						
DSE3.1	**Contractor ESG requirements**	**S**	**2.00%**				
	1.1. Business ethics			This Indicator examines the entity s strategy to ensure contractors support the entity s ESG objectives and follow ESG management requirements.	N/A	Qualitative	Technical requirements
	1.2. Child labor						
	1.3. Community engagement						
	1.4. Environmental process standards						
	1.5. Environmental product standards						
	1.6. Health and well-being						
	1.7. Human rights						
	1.8. Human health-based product standards						
	1.9. Occupational safety						
	1.10. Labor standards and working conditions						

Code	Indicator | Sub-options	E|S|G	Score	Terminology	Supportive measures | Standard|Guidline	Qualitative | Quantitative	Reporting approach
DSE3.2	**Contractor monitoring methods**	**S**	**2.00%**				
	1.1. Contractor ESG training			Monitoring measures ensure that contractors comply with the contractual specifications and requirements regarding ESG issues.	N/A	Qualitative	Technical measures
	1.2. Contractors provide an update on environmental and social aspect during construction						
	1.3. External audits by third party						
	1.4. Internal audits						
	1.5. Weekly/monthly (on-site) meetings and/or ad hoc site visits						
DSE4	**Community engagement program**	**S**	**2.00%**				
	1.1. Community health and well-being			A structured and comprehensive approach to support community assosiated with the developed project	N/A	Qualitative	Technical measures
	1.2. Effective communication and process to address community concerns						
	1.3. Employment creation in local communities						
	1.4. Enhancement programs for public spaces						
	1.5. ESG education program						
	1.6. Research and network activities						
	1.7. Resilience, including assistance or support in case of disaster						
	1.8. Supporting charities and community groups						
DSE5.1	**Community impact assessment**	**S**	**2.00%**				
	1.1. Housing affordability			Direct and indirect socio-economic impact of the built environment to create a prosperous and sustainable environment	N/A	Qualitative	Technical measures
	1.2. Impact on crime levels						
	1.3. Livability score						
	1.4. Local income generated						
	1.5. Local job creation						
	1.6. Local residents well-being						
	1.7. Walkability score						
DSE5.2	**Community impact monitoring**	**S**	**2.00%**				
	1.1. Analysis and interpretation of monitoring data			A structured approach towards measuring and managing the impact of community engagement projects on the local community.	N/A	Quantitative	Technical measures
	1.2. Development and implementation of a communication plan						
	1.3. Development and implementation of a community monitoring plan						
	1.4. Development and implementation of a risk mitigation plan						
	1.5. Identification of nuisance and/or disruption risks						
	1.6. Identification of stakeholders and impacted groups						
	1.7. Management practices to ensure accountability for performance goals and issues identified during community monitoring						

Appendix B BIM Integration Analysis

ESG Requirements Aspect						
Code	**Indicator | Sub-options**	**Potential BIM application**	**BIM information requirement**	**BIM workflow and interoperability**	**BIM tools**	**Assessment and output**
DRE2	**Site selection requirements**					
	1.1. Connect to multi-modal transit networks	N/A	N/A	N/A	N/A	N/A
	1 2. Locate projects within existing developed areas	N/A	N/A	N/A	N/A	N/A
	1 3. Protect, restore, and conserve aquatic ecosystems	N/A	N/A	N/A	N/A	N/A
	1.4. Protect, restore, and conserve farmland	N/A	N/A	N/A	N/A	N/A
	1 5. Protect, restore, and conserve floodplain functions	N/A	N/A	N/A	N/A	N/A
	1.6. Protect, restore, and conserve habitats for native, threatened and endangered species	N/A	N/A	N/A	N/A	N/A
	1.7. Protect, restore, and conserve historical and heritage sites	N/A	N/A	N/A	N/A	N/A
	1.8. Redevelop brownfield sites	N/A	N/A	N/A	N/A	N/A
DRE3	**Site design and development requirements**					
	1.1. Manage waste by diverting construction and demolition materials from disposal	N/A	N/A	N/A	N/A	N/A
	1.2. Manage waste by diverting reusable vegetation, rocks, and soil from disposal	N/A	N/A	N/A	N/A	N/A
	1 3. Minimize light pollution to the surrounding community	N/A	N/A	N/A	N/A	N/A
	1.4. Minimize noise pollution to the surrounding community	N/A	N/A	N/A	N/A	N/A
	1 5. Perform environmental site assessment	N/A	N/A	N/A	N/A	N/A
	1.6. Protect air quality during construction	N/A	N/A	N/A	N/A	N/A
	1.7. Protect and restore habitat and soils disturbed during construction and/or during previous development	N/A	N/A	N/A	N/A	N/A
	1 8. Protect surface water and aquatic ecosystems by controlling and retaining construction pollutants	N/A	N/A	N/A	N/A	N/A
Material Aspect						
DMA1	**Materials selection requirements**					
	1. Requirement for disclosure on environmental & health attribute of building matrial					
	1.1. Environmental Product Declarations	BIM can be used to obtain information about material EPD in compliance with defined standards. LCA tools are integrated with generic and specific EPDs used to conduct life cycle assessment	-	-	EPD Database - Ökobaudat - IBU.data Product specicif EPDs EPD libraries	Life Cycle Assessment - EPDs (Cradle to gate)
	1 2. Health Product Declarations	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	-	-	-	MSD Sheet
	2. Materia characteristics specifications					
	2.1. Locally extracted or recovered materials	The information included in the material Life cycle assessment at: A1 - Raw material extraction	- Material (type, properties quantity)	see LCA	see LCA	Life Cycle Assessment A1 - Raw material extraction
	2 2. Low embodied carbon materials	The information included in the material Life cycle assessment at different stages of the development: A1-A3, A4, A5 (Cradle to practical completion)	- Material (type, properties quantity)		LCA	Life Cycle Assessment - A1-A3, A4, A5 - Embodied carbon emission
	2 3. Low-emitting VOC materials	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	N/A	N/A	N/A	No assessed

Code	Indicator | Sub-options	Potential BIM application	BIM information requirement	BIM workflow and interoperability	BIM tools	Assessment and output
	2.4. Materials and packaging that can easily be recycled	BIM can be used to obtain information regarding material EPD in compliance with the defined standards.	- Material (type, properties quantity)	see LCA	see LCA	Life Cycle Assessment - Embodied carbon emission
	2 5. Materials that disclose environmental impacts	The LCA evaluates the environmental impact of materials from their source to their practical use using local, manufacturer and third-party verified data.	- Material (type, properties quantity)			Life Cycle Assessment - Embodied carbon emission
	2.6. Materials that disclose potential health hazards	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	N/A	N/A	N/A	No assessed
	2.7. Rapidly renewable materials and recycled content materials	The information included in material Life cycle assessment beyond its end of life (Cradle-Cradle) at: D - Potential benefits and loads (recovery, reuse, and recycling potential)	- Material (type, properties quantity)	see LCA	see LCA	beyond Life Cycle Assessment - D (Cradle to Cradle)
	2 8. "Red list" of prohibited materials or ingredients that should not be used on the basis of their human and/or environmental impacts	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	N/A	N/A	N/A	No assessed
	2 9. Third-party certified wood-based materials and products	BIM tools for LCA also consist of database for material EPD which are third-party verified.	N/A	N/A	N/A	No assessed
DMA2.1	**Life cycle assessments**					
	1.1 Assessment	The BIM model can be used to perform life cycle analysis of the entire building or specific materials used materials. However, BIM software tools are available that can perform life cycle assessments of building materials using manufacturer-specific or third-party verified EPDs.	- Building envelope (wall, roof, floor, finish, etc.) - Material (type, property quantity) - Material properties (type, quantities) - EPDs	Open BIM workflow: - IFC - gbXML Closed BIM workflow: - Direct link BOQ (Spreadsheet)	LCA tools - SimPro - ATHENA Impact Estimator - TallyLCA - One Click LCA - EC3 BIM Viewers - Solibri - Desite -	Life Cycle Assessment
	1 2. Boundaries of the calculation	Life cycle assessment can be conducted at different boundary stages of the development project from production to completion, and also considered benefits beyond the material life such as recovery, recycling, and reuse.				Cradle-to-gate Cradle-to-practical completion/handover Use stage End-of-life stage Cradle-to-grave Whole life
	1 3. Standards/tools applied:	Multiple standards and assessment tools are used to conduct a comprehensive life cycle assessment.				LCA Standard - ISO 14025 - ISO 14040 - ISO 14044 - EN 15804 - ISO 21931
DMA2.2	**Embodied carbon**					
	1.1. Embodied carbon intensity for new construction projects:	BIM software for LCA can be utilised to determine the embodied carbon emission of material. Another effective method, particularly in the early stages, is using the Autodesk Insight Tech plug-in for Revit. This analytical tool assesses embodied carbon emissions of building materials.	- Building envelope (wall, roof, floor, finish, etc.) - Material (type, property quantity) - Material properties (type, quantities) - EPDs	Open BIM workflow: - IFC - gbXML Closed BIM workflow: - Direct link BOQ (Spreadsheet)	- SimPro - ATHENA Impact Estimator - TallyLCA - One Click LCA - EC3 - One Click LCA	Embodoed carbon - A1-A4, B2-B5, C2-C4 * (CO_2e/Kg)
	1 2. Building layers included in the scope	Embodied carbon emissions can be calculated for different building layers, finishes and MEP components.				Substructure Superstructure Finishes Fixed FF&E Building services (MEP) Furniture and appliances
			Energy Aspect			
DEN1	**Energy efficiency requirements**					
	1. Requirements for planning and design					
	1.1. Development and implementation of a commissioning plan	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	—	—	—	N/A
	1 2. Integrative design process	Collaboration and communication among different stakeholders during the initial project stages to optimise design is one of the key attributes of BIM.	—	—	—	- Preliminary analysis - Energy analysis - Lightning analysis

Code	Indicator | Sub-options	Potential BIM application	BIM information requirement	BIM workflow and interoperability	BIM tools	Assessment and output
	1.3. To exceed relevant energy codes or standards	BIM-based energy analysis software is used to analyse the total energy consumption of a facility according to various standard requirements.	—	—	—	- International Energy Conservation Code (2012) - DIN 18599 - ASHRAE 90.1 - ANSI/ASHRAE 140
	1.4. Maximum energy-use intensity post-occupancy	Energy analysis using simulation tools can provide results regarding the energy use intensity (EUI) of a facility, given the total annual energy consumption per area	—	—	—	Regulatory requirement on minimum EUI (kWh/m2/a)
	2. Common energy efficiency measure					
	2.1. Air conditioning	The potential energy load for heating and cooling can be analysed using BIM-BPS tools. Energy simulation tools contain different HVAC system options, each with its own efficiency ratings and specifications.	- Location (weather data) - Building orientation - Building envelope - Fenestration - Material thermal properties - Thermal zones - Systems (HVAC) - System efficiency - Operational Schedule	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- Energyplus - IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - HVAC systems (energy consumption) (kWh)
	2.2. Commissioning	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	2.3. Energy modeling	BIM model can be simulated to analyse the total energy consumption considering all mechanical and electrical systems and building properties.	- Location (weather data) - Building orientation - Building envelope - Fenestration - Material thermal properties - Thermal zones - Systems (HVAC, lightning) - Operational Schedule	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - EUI (MJ/m2/a)
	2.4. High-efficiency equipment and appliances	Energy simulation tools contains different HVAC and lighting system options, each with its own efficiency ratings and characteristics. users can select multiple alternatives in the analysis to identify the most energy-efficient solutions for the building design	- HVAC system - Lightning sytem - Technical properties (efficiency, service life, etc.)	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - HVAC and electrical systems type (energy saving)
	2.5. Lighting	Analysing the potential energy savings of natural daylight is possible with daylight simulation, considering the climate condition building's design, and glazing. Energy effiecient lightning units can be consider in design and simulation, to reduse the total energy consumption. Daylight dynamic control sensors can be considered in the energy analysis for efficient consumption from lighting	- Location (weather data) - Building orientation - Building envelope - Fenestration - Material properties (glazing) - System load (lightning) - Lightning type (LEDs CFLs) - Technical properties (efficiency)	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - Daylight (energy saving) Daylight analysis - Daylight factor - Glazing factor
	2.6. Occupant controls	Simulation tools consider control measures to optimise energy performance of building	- Control method (dayliht, occupancy, daylight and occupancy)	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - Control method (energy saving)
	2.7. Passive design	BIM can utilise the building design features, such as building orientation, window area, and thermal mass, to implement passive measures that will reduce mechanical heating, cooling, ventilation and lighting demand	- Location (weather data) - Building orientation - Material properties (u-value, thermal mass, thermal resistance) - Shading systems - Openings (windows, skylight)	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - Natural ventilation - Daylight - Efficient heating - Efficient cooling

Code	Indicator | Sub-options	Potential BIM application	BIM information requirement	BIM workflow and interoperability	BIM tools	Assessment and output
	2.8. Space heating	The potential energy load for heating and cooling can be analysed using BIN-BPS tools. Alternative measures, such as orientation and materials, can be considered to improve energy efficiency. In addition, Energy simulation tools contain different HVAC system options, each with its own efficiency ratings and specifications.	- Location (weather data) - Building orientation - Building envelope - Fenestration - Material thermal properties - Thermal zones - Systems (HVAC) - System efficiency - Operational Schedule	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - HVAC systems (energy consumption) (kWh)
	2.9. Ventilation	Model can be analysed to calculate the annual energy consumption of HVAC system. Users can select multiple alternatives in the analysis to identify the most energy-efficient solutions for the building design. Simulation tools can also be used to obtain information regarding natural ventilation potential and annual energy savings from natural ventilation by considering number of air openings.	- Location (weather data) - Building orientation - Building envelope - Fenestration - Thermal zones - Systems (HVAC) - System efficiency - Operational Schedule	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - HVAC systems (energy consumption) (kWh) - Energy saving fron natural ventilation (kWh)
	2.10. Water heating	The potential energy load for heating and cooling can be analysed using BIN-BPS tools. Alternative measures, such as orientation and materials, can be considered to improve energy efficiency. In addition, Energy simulation tools contain different HVAC system options, each with its own efficiency ratings and specifications.	- System type (Heating) - Technical properties (dimension, efficiency, service life, etc.)	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Design Builder - BIM Energy - Autodesk insight	Energy analysis - Domestic hot water (energy consumption)
DEN2.1	**On-site renewable energy and low carbon technologies**					
	1.1. Biofuels	N/A	N/A	N/A	N/A	N/A
	1.2. Geothermal	N/A	N/A	N/A	N/A	N/A
	1.3. Hydro	N/A	N/A	N/A	N/A	N/A
	1.4. Solar/photovoltaic	Solar energy potential can be simulated to analyse the energy production capacity of a building and evaluate the system payback period.	- Location (weather data) - Building/system Orientation - Space (area covered) - System properties (panel type, efficiency, dimension)	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- IES-Virtual Environment - Green Building studio - Autodesk insight	Solar analysis - PV energy generation
	1.5. Wind	GBS can also be used to analyse the annual energy production potential based on location weather data. However, there is a lack of flexibility in its use as the analysis does not consider the system properties and its efficiency.	- Location (weather data)	OpenBIM workflow - gbXML	Simulation tool - Green Building Studio	Wind analysis - Wind energy generation
DEN2.2	**Net zero carbon design and standards**					
	1. Net zero carbon design					
	1.1. Net zero carbon - construction	The BIM method for life cycle assessment can be used to assess the building's Life-cycle impacts of construction, including materials extraction, manufacturing, transport to the site, installation. Entity can define carbon-reducing options for net zero target based on the LCA result.	See LCA	See LCA	See LCA	Life Cycle Assessment - Caborn emissions A1-A3, A4, A5 (Cradle-to-practical completion)
	1.2. Net zero carbon - operational energy	BIM can support this requirement through energy modelling and simulation to optimise building energy performance. These include analysing different design scenarios for energy efficiency and integrating on-site renewable energy systems to minimise operational carbon emissions and support net-zero targets.	- Location (weather data) - Building orientation - Space properties (area, volume, occupancy) - Building envelope (wall, roof, floor window, etc.) - Properties (u-value, therma mass, thermal resistance) - Systems load (MEP) - Renewable enetgy system (type, efficiency, dimension)	OpenBIM workflow - gbXML	BIM authoring tool - Revit Simulation tool - Green Building Studio	Building Performance Simulation (Energy analysis) - Annual energy use (Building) - Annual energy generation (Onsite renewable)

Code	Indicator | Sub-options	Potential BIM application	BIM information requirement	BIM workflow and interoperability	BIM tools	Assessment and output
	2. net zero carbon code/standard					
	2.1. National/local green building council standard	Based on the LCA result regarding building embodied carbon, net zeor target can be set following different standards	—	—	—	- Green Building Council Finland - Sweden Green Building Council - UK Green Building Council - Canada Green Building Council - DGNB
	2.2. National/local government standard	Based on the LCA result regarding building embodied carbon, net zeor target can be set following different standards	—	—	—	National Carbon Offset Standard for Building - Australia
	2.3. International standard, specify	Based on the LCA result regarding building embodied carbon, net zeor target can be set following different standards	—	—	—	Zero Carbon Certification - International Living Future Institute (ILFI)
Water Aspect						
DWT1	**Water conservation strategy**					
	1. Requirements for planning and design					
	1.1. Development and implementation of a commissioning plan	N/A	N/A	N/A	N/A	N/A
	1.2. Integrative design for water conservation	One of BIM's attributes is to facilitate collaboration and communication among various stakeholders during the early stages of a project to optimise design.	—	—	—	Water use analysis
	1.3. Requirements for indoor water efficiency	BIM simulation tools can be used to estimate indoor water usage by considering multiple factors such as the number of people, occupied time, and water facilities in the building. The software also incorporated circularity measures to estimate water saving from the use of grey water reclamation, rainwater harvesting, and portable water source.	—	—	—	Water efficiency - Efficieent discharge - Grey water re-use for irregarion - Storm watre collection for irregation
	1.4. Requirements for outdoor water efficiency	Simulation tools considering the irrigation area, the presence of a pool, and other outdoor fixtures and equipment. and take into account of efficiency measures such as native vegetation that do not require irrigation.	—	—	—	Water efficiency - Timed sprinklers - Native vegitation - Grey water re-use for non portable - Storm watre collection non portable
	1.5. Requirements for process water efficiency	N/A	N/A	N/A	N/A	N/A
	1.6. Requirements for water supply	N/A	N/A	N/A	N/A	N/A
	1.7. Requirements for minimum water use intensity post-occupancy	N/A	N/A	N/A	N/A	Water use analysis - Water use intensity (liters/m2/yr)
	2. Common water efficiency measures include					
	2.1. Commissioning of water systems	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	2.2. Drip/smart irrigation	The use of timed sprinklers irrigation system is considered in water use analysis to minimise the outdoor water usage.	System can be represented in a digital model, but information cannot be exchanged with the simulation tool for assessment.	OpenBIM workflow - gbXML	- Green Building Studio	Water use analysis - Water saving from timed sprinlers (liters/year)
	2.3. Drought tolerant/low-water landscaping	Native vegetation landscaping is considered in water use analysis to take into account the water use reduction from less or no irrigation. Vegetations can be represented in the BIM model and defined properties.	Vegetation can be represented in a digital model but information cannot be exchanged with the simulation tool for assessment.	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- Green Building Studio - IES Virtual Environment	Building Parformance Simulation (Water use analysis) - Water saving from native vegetation (liters/year)

Code	Indicator | Sub-options	Potential BIM application	BIM information requirement	BIM workflow and interoperability	BIM tools	Assessment and output
	2.2. Drip/smart irrigation	The use of timed sprinklers irrigation system is considered in water use analysis to minimise the outdoor water usage.	System can be represented in a digital model, but information cannot be exchanged with the simulation tool for assessment.	OpenBIM workflow - gbXML	- Green Building Studio	Water use analysis - Water saving from timed sprinlers (liters/year)
	2.3. Drought tolerant/low-water landscaping	Native vegetation landscaping is considered in water use analysis to take into account the water use reduction from less or no irrigation. Vegetations can be represented in the BIM model and defined properties.	Vegetation can be represented in a digital model but information cannot be exchanged with the simulation tool for assessment.	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- Green Building Studio - IES Virtual Environment	Building Parformance Simulation (Water use analysis) - Water saving from native vegetation (liters/year)
	2.4. High-efficiency/dry fixtures	BIM model can integrate different object libraries for fixtures and systems with no water requirement.	- Systems (Plumbing) - Object libraries (toilet fixture) - Technical properties (flushing capacity)	OpenBIM workflow - IFC - gbXML Closed BIM worflow - Direct link	- Green Building Studio - IES Virtual Environment	Building Parformance Simulation (Water use analysis) - Water saving from native vegetation (liters/year)
	2.5. Leak detection system	N/A	N/A	N/A	N/A	Not assessed
	2.6. Occupant sensors	N/A	N/A	N/A	N/A	Not assessed
	2.7. On-site wastewater treatment	N/A	N/A	N/A	N/A	N/A
	2.8. Reuse of stormwater and greywater for non-potable applications	Measures to achieve Net-Zero water use, like greywater reclamation and Stormwater harvesting systems, can be included in a BIM workflow for water use analysis. These measures are taken into account during water use analysis to determine the possible water conservation.	Systems can be represented in a digital model, but information cannot be exchanged with the simulation tool for assessment.	OpenBIM workflow - gbXML	- Green Building Studio	Water use analysis - water net zoro saving from Greywater Reclamation and Rainwater Harvesting (liters/year)
			Water Aspect			
DWS1	**Waste management strategy**					
	1. Management and construction practices					
	1.1. Construction waste signage	N/A	N/A	N/A	N/A	N/A
	1.2. Diversion rate requirements	N/A	N/A	N/A	N/A	N/A
	1.3. Education of employees/contractors on waste management	N/A	N/A	N/A	N/A	N/A
	1.4. Incentives for contractors for recovering, reusing and recycling building materials	N/A	N/A	N/A	N/A	N/A
	1.5. Targets for waste stream recovery, reuse and recycling	N/A	N/A	N/A	N/A	N/A
	1.6. Waste management plans	N/A	N/A	N/A	N/A	N/A
	1.7. Waste separation facilities	Proper construction site utilisation by creating site layout and plan layout can help manage the space efficiently, enabling the creation of on-site waste separation facilities	2D plans	—	BIM tool: - Revit - ArchiCad	Site planning - Site layout
	2. On-site waste monitoring					
	2.1. Hazardous waste monitoring	4D phase planning an simulation	- Building envelop - Matrial - Material type -Material properties	- IFC	BIM authoring tool: - Revit - ArchiCAD	4D Simulation - Construction activity scedulling scheduling
	2.2. Non-hazardous waste monitoring					
			Stakeholder Engagement Aspect			
DSE1	**Health & Well-being**					
	1. Requirements for planning and design					
	1.1. Health Impact Assessment	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	1.2. Integrated planning process	One of BIM's attributes is to facilitate collaboration and communication among various stakeholders during the early stages of a project to optimise design	Model attribute depends on the analysis conducted.	Depends on the analysis and BIM tool utilised	Depend on the analysis	- lightning analysis - Rule-set model checking - Air-flow analysis - Thermal comfort
	2. Common occupant health and well-being measures					

Code	Indicator | Sub-options	Potential BIM application	BIM information requirement	BIM workflow and interoperability	BIM tools	Assessment and output
	2.1. Acoustic comfort	There is no software available that can analyse sound using BIM models enriched with acoustic data.(Sušnik et al, 2021). Attempts have been documented in the literature to incorporate acoustic analysis into design authoring software like Revit using geometric information and assigning absorption coefficients to indoor materials. Researchers utilise the Revit API or Dynamo to integrate solutions into Revit. (Nik-Bakht et al., 2021).	N/A	N/A	N/A	N/A
	2.2. Active design features	N/A	N/A	N/A	N/A	N/A
	2.3. Biophilic design	N/A	N/A	N/A	N/A	N/A
	2.4. Commissioning	N/A	N/A	N/A	N/A	N/A
	2.5. Daylight	Simulation tools are utilised for daylight analysis based on building design, location and orientation. Room glazing and daylight factors can be analysed to better optimise building design by considering shading and glare protection devices to avoid visual discomfort from direct solar gain.	- Location (weather data) - Building orientation - Space (room) - Building envelope (windows, skylights, and curtain walls) - Material properties - Shading and glare protection device	Open BIM workflow: - IFC - gbXML Closed BIM workflow: - Direct link	BIM authoring tool: - Revit - ArchiCAD Simulation tools: - Revit lighting analysis - IES-Virtual Environment - Green Building studio - Radiance - DaySim	Daylight analysis - Glazing factor - Daylight factor (DF) - Daylight Autonomy
	2.6. Ergonomic workplace	N/A	N/A	N/A	N/A	N/A
	2.7. Humidity	BIM tools use location weather data to obtain information regarding relative humidity. The humidity is a factor that influences the energy consumption for heating and cooling and thermal comfort.	- Location (weather data)	Open BIM workflow: - IFC - gbXML Closed BIM workflow: - Direct link	BIM authoring tool: - Revit - ArchiCAD Simulation tools: - Green Building Studio - IES-Virtual Environment	Thermal comfort analysis - Relative humidity (%) - Absolute hunidity (g.m-3)
	2 8. Illumination	BIM model can be used to render the illumination levels in space through daylighting as well as artificial light sources	- Location (weather data) - Building orientation - Space (room) - Building envelope (windows, skylights, and curtain walls) - Material properties (reflectivity, glazing) - Artificial lighting fixture	Open BIM workflow: - IFC - gbXML Closed BIM workflow: - Direct link - propritor format	BIM authoring tools: - Revit - ArchiCAD Simulation tools: - Revit lightning and rendering function - IES-Virtual Environment - Radiance - Sketch-up - DaySim - Sketch-up	Lightning analysis - Illuminance level (lux)
	2 9. Inclusive design	N/A	N/A	N/A	N/A	N/A
	2.10. Indoor air quality	The BIM model can be utilised for HVAC system analysis and accurately analyse the aur exchange rate from mechanical ventilation, and using CFD simulation for natural ventilation. VOC concentration within space can only be measured after completion.	- Location (climate data) - Building envelope (windows, skylight) - Space properties (area, volume) - Exterior openings (Window, Chimney, skylight) - HVAC systems	Open BIM workflow: - IFC - gbXML Closed BIM workflow: - Direct link CAD file: - DWG	BIM authoring tools: - Revit - ArchiCAD Simulation tools: - IES-Virtual Environment - Autodesk CFD - Revit - SimScale	Air flow analysis - Air exchange rate (m3/h)
	2.11. Natural ventilation	Different design strategies for natural ventilation can be integrated into the BIM model (such as air-driven and buoyancy-driven ventilation) by creating exterior openings to facilitate airflow within the building space.	- Building envelope (windows, skylight) - Space properties (area, volume) - Exterior openings (Window, Chimney, skylight)	Open BIM workflow: - IFC - gbXML Closed BIM workflow: - Direct link CAD file: - DWG	BIM authoring tools: - Revit - ArchiCADSimulation tools - IES-Virtual Environment - Autodesk CFD - Revit - SimScale	Air flow analysis - Air exchange rate (m3/h)
	2.12. Occupant controls	N/A	N/A	N/A	N/A	N/A
	2.13. Physical activity	N/A	N/A	N/A	N/A	N/A
	2.14. Thermal comfort	BIM simulation software IES-VE l can be used to simulate thermal comfort. The software contains a psychometric chart which presents a range of different attributes that influence the comfort matrices, such as the PMV index. The simulation tool also complies with the standard DIN EN 12831 standard code.	- Location (climate data) - Building envelope (windows, skylight) - Material properties (solar transmittance, emissivity, and conductivity) - Space properties (area, volume) - Exterior openings (Window, Chimney, skylight) - HVAC systems	Open BIM workflow: - IFC - gbXML Closed BIM workflow: - Revit direct link CAD file: - DWG	BIM authoring tool: - Revit - ArchiCAD Simulation tool: - IES-Virtual Environment - Autodesk CFD - Revit - SimScale	Thermal comfort analysis - PMV-Index
	2.15. Water quality	N/A	N/A	N/A	N/A	N/A

Code	Indicator | Sub-options	Potential BIM application	BIM information requirement	BIM workflow and interoperability	BIM tools	Assessment and output
DSE2.1	**On-site safety**					
	1.1. Availability of medical personnel	N/A	N/A	N/A	N/A	N/A
	1.2. Communicating safety information	Communication of safety information can be facilitated using BIM tools for construction management with the involvement of all teams. Such tools can be used for daily incident reports and defined safety checklists by safety personnel.	- Building envelope - Component properties	Open BIM workflow: - IFC	BIM authoring tool: - Revit - ArchiCAD 4D BIM modelling tools: - Synchro 4D - Navisworks	4D Simulation - Construction process schedulling
	1.3. Continuously improving safety performance	N/A	N/A	N/A	N/A	N/A
	1.4. Demonstrating safety leadership	N/A	N/A	N/A	N/A	N/A
	1.5. Entrenching safety practices	N/A	N/A	N/A	N/A	N/A
	1.6. Managing safety risks	4D-BIM sequence planning of construction activities can enhance safety planning and communication.	- Building envelope - Component properties	Open BIM workflow: - IFC	BIM authoring tool: - Revit - ArchiCAD 4D BIM modelling tools: - Synchro 4D - Navisworks	4D Simulation - Construction process schedulling
	1.7. On-site health and safety professional (coordinator)	N/A	N/A	N/A	N/A	N/A
	1.8. Personal Protective and Life Saving Equipment	N/A	N/A	N/A	N/A	N/A
	1.9. Promoting design for safety	Rule-based model checking can be employed during the design phase to ensure ensure that the developed building model meets all the safety requirements.	- Building envelope - Systems	IFC	BIM authoring tool: - Revit Model checking tool: - Solibri	Rule-based model checking - Checking for safety regulation
	1.10. Training curriculum	visualisation using BIM 4D simulation and Virtual Reality (VR)	see [1 9]	see [1.9]	see [1.9]	Visualisation
DSE2.2	**Safety metrics**					
	1.1. Injury rate	Construction management platforms such as Autodesk construction cloud can create a checklist template for onsite safety metrics monitoring. Safety issues can be reported and monitored by all project	No data exchange from the BIM model	-	Construction management cloud platform: - Autodesk construction cloud	Cloud-based collaboration - Daily insident report
	1.2. Fatalities					
	1.3. Near misses					
	1.4. Lost day rate					
	1.5. Severity rate					
DSE3.1	**Contractor ESG requirements**					
	1.1. Business ethics	BIM cannot support the assessment of this requirement. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	1.2. Child labor					
	1.3. Community engagement					
	1.4. Environmental process standards					
	1.5. Environmental product standards					
	1.6. Health and well-being					
	1.7. Human rights					
	1.8. Human health-based product standards					
	1.9. Occupational safety					
	1.10. Labor standards and working conditions					
DSE3.2	**Contractor monitoring methods**					
	1.1. Contractor ESG training	BIM cannot support the assessment of this measure. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	1.2. Contractors provide an update on environmental and social aspect during construction					
	1.3. External audits by third party					
	1.4. Internal audits					
	1.5. Weekly/monthly (on-site) meetings and/or ad hoc site visits					
DSE4	**Community engagement program**					
	1.1. Community health and well-being	BIM cannot support the assessment of this measure. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	1.2. Effective communication and process to address community concerns					
	1.3. Employment creation in local communities					
	1.4. Enhancement programs for public spaces					
	1.5. ESG education program					
	1.6. Research and network activities					
	1.7. Resilience, including assistance or support in case of disaster					
	1.8. Supporting charities and community groups					

Code	Indicator | Sub-options	Potential BIM application	BIM information requirement	BIM workflow and interoperability	BIM tools	Assessment and output
DSE5.1	**Community impact assessment**					
	1.1. Housing affordability	BIM cannot support the assessment of this measure. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	1.2. Impact on crime levels					
	1.3. Livability score					
	1.4. Local income generated					
	1.5. Local job creation					
	1.6. Local residents' well-being					
	1.7. Walkability score					
DSE5.2	**Community impact monitoring**					
	1.1. Analysis and interpretation of monitoring data	BIM cannot support the assessment of this measure. Manual evaluation is necessary.	N/A	N/A	N/A	N/A
	1.2. Development and implementation of a communication plan					
	1.3. Development and implementation of a community monitoring plan					
	1.4. Development and implementation of a risk mitigation plan					
	1.5. Identification of nuisance and/or disruption risks					
	1.6. Identification of stakeholders and impacted groups					
	1.7. Management practices to ensure accountability for performance goals and issues identified during community monitoring					

Appendix C Stakeholders BIM Workflow Analysis

Indicator Code	Indicator | Sub-options	BIM Tools and application
		Material Aspect
DMA1	**Materials selection requirements**	**Internal tool, DESITE BIM, CAALA, Madaster, Concula**
	1. Requirement for disclosure on environmental & health attribute of building matrial	
	1.1. Environmental Product Declarations	Product specific EPDs and Generic datasets are integrated into BIM workflow for LCA
	1.2. Health Product Declarations	
	2. Materia characteristics specifications	
	2.1. Locally extracted or recovered materials	Considered at the product stage of LCA or as part of EPDs
	2.2. Low embodied carbon materials	Embodied carbon of material is assessed
	2.3. Low-emitting VOC materials	
	2.4. Materials and packaging that can easily be recycled	
	2.5. Materials that disclose environmental impacts	
	2.6. Materials that disclose potential health hazards	
	2.7. Rapidly renewable materials and recycled content materials	Material detachability and recycled content can be evaluated through circularity assessment
	2.8. "Red list" of prohibited materials or ingredients that should not be used on the basis of their human and/or environmental impacts	
	2.9. Third-party certified wood-based materials and products	
DMA2.1	**Life cycle assessments**	LCA is conducted at all stages (while life cycle)
DMA2.2	**Embodied carbon**	Embodied carbon emmission is assessed at different stages (Cradle to practical completion and end of life)

Indicator Code	Indicator | Sub-options	BIM Tools and application	
		Energy Aspect	
		IES- Virtual Environment	**Solar Computer**
		Open BIM - IFC - gbXML Closed BIM - Direct link	Open BIM - IFC Closed BIM - Direct linkOpen BIM IFC, Direct link
DEN3	**Energy efficiency requirements**		
	1. Requirements for planning and design		
	1.1. Development and implementation of a commissioning plan	Not applicable	Not applicable
	1.2. Integrative design process	Facilitates integrative design by allowing the analysis of various building components and systems while considering location strategies and building physics for energy efficiency.	Facilitates integrative design by allowing the analysis of various building components and systems while considering location strategies and building physics for energy efficiency.
	1.3. To exceed relevant energy codes or standards	Provides the ability to model energy performance and assess compliance with energy codes and standards such as ASHRAE 90.1	Model energy performance and assess compliance with German Buidling Energy act (Gebäudeenergiegesetz, GEG) and DIN V 18600
	1.4. Maximum energy-use intensity post-occupancy	Can simulate and predict post-occupancy energy usage for building designs.	Can simulate the annual primaty energy demand of the building
	2. Common energy efficiency measure		
	2.1. Air conditioning	Support the modeling and optimisation of space cooling/air conditioning systems.	Calculate cooling load and allow for system modelling optimisation
	2.2. Commissioning	Not applicable	Not applicable
	2.3. Energy modeling	Conduct comprehensive energy modeling and analysis of building	Conduct energy analysis of the building
	2.4. High-efficiency equipment and appliances	Allows users to specify and assess the energy efficiency of building equipment.	Facilitates designing of system based on manufacturer data on consumption and efficiency

Indicator Code	Indicator | Sub-options	BIM Tools and application	
		IES- Virtual Environment	**Solar Computer**
	2.5. Lighting	Includes lighting system design and daylighting analysis.	Considers lighting control for energy modelling and energy-efficient fixture (LED)
	2.6. Occupant controls	Assess the impact of different occupant control strategies on energy use.	Assess the impact of daylight-dependent lighting contro
	2.7. Passive design	Supports passive design strategies for energy-efficient buildings such as natural daylight and ventilation	Supports passive design strategies for energy-efficient buildings such as passive cooling strategy
	2.8. Space heating	Support the modeling and optimisation of space heating systems.	Calculate heating load and allow for system modelling optimisation
	2.9. Ventilation	Supports modeling and analysis of natural and mchanical ventilation systems and calulate the volume	Calculate model ventilation system and determine the air volume flows
	2.10. Water heating	Assess domestic hot water consumption and heating system modelling.	Calculate water heating load and storage volume requirement
DEN2.1	**On-site renewable energy and low carbon technologies**	**IES- Virtual Environment**	**Solar Computer**
	1.1. Biofuels	Not applicable	Not applicable
	1.2. Geothermal	Not applicable	Not applicable
	1.3. Hydro	Not applicable	Not applicable
	1.4. Solar/photovoltaic	Can model, analyse, and optimise solar photovoltaic systems for energy production.	Can model and design solar/photovoltaic.
	1.5. Wind	Can evaluate wind turbine installations for energy generation.	Not applicable
Stakeholder Engagement Aspect			
Indicator Code	**Indicator | Sub-options**	**BIM Tools and application**	
		IES- Virtual Environment	**TRNSYS**
		Open BIM - IFC, gbXML Closed BIM - Direct link	Closed BIM Direct link (Sketchup pligin)
DSE1	**Health & Well-being**		
	1. Requirements for planning and design		
	1.1. Health Impact Assessment	Not applicable	Not applicable
	1.2. Integrated planning process	Supports integrative design processes, which can contribute to occupant well-being and energy-efficient designs.	Simulate HVAC and other systems that affect and thermal.
	2. Common occupant health and well-being measures		
	2.1. Acoustic comfort	Not applicable	Not applicable
	2.2. Active design features	Not applicable	Not applicable
	2.3. Biophilic design	Not applicable	Not applicable
	2.4. Commissioning	Not applicable	Not applicable
	2.5. Daylight	Facilitates daylighting analysis to assess different daylight measures	Facilitates daylighting analysis to assess different daylight measures
	2.6. Ergonomic workplace	Not applicable	Not applicable
	2.7. Humidity	Considers indoor humidity levels and their impact on comfort.	Can simulate humidity control systems and comfort impact
	2.8. Illumination	Provides illumination and lighting design analysis.	Assess illuminance levels
	2.9. Inclusive design	Not applicable	Not applicable
	2.10. Indoor air quality	Supports indoor air quality assessment and ventilation modeling.	Not applicable
	2.11. Natural ventilation	Uses zonal air flow model to analyses air movement in the building fron natural ventilation.	Not applicable
	2.12. Occupant controls	Can assess the impact of occupant control strategies on energy use	Can assess the impact of occupant control strategies on energy use
	2.13. Physical activity	Not applicable	Not applicable
	2.14. Thermal comfort	Using VistaPro, thermal comfort level can be calculated based on ASHRAE standard for PPM and PPD	Facilitate adaptive comfort calculation based on ASHRAE standard for PPM and PPD
	2.15. Water quality	Not applicable	Not applicable

Appendix D ESG indicator scoring

Indicators | Sub-Indicators	Total Weight according to GRESB scoring			Potential weight gained from analysis			Potential weight gained from interview		
	Indicator weight	Section weight	Sub-option weight	Indicator weight	Section weight	Sub-option weight	Indicator weight	Section weight	Sub-option weight
ESG strategy during development	4.00			0.00			0.00		
Site selection requirements	4.00			0.00			0.00		
Site design and development requirements	4.00			0.00			0.00		
Materials selection requirements	6.00			5.00			5.00		
1. Requirement for disclosure on environmental & health attribute of building matrial		1/3			1/6			1/6	
1.1. Environmental Product Declarations			1/2			1/2			1/2
1.2. Health Product Declarations			1/2			0			0
2. Materia characteristics specifications		2/3			2/3			2/3	
2.1. Locally extracted or recovered materials			1/4			1/4			1/4
2.2. Low embodied carbon materials			1/4			1/4			1/4
2.3. Low-emitting VOC materials			1/4			1/4			1/4
2.5. Materials and packaging that can easily be recycled			1/4			0			0
2.6. Materials that disclose environmental impacts			1/4			1/4			1/4
2.7. Materials that disclose potential health hazards			1/4			0			0
2.8. Rapidly renewable materials and recycled content materials			1/4			0			0
2.9. "Red list" of prohibited materials or ingredients that should not be used on the basis of their human and/or environmental impacts			1/4			0			0
2.10. Third-party certified wood-based materials and products			1/4			0			0
Life cycle assessments	Not scored			Not scored			Not scored		
Embodied carbon	Not scored			Not scored			Not scored		
Energy efficiency requirements	6.00			5.00			5.00		
1. Requirements for planning and design		1/6			1/6			1/6	
1.1. Development and implementation of a commissioning plan			1/2			0			0
1.2. Integrative design process			1/2			1/2			1/2
1.3. To exceed relevant energy codes or standards			1/2			1/2			1/2
1.4. Requirements for minimum energy use intensity post-occupancy			1/2			1/2			1/2
2. Common energy efficiency measure		2/3			2/3			2/3	
2.1. Air conditioning			1/4			1/4			1/4
2.2. Commissioning			1/4			0			0
2.3. Energy modeling			1/4			1/4			1/4
2.4. High-efficiency equipment and appliances			1/4			1/4			1/4
2.5. Lighting			1/4			1/4			1/4
2.6. Occupant controls			1/4			1/4			1/4
2.7. Passive design			1/4			1/4			1/4
2.8. Space heating			1/4			1/4			1/4
2.9. Ventilation			1/4			1/4			1/4
2.10. Water heating			1/4			1/4			1/4
On-site renewable energy and low carbon technologies	6.00			6.00			6.00		
1.1. Biofuels			1			0			0

Indicators | Sub-Indicators	Total Weight according to GRESB scoring			Potential weight gained from analysis			Potential weight gained from interview		
	Indicator weight	Section weight	Sub-option weight	Indicator weight	Section weight	Sub-option weight	Indicator weight	Section weight	Sub-option weight
1 2. Geothermal			1			0			0
1 3. Hydro			1			0			0
1.4. Solar/photovoltaic			1			1			1
1 5. Wind			1			1			1
Net zero carbon design and standards	**2.00**			2.00			0.00		
1. Net zero carbon		3/4			3/4			0	
1.1. Net zero carbon - construction			1			1			0
1.2. Net zero carbon - operational energy			1			1			0
2. net zero carbon code/standard		1/4			1/4			0	
2.1. National/local green building council standard			1			1			0
2.2. National/local government standard			1			1			0
2.3. International standard, specify			1			1			0
Water conservation strategy	**5.00**			3.75			0.00		
1. Requirements for planning and design		1/4			1/4			0	
1.1. Development and implementation of a commissioning plan			1/2			0			0
1.2. Integrative design for water conservation			1/2			1/2			0
1.3. Requirements for indoor water efficiency			1/2			1/2			0
1.4. Requirements for outdoor water efficiency			1/2			1/2			0
1.5. Requirements for process water efficiency			1/2			0			0
1.6. Requirements for water supply			1/2			0			0
1.7. Requirements for minimum water use intensity post-occupancy			1/2			1/2			0
2. Common water efficiency measures include		1/2			1/2			0	
2.1. Commissioning of water systems			1/4			1/4			0
2.2. Drip/smart irrigation			1/4			0			0
2.3. Drought tolerant/low-water landscaping			1/4			1/4			0
2.4. High-efficiency/dry fixtures			1/4			1/4			0
2.5. Leak detection system			1/4			0			0
2.6. Occupant sensors			1/4			0			0
2.7. On-site wastewater treatment			1/4			0			0
2.8. Reuse of stormwater and greywater for non-potable applications			1/4			1/4			0
Waste management strategy	**5.00**			2.50			0.00		
1. Management and construction practices		3/4			1/4			0	
1.1. Construction waste signage			1/3			0			0
1.2. Diversion rate requirements			1/3			0			0
1.3. Education of employees/contractors on waste management			1/3			0			0
1.4. Incentives for contractors for recovering, reusing and recycling building materials			1/3			0			0
1.5. Targets for waste stream recovery, reuse and recycling			1/3			0			0
1.6. Waste management plans			1/3			0			0
1.7. Waste separation facilities			1/3			1/3			0
2. On-site waste monitoring		1/4			1/4			0	0
2.1. Hazardous waste monitoring			1/2			1/4			0
2.2. Non-hazardous waste monitoring			1/2			1/4			0

Indicators | Sub-Indicators	Total Weight according to GRESB scoring			Potential weight gained from analysis			Potential weight gained from interview		
	Indicator weight	Section weight	Sub-option weight	Indicator weight	Section weight	Sub-option weight	Indicator weight	Section weight	Sub-option weight
Green building standard requirements	4.00			0.00			0.00		
Green building certifications	9.00			0.00			0.00		
Health & Well-being	2.00			1.25			1.25		
1. Requirements for planning and design		1/4			1/8			1/8	
1.1. Health Impact Assessment			1/2			0			0
1.2. Integrated planning process			1/2			1/2			1/2
2. Common occupant health and well-being measures		1/2			1/2			1/2	
2.1. Acoustic comfort			1/4			0			0
2.2. Active design features			1/4			0			0
2.3. Biophilic design			1/4			0			0
2.4. Commissioning			1/4			0			0
2.5. Daylight			1/4			1/4			1/4
2.6. Ergonomic workplace			1/4			0			0
2.7. Humidity			1/4			1/4			1/4
2.8. Illumination			1/4			1/4			1/4
2.9. Inclusive design			1/4			0			0
2.10. Indoor air quality			1/4			1/4			1/4
2.11. Natural ventilation			1/4			1/4			1/4
2.12. Occupant controls			1/4			1/4			1/4
2.13. Physical activity			1/4			0			0
2.14. Thermal comfort			1/4			1/4			1/4
2.15. Water quality			1/4			0			0
On-site safety	1.50			1.50			0.00		
1.1. Availability of medical personnel			1/4			0			0
1.2. Communicating safety information			1/4			1/4			0
1.3. Continuously improving safety performance			1/4			0			0
1.4. Demonstrating safety leadership			1/4			0			0
1.5. Entrenching safety practices			1/4			0			0
1.6. Managing safety risks			1/4			1/4			0
1.7. On-site health and safety professional (coordinator)			1/4			0			0
1.8. Personal Protective and Life Saving Equipment			1/4			0			0
1.9. Promoting design for safety			1/4			1/4			0
1.10. Training curriculum			1/4			0			0
Safety metrics	1.50			1.50			0.00		
1.1. Injury rate			1/4			1/4			0
1.2. Fatalities:			1/4			1/4			0
1.3. Near misses:			1/4			1/4			0
1.4. Lost day rate			1/4			1/4			0
1.5. Severity rate			1/4			1/4			0
Contractor ESG requirements	2.00			0.00			0.00		0
Contractor monitoring methods	2.00			0.00			0.00		0
Community engagement program	2.00			0.00			0.00		0
Community impact assessment	2.00			0.00			0.00		0
Community impact monitoring	2.00			0.00			0.00		0

Appendix D Interview Participants

Interview A

Organisation	PATRIZIA
Participant name	Konrad Hedemann
Position	Senior Associate ESG Manager
Location	München, Germany
Date conducted	15. August 2023
Interview time	40 min

Interview B

Organisation	LaSalle Investment Management
Participant name	YASMIN LE
Position	Sustainability Specialist
Location	London, England
Date conducted	08th September, 2023
Interview time	33 min

Interview C

Organisation	Vasakronan AB
Participant name	Claire Mirjolet
Position	Project Manager Sustainability
Location	Stockholm, Sweden
Date conducted	21th September, 2023
Interview time	34 min

Interview D

Organisation	ACCUMULATA Group GmbH
Participant name	Lena Vincentelli
Position	Sustainability Manager
Location	Munich, Germany
Date conducted	25th September 2023
Interview time	43 min

Interview E

Organisation	EPEA GmbH – Part of Drees & Sommer
Participant name	Pascal Keppler
Position	Head of Green Tech
Location	Stuttgart, Germany
Date conducted	26th July 2023
Interview time	30 min

Interview F

Organisation	LIST Eco GmbH & Co. KG
Participant name	Karina Große Lögten
Position	Sustainable Construction Analyst (Circularity expart)
Location	Hamburg, Germany
Date conducted	27th July 2023
Interview time	35 min

Interview G

Organisation	Averdung Ingenieure & Berater GmbH
Participant name	Christian Herbst
Position	Project Manager and Technical Planner
Location	Hamburg, Germany
Date conducted	29th August 2023
Interview time	29 min

Interview H

Organisation	ATP sustain GmbH
Participant name 1	Klara Meier
Participant name 2	Sophia Sauer
Position	Energy and Sustainability Consultants
Location	Munich, Germany
Date conducted	29th August 2023
Interview time	41 min

Appendix F Interview Questions Guide

ESG Analysts

1. What ESG standards or guidelines do you follow and report for development projects?
2. How do you benchmark and collect data regarding the embodied carbon emission of construction materials?
3. How do you collect data on the potential energy use of a development project?
4. How do you collect data on the potential water use of the building?
5. Do you have a net-zero carbon strategy for development projects in the construction and operation?
6. What major challenges do you face regarding the ESG assessment of a development project?
7. Do you find ESG standards and frameworks well-defined and clear, or are there areas where improvement is needed?
8. What innovative approaches or strategies have you implemented to overcome the ESG assessment challenges of a development project?

Building Planners and Consultants

1. Which sustainability guidelines have you utilised in development projects?
2. How would you describe your BIM workflow for LCA and embodied carbon assessment of building materials?
3. How would you describe your BIM workflow for energy analysis?
4. How would you describe your BIM workflow for Indoor environmental assessment?
5. Do you assess potential water use in a BIM workflow?
6. Do you define a BIM use case for waste management?
7. What are your primary challenges when integrating BIM and sustainability evaluation?
8. How do you aggregate analytical results from different software for documentation?

Erklärung

Ich versichere an Eides Statt,

1. dass ich die Arbeit selbständig und ohne fremde Hilfe angefertigt habe,
2. dass ich alle Abschnitte, die wörtlich oder annähernd wörtlich aus einer Veröffentlichung entnommen sind, als solche kenntlich gemacht habe,
3. dass die Arbeit noch nicht veröffentlicht und auch noch keiner anderen Prüfungsbehörde vorgelegt worden ist,
4. dass ich keine Kopien von Softwareprogrammen des Lehrstuhls angefertigt habe und alle Programme, die mir zur Verfügung gestellt wurden, entweder zurückgegeben oder gelöscht habe.

Ich erkläre mich damit einverstanden, dass der Lehrstuhl für Bauprozessmanagement und Immobilienentwicklung die von mir hiermit vorgelegte Master's Thesis zur weiteren Bearbeitung bzw. Veröffentlichung verwenden kann.

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