



**Co-funded by the
European Union**

ERASMUS MUNDUS JOINT MASTER DEGREE

**MASTER DEGREE IN SUSTAINABLE DESIGN, CONSTRUCTION
AND MANAGEMENT OF THE BUILT ENVIRONMENT**

MBUILD

BIM-Based LCA Framework: Improving LCA Automation and Accuracy in Green Building Assessment in Germany

ARTYOM LUKYANENKO

Supervision: Christian Baier, THM; Katja Herbst, woscim

Co-supervision: Kerstin Lenz, THM, Anna Zakrisson, woscim

Gießen, September 2025



**Co-funded by the
European Union**

ERASMUS MUNDUS JOINT MASTER DEGREE

**MASTER DEGREE IN SUSTAINABLE DESIGN, CONSTRUCTION
AND MANAGEMENT OF THE BUILT ENVIRONMENT**

MBUILD

BIM-Based LCA Framework: Improving LCA Automation and Accuracy in Green Building Assessments in Germany

LUKYANENKO ARTYOM

Supervision: Christian Baier, THM; Katja Herbst, woscim

Co-supervision: Kerstin Lenz, THM, Anna Zakrisson, woscim

Gießen, September 2025



MBUILD

ERASMUS MUNDUS JOINT MASTER IN SUSTAINABLE DESIGN, CONSTRUCTION AND MANAGEMENT OF THE BUILT ENVIRONMENT

✉ mbuild@fe.up.pt

🌐 www.mbuild.eu

Edited by



FACULDADE DE ENGENHARIA
DA UNIVERSIDADE DO PORTO

Rua Dr. Roberto Frias
4200-465 Porto
PORTUGAL

☎ +351-22-508-1400

✉ feup@fe.up.pt

🌐 www.fe.up.pt



TECHNISCHE HOCHSCHULE
MITTELHESSEN

Wiesenstraße 14
D – 35390 Gießen
DEUTSCHLAND

☎ +49-641-309-0

✉ info@thm.de

🌐 www.thm.de



UNIVERSIDAD DE CANTABRIA

Avda. De los Castros, s/n
39005 Santander
ESPAÑA

☎ +34-942-20-10-18

✉

informacion.general@unican.es

🌐 <https://web.unican.es>

Partial reproductions of this document will be authorized provided that the Author is mentioned, and reference is made to MBUILD ERASMUS MUNDUS JOINT MASTER IN SUSTAINABLE DESIGN, CONSTRUCTION AND MANAGEMENT OF THE BUILT ENVIRONMENT, Portugal, Germany, Spain, 2024.

The opinions and information included in this document represent only the views of the Author and the Publisher cannot accept any legal or other responsibility in relation to errors or omissions that may exist.

This document was produced from an electronic version provided by the respective Author.

You will when you believe

ACKNOWLEDGEMENTS

To begin with, I would like to thank the entire MBUILD programme, its coordinators Jorge Moreira da Costa (UP), Christian Baier (THM) and Elena Blanco (UC), and all the staff and professors involved in this Master's programme. MBUILD was a pivotal point in my life, opening my horizons and enabling an enthusiastic young graduate to explore the role of sustainability and contribute to a better future for our planet. This programme was a unique experience that reinforced my purpose in life: to share knowledge, continuously improve myself and build a better living environment for society.

This journey would not have been possible without my dearest colleagues: the 16 smartest and most ambitious people brought together from all over the world. It was my honour to learn with and from them, generate brilliant ideas and solutions, and create amazing memories, to which I am forever grateful. I would particularly like to thank Josef, Paola and Natalia, who became my close friends and filled my heart with love, support and gratitude when I needed it.

I am also deeply grateful to my family members in Kazakhstan, Russia, the USA and Germany, especially my mother Yelena, my father Andrei and my sister Yelena, for their unwavering support throughout my studies. They always taught me to be strong and see things through - exactly the skills that brought me to this programme and will continue to help me reach the unreachable. My heart is always with them and, although we are thousands of kilometres apart, I always feel their love and care.

Lastly, I would like to express my heartfelt thanks to my wonderful friends in Kazakhstan, especially my best friend Aisha, for their unconditional love, support and encouragement. It is a blessing to have such friends who have helped me learn the best parts of myself and celebrated the highs and lows of my life, no matter what. For many years, we have been growing together, sharing our love & support, and carrying our friendship through countries and continents, to which I remain truly grateful.

Thank you!

Большое спасибо!

Көп рахмет!

ABSTRACT

As sustainable development becomes one of the primary focuses in construction sector, the demand for a robust environmental performance evaluation through the Life Cycle Assessment (LCA) is increasing, particularly in the context of Green Building Ranking Systems (GBRS). Building Information Modelling (BIM) is recognized as a useful methodology to support the LCA integration at different project stages to overcome the fragmented and data-intensive nature of the sector and provide reliable project information, combining both geometrical and semantic data in a structured and consistent form. However, current stage of BIM-LCA integration is often characterized with insufficient level of information in a BIM model, noticeable data losses during the data transfer, and lack of interoperability between the BIM and LCA tools. This study analyses the BIM-to-LCA data transfer using an IFC-based data exchange approach, and develops a comprehensive BIM-model export ruleset based on a real-world residential project located in Germany, which is currently at the construction stage.

The study begins with the transfer of a considered construction project to a BIM-based methodology, developing a BIM model in Revit based on architectural 2D drawings and Building Element Catalogue (BTK), with particular attention to semantic consistency, quantity take-offs, and alignment with DGNB and QNG requirements for LCA. The model is then exported through 3 defined version of IFC (IFC 2x3 CV 2.0, IFC 4.0 RV, and IFC 4.0 DTV) and imported to the CircularLCA software to evaluate the data import quality and identify the gaps across different types of model information. Based on these findings, a custom ruleset is developed with the goal of preventing the observed data transfer limitations, especially in multi-layered elements, enriching the BIM model with supportive data, and improving environmental data mapping in the LCA software.

The application of the ruleset showed the efficiency of structured and informed data transfer strategy in a BIM-LCA workflow by eliminating the data losses for considered building elements and providing consistent data for further environmental assessment in the LCA software. However, the methodology did not significantly improve the automated data mapping in the LCA tool, relying mostly on manual labelling effort. In addition, several limitations of the BIM-IFC-LCA workflow were identified, which are related to limited support of multi-layered elements and interoperability between the applied technologies.

Keywords: Building Information Modelling, Life Cycle Assessment, semantic data transfer, IFC, environmental data mapping, Green Building Ranking System

GENERAL INDEX

ACKNOWLEDGEMENTS	i
ABSTRACT	ii
INDEX OF FIGURES	vii
INDEX OF TABLES	x
SYMBOLS, ACRONYMS & ABBREVIATIONS	xii
1. INTRODUCTION	1
1.1.THE CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT	1
1.2.THE ROLE OF CONSTRUCTION INDUSTRY IN SUSTAINABLE DEVELOPMENT	3
1.3.SUSTAINABLE CONSTRUCTION PRACTICES	4
1.4.CONTEXT	6
1.5.RESEARCH PROBLEM & OBJECTIVES	7
2. BACKGROUND.....	9
2.1.BIM.....	9
2.1.1.WHAT IS BIM?.....	9
2.1.2.APPLICATION AND SCOPE	9
2.1.3.KEY ENABLING TECHNOLOGIES	12
2.1.4.DATA EXCHANGE	13
2.2.LCA	19
2.2.1.WHAT IS LCA?	19
2.2.2.LCA METHODOLOGY	19
2.2.3.ENVIRONMENTAL IMPACTS.....	22
2.2.4.DATA SOURCE	23
2.2.5.ASSESSMENT TOOLS.....	25
2.2.6.CIRCULARLCA	26
2.3.GREEN BUILDING RANKING SYSTEMS.....	28
2.3.1.WHAT IS GBRS.....	28
2.3.2.DGNB	29

2.3.3.QNG	30
2.3.4.LCA WITHIN GBRS	30
3. STATE OF THE ART	34
3.1.LITERATURE REVIEW.....	34
3.2.GAPS AND LIMITATIONS.....	36
4. METHODOLOGY	37
4.1.SCOPE OF STUDY	37
4.2.APPROACH OBJECTIVES.....	37
4.3.METHODOLOGY WORKFLOW.....	38
4.3.1.DEVELOPMENT OF A BIM MODEL	38
4.3.2.IFC MODEL SETUP AND EXPORT	39
4.3.3.IFC MODEL CHECKING	40
4.3.4.IFC MODEL IMPORT TO THE CIRCULARLCA	40
4.3.5.PRELIMINARY DATA IMPORT QUALITY EVALUATION	41
4.3.6.BIM MODEL EXPORT RULESET DEVELOPMENT	41
4.3.7.EXPORT RULESET APPLICATION	42
4.3.8.FINAL DATA QUALITY IMPORT EVALUATION & ENVIRONMENTAL DATA MAPPING.....	43
5. CASE STUDY.....	44
5.1.CASE OVERVIEW.....	44
5.1.1.PROJECT DESCRIPTION	44
5.1.2.BASIC DIMENSIONS AND USE	45
5.1.3.SUSTAINABLE PRACTICES.....	47
5.2.METHODOLOGY APPLICATION	48
5.2.1.DEVELOPMENT OF A BIM MODEL	48
5.2.2.IFC MODEL SETUP AND EXPORT	53
5.2.3.MODEL IMPORT TO SOLIBRI SOFTWARE	55
5.2.4.MODEL IMPORT TO CIRCULARLCA SOFTWARE.....	56
5.2.5.PRELIMINARY DATA EVALUATION AND MAPPING.....	58
5.2.6.BIM-MODEL EXPORT RULESET DEFINITION	67
5.2.7.RULESET APPLICATION.....	73
5.2.8.FINAL DATA IMPORT QUALITY EVALUATION	74

5.2.9. ENVIRONMENTAL DATA MAPPING.....	74
5.2.10. LIMITATIONS OF THE METHODOLOGY APPLICATION	75
6. RESULTS AND DISCUSSION	76
6.1. WORKFLOW SHIFT TO BIM-BASED MODELLING AND ANALYSIS	76
6.1.1. ADVANTAGES OF BIM MODELLING FOR LCA ANALYSIS	77
6.1.2. CHALLENGES OF BIM MODELLING DEVELOPMENT	77
6.2. PRELIMINARY IFC IMPORT QUALITY EVALUATION RESULTS	78
6.2.1. COMPARISON OF DATA IMPORT THROUGH DIFFERENT IFC SCHEMES	78
6.2.2. LIMITATIONS OF THE REVIT-IFC-CIRCULARLCA DATA TRANSFER	79
6.3. BIM MODEL EXPORT RULESET	81
6.3.1. EXPORT RULESET DEVELOPMENT	81
6.3.2. IMPACT OF THE RULESET TO THE DATA IMPORT QUALITY.....	81
6.4. ENVIRONMENTAL DATA MAPPING	82
7. CONCLUSION	83
8. REFERENCES	85
9. ANNEXES	92

INDEX OF FIGURES

Figure 1. Current state of the planetary boundaries. Source: Richardson, K., Bendtsen, J., Nogués-Bravo, D., Steffen, W., Lucht, W., Donges, J. F., Drüke, M., von Bloh, W., Feulner, G., Gerten, D., Porkka, M., & Virkki, V. (2023). Earth beyond six of nine planetary boundaries. <i>Science Advances</i> , 9(37). https://doi.org/10.1126/sciadv.adh2458	2
Figure 2. Sustainable Development Goals. Source: UNDP. (n.d.). Sustainable Development Goals. Retrieved June 14, 2025, from https://www.undp.org/sustainable-development-goals	2
Figure 3. EU Construction Sector Key Facts and Figures. Source: European Commission. (2024). CONSTRUCTION INDUSTRIAL ECOSYSTEM. https://doi.org/10.2873/474024	3
Figure 4. Mind map summary of the dissertation context.....	7
Figure 5. BIM application across a project life-cycles. Source: BuildLACCD. (2019). LACCD Building Information Modeling Standards.	10
Figure 6. The BIM-application scope for the Sustainability Integration. Source: Akbari, S., Sheikhhoshkar, M., Pour Rahimian, F., el Haouzi, H. B., Najafi, M., & Talebi, S. (2024). Sustainability and building information modelling: Integration, research gaps, and future directions. <i>Automation in Construction</i> , 163, 105420. https://doi.org/10.1016/J.AUTCON.2024.105420	11
Figure 7. BIM application levels. Source: Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers (3rd ed.).....	12
Figure 8. BIM wall element. Source: Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers (3rd ed.).....	13
Figure 9. IFC architecture schema. Source: Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers (3rd ed.).....	15
Figure 10. IFC structure of a wall. Source: Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers (3rd ed.).....	16
Figure 11. Phases of LCA framework. Source: ISO 14040:2006 - Environmental management — Life cycle assessment — Principles and framework. (2006). https://www.iso.org/standard/37456.html	20
Figure 12. LCA stages of the construction project. Source: DIN EN 15978:2012-10, Nachhaltigkeit von Bauwerken_ - Bewertung der umweltbezogenen Qualität von Gebäuden_ - Berechnungsmethode; Deutsche Fassung EN_15978:2011. (2012). https://doi.org/10.31030/1917049	21

Figure 13. Example of CircularLCA product for outside precast concrete wall. Source: Concular. (2025). CircularLCA – Ökobilanzierung und Gebäuderessourcenpass - CircularLCA. https://circularlca.de/	28
Figure 14. DGNB certification versins and typologies. Source: DGNB. (2025). About the DGNB System . https://www.dgnb.de/en/certification/important-facts-about-dgnb-certification/about-the-dgnb-system	29
Figure 15. Cost groups according to DIN 276. Source: DIN 276. (2018). DIN 276:2018-12, Kosten im Bauwesen. https://doi.org/10.31030/2873248	31
Figure 16.Scope of the study	37
Figure 17. Study methodology workflow process	38
Figure 18. BIM model development procedure	39
Figure 19. IFC model setup and export procedure	39
Figure 20. IFC model check procedure	40
Figure 21. IFC Model import procedure	40
Figure 22. Preliminary software application procedure	41
Figure 23. Export ruleset application procedure	43
Figure 24. Parkblick rendered model. Source: woscim. (2025). woscim . https://www.woscim.de/	44
Figure 25. 1st Floor Plan. Source: woscim. (2025). woscim . https://www.woscim.de/	45
Figure 26. Example of external walls description in Building Element Catalogue. Source: woscim. (2025). woscim . https://www.woscim.de/	48
Figure 27. Example of project building elements in Revit.....	50
Figure 28. Example of material assembly of an external wall	50
Figure 29. CAD file export feature in Revit	51
Figure 30. 1st floor modelling process based on imported CAD drawings	51
Figure 31. BIM model 3D view	52
Figure 32. BIM model floor plan view	52
Figure 33. BIM model elevation view	53
Figure 34. IFC export through Concular export setup	55
Figure 35. Property sets exported through Concular export setup.....	55
Figure 36. Solibri semantic data check rules	56
Figure 37. Solibri wall base quantities check rule.....	56
Figure 38. CircularLCA project creation	57
Figure 39. CircularLCA model import	57
Figure 40. Model view in CircularLCA.....	58
Figure 42. BIM model walls to floors intersection root cause	61

Figure 43. BIM model walls to walls intersection root cause	61
Figure 45. BIM walls separation root cause example	65
Figure 46. CircularLCA Ruleset editor window	67
Figure 47. Solibri Ruleset overview	73
Figure 48. Solibri model checking results	74

INDEX OF TABLES

Table 1. Sustainability aspects and practices in construction (Carvajal-Arango et al., 2019)	4
Table 2. Key enabling digital technologies in sustainable construction (Askar et al., 2025).....	5
Table 3. IFC versions comparison (buildingSMART, 2025).....	17
Table 4. BIM Level of Details (Autodesk, 2025)	18
Table 5. Level of Information rules (Solibri, 2023)	18
Table 6. LCA environmental impact categories (EN 15804:2012+A2:2019, 2019)	23
Table 7. LCA databases across EU	25
Table 8 . DGNB Ranking System (DGNB, 2025).....	30
Table 9. LCA analysis comparison in DGNB and QNG (DGNB, 2025; QNG, 2025)	32
Table 10. Parkblick project description (woscim, 2025)	46
Table 11. Parkblick sustainability measures.....	47
Table 12. DGNB and QNG LCA analysis element scope requirements (DGNB, 2025; QNG, 2025)	49
Table 13. Types of data interpreted by CircularLCA software. Souce: Concular.....	54
Table 14. Data import quality evaluation matrix example for wall elements.....	60
Table 15. IFC 2x3 CV preliminary data quality import evaluation results	60
Table 16. IFC 4 RV preliminary data import quality evaluation results.....	64
Table 17. IFC 4.0 DTV preliminary data quality evaluation results.....	66
Table 18. BIM model export ruleset structure	68
Table 19. IFC versions comparison for BIM model export to CircularLCA.....	69
Table 20. Modelling example recommendations for a wall element	71
Table 21. Custom Property set Pset_CircularLCA	71
Table 22. Elements' properties mapping according to the IFC 2x3 CV scheme (buildingSMART, 2025). 72	
Table 23. IFC 2x3 CV final data import quality evaluation for wall elements.....	74
Table 24. Auto-mapping results for the model excluding (left) and including (right) custom property set	75
Table 25. Identity data import results comparison.....	78
Table 26. Base quantities data import results comparison	78
Table 27. Common properties data import results comparison	79
Table 28. Material information data quality results.....	79
Table 29. Revit-IFC-CircularLCA workflow limitations	80

SYMBOLS, ACRONYMS AND ABBREVIATIONS

EGD - European Green Deal

EU - European Union

EN – European Standard

ISO – International Organization for Standardization

RIBA – The Royal Institute of British Architects

SDGs – Sustainable Development Goals

BIM – Building Information Modelling

CDE – Common Data Environment

IFC - Industry Foundation Classes

LOD – Level of Development

MEP - Mechanical, Electrical and Plumbing

EPD - Environmental Product Declaration

LCA – Life Cycle Assessment

LCC – Life Cycle Cost

LCI – Life Cycle Inventory

LCIA – Life Cycle Impact Assessment

WBLCA – Whole Building Life Cycle Assessment

DGNB – German Sustainable Building Council

QNG - Qualitätssiegel Nachhaltiges Gebäude (Sustainable Building Quality Seal)

GEG – German Building Energy Act

cm – Centimetres

kg – Kilograms

Gt - Gigatons

m - Meters

m² - Square Meters

MJ - Megajoule

un – Unit

AP – Acidification Potential

ADPE – Abiotic Depletion Potential (ADP-Elements) for Non-Fossil Resources

ADPF - Abiotic Depletion Potential (ADP-Fossil Fuels) for Fossil Resources

CFC - Chlorofluorocarbon

CO² – Carbon Dioxide

C₂H₄ – Ethene

EP – Eutrophication Potential

FOLA – Formation of Ozone of Lower Atmosphere

GWP – Global Potential Warming

GHG – Greenhouse Gas

POCP – Photochemical Ozone Creation Potential

ODP – Ozone Depletion

SO² - Sulphur Dioxide

BOQ - Bill of Quantities

BTK – Building Element Catalogue

ID – Identity Data

BQ- Base Quantities

CP- Common Properties

MI – Material Information

CV- Coordination View

RV - Reference View

DTV- Design Transfer View

GFA – Gross Floor Area

Pset – Property Cet

1

INTRODUCTION

1.1. THE CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Climate change is considered as an evolving and multifaceted challenge of the 21st century. This phenomena involves the long-term changes in the climate conditions, such as average temperature and weather conditions. The primary cause of the climate change is the anthropogenic processes of humanity, including industrial activities, fossil fuel exploitation, and land use, which in turn produces and increases the concentration of greenhouse gases (GHG) in the atmosphere (Fawzy et al., 2020). The later leads to the climate system alterations that are observed nowadays, such as average temperature increase, extreme weather events, rise of the sea level, and deterioration of biodiversity. The 2020 Lancet Countdown report states that climate change represents the threat not only to the environment, but also to the health, social and economic factors of the globe (Watts et al., 2021).

Within the scientific society, the climate change is also discussed as a part of a broader definition of planetary boundaries. This concept refers to the group of environmental limits of the planet that define the acceptable living conditions for the human population. The research by Richardson et al. (2023) reports the exceedance of a climate change as well as 5 other planetary boundaries out of 9, including those related to land system and freshwater. Figure 1 illustrates the defined planetary boundaries and the extent of their transgression. Considering the current state of the boundaries and the high risk of climate change, the study emphasizes the drastic effect of the human activity on the planetary conditions and the resilience of the environment.

To respond to the escalating risks related to climate change and exceeded planetary boundaries, the global and international communities have been working on the strategies for sustainable transformation. One of the milestones towards sustainability is the Paris Agreement, introduced by the United Nations Framework Convention on Climate Change and signed by the 195 parties (UN Climate Change, n.d.). The Agreement encourages the participating countries to maintain the average temperature rise below 1.5°C and achieve the carbon neutrality by 2050. For this purpose, the members are expected to implement Nationally Determined Contributions (NDCs) to tackle the climate crisis on a national level.

Another strategy towards global sustainability is 2030 Agenda for Sustainable Development by the UN, which established 17 Sustainable Development Goals (SDGs). The SDGs cover the wide range of areas that are crucial to achieve environmental, social and economic sustainability. Figure 2 provides the name of each goal defined by the UN. The studies suggest that the SDGs are able to expedite the progress towards the sustainable and zero-carbon environment, however, they require the complex shift in all the social domains (Sachs et al., 2019).

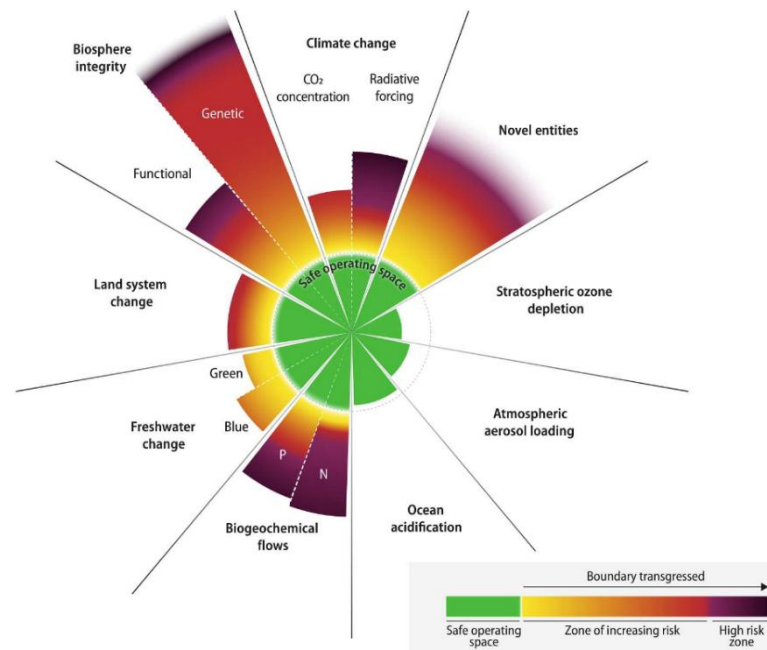


Figure 1. Current state of the planetary boundaries. Source: Richardson, K., Bendtsen, J., Nogués-Bravo, D., Steffen, W., Lucht, W., Donges, J. F., Drüke, M., von Bloh, W., Feulner, G., Gerten, D., Porkka, M., & Virkki, V. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, 9(37). <https://doi.org/10.1126/sciadv.adh2458>



Figure 2. Sustainable Development Goals. Source: UNDP. (n.d.). Sustainable Development Goals. Retrieved June 14, 2025, from <https://www.undp.org/sustainable-development-goals>

As a leading actor in sustainable transitioning, the European Union has established a carbon neutrality roadmap as a part of the European Green Deal (EGD). The EGD is a complex framework that is aimed to transform the EU economic model to achieve net-zero targets. Therefore, it tackles multiple sectors of

EU economy, institutions and policies, such as energy, agriculture, mobility, and circular economy (European Commission, n.d.). Bongardt & Torres (2022) state that EGD is a crucial model for the EU to integrate the environmental awareness not only on political, but also on economic and social level. Thus, EU will be able to establish a long-term, resilient and inclusive progress.

1.2. THE ROLE OF CONSTRUCTION INDUSTRY IN SUSTAINABLE DEVELOPMENT

Construction sector is a crucial area for enhancing life-quality and meeting the social and sustainable requirements. Meanwhile, it is also the most resource-intensive sector globally, which utilizes around 40% of raw materials and produces approximately 50% of GHGs (Bonoli et al., 2021; Lima et al., 2021). Therefore, the research and company experts in architecture, engineering and construction sector (AEC) has recognized the importance of environmental awareness and sustainable shift in the industry, which can improve the efficiency and reduce the environmental effect (Carvajal-Arango et al., 2019).

In case of European Union, construction sector is the 2nd major industry in EU economic system, which contributes up to 9.6% economic value. The European Commission (2024) report also indicates that 37.5% of waste and 36% of energy related GHGs in EU are produced by construction sector. Thus, the Commission highlights the role of the sector in the EU's economic and sustainable development. As a

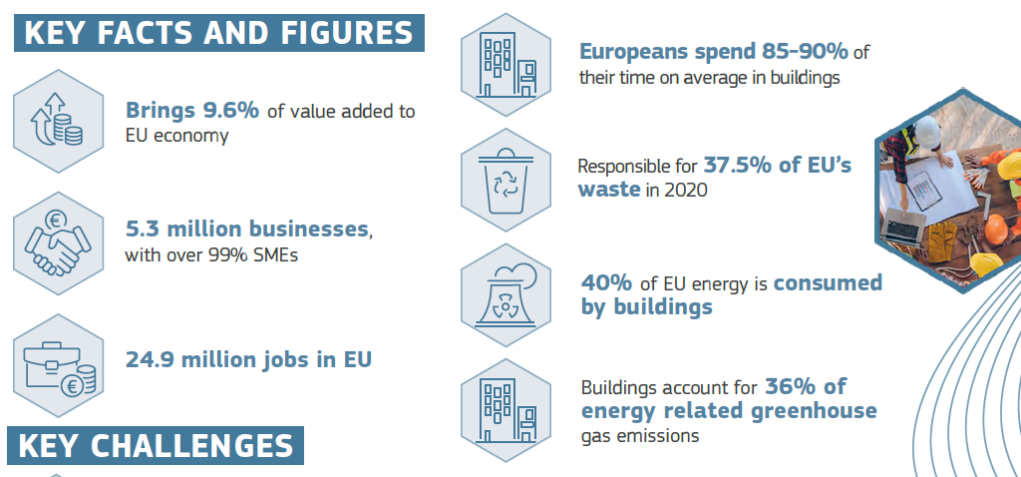


Figure 3. EU Construction Sector Key Facts and Figures. Source: European Commission. (2024). CONSTRUCTION INDUSTRIAL ECOSYSTEM. <https://doi.org/10.2873/474024>

part of the Green Deal and Industrial Strategy, the European Commission (2023) developed a Transition Pathway for Construction strategic framework, which refers to the sustainable, digital and resilient transformation of the industry.

Although construction industry plays a crucial role in the EU economy and life-quality, it faces significant challenges that hinder its further development. The Commission identify the primary issues as lack of labour force, insufficient productivity, and slow rate of innovation. Considering the industry's high fragmentation and SMEs domination, those challenges limit the sector's ability to modernize and contribute to the green and sustainable targets. By faster adoption of circular, digital and industrial practices, the sector will be able to optimize the material use, environmental performance and resilience of the built environment. Together with further digitalization, cross-collaboration and strong financial support, it will be achievable to align the construction industry with the EU's and global sustainability goals (European Commission, 2023).

1.3. SUSTAINABLE CONSTRUCTION PRACTICES

Modern research and development in construction show multiple practices and technologies in construction, which can potentially contribute to the industry's sustainable shift. The study of Carvajal-Arango et al. (2019) defines the dimensions of environmental, economic and social aspects of sustainability, which are provided in Table 1. According to this definition, the environmental part emphasizes the optimization and reduction of resource usage, such as materials, water, and energy. Meanwhile, the social aspect focuses on the improvement of life-quality of society, including the workers. Finally, the maximization of budgeting through operation and maintenance expenditures are considered as a priority for the economic factor. The application and combination of different practices contribute to a more sustainable building, which is advantageous for both environment and society. Those practices can be applied at the different project phases, such as planning, design, construction and maintenance, and it is crucial to thoroughly consider the challenges at each phase to achieve sustainability goals (Vijayan et al., 2023).

Table 1. Sustainability aspects and practices in construction (Carvajal-Arango et al., 2019)

Environmental	Economic	Social
• Energy consumption • Water consumption • Waste Management • Atmospheric emissions • Noise emissions • Material consumption • Affection to soil quality • Affection to fauna and flora • Embodied energy • Use of recycled materials • Visual impact	• Construction costs • Quality • Construction time • Productivity • Value creation • Uncertainties and risks	• Safety and health • Working conditions • Respect for the local community • Influence on the local economy • Community disturbance • Relationship and communication improvement • Enhance employee skills • Diversity in teamwork and equal employment opportunities • Employee retention • Project declaration of general interest • Public participation and control on the project.

The analysis of literature in sustainable construction also defined 2 primary groups of sustainable methodologies, policy-oriented and product-oriented. The systematic approaches towards more sustainable construction projects in general shapes the policy-oriented dimension, which include such concepts as circular economy or recycling policy. Those help to guide the industry in a wider scale, providing overall methodologies and approaches to develop a sustainable industry. Product-oriented frameworks, in turn, focuses on specific tools and products, which can contribute to a better efficiency

and performance of a project. These tools allow to facilitate product development and analysis and reduce the environmental impacts (Bonoli et al., 2021).

One of the major focuses in product-oriented solutions is the Life Cycle Thinking and Life Cycle Analysis (LCA) in product development and evaluation (Bonoli et al., 2021). The advantage of a life-cycle approach is the comprehensive consideration of multiple environmental impacts throughout the project's stages. Study of (Lima et al., 2021) also identifies LCA as one of the leading topics in construction industry research, along with materials and energy performance. The environmental assessment support the evaluation of sustainability at the different construction project phases, with the ultimate goal of reducing the natural resources & energy consumption, decreasing the carbon footprint, and improving the performance. Meanwhile, LCA is recognized as an efficient and objective method to conduct the environmental assessment throughout the life-cycle in the following aspects: energy & resources usage, emissions & waste generation, life cycle environmental impact.

Digital tools also play a significant role in the application and optimization of sustainable construction practices. The capabilities of digital technologies to design, simulate and evaluate different aspects of construction projects allow to contribute to multiple sustainable principles, including energy efficiency, LCA, and management. Multiple studies particularly highlight Building Information Modelling as a useful methodology for digital tools application and project optimization (Li et al., 2025). The study of (Hao et al., 2020) shows an effective application of BIM for LCA analysis and carbon emissions estimation for pre-fabricated housing projects. Figueiredo et al. (2021) also displays the methodology based on BIM and LCA for an optimized materials selection according to carbon and energy performance. The study of (Askar et al., 2025) identifies other key enabling digital technologies, crucial for sustainable construction, which are provided in Table 2.

Table 2. Key enabling digital technologies in sustainable construction (Askar et al., 2025)

Application area	Enabling technologies
Data acquisition	Sensors
	Internet of Things (IoT)
	3D scanning
Automating processes	Robotics
	3D printing
	Drones
Digital information and analysis	Building Information Modelling (BIM)
	Virtual/ Augmented Reality (VR and AR)
	Artificial Intelligence (AI)
	Digital Twins (DT)

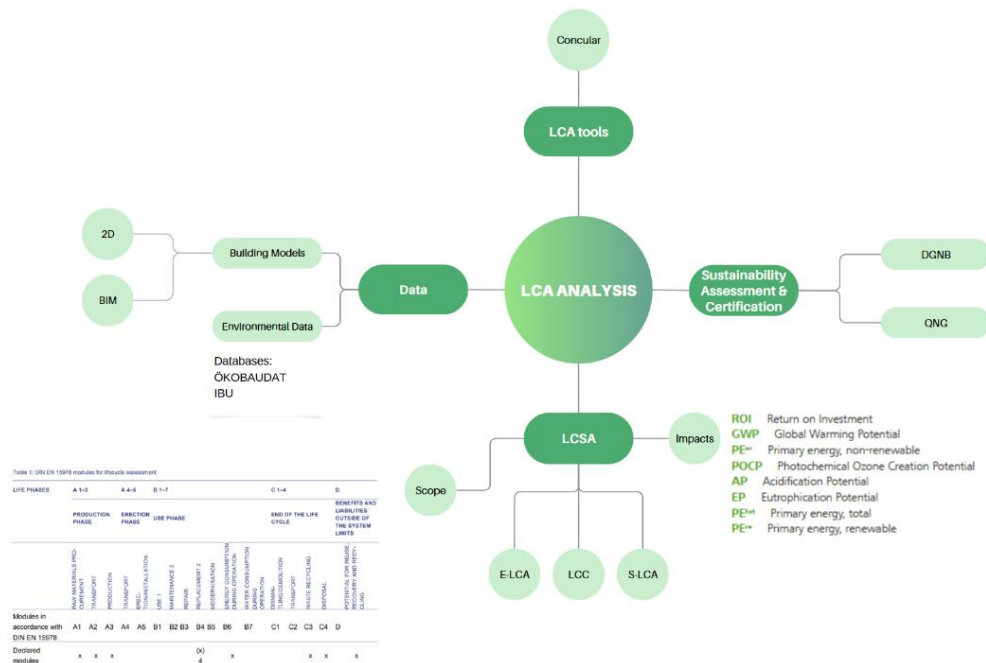
1.4. CONTEXT

As a part of the MBUILD Master Program and final dissertation, the author initiated a collaborative work with the German sustainability consulting & project management company. This cooperation provided an opportunity to apply the knowledge and skills obtained during the MBUILD in a real-life context. In addition, the project contributed to the collaboration between the academia and the industry, applying the modern research developments within a company's framework. Finally, the dissertation supported the company in further digitalization and optimization of their internal sustainability assessment methodology.

Woscim is a German company which provides services in project management and sustainability consulting at different phases of construction projects. The mission of the company is to facilitate efficiency and sustainability in construction industry, addressing the ecological, social and economic needs through integrated solutions. As a young and dynamic company, woscim has a strong focus on the integration of modern methodologies for sustainability assessment and consulting, particularly in alignment with German certification systems such as DGNB and QNG (woscim, 2025).

Following the company's vision, the author collaborated with woscim to explore the integration of LCA into construction stage of a building project. The dissertation was aiming to optimize the LCA analysis process and accuracy through the implementation of the BIM and developing a BIM-LCA assessment workflow. This included the creation of a BIM model with the necessary level of details to export to the professional LCA software and provide quality data for environmental impacts calculations that satisfy the DGNB and QNG certification requirements. The dissertation evaluated the influence of BIM model and export quality on the LCA outcome and decision-making.

The dissertation was based on a real-life residential building provided by the company. The BIM model was developed according to the existing drawings and materials takeout. Throughout the dissertation, this model was applied as a basis for LCA assessment through professional software tool. This approach allowed to examine different modelling strategies, detail levels, and export methods, and observe their influence on the data quality to achieve reliable analysis results. Thus, the dissertation showed the effect of digital tools on the quality and accuracy of sustainability assessment in the construction industry. Finally, this collaboration provided a practical value to woscim and its consulting services, observing the industry trends in digital tools and methodologies.



1.5. RESEARCH PROBLEM & OBJECTIVES

Life Cycle Analysis (LCA) is a pivotal methodology for the environmental and sustainable performance evaluation of a built environment. However, the LCA application is constrained by inefficient and manual data transfer from a building project. In Germany, the majority of construction projects are based on 2D modelling, which further hinders the analysis process and increases the risk of error. Therefore, this dissertation hypothesizes that developing structured guidelines for a BIM model development and export tailored to LCA software can enhance automation, accuracy, and consistency of environmental impacts assessment. As a result, the more precise LCA estimations will better align with the requirements of Green Building Ranking Systems (GBRS), promoting a more informed and data-driven decision making process. Thus, the research question of this study is:

How can BIM modelling and export methods be structured to enable accurate and automated data transfer into LCA software, in order to support reliable environmental assessments aligned with Green Building Rating System (GBRS) requirements?

To address the research question and define a practical guideline for consistent and automated data export, the following objectives are defined:

1. Analyse BIM-to-LCA export methods:

The IFC based export methods will be evaluated according to its consistency, reliability, and compatibility with LCA software tool. As a result, the primary challenges and the most effective practices will be integrated into the workflow.

2. Define the required types of information of a BIM model for compatibility with LCA software:

The key parameters of a BIM model will be defined and set to integrate in BIM model and facilitate accurate data transfer to the LCA software.

3. Support the automated data mapping:

The auto mapping methods in LCA software will be analysed to reduce the time and improve the automation of building materials and elements labelling.

4. Reduce error risk and enhance LCA accuracy:

By framing the model development and export ruleset, the investigation aims to minimise manual interactions, improve the calculations accuracy, and facilitate more precise LCA outputs.

5. Support the AEC sector transition to BIM-based design and analysis:

The advantages of a BIM-based workflow for an environmental performance evaluation will be demonstrated, thus facilitating the adoption of BIM methodology and integration with LCA.

2

BACKGROUND

2.1. BIM

2.1.1. WHAT IS BIM?

BIM is a collaborative management of the physical and functional properties of a construction project through a digital model (Datta et al., 2023). The ISO 19650 defines BIM as “use of a shared digital representation of a built asset to facilitate design, construction, and operation processes to form a reliable basis for decisions” (ISO, 2018). The methodology is based on the structured and integrated information management throughout the life-cycle, starting from conceptual design to the end-of-life. It also facilitates collaboration among stakeholders, including architects, engineers, and other experts involved in the project (Sacks et al., 2018).

BIM has become an essential facilitator of processes in AEC. Moreover, Building Information Modelling is a crucial tool in advancing sustainability of construction sector. Through integration of BIM, practitioners develop one or multiple digital representations of a project. Once finished, the models contain precise geometry, special relationship, material characteristics and embedded data, which is utilized as a primary reference across the project stages. This leads to a significantly higher level of accuracy and monitoring compared to the traditional project delivery method (Sacks et al., 2018).

The conventional project delivery is often criticized due to high fragmentation and inefficient 2D-drawings based communication. Multiple errors and inconsistency results in higher costs, time delays, and lawsuits. Moreover, it noticeably hinders the critical assessment of the early-stage design, cost & time schedules and other project aspects, making it challenging to implement changes in the project. Meanwhile, The BIM integrated approach to design and construction processes increases the quality of construction projects while reducing the project costs and execution time. In addition, BIM allows a better maintenance, facility management and future adjustments (Datta et al., 2023; Sacks et al., 2018).

2.1.2. APPLICATION AND SCOPE

BIM supports a project through the whole lifecycle, providing a framework for cooperation, supervision and optimization from pre-design to operation. The main advantage of this methodology is the capability to generate and coordinate systemized, cross-compatible information that is exchanged and accessed among different stakeholders. The information can include 2D documentation, such as plans and schedules, and 3D visualization that are available and updated along the project development. Therefore, a more comprehensive understanding of a building's stage and progress is achieved. BuildLACCD (2019) defines the application purposes of BIM across various life stages, illustrated in Figure 5.

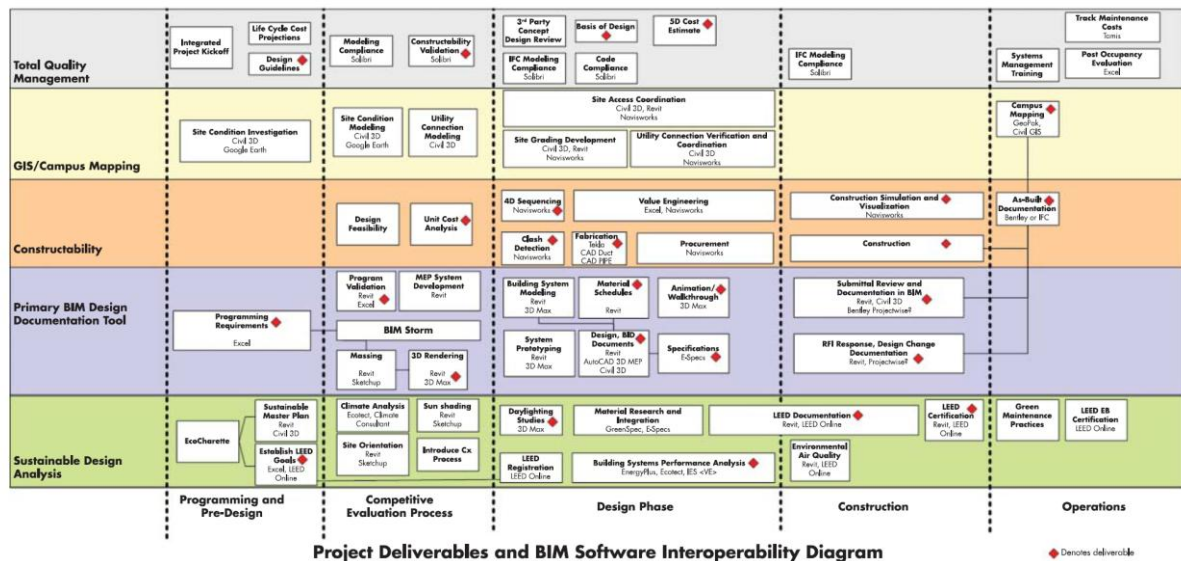


Figure 5. BIM application across a project life-cycles. Source: BuildLACCD. (2019). LACCD Building Information Modeling Standards.

According to BuildLACCD (2019), the following application purposes of BIM are defined:

Pre-design and programming

At the pre-design and programming phase, the master planning is modelled that provide definitions for spaces and adjacency of a project. Project stakeholders utilize BIM framework to include data such as GIS, as-built, and design guidelines, facilitate a proper decision-making at the initial stage, and satisfy the programming requirements.

As-built data

For the as-built phase, the “begin with the end” logic is applied, in which the necessary data regarding building elements, their characteristics, performance and maintenance is recorded. Such an approach allows facility managers to access and utilize the information after the completion of the construction.

Site conditions

To ensure special compatibility and design coordination, BIM is also applied to generate 3D models of the surrounding terrain, utilities and structures.

Architectural model

The architectural modelling phase in BIM is a gradual and synchronized process, in which the development starts with basic massing shapes and layouts. Along the timeline, the model is updated with more detailed information about the walls, floors, roofs and other elements, as well as their properties, such as geometry, materials or environmental performance. This information is also linked with the schedules and other validation tools to monitor the progress and alignment with the program requirements.

System model

Together with the architectural models, various systems, including MEPF and structure, are also modelled and included in BIM. Thus, a multi-disciplinary and integrated project coordination is achieved. The

models are developed separately and uploaded to a shared reference point for a project coordination. Similar to architectural, the system models are also updated with a more detailed information through the project, such as type of equipment, location, performance and clearance zone. BIM is also capable to include metadata, that contains the connection of system to a specific zone or room. This allows a more precise designing and performance assessment.

5D Estimation

A strong advantage of BIM is its capability to contain materials and elements quantities that are connected and automatically updated with the project model. This feature facilitates a more accurate cost estimation and time scheduling.

Energy Performance and Life Cycle Analysis

BIM information can be applied and enriched with energy modelling and materials data for environmental performance analysis. Therefore, a sufficient reduction of resources can be achieved. Further, this information can be utilized for Green Building Ranking Systems. Figure 6 illustrates the broader scope of BIM application for sustainability purposes.

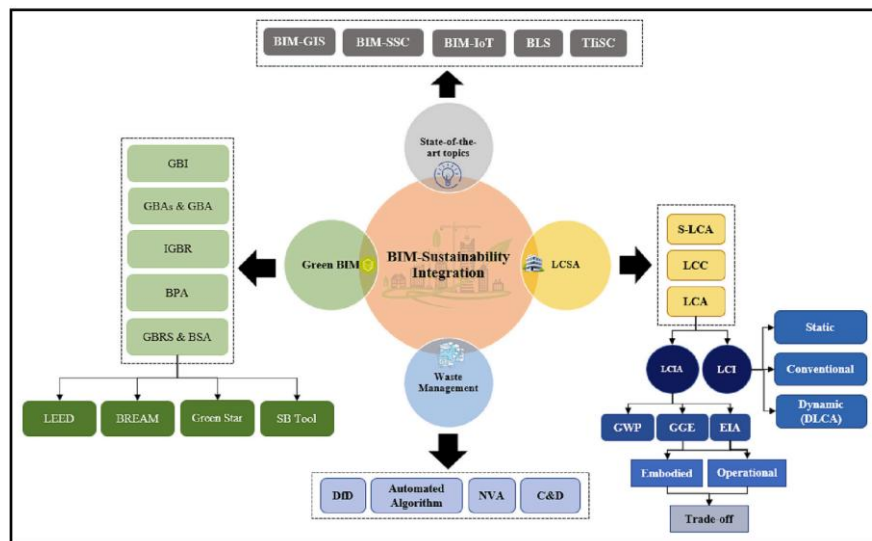


Figure 6. The BIM-application scope for the Sustainability Integration. Source: Akbari, S., Sheikhhoshkar, M., Pour Rahimian, F., el Haouzi, H. B., Najafi, M., & Talebi, S. (2024). Sustainability and building information modelling: Integration, research gaps, and future directions. *Automation in Construction*, 163, 105420. <https://doi.org/10.1016/j.autcon.2024.105420>

Design Visualization

BIM can significantly support the project and its stakeholders by providing comprehensive and detailed visuals, including 3D rendering, animation, 4D construction process. Thus, the stakeholders monitor and supervise the process execution with a higher precision.

Together with the BIM application purposes throughout the life-cycle, another way of framing the BIM application is through the BIM levels. These levels refer to the extent of BIM maturity in a project, which considers the level of collaboration among stakeholders and advancement of tools application. Figure 7 illustrates the BIM Level framework according to the UK Government BIM Task Group (Innovative UK, 2017).

- Level 0: This level refers to unsupervised CAD, which contains 2D drawing and PDF documents. The collaboration and workflow framework do not exist at this stage.
- Level 1: This level includes 3D CAD conceptual models and 2D plans for product specification. The managed and assessable work environment is developed based on the Common Data Environment (CDE), but the models are not exchanged among the stakeholders
- Level 2: At this level, a collaborative working environment is established, in which the stakeholders develop the specific 3D models separately. Those models are exchanged in a standardized format, such as IFC or COBie, which allows the parties to assess and apply the models for other purposes. As a result, a federated BIM model is developed.
- Level 3: The highest extent of BIM application refers to the seamless collaboration among all the parties through a integrated single BIM model that is stored in a centralized cloud platform. Accordingly, the stakeholders are able to modify the project simultaneously.

The escalation from Level 0 to Level 3 allows to switch project development from a decentralised and drawings & plans-based to an integrated and data-driven execution. When reaching the last level, BIM provides a shared ecosystem that involves all the stakeholders and allows informed design, performance analysis and decision making at different life-cycle stages (Sacks et al., 2018).

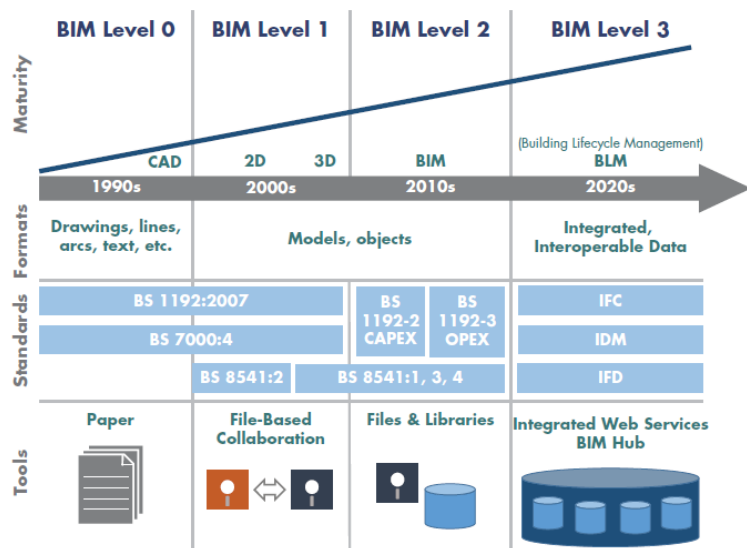


Figure 7. BIM application levels. Source: Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers* (3rd ed.).

2.1.3. KEY ENABLING TECHNOLOGIES

The main feature of BIM that distinguishes it from the conventional CAD systems is object-based parametric modelling. This type of modelling defines a building element as an object with specific parameters and relation to other elements. When developing an object-based model, the objects' properties, such as shape, geometry, and embedded data can be updated automatically according to

the changes input by a user. Such an object's behaviour is also referred as a design behaviour. Through this feature, the modifications in the projects are better coordinated and automatically transferred to other disciplines, such as cost & time scheduling, energy analysis and environmental performance (Sacks et al., 2018).

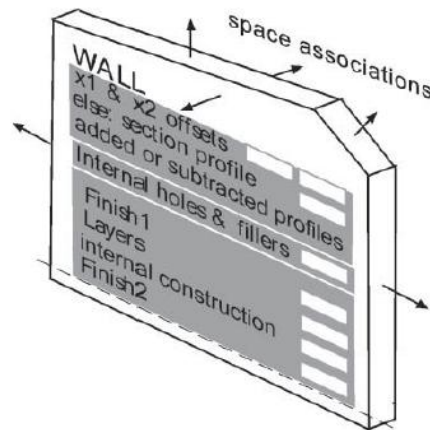


Figure 8. BIM wall element. Source: Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers* (3rd ed.).

When an object is modelled in BIM, it is assigned with the object class, such as walls, floors, windows and etc.. With the help of the class, the objects are predefined specific with geometrical, behavioural and metadata. One of the widely integrated classification is OmniClass, which is a standardized framework to classify elements, products and spaces of a construction project. OmniClass allows to develop a consistent and standardized project information, which can be analysed and monitored by other stakeholders (Construction Specifications Institute, 2025).

Nowadays, multiple applications exist to implement BIM into the project according to specific purposes. Figure 5 shows the examples of BIM applications which are applied for particular tasks at different project stages. Overall, BIM tools are divided into 3 primary categories:

BIM tools are utilized for the tasks that do not require geometrical modelling, including cost estimation, time scheduling or energy analysis.

BIM platforms are the primary applications for modelling. The platforms support the essential building and element modeling with corresponding data. The functionality of platforms include 3D modeling, drafting, clash detection, and documentation. One of the most widely applied BIM platforms is Autodesk Revit. Revit provides capabilities for parametric modeling, customized object modeling, and bidirectional data processing for materials takeoff and scheduling. In addition, multiple external tools are adopted to interaction with Revit for quantity analysis, cost calculations, energy modeling and environmental assessment (Autodesk, 2025).

BIM environments refer to the general ecosystem of tools, platforms, data libraries, cloud platforms and platforms to support the interoperability and collaboration within the project.

2.1.4. DATA EXCHANGE

Data exchange is a crucial factor for effective BIM application, as it supports the cooperation among the stakeholders, disciplines and applications along the project progress. Therefore, it is important that the BIM information is exchanged and applied properly to serve various project deliverables such as design,

time scheduling, cost analysis, environmental performance and facility management. Nowadays, a number of data exchange methods are applied within the BIM framework. According to Sacks et al. (2018), the 3 primary types of data exchange in BIM are:

Direct Link / API-Based Exchange.

This type of exchange refers to the direct connection between different software through programming interface (API). In this case, the information can be shared in real-time and through a customized workflow.

File-Based Exchange

This exchange process involves the application of software specific (RVT, DGN, PLN, DXF) or open standards files. The mostly applied open standard file type is Industry Foundation Classes (IFC), which supports vendor-neutral and multi-disciplinary exchange among parties.

Server-Based Exchange

In this approach, the BIM data is shared through a shared server or database, commonly referred as Common Data Environment (CDE). The CDEs are often based on IFC schemas and enable concurrent data exchange, versions monitoring and quality control. Through the server based approach, a higher scalability and more efficient management are achieved.

To ensure the consistency and transparency in data exchange, the buildingSMART developed IFC as an open-use data model for construction objects, including buildings and infrastructure. The IFC refers to the ISO 16739 standard which applies EXPRESS modelling language in IFC based on ISO-STEP. The primary goal of the IFC is to cover and provide a wide range of building-related data, such as geometry, materials, relationship or assembly processes (buildingSMART, 2025).

The data within the IFC is structured hierarchically, which facilitates the consistency of a building information coordination. Figure 10 provides an example of the IFC architecture of a wall element. The structural architecture is based on providing comprehensive definition of an object, related properties, and the relationship between the two. The object-centred model of data includes the physical objects, which define the physical elements such as wall (IfcWall), and abstract object, which cover such concepts as processes, roles, or spatial hierarchy. One of the main concepts of the IFC structure are entities, attributes, properties, and relationships (Theißen et al., 2020,).

Entities are core classes that define the objects. Through the hierarchical structure of a model, particular entities (e.g. IfcWall) are derived from more abstract entities (IfcElement, IfcProduct, IfcObjectDefinition, IfcRoot)

Attributes are provided from entities' definition and have intrinsic, non-optional characteristics. As an example, the attribute GlobalId is assigned to each entity in the model as a unique identification, and is inherited from IfcRoot. Another example is ObjectPlacement, which is inherited from IfcProduct and refers to the location and orientation of a physical object.

Properties are the functions that enriches the entities with the more semantic information, which compared to the attributes, are more extensible and descriptive. The properties are often structured in Property Sets (PSet_). In case of an IfcWall, Pset_WallCommon can define if the wall is external (IsExternal) or structural (LoadBearing).

Another function of assigning quantity list to an element is **Quantity Sets** (Qto_), which provide the basic quantities of an object from its geometry. For the IfcWall, Qto_WallBaseQuantities set contains the NetVolume and NetSideArea of an object.

To assign the properties to the entities, the **Relationships** (IfcRelationships) are implemented. With the help of IfcRelDefinesByProperties, the Property Sets are connected to the elements. (Sacks et al., 2018; Theißen et al., 2020b)

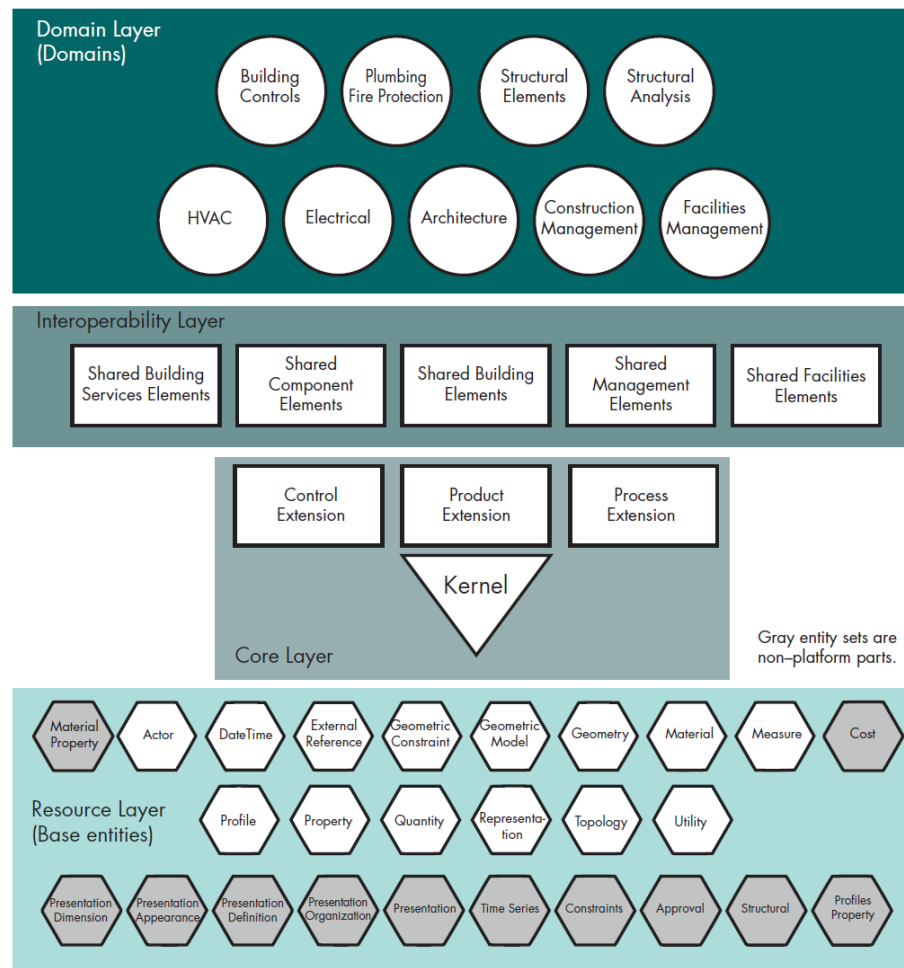


Figure 9. IFC architecture schema. Source: Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers* (3rd ed.).

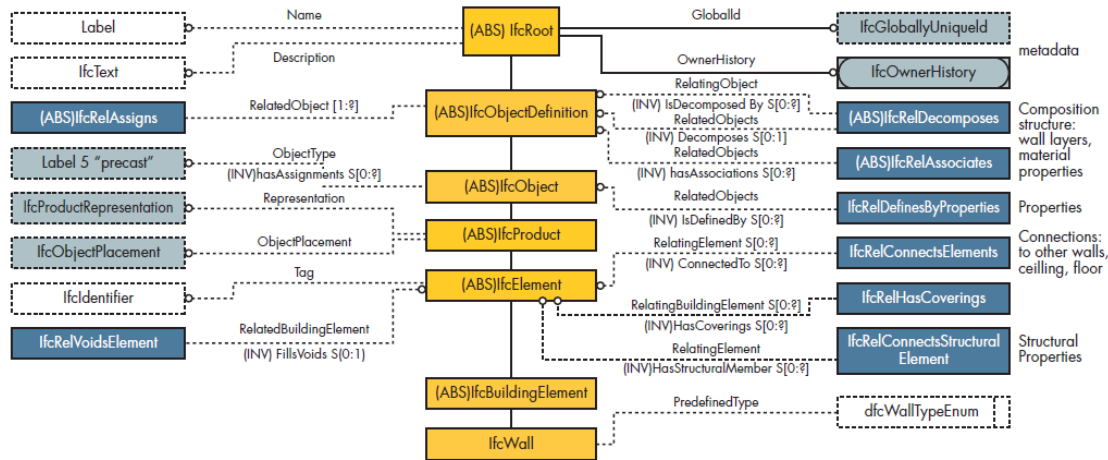


Figure 10. IFC structure of a wall. Source: Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers* (3rd ed.).

The IFC interoperability and data consistency also depends on the version of the schema. According to buildingSMART (2025), 2 major releases have been applied in the AEC industry, which are IFC 2.3 and IFC 4.0, and the new IFC 5 release is under development. The evolution of the IFC schemas is proportional to the growing attention to the accessible and reliable data exchange. The first versions, including IFC 1.0 and IFC 2x3, are the major development in the industry interoperability, however their applicability is limited in projects with wider scale and multidisciplinary. The 4.0 IFC release introduced better support to geometrical and functional parameters, as well as extended the application scope for infrastructure projects. Nevertheless, the version still lacks flexibility and capability for a real time data share. The developing IFC 5 can potentially overcome these challenges by integrating language independent methodology, Entity-Component-System (ECS) model structure, and Universal Scene Description (USD). This will enable a more efficient collaboration and compatibility with digital twins and cloud platforms (buildingSMART, 2024). Table 3 provides detailed comparison between IFC 2.3.0.1 and IFC 4.0.2.1

Table 3. IFC versions comparison (buildingSMART, 2025)

	IFC 2.3.0.1	IFC 4.0.2.1
Status	Final	Final
Primary Domain	Buildings	Buildings and Infrastructure
Model View Definition options	Coordination View, Space Boundary Addon View, Basic FM Handover View, Structural Analysis View	Reference View, Design Transfer View (Draft), Quantity Takeoff View (Draft), Energy Analysis View (Draft), Product Library View (Draft)
Number of Property Sets	300+	600+
Number of Entities	600+	800+
Major Updates (comparing to the oldest version)	Introduced more reliable, standardized schemas that enhanced the coordination between architectural, structural and MEP disciplines.	Expanded the schema to improve the data-richness of a BIM workflow and include infrastructure projects.

The effectiveness of BIM data exchange is also defined by the amount of details and information that are included into the model. Level of Development (LOD) refers to the extent of details and information of a specific element in a model at different project cycles. According to the LOD, the information about element properties is defined for design, documentation, evaluation, or construction.

Table 4 provides detailed information on LOD and the required information (Autodesk, 2025b).

Table 4. BIM Level of Details (Autodesk, 2025)

Level of Properties Development		
LOD 100 – conceptual design	–	The model consist of simple forms and object sizes excluding detailed information. It is utilized to illustrate the general idea and design.
LOD 200 – schematic design	–	The model involves the integration of approximate details of the elements, including shape, location and size. The schematic design contributes to a better understanding of the early design concept and spatial relationship.
LOD 300 – detailed design		At this stage, the model is refined with precise information on geometry, sizes, shapes and components. The detailed design serves as a reference for documentation and management of different disciplines.
LOD 350 – construction documentation	–	The model contains detailed information regarding assembly, manufacturing and construction processes.
LOD 400 – fabrication and assembly	–	At this level, detailed models for fabrication and assembly are input for particular connections and elements.
LOD 500 – as-built or facility management		This model stage refers to the as-built conditions of a project, including existing and operating elements. This supports the facility-management and maintenance.

The LOD consists of the Level of Geometry (LoG), which defines the degree of information related to geometry and shapes, and Level of Information (LoI) that refers to the semantic data. When specific characteristics are attributed to an object, such as material properties, classification, or structural function, this information is transferred according to the corresponding LoI. Table 5 provides examples of rules and types of information that define the LoI

Table 5. Level of Information rules (Solibri, 2023)

Rule	Example
Common practice	Component Name
General specifications	"LoadBearing", "IsExternal" properties
Project-specific specifications	"Volume", "Area", "Length", other custom properties

2.2. LCA

2.2.1. WHAT IS LCA?

To address the environmental challenges in the construction industry, Life Cycle Assessment (LCA) has become an important framework to improve the sustainability of sector. LCA is defined as a scientific methodology to assess the environmental impacts of a product, process or a system through all the life stages, starting with the extraction of raw materials to production, application and disposal. This approach provides a holistic overview of the environmental performance and leads to the information-driven decision making. (Carvalho et al., 2025).

The LCA methodology is framed by the international standards ISO 14000 on Environmental Management and LCA, mainly ISO 14040 (Principles and Frameworks) and ISO 14044 (Requirements and Guidelines). To govern the proper application of LCA in the construction sector, industry-specific standards on sustainability of construction works are also established by the European Union, including EN 15978 and EN 15643 (Jolliet, 2020; Larsen et al., 2022).

In the construction sector, the application of LCA enables the identification and prevention of excessive resource consumption, energy use, and emissions generation. The methodology allows to evaluate and compare the alternatives for materials, elements and designs, and enables the application of an option with lower impact (Carvalho et al., 2025).

The LCA has been recently transformed into a wider concept of Life Cycle Sustainability Assessment, which together with the environmental (LCA), covers the economic (LCC) and social (S-LCA) aspects of sustainability. While the concept lacks the application maturity, it shows the industry's improvement towards a multi-dimensional and comprehensive sustainability performance (Hauschild et al., 2018).

The primary advantage of LCA is its ability to capture a wider scope of life cycle performance and environmental impacts. LCA enables to analyse the performance of a product or a system that consist of numerous processes and consume a large amount o resources. Another benefit of LCA is its quantitative nature that leads to the "best estimate" principle. Such a feature allows to numerically observe and evaluate the environmental performance, resulting in more objective comparison (Hauschild et al., 2018; Jolliet, 2020).

2.2.2. LCA METHODOLOGY

According to ISO 14040 and ISO 14044 (2006), the 4 main phases are defined for the LCA, which are implemented iteratively throughout the analysis process: Goal and Scope Definition, Inventory Analysis, Impact Assessment and Interpretation. Figure 10 illustrates the procedure of LCA phases application.

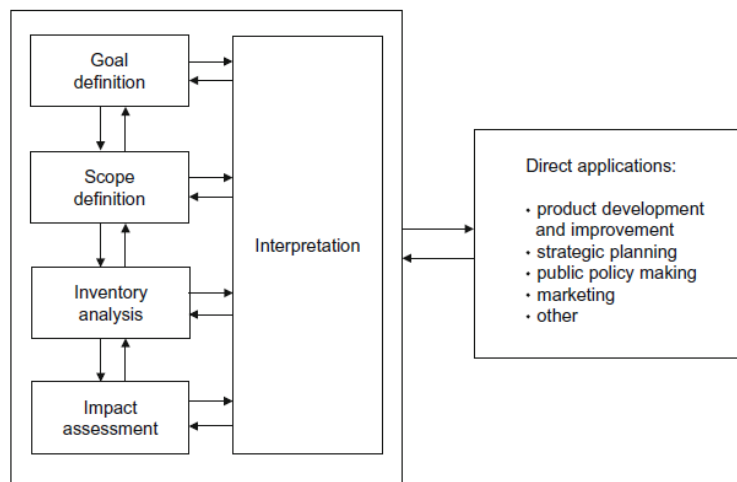


Figure 11. Phases of LCA framework. Source: ISO 14040:2006 - Environmental management — Life cycle assessment — Principles and framework. (2006). <https://www.iso.org/standard/37456.html>

Goal and Scope

At the first phase, the objective of the analysis is identified. The examples of study goals can be the system optimization, product comparison, or policy design. The important aspect of this phase is the establishment of the functional unit, which is a numerical representation of the output achieved through the system. The functional unit is utilized as a reference during the analysis and allows to compare the analysis results objectively. Moreover, the goal and scope phase defines the system boundaries of the study, which refers to the scope of the life cycle stages that are taken into consideration (e.g., cradle-to-gate or cradle-to-grave). Finally, the type of assessment is chosen at this stage, which can be attributional – describing the evaluated system, or consequential – analysing the alternative outputs of various decisions. Accurate definition of a goal and scope is crucial to establish clear analysis process and achieve plausible output (Hauschild et al., 2018; Jolliet, 2020).

For a consistent application of the LCA in the construction projects, the EN 15978 (2012) specifies the life cycle stages that should be considered in the analysis. Figure 12 provides the detailed structure of the construction project life cycle. The phases are divided into 4 primary groups, which are product, construction, use, and end-of-life, with an additional modules of benefits beyond the system boundaries.

(A1-A3) Product Stage – this stage includes the processes related to the raw materials extraction, transportation to the manufacturing facility, manufacturing of building elements, which overall significantly affect the embodied environmental impact through energy consumption and emissions.

(A4-A5) Construction Stage – this stage considers the transportation of building products to the construction site and physical assembly of a building. The environmental impacts are observed during the equipment utilization, on-site energy consumption and waste generation.

(B1-B7) Use Stage – the stage starts when the building is operational and includes the activities associated with its service life, such as energy and water use, maintenance, repair, refurbishment and replacement.

(C1-C4) End-of-Life Stage – the end of the life cycle refers to the dismantling and demolishing of a building, and its materials are sorted for transport, treatment and disposal. The waste generation, energy used in demolition and material disposal method influence the environmental impacts at this stage.

(D) Beyond System Boundary – this stage takes into account potential benefits from such measures as reuse, recycling and energy recovery of materials after the end of life.

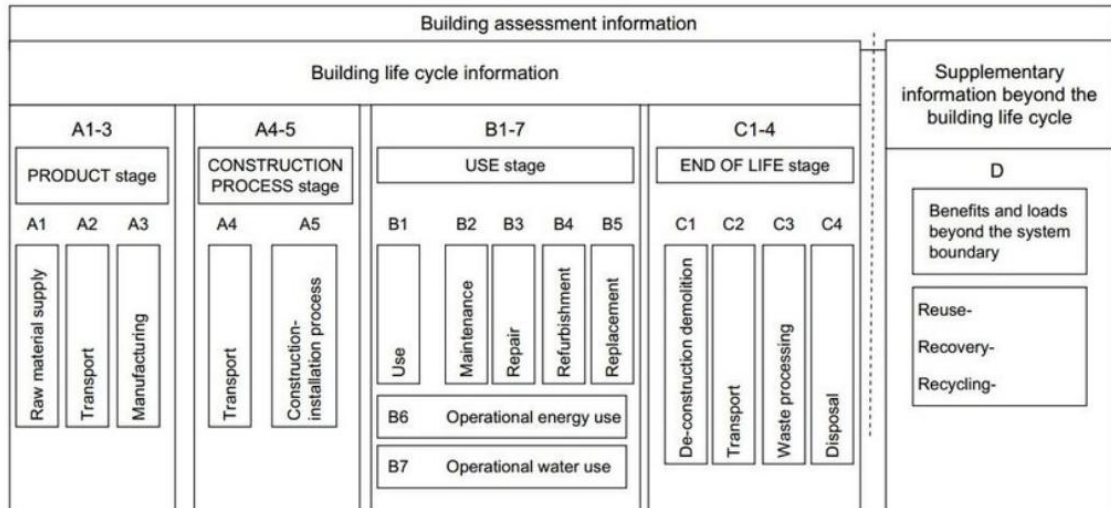


Figure 12. LCA stages of the construction project. Source: DIN EN 15978:2012-10, *Nachhaltigkeit von Bauwerken_ - Bewertung der umweltbezogenen Qualität von Gebäuden_ - Berechnungsmethode; Deutsche Fassung EN_15978:2011.* (2012). <https://doi.org/10.31030/1917049>

Life Cycle Inventory Analysis (LCIA)

After the clear goal and scope are established, the next phase, Life Cycle Inventory Analysis, covers the collection of the data relevant for the study objective. At this stage, the inputs and output flows involved into the considered system, such as consumed resources or generated emissions, are quantified. Hauschild et al. (2018) identifies 6 steps that should be undertaken for an accurate LCI:

- Definition the model and processes of LCI
- Data management and collection
- Development of unit processes and quality control
- Development and estimations of LCI model
- Sensitivity analysis and uncertainty management
- Documentation and reporting

The important aspect of the LCIA stage is data, which is collected across all considered stages and flows. The primary sources of the data are LCA databases, academic literature, industry or government reports (Hauschild et al., 2018).

Life Cycle Impact Assessment

At the LCIA phase, the environmental impacts are quantified based on the data obtained from inventory analysis. The LCI data is transferred to the environmental impacts through assigning to the relevant environmental categories and indicators. This process includes the following steps: 1) Classification, which links associated emission outputs and consumed resources to the specific environmental impact category

2) Characterization, which estimate the influence of each flow to the category through the assigned equivalency factor

Optional steps can also be undertaken to achieve more accurate and transparent results:

3) Normalization, which uses reference data to compare it with the analysis estimations, such as average annual impact per capita

4) Weighting and valuation, which translates different impact categories into a common score

Through LCIA, the most affecting resources and processes in the life cycle are identified (Hauschild et al., 2018; Jolliet, 2020).

Interpretation

The final phase of the LCA is Interpretation, which evaluates the plausibility and consistency of the study results according to the defined objectives. The process includes identifying the major sources of contribution, analysing uncertainties, and conducting the sensitivity analysis to check results' plausibility. Due to the iterative nature of the LCA, the interpretation conclusions can be used to adjust the previous phases (Jolliet, 2020).

2.2.3. ENVIRONMENTAL IMPACTS

The evaluation of the environmental impacts associated with all the life-cycle stages is the primary focus of the LCA analysis. During the LCIA phase, the system inputs and outputs are translated to the environmental impact categories. The European standard EN 15804:2012+A2:2019 (2019) identifies the primary categories that have to be evaluated through LCA, which are provided in Table 6. Each of the categories provides a numerical quantity of a particular environmental impact resulted from resource or emissions involved in the life cycle. These categories set the reference for the Environmental Product Declaration (EPD) structure and ensures the consistent output of the LCA in the construction sector.

Table 6. LCA environmental impact categories (EN 15804:2012+A2:2019, 2019)

Impact category	Unit	Description
Global Warming Potential fossil (GWP-fossil)	kg CO ₂ eq	Measures the potential contribution of greenhouse gas emissions from fossil sources (e.g., CO ₂ , CH ₄ , N ₂ O) to climate change over a 100-year time horizon.
Global Warming Potential biogenic (GWP-biogenic)	kg CO ₂ eq	Captures the net carbon exchange between biogenic carbon (from renewable biological sources) and the atmosphere, including emissions and removals.
Global Warming Potential land use and land use change (GWP-luluc)	kg CO ₂ eq	Accounts for emissions and removals due to changes in land use (e.g., deforestation, soil degradation).
Ozone Depletion Potential (ODP)	kg CFC-11 eq	Assesses the potential impact of substances (e.g., halons, CFCs) on the depletion of the stratospheric ozone layer, which protects life from UV radiation.
Acidification Potential (AP)	mol H ⁺ eq	Evaluates emissions that contribute to acid rain formation, which can damage aquatic and terrestrial ecosystems as well as built environments.
Eutrophication Potential freshwater (EP-freshwater)	kg P eq	Measures nutrient discharges that may cause excessive algae growth in freshwater bodies, leading to oxygen depletion and ecosystem degradation.
Eutrophication Potential marine (EP-marine)	kg N eq	Quantifies nitrogen-based emissions that stimulate algal blooms in marine ecosystems.
Eutrophication Potential terrestrial (EP-terrestrial)	mol N eq	Evaluates atmospheric emissions of nitrogen compounds that affect nutrient balance in soils.
Photochemical Ozone Formation Potential (POCP)	kg NMVOC eq	Estimates emissions of non-methane volatile organic compounds (NMVOCs) and other precursors that contribute to the formation of ground-level (tropospheric) ozone or "smog."
Abiotic Depletion Potential fossil fuels (ADPF)	MJ	Measures the depletion of non-renewable fossil energy resources, such as oil, coal, and natural gas.
Abiotic Depletion Potential elements (ADPE)	kg Sb eq	Assesses the depletion of non-renewable mineral resources, using antimony (Sb) as a reference element.
Water Use (WU)	m ³	Represents the net use of freshwater resources throughout the life cycle, excluding the release of water back to the environment.

2.2.4. DATA SOURCE

As LCA analysis relies on the high amount of data, the data source is a crucial factor that impacts the accuracy and quality of the study. There are 2 primary categories of databases that are used for LCA, which are generic and specific (Palumbo et al., 2020a).

- **Generic databases** contains generalized and averaged data for products, processes and services in multiple sectors. The major providers of the generic data are academic entities, consulting companies or governmental organizations.
- **Specific databases** in contrast, represent a more accurate data for specific services or products, as it is often based on real-life data. The specific databases include the data from manufacturing entities. In the construction sector, after the real-life data is collected, it is often provided in the EPD, which is a standardized form of a report that documents environmental impacts of a particular product.

According to the EN 15978 (2012), the specific databases are recommended over the generic to achieve more accurate and reliable results of LCA analysis in a construction project.

EPDs are important part of the LCA analysis of construction projects and the integration of the life-cycle approach to the evaluation and design of a building. The EPD standardized report provide quantified data on environmental impacts according to the standardized LCA method. The EPDs are regulated by EN 15804:2012+A2:2019, ISO 14025:2011 and ISO 21930:2017, developed on voluntary basis, and verified by the third-party (Del Rosario et al., 2021). According to the latest edition of the standard, the EPDs are required to include product stage (A1-A3), together with end-of-life (C1-C4) and benefits beyond the system boundaries (D)(EN 15804:2012+A2:2019, 2019).

Although Environmental Product Declarations are aimed to provide consistent and transparent data on environmental impacts, the access to the reports may be challenging due to confidentiality, restrictions in license, or not centralized data access. To address this issue and support the growing demand in LCA integration, multiple open-access databases have been developed across the European Union. Therefore, a high-quality, reliable and machine-readable data can be provided to the practitioners(Säynäjoki et al., 2020; Takano et al., 2014). The list of the major specific databases for construction industry in EU is provided in Table 7

Table 7. LCA databases across EU

Database	Country	Type	Description
IBU	Germany	Specific (EPD)	Managed by the <i>Institut Bauen und Umwelt e.V.</i> ; offers verified EPDs in both human-readable and digital ILCD+EPD formats. Part of the InData initiative; compatible with LCA tools (<i>Institut Bauen Und Umwelt e.V.</i> , 2025).
ÖKOBAUDAT	Germany	Generic Specific	Official national LCA database for buildings; mandatory for BNB certification. Provides open-access data compliant with EN 15804+A2 and ILCD+EPD standards (<i>ÖKOBAUDAT</i> , 2025).
EPD Denmark	Denmark	Specific (EPD)	National EPD platform publishing third-party verified environmental declarations; supports integration with digital LCA tools and Danish building regulations (<i>EPD Denmark</i> , 2025).
Bau-EPD	Austria	Specific (EPD)	Austrian database for EPDs of construction products; coordinated by national institutes and aligned with EN 15804 requirements. Part of the InData network (<i>Bau-EPD</i> , 2025).
INIES	France	Generic Specific	French national environmental and health database for construction products; integrates with digital assessment tools. Data complies with EN 15804 and French NF standards (<i>Inies</i> , 2025).
OpenDAP	Spain	Specific (EPD)	Spanish EPD database supported by the Ministry for Ecological Transition and AENOR; aims to centralize open-access EPDs in line with EN 15804 and ILCD+EPD format (<i>European Data</i> , 2025).

2.2.5. ASSESSMENT TOOLS

The primary purpose of the software assessment tools is to support LCA across its phases, such as modeling, calculation and environmental impacts interpretation. Due to the growing interest in LCA application across different economic sectors, including construction, the number of professional software tools increased significantly over the last decades. Current software solutions are able to support practitioners in academia, industry and government, providing a wide range of application purposes:

- Environmental impact assessment
- Life cycle costing
- Material flow evaluation

- Life cycle management
- Green building ranking systems (GBRS) (Picardo et al., 2023)

Su et al. (2020) also identifies the selection criteria for a suitable software tool:

- Project stage
- User expertise
- Data source
- Integration methods

Scope and objectives of the analysis

These criteria highlights that the tools are able to serve various purposes, and no universal solution exist on the market. Therefore, the context of the application should be analyzed while selection the relevant tool. Another the primary aspects that influence the evaluation results is the LCI database. Thus, it is important to consider the compatibility with the databases for an effective software choice. The list below provides the major LCA tools that are available in the market, as well as corresponding databases:

One Click LCA - A collaborative platform containing over 90,000 data entries, highly specialized in the construction and building sector. It offers integration with various tools, including Excel, Revit, IFC, IESVE, gbXML-based energy models, and other digital environments (Picardo et al., 2023).

Compatible databases: One Click own Database, ecoinvent, other

GaBi - Widely adopted by industry professionals, research institutions, and consultants across over 80 countries. The tool provides advanced functionalities and analysis modules tailored for experienced LCA practitioners (Picardo et al., 2023).

Compatible databases: GaBi database, ecoinvent, Environmental Footprint database, US Life Cycle Inventory database

Open LCA - The only professional-grade open-source software that supports ecological, social, and economic LCA, along with carbon and water footprinting, eco-design, environmental product declarations, and life cycle costing (Picardo et al., 2023).

Compatible database: Open LCA own database, ecoinvent, ELCD, Environmental Footprint database, Okobaudat, other

CircularLCA - A specialized tool developed by Concular for evaluating the environmental impacts and circularity of the building projects (Concular, 2025).

Compatible database: Okobaudat, QNG, EPD Norway, EPD International

2.2.6. CIRCULARLCA

CircularLCA is a professional software tool designed to integrate and optimize the Life Cycle Analysis, covering additional aspects of building's sustainability performance such as circularity indexing. The tool is designed by the German company Concular, which focuses on establishing the digital and efficient ecosystem for circular construction through project development, advising, and software design. The primary goal of CircularLCA is to provide the AEC experts, including planners, architects and sustainability experts, with a data-driven platform that support informed decision making for environmental performance optimization of building projects (Concular, 2025).

CircularLCA is designed as a user-friendly, automated and effective platform, enabling creation of LCAs and Building Resource Passes to support different Green Building Ranking Systems and regulatory frameworks, such as DGNB, QNG, BNB and EU Taxonomy.

The analysis process is streamlined with efficient data import, data labelling through multiple environmental databases, and automated calculation and interpretation of environmental impacts. The analysis starts with the import of project data to the software, which can be conducted through an Excel spreadsheet or BIM model. In case of BIM, the software support the direct import of a BIM information from the IFC file. During the import, the software processes the information related to materials, quantities and properties assigned to the IFC model. This enables the user to upload a BIM model and quickly access the semantic information automatically retrieved by the software.

After the base for the analysis is imported, the user is enabled to label the project elements with the appropriate environmental data. CircularLCA contains multiple environmental databases, including Ökobaudat, EPD Norway, QNG, IBU, EPD International, Eco Platform, MRPI, EcoSMDP, EPD Norge, EPD Hub, Environdec, ec3 and Association PEP. In addition, CircularLCA provides custom product database, in which products contain multiple environmental data records. This allows to align the estimations with multiple GBRS simultaneously, without changing the data labelling for a particular certification system (Figure 13). The data mapping can be conducted through 3 main methods:

- Manual Mapping – the user manually searches the connected database to assign the appropriate data.
- AI-Based Mapping – the software enables the automated environmental data mapping through Artificial Intelligence. The AI works based on an algorithm, which processes the elements' data and identifies the most matching data profile. The software analyses the element parameters such as Project Name, Material, IFC Class and IsExternal.
- Rule-Based Mapping- CircularLCA currently provides a beta version of a rule-based mapping, which allows to establish rules between element and database products properties and identify the suitable profile accordingly. The method enables to narrow down the environmental data, and when more than one environmental product satisfy the rules, the last-edited product is selected.
- In addition, CircularLCA supports the iterative updating of project model. When the same model is uploaded to the software after the updates, previously mapping information is stored and applied to the new model.

After the project elements are linked to the environmental data, the LCIA runs automatically and provides the values for the environmental impacts with high speed. The calculations take into account the certification system that is selected for an analysis. After the estimations are finished, it is possible to compare the environmental impacts of various models, elements, as well as develop a report suitable for investors and stakeholders (Circular, 2025).

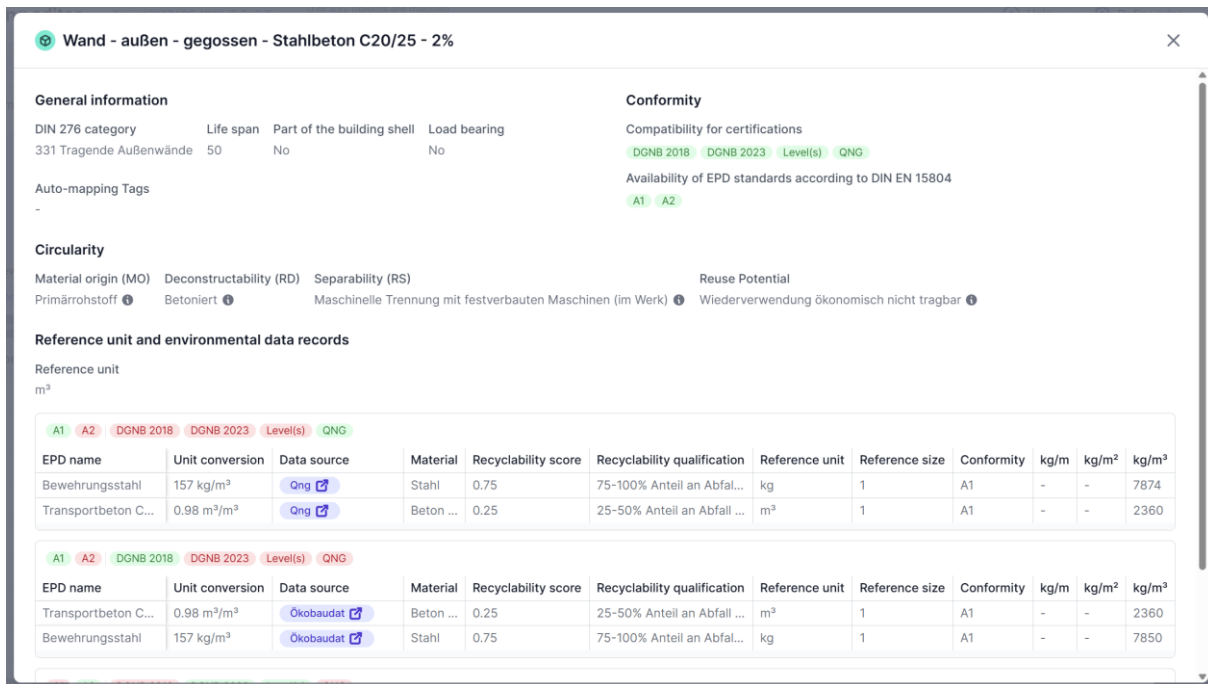


Figure 13. Example of CircularLCA product for outside precast concrete wall. Source: Concular. (2025). CircularLCA – Ökobilanzierung und Gebäuderessourcenpass - CircularLCA. <https://circularlca.de/>

2.3. GREEN BUILDING RANKING SYSTEMS

2.3.1. WHAT IS GBRS

Green Building Ranking Systems (GBRS) refer to the evaluation frameworks of the built environment sustainability performance. Such assessment systems are established and supervised by national or international-scale organizations, such as Green Building Councils (GBC). The main focus of the GBRS is to improve the environmental performance of the construction industry and implement sustainable principles across the life cycle stages of a project (Chandrasekaran & Dvarionienė, 2022). Currently, the following ranking systems are the most applied and recognized internationally:

- BREEAM – UK
- LEED – USA
- DGNB – Germany
- HQE – France

The evaluation criteria varies across the evaluation frameworks, however, the majority of the GBRS cover such performance categories as energy consumption, water use, building materials, emissions generation, indoor quality, site ecology and resilience. Further, several systems, including DGNB, apply a more comprehensive assessment through integrating social and economic pillars of sustainability (Chandrasekaran & Dvarionienė, 2022).

Along with the promotion of a more sustainable built environment, the evaluation systems are also becoming relevant for the economic and governmental benefits, particularly in European Union. In such

countries as Germany, the importance of the GBRS systems is growing through the link with state investments, corporate reporting, and opportunity to receive green financing (Grossarth, 2024).

2.3.2. DGNB

The DGNB certification system is supervised by The German Sustainable Building Council (DGNB), which established the system in 2009. Currently, DGNB is recognized as one of the leading and comprehensive sustainability assessment frameworks in Europe that is being integrated globally (Grossarth, 2024).

Comparing to the other certification methodologies, which mostly evaluate the environmental and energy performance of a project, DGNB integrates the holistic sustainability approach by also covering economic and social factors. Moreover, the system integrates the live-cycle approach through evaluating all the project life-phases, and takes into account the technical, process and location-specific factors of an analysed object (DGNB, 2025). The weighted percentage of each category is:

- Environmental Category – 22.5%
- Economic Category – 22.5%
- Sociocultural and Functional Category – 22.5%
- Technical Category – 15%
- Process Category – 12.5%
- Site Quality – 5%

According to the specific type and use of a building, the project is evaluated through 30-40 criteria with an individual score from 0 to 10. The latest version of the system, published in 2023, includes more than 10 building typologies (e.g. residential, hotel, educational facility, office building, supermarket, production facility, shopping mall, logistics warehouse, car parks, commercial building) at various construction phases and scale (DGNB, 2025). Figure 14 provides an overview on the certification system's versions and typologies.

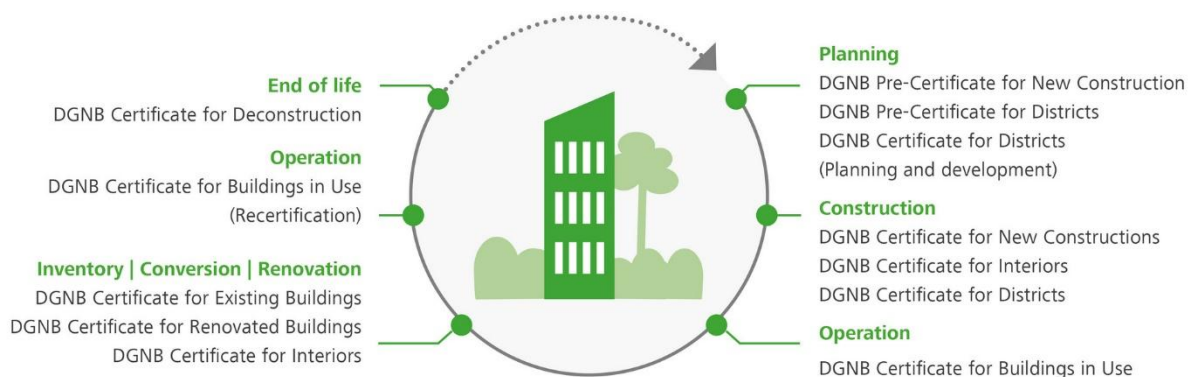


Figure 14. DGNB certification versions and typologies. Source: DGNB. (2025). About the DGNB System . <https://www.dgnb.de/en/certification/important-facts-about-dgnb-certification/about-the-dgnb-system>

After the evaluation is completed, a project is assigned with the corresponding label. The list of the labels and minimum overall score is described in Table 8.

Table 8 . DGNB Ranking System (DGNB, 2025)

DGNB Certification Level	Minimum Overall Score
Bronze (for existing buildings only)	$\geq 35\%$
Silver	$\geq 50\%$
Gold	$\geq 65\%$
Platinum	$\geq 80\%$

2.3.3. QNG

The Qualitätssiegel Nachhaltiges Gebäude (QNG) is the certification system established by the German federal government and Federal Ministry of Housing, Urban Development and Building (BMWSB) as a part of the national building sustainability strategy. The system is based on the former BNB (Bewertungssystem Nachhaltiges Bauen), and was developed under the supervision of DGNB and scientifically supported by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) (Grossarth, 2024).

Compared to the DGNB, which was established by a non-profit organization, the QNG system is represented by the federal government, and is focused on public developers of residential and non residential projects. Nevertheless, the private developers are also to utilize the system. The system can be used as a source of an object's characteristics and performance for financial entities, insurance companies and real estate specialists. By the end of the evaluation, the system assigns two types of certification: QNG PLUS and QNG PREMIUM (QNG, 2025). The list below shows the included categories and the corresponding weighted score:

- Environmental Category – 22.5%
- Economic Category – 22.5%
- Sociocultural and Functional Category – 22.5%
- Technical Category – 22.5%
- Process Category – 10%

2.3.4. LCA WITHIN GBRS

As the life-cycle evaluation becomes an important aspect of a building project, LCA is becoming an integrated part of the certification systems globally. Many GBRS systems include a number of qualitative criteria, and with the application of LCA, the certification frameworks become more quantitative data-driven and support a more accurate decision making. The LCA within GBRS not only facilitates a more comprehensive sustainability analysis, but also promotes innovative and informed selection of construction materials, methods, and design (Sartori et al., 2021).

Currently, several GBRS framework, particularly in Europe, implement LCA as one of the primary requirements. Such an approach is also supported by DGNB and QNG systems (Hauke & Hein, 2024). In the DGNB, LCA is a primary focus of the indicator ENV1.1 – Building life cycle assessment, which contributes to the 9-9.5% of score depending on the building type and use. The points are distributed among the following criteria:

- Integration of LCA during the planning phase
- Optimization through comparison of design variants
- Compliance with reference and target values
- Bonus points for climate neutrality - Agenda 2030
- Circular economy strategies
- Limiting halogenated refrigerants

The methodology allows to choose partial, simplifies or complete calculation method, according to which the scope of materials and elements is defined. To evaluate the environmental impact results from the LCA, DGNB provides a reference values for GWP, PENRT and other categories, which are based on the performance of buildings certified by DGNB since 2017. The points are awarded if the results meet the reference score, and the additional points are assigned for surpassing the targets (DGNB, 2025; Sartori et al., 2021).

In contrast, the LCA in QNG is not associated with the scoring but recognized as a mandatory compliance criteria. This is especially relevant for projects, that apply for the government funding (QNG, 2025). QNG identifies the target values for the 2 primary indicators:

- Global Warming Potential (GWP)
- Non-renewable Primary Energy Demand (PENRT)

The scope of the elements included in the study is defined by the Cost Groups (Kosten Gruppen), which is a German building classification system that divides the elements according to the involved costs (DIN 276, 2018).

100	LAND	500	OUTSIDE AREAS
200	PREPARATION AND DEVELOPMENT	600	FURNISHINGS AND WORKS OF ART
300	BUILDING AND BUILDING CONSTRUCTION	700	CONSTRUCTION COSTS
400	TECHNICAL EQUIPMENT	800	FINANCING

Figure 15. Cost groups according to DIN 276. Source: DIN 276. (2018). DIN 276:2018-12, Kosten im Bauwesen. <https://doi.org/10.31030/2873248>

Table 9 summarizes and compares the primary specifications of LCA analysis within the DGNB and QNG framework.

Table 9. LCA analysis comparison in DGNB and QNG (DGNB, 2025; QNG, 2025)

Criterion	DGNB	QNG
1. Weight of LCA	Accounts for 9.5–10% of total certification score (ENV1.1)	Mandatory criterion, no points awarded;
2. Life Cycle Phases Included	Based on EN 15978, includes Modules A1–A3, B4, B6, C1–C4, and D	Based on EN 15978, requires A1–A3, B4, B6, C3, C4
3. Environmental Impact Categories	Climate change: Global warming potential (GWP) Destruction of the stratospheric ozone layer: Ozone depletion potential (ODP) Summer smog, ground-level ozone: Photochemical ozone creation potential (POCP) Acidification of soil, forest dieback and fish mortality: Acidification potential (AP) Eutrophication of surface water: Eutrophication potential (EP) Non-renewable primary energy demand (PE nr) Total primary energy demand (PE tot) Proportion of renewable primary energy Abiotic, non-energy resource consumption: Abiotic basic resource depletion potential (ADP elements) Water consumption: Net use of fresh water (FW)	Global Warming Potential (GWP) Non-renewable Primary Energy Demand (PENRT)
4. Parts of the Building Assessed	Varies by method: Partial: • External and basement walls • Roofs • Internal floors and celinigs • Ground-level floor • Foundations • Internal walls • Load bearing structure	• Cost Groups 300, 400 • Material that make up more than 1% of the total mass of the building

	Simplified: • External and basement walls • Roofs • Internal floors and celinigs • Ground-level floor • Foundations • Internal walls • Heating and cooling systems • Other building installations Complete • Material that make up more than 1% of the total mass of the building	
5. Database	A database that satisfies DIN EN 15084. Example: IBU, Ökobaudat	QNG – LCA calculations table, which includes the environmental impacts based on cost groups elements

STATE OF THE ART

3.1. LITERATURE REVIEW

The construction industry is currently shifting towards digital transformation, where Building Information Modelling is considered as a crucial methodology to address the high fragmentation and information intensity of a sector. BIM enables a common environment for collaborative management of data types such as project design, material flow, performance and operation. Therefore, the methodology facilitates communication among the involved stakeholders, reduces the risk of error, and supports informed decision making in design and materials selection, resulting in project decarbonization through its lifecycle (Mitera-Kielbasa & Zima, 2024; Panteli et al., 2020). Nevertheless, BIM adoption in the industry is still limited. Wiesneth (2022) reports that the number of practitioners in medium and large construction entities in Germany that actively applies BIM in their project does not exceed 20%. Among the primary barriers for BIM integration are resistance to change, lack of professional skills, lack of relevant guidelines, and ineffective contractual forms (Charef et al., 2019). These challenges contribute to the continued predominance of fragmentation and low-productivity of project workflow, hindering the sustainable development and innovation of the sector.

Meanwhile, Life Cycle Analysis is gaining a wider recognition as an effective method for numerically evaluating the environmental performance of construction projects through the life cycle stages. Multiple studies reveal the LCA's contribution to the effectiveness of decision-making during the design and construction stages. The case study of Dsilva et al. (2023) showed that the application of LCA for structural materials selection during the pre-construction phase could achieve 26% of reduction in building's embodied carbon, prioritizing concrete and steel materials with recycled and by-product compounds. Another study of Cheng et al. (2020) illustrated the application of LCA for a design phase of Guangdong Inkstone Culture Museum, where the GHG of a wide range of construction materials were compared, and the alternatives with lower emission were applied in the project. LCA allows to make effective decisions not only based on emissions, but also considering human health, resource consumption and influence on ecosystem (Najjar et al., 2022).

Although LCA shows a positive impact on environmental performance, the complexity of construction projects, particularly a wide scope of building design and material selection, introduces a high uncertainty in comparison and justification of outcome results (Feng et al., 2022). When relying on conventional CAD modelling, the analysis processes, such as quantity surveying, are conducted manually, increasing the time, human error, and reducing the output accuracy (Cheng et al., 2020). In addition, the LCA estimation significantly vary based on data inputs, study methodology, and databases. Chastas et al. (2018) states that the application of different environmental databases can result in around 50% deviation of LCA outcomes. Therefore, transparent and consistent LCA guidelines are required to improve the estimation accuracy and reliability (Dsilva et al., 2023).

In recent years, the integration of BIM and LCA has been investigated by multiple studies, proposing BIM framework as a solution for LCA outcomes inconsistency and sensitivity. The studies highlight the primary advantages of BIM-LCA integration as automated extraction of material quantities, reduced manual input, faster analysis workflow, and higher precision of quantity takeoff and environmental impacts assessment at early-stage design and construction stage (Cheng et al., 2020; Kumar et al., 2025; Palumbo et al., 2020a). The BIM-based estimation tool enabled an automated estimation of embodied carbon and benchmarking with RIBA climate change targets through the IFC file export (Alwan & Ilhan

Jones, 2022). Another study applied a BIM-based LCA approach for a prefabricated building analysis and highlighted over 90% of analysis time reduction compared to the conventional LCA methodology (Xu et al., 2022). Regardless of the noticeable advantages of BIM-LCA approach, the majority of the solutions involve manual and semi-automated processes, as well as lack consistent project information transfer (Safari & AzariJafari, 2021).

One of the major challenges in BIM-based LCA approach is the lack of consistency of information exchange. While the data exchange process is the most crucial aspect of BIM-LCA integration, it remains limited due to immature semantic data in a BIM model. According to studies, current BIM application often lacks the appropriate level of details at different project stages, which restrains the robust impact assessment (Palumbo et al., 2020b; Safari & AzariJafari, 2021). Fnais et al. (2022) states that BIM often do not contain information necessary for the environmental evaluation. Identifying the necessary Level of Development (LOD) is studied as a solution to enhance BIM model maturity for LCA purposes. Through the alignment of LCA with LOD, a higher completeness of information for environmental data matching and estimation can be achieved (Kumar et al., 2025; Palumbo et al., 2020).

In addition, the issues of limited interoperability between the BIM and LCA tools is often observed in multiple studies. Although such technologies as BIM has a great potential to improve the precision and consistency of LCA at the project early-stage, the current stage of the BIM and LCA software development still requires enhanced interoperability, understandable interface, and methodological standards to provide consistent results and expand the BIM-LCA industry adoption (Kumar et al., 2025). In addition, the study of (Lu et al., 2019), revealed the critical issue of data loss during the information export from BIM to LCA software. While exporting the BIM model from Revit to GTJ2018, the loss of information related to building materials and elements were identified in the study outcomes.

Other studies suggest that the application of IFC for data exchange can support a structured, vendor-neutral data export from BIM to LCA (Xu et al., 2022). Thießen et al. (2020) applied the BIM-LCA integration through IFC to enhance the automation of the whole building LCA analysis in the context of German BNB building evaluation system. In another study of Horn et al. (2020), IFC was utilized as a data exchange method between BIM and LCA software to improve the data availability at the project's early stage. However, the studies highlight the lack of IFC capabilities for wider application due to missing entities, attributes and properties in the scheme, as well as interoperability issues with other LCA and BIM software (Thießen et al., 2020; Horn et al., 2020).

Another noticeable limitation in BIM-LCA workflow is limited and inconsistent auto mapping between the BIM elements and the environmental data. In the study of Durão et al. (2020), it was identified that the environmental data is often cannot be properly linked to the BIM object due to the limited software capabilities. This requires the user to conduct manual mapping, which decreases the analysis' time efficiency and increases the risk of error. Safari & AzariJafari (2021) highlights that without effective auto-mapping method, the analysis relies heavily on the practitioners' competences in building materials and environmental databases.

Although GBRS are globally applied as a comprehensive framework for building environmental performance evaluation, they include inefficient and unclear guidelines for LCA, particularly in boundaries for a system and building elements (Chandrasekaran & Dvarionienė, 2022). In addition, different systems provide varying LCA requirements and assessment methods. According to Feng et al. (2022), this issue limits the comparability of the whole building LCA outputs. Another study of Del Rosario et al. (2021) revealed the 50% difference in GWP estimation outputs, caused by the difference in LCA framework of Level (s) and DGNB systems. Therefore, an alignment between LCA methodology and GBRS is crucial to ensure the reliability of LCA outcomes and justified decision-making.

3.2. GAPS AND LIMITATIONS

- According to the literature review, several core gaps and limitations that hinders the effective integration and wider adoption of BIM and LCA have been identified:
- **BIM Low Industry Adoption:** Although BIM shows a high potential for the AEC industry, the adoption of the methodology among the practitioners remains limited. This is caused by such noticeable barriers as resistance to change and lack of professional skills. This primary limitation highlights the necessity for more efficient training of practitioners and industry-wide standards to enable BIM and BIM related workflows, including BIM-LCA.
- **Insufficient Semantic Richness in BIM Models:** Current practices for BIM model development provide the models that have sufficient geometrical but low semantical level of information for environmental assessment. BIM models often have a inconsistent and inadequate Level of Development or lack the information necessary for effective and robust LCA. This gap underscores the need for protocols and rulesets for model standards that will guide the practitioners and support the inclusion of required model parameters.
- **Interoperability problems between a BIM and LCA software:** The data export from a BIM tool to an LCA software is often characterized with interoperability challenges, which result in data loss. The required information regarding the materials and elements can be lost or corrupted during the export process. Therefore, more comprehensive data exchange guidelines and schemas are crucial for efficient interoperability between LCA and BIM tools.
- **Unreliable Automated Data Mapping:** A major challenge in the BIM-LCA workflow is limited capabilities of LCA software to automatically label the BIM elements with appropriate environmental data. Many LCA processes still rely on manual mapping, which is often time-inefficient, increases the risk of human error, and significantly rely on practitioners' expertise. This gap highlights the need for more efficient mapping procedures and algorithms integrated to the LCA software.
- **Inconsistent Methodologies and Benchmarking Standards:** The LCA process is highly affected by the LCA methodology and environmental databases. Meanwhile, multiple Green Building Ranking Systems provide different guidelines and rely on different databases, which significantly increases the deviations of LCA outcome and complicated the comparison for one or between other projects. There is a clear need for harmonized and aligned LCA methodologies to provide the practitioners with more consistent and comparable results.

Finding solutions for these limitations is important for expanding the practical adoption of BIM and LCA in the construction industry. The aim of this study is to address some of these gaps by developing a framework for improving data consistency of information export from BIM to LCA tool and automating the data labelling processes. Therefore, the study will contribute to the more reliable, efficient and consistent BIM-based environment performance evaluation.

METHODOLOGY

4.1. SCOPE OF STUDY

Based on the conducted literature review, the aim of this study is to address the interoperability gap between the BIM and LCA software tools, particularly focusing on the standardization and consistency of data transfer from the BIM tool to the LCA tool. Therefore, the main objective of the study is not to conduct a whole-building LCA, but to define and design a methodological framework for the data exchange that precedes the analysis. Through the study, the focus will be concentrated on the initial stage of data preparation and export, which are considered as primary challenges for interoperability issues. The primary focuses included to the scope of the study are illustrated in Figure 16.

The scope of the research is based on two primary areas:

1. **Defining information requirements for an “LCA-Ready” BIM Model:** the study will define the essential attributes of a BIM model to be properly developed for LCA. In particular, the specific element and material properties and attributes that must be included to the BIM model to promote an accurate assessment will be identified.
2. **Establishing Standardized Data Export Rules and Settings:** the second primary aspect will focus on the important process of data transferring from the BIM software to the professional LCA software. As an output, the study will establish a clear set of rules and procedures to ensure the data consistency and avoid information loss.

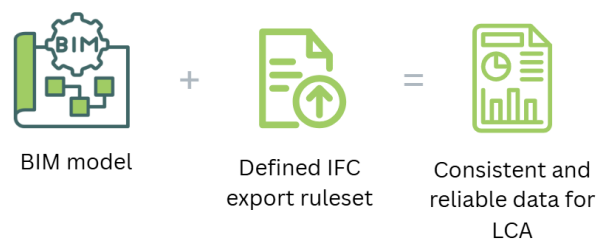


Figure 16.Scope of the study

4.2. APPROACH OBJECTIVES

By following the study approach, the objective is to provide AEC practitioners with an overview of an LCA workflow based on a BIM model. By demonstrating a practical application of BIM-based LCA framework, the study will discover the critical processes and highlight the aspects of a model development and data transfer required to achieve reliable and consistent LCA results. Therefore, the approach will serve as a practical guide, describing the step-by-step processes of shifting from conventional, often manual LCA workflow to a more automated and integrated LCA analysis, and providing a roadmap for practitioners seeking to adopt the BIM-based LCA workflow for integration into certification systems evaluation.

4.3. METHODOLOGY WORKFLOW

The methodology workflow of this study for integrating Building Information Modelling with Life Cycle Analysis is designed in a structured, iterative process and consists of 2 main blocks. Throughout the workflow, the initial preparation, adjustment and validation of IFC models are observed.

In Block 1, the initial setup and preliminary evaluation of the BIM-LCA workflow is conducted. A BIM building model is designed through Autodesk Revit, which is further exported to the IFC format. Further, the IFC model checking is conducted using Solibri to evaluate the consistency and completeness of the data. The checked model is then imported to the CircularLCA software for environmental performance analysis. This stage enables to conduct a preliminary LCA-BIM workflow application, identifying limitations in model's setup and export configuration. Analysing the preliminary data import quality, the improvements are suggested and applied in Block 2. At this stage, an export ruleset is developed to enrich & adjust the BIM model, establish a standardized export process, and check the exported model before the import. Thus, the data import quality to the CircularLCA is ensured, and the final model is imported to the software for the final data import quality evaluation and environmental data mapping.

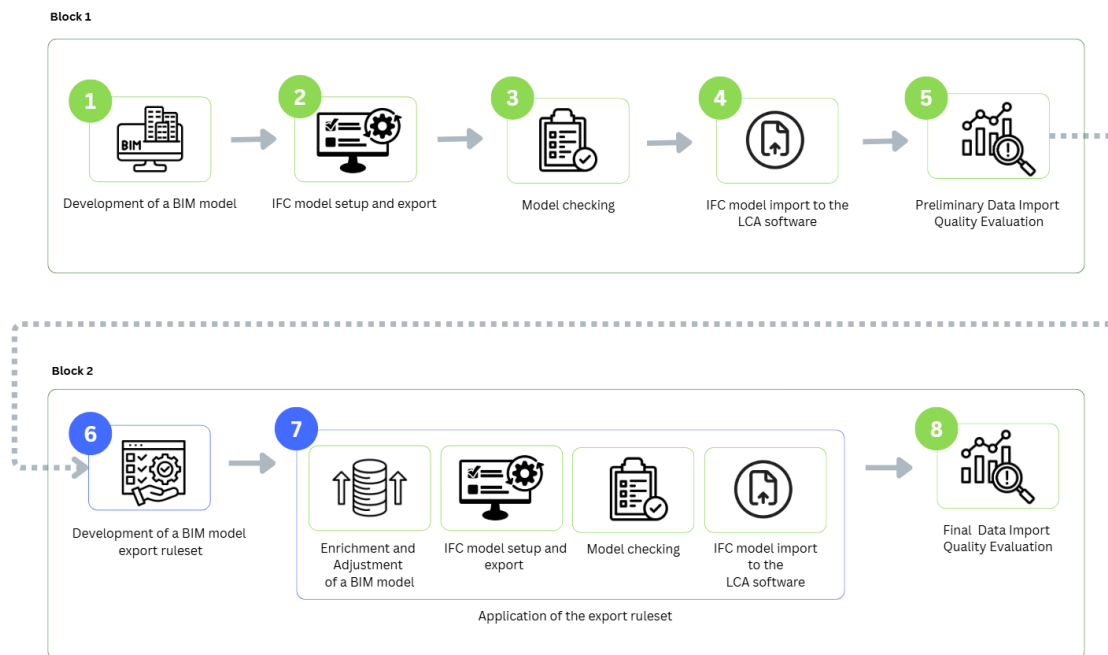


Figure 17. Study methodology workflow process

4.3.1. DEVELOPMENT OF A BIM MODEL

The first step of the study is to develop a BIM model that is based on a real-life case of a residential building currently under construction. The model is developed using Autodesk Revit and serves as a primary digital representation of geometric and semantic information for further study analysis and LCA integration. The 2 central sources of the model are 2D architectural drawings, which include floor plan and elevation views and provide the spatial and geometrical basis for the building components, and a building element catalogue (Bauteilkatalog), which contains the quantity takeoff of construction systems and elements. According to these files, the scope of the building **elements, materials and properties** enriched into the model are identified. Due to the time limits of the study, it is decided to consider only architectural system of a building.

To ensure the relevance for future building certification assessment, the scope of the elements and materials in the model is aligned with the LCA requirements set by QNG and DGNB certification systems. The scope of the BIM model development is illustrated in Figure 18.

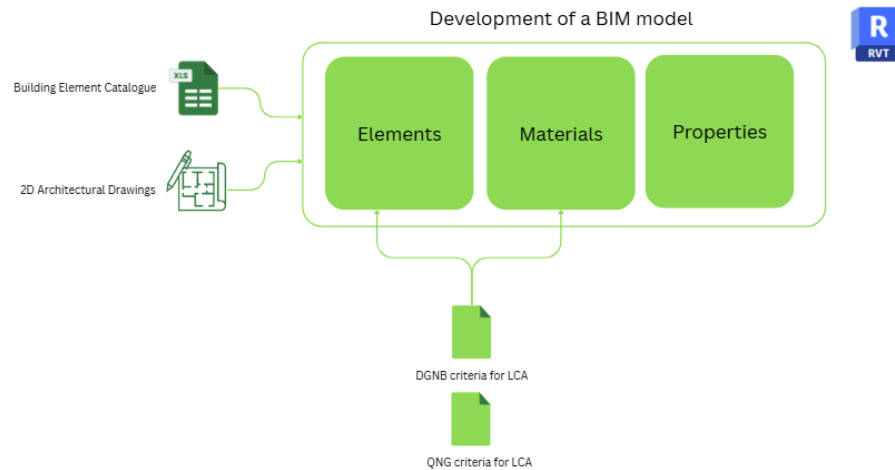


Figure 18. BIM model development procedure

4.3.2. IFC MODEL SETUP AND EXPORT

After the BIM model is developed, the next stage involves the setting of export properties from Revit to IFC format aligning with the requirements of the CircularLCA software. The setup stage is important for ensuring that the data included to the BIM model, including information on common properties and quantities of elements and materials, is successfully transformed to the IFC model. Therefore, the CircularLCA requirements of semantic information types which are received by the software are considered.

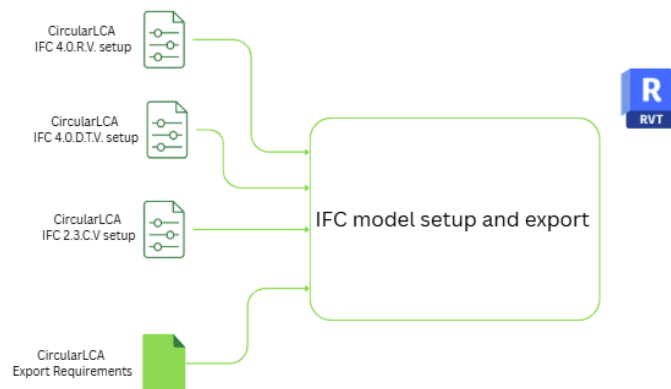


Figure 19. IFC model setup and export procedure

4.3.3. IFC MODEL CHECKING

When the BIM model is exported to the IFC format through a particular configuration (IFC 4.0 Reference View or IFC 2x3 Coordination View), it is imported into Solibri software for model checking. At this stage, a custom check ruleset is developed to evaluate the consistency and completeness of the semantic data in an IFC model. The ruleset evaluates all the modelled building objects according to the information required for the environmental analysis.

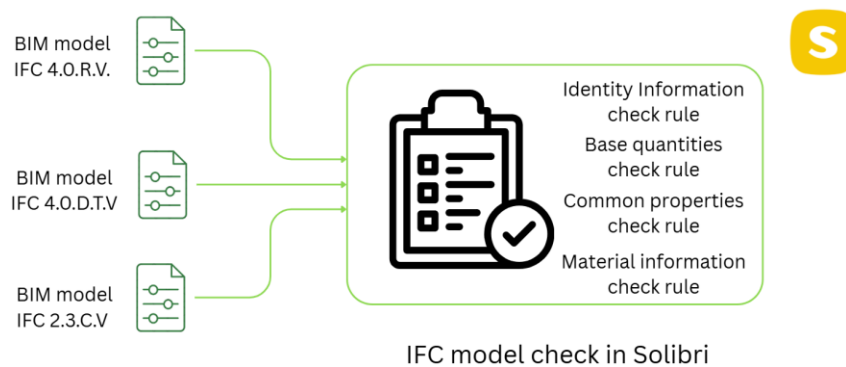


Figure 20. IFC model check procedure

4.3.4. IFC MODEL IMPORT TO THE CIRCULARLCA

After the model check in Solibri, the model is imported into the CircularLCA software for further processing. During the import process, the software parses the semantical information to establish material quantities and predefined properties for the model's elements. As a result, the user receives the list of elements with corresponding properties, as well as a 3D visualisation of a model. At this stage, it is important to validate the results from Solibri model check and report other data losses if occurred.

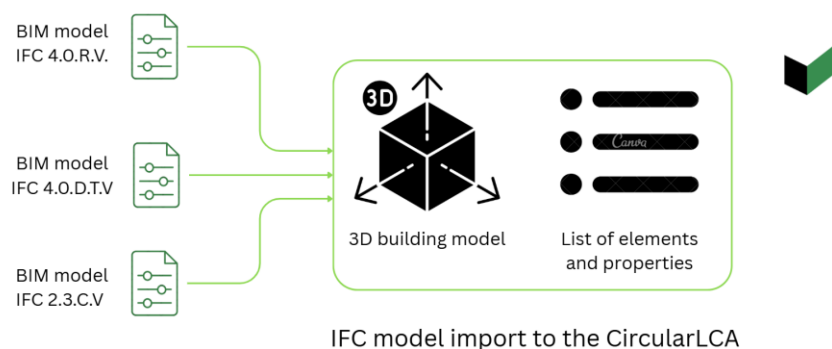


Figure 21. IFC Model import procedure

4.3.5. PRELIMINARY DATA IMPORT QUALITY EVALUATION

Based on the results from Solibri and CircularLCA, a structured evaluation of data import quality is conducted to identify limitations in the BIM-to-IFC-to-CircularLCA workflow. This evaluation aims to assess the consistency and completeness of semantic data imported into the CircularLCA software from various IFC model versions.

To perform this evaluation, a custom comparison matrix is developed in Excel. The matrix includes a selected set of building elements from the case study project and covers the four key categories of semantic information interpreted by CircularLCA:

- Identity Data
- Base Quantities
- Common Properties
- Material Information

For each element and data category, the quality of import is visually classified using a three-level color code:

- **Green:** Fully imported and correctly interpreted
- **Orange:** Partially imported or inconsistently interpreted
- **Red:** Not imported or not interpretable by the software

This qualitative method enables the identification of data gaps in the established data types for the considered elements. The assessment is applied separately to three IFC versions supported by CircularLCA (IFC 2x3 Coordination View 2.0, IFC 4.0 Reference View, and IFC 4.0 Design Transfer View), allowing for a comparative evaluation.

If an element appears with missing or partial data, it is further examined to identify root causes. These findings inform the subsequent development of targeted modelling recommendations and property mapping strategies used in the ruleset definition.

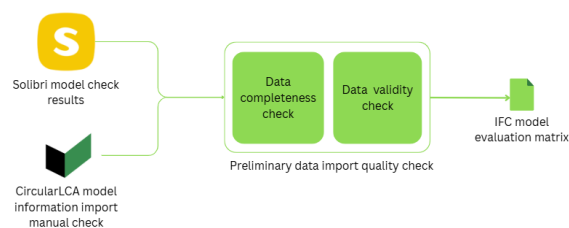


Figure 22. Preliminary software application procedure

4.3.6. BIM MODEL EXPORT RULESET DEVELOPMENT

Based on the insights gathered during the preliminary evaluation of IFC data import quality, a BIM export ruleset is developed to enhance the consistency, completeness, and reliability of data transferred from Revit to CircularLCA. The primary objective of the ruleset is to address observed data gaps and to provide a standardized framework that improves the semantic alignment between BIM models and LCA software.

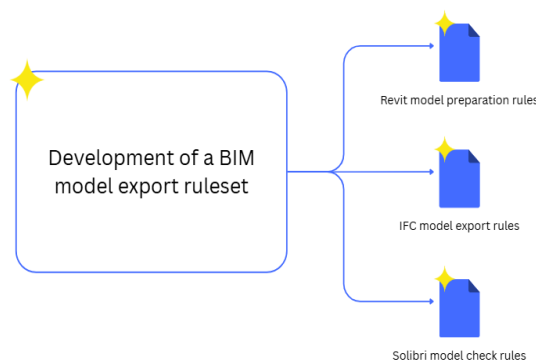
The ruleset is structured across three stages of the BIM export process: **before export**, **during export**, and **after export**. Each stage includes specific recommendations and technical instructions aimed at minimizing data loss and ensuring compatibility with the IFC schema and CircularLCA import requirements.

This structured ruleset ensures that the exported IFC model is not only compatible with CircularLCA's interpretation logic but also robust in terms of semantic completeness and reusability. The next step involves applying the developed ruleset to the case study model to test its effectiveness.

The first part of the ruleset includes the procedures and recommendations to be implemented to the BIM model **before the export** process. This includes selection of the IFC model aligned with the model, analysis and adjustment of building elements according to the modelling requirements, definition of the required and optional properties and introduction of the custom properties that enriches the model with the data missing during the preliminary evaluation. Moreover, these rules define the labelling map for the model properties to be properly assigned and allocated for further export to the IFC model.

The next part of the ruleset provides the crucial steps to be considered **during the export**, which is selection of an appropriate IFC export setup, ensuring the export of the desirable properties, and application of the user-defined export configuration for the custom properties export.

After the export of the model, the ruleset implements the model checking step, in which the custom model checking ruleset is applied in Solibri to verify that the desirable properties are included and defined in the IFC model.



4.3.7. EXPORT RULESET APPLICATION

Once the ruleset is defined, it is applied to a BIM model developed for the case study project. The application focuses on architectural and structural elements aligned with DGNB and QNG LCA requirements. IFC 2x3 Coordination View 2.0 is selected as the target export format based on its compatibility with the model structure and preliminary performance. The structured three-stage export procedure ensure that the initial model is adjusted and enriched with the required level of semantic data, correctly exported to the IFC format, and verified through the model checking procedure before importing it to the software

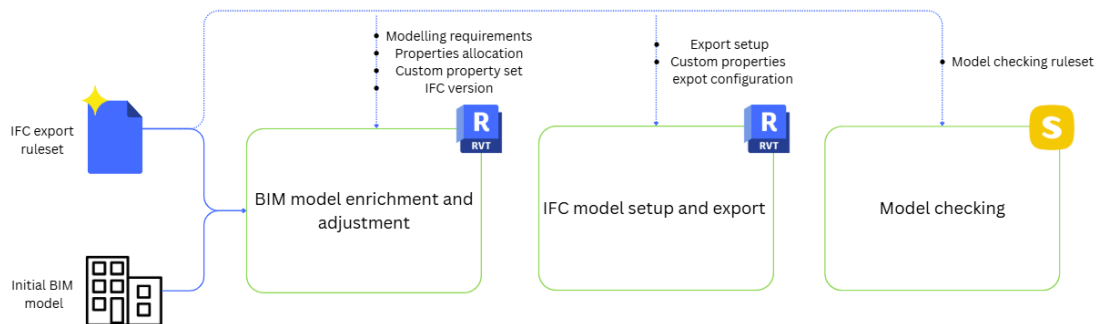


Figure 23. Export ruleset application procedure

4.3.8. FINAL DATA QUALITY IMPORT EVALUATION & ENVIRONMENTAL DATA MAPPING

Following the application of the BIM export ruleset, a final evaluation of data import quality is conducted to assess the effectiveness of the proposed methodology and verify the readiness of the IFC model for environmental assessment. The goal is to determine whether the model now contains complete and correctly interpreted semantic information necessary for Life Cycle Assessment (LCA) within the CircularLCA platform.

This final evaluation serves as a critical control point in the methodology, confirming whether the modeled elements, assigned properties, and applied export settings have effectively addressed previously observed issues. The outcome provides empirical evidence of the improvements achieved through the use of the ruleset.

In parallel, the environmental data mapping process is initiated within CircularLCA. The software provides two methods for linking model data to environmental product declarations (EPDs): AI-based auto-mapping and rule-based mapping. Based on earlier observations of AI mapping limitations, only the rule-based approach is considered in this study. The rule-based mapping allows the user to define conditional relationships between BIM properties (e.g., material name, KG DIN 276 code, EPD name) and database entries using a configurable set of logical operators.

The success of this mapping process depends directly on the availability and consistency of custom properties assigned during modeling. Therefore, the completeness of environmental mapping is evaluated qualitatively by testing selected rules and verifying if the model data enables automatic linkage to appropriate EPDs. This final step validates the ability of the BIM model to support LCA automation and highlights any remaining limitations in semantic alignment or schema constraints.

5

CASE STUDY

5.1. CASE OVERVIEW

5.1.1. PROJECT DESCRIPTION

The case study is based on the Parkblick project, which involves the construction of a multi-family residential building located in Leipzig, Germany. The development program includes 26 private apartments, 6 vehicle parking spaces, as well as commercial spaces on the ground floor. The project is designed following modern architectural standards and technical guidelines, emphasizing both aesthetic and sustainable solutions. By the time of the study, the project was on the construction stage (woscim, 2025).

Throughout the project development, sustainability strategies play a vital role. The building design aligns with the Effizienzhaus 40 standard under the German Building Energy Act (GEG 2024) and aims to achieve the Qualitätssiegel Nachhaltiges Gebäude Plus (Sustainable Building Quality Seal Plus) and DGNB Silver for New Construction Buildings labels.



Figure 24. Parkblick rendered model. Source: woscim. (2025). woscim . <https://www.woscim.de/>

5.1.2. BASIC DIMENSIONS AND USE

Parkblick is a mixed-use development, combining residential, commercial, and utility spaces. Residential use spans multiple floors, while the basement includes storage and building services, and the ground floor features adaptable commercial units. Figure 25 illustrates the floor plan of the first floor that includes residential units, and Table 10 provides detailed description of project's dimension, use type, and applied materials.



Figure 25. 1st Floor Plan. Source: woscim. (2025). woscim . <https://www.woscim.de/>

Table 10. Parkblick project description (woscim, 2025)

Basic dimensions	
Gross Floor Area (GFA)	3,575.9 m ²
Net Room Area (NRA)	2,996.66 m ²
Num. of residential units	26
Parking spaces	6 (3 prepared for Electric Vehicles charging)
Floor height	3 m
Building use by level	
Basement	Technical and utility rooms (HVAC, electrical) Tenant storage units Bicycle and stroller room
Ground Floor	Commercial space Parking spaces
1st – 6th floor	Residential units with balconies/loggias
Materials used	
Structural & outer walls	Reinforced concrete, sand-lime brick, aerated concrete
Slabs	Basement – Waterproof reinforced concrete Ground floor – 6th floor -reinforced concrete
Facade	Plaster facade with classic decorative elements, belts and cornices, grooves, and plaster mirrors
Interior walls	Reinforced concrete, sand-lime brick, or gypsum stud walls
Interior finishes	Plaster
Windows	Triple-glazed PVC with sun protection and electrical shading system
Flooring	Living areas: Multi-layer oak parquet Wet rooms: Ceramic tiles Balconies/Loggias: Siberian larch or composite decking
Roof	Pitched roof – wooden construction with concrete tiles Flat roof – reinforced concrete covered with bituminous

5.1.3. SUSTAINABLE PRACTICES

The building project incorporates a comprehensive set of sustainable measures to achieve energy efficiency, indoor climate, and overall environmental performance. which are described in Table 11.

Table 11. Parkblick sustainability measures

Sustainable measures	Description
Energy efficiency certification	GEG Energy level A+ Effizienzhaus 40
Green building certification (intended)	QNG Plus DGNB Silver
Renewable energy	Rooftop photovoltaic system with battery storage
Heating & cooling systems	Air-to-water heat pump Low-temperature system with underfloor heating and individual room control
Ventilation	Centralized mechanical ventilation with heat recovery Fresh air supplied to all rooms via filtered ductwork
Rainwater infiltration	Rainwater infiltration system installed in the inner courtyard

5.2. METHODOLOGY APPLICATION

5.2.1. DEVELOPMENT OF A BIM MODEL

The study methodology, which is described in Chapter 4, was applied to the Parkblick project to test its efficiency and observe the BIM-based LCA workflow in real case study. To begin the modelling process, two core sources of information were received:

1. Building Element Catalogue (BTK)(Figure 26): this source contained the detailed information about the building elements. This included Cost Groups (KG DIN 276), Element Number (Bauteil-Nr), Name of technical system and component layers (Bauteilschichten bzw. Name der technischen Anlage), Discipline (Gewerk), Layer Thickness (Schichtdicke), Area (Fläche), Volume (Volumen) and Number of Elements (Anzahl der Elemente).
2. 2D Architectural drawings (Figure 25): this source included floor plans, elevation views, and sections cuts in PDF and DWG formats. This information was applied to interpret geometrical configuration of the building and the elements.

KG DIN 276 - (1. - 3. Ebene)	Bauteil-Nr. + Schicht- Bezeich.	Bauteilschichten bzw. Name der technischen Anlage	Gewerk	Schicht- dicke m	Fläche m2	Volumen m3	A E
	AW 03	Außenwand Gasporenbeton		0.514	900.00	507.600	
335 Außenwandbekleidungen außen	A	Kalk-Zement Leichtputz	Außenputz	0.02	900.00	18.000	
331 Tragende Außenwände	B	Wärmedämmziegel / Porenbeton Ytong	Rohbau	0.48	900.00	432.000	
331 Tragende Außenwände		Zement-Dünnbettmörtel	Rohbau	0.000	900.00	45	
336 Außenwandbekleidungen innen	C	Aufbrennsperre	Innenputz	0.001	900.00	0.900	
336 Außenwandbekleidungen innen	D	Innenputz Kalk-Gips	Innenputz	0.01	900.00	9.000	
336 Außenwandbekleidungen innen	E	Grundierung	Maler	0.001	900.00	0.900	
336 Außenwandbekleidungen innen	F	Malervlies	Maler	0.001	900.00	0.900	
336 Außenwandbekleidungen innen	G	Anstrich	Maler	0.001	900.00	0.900	
	AW 04	Außenwand Giebelwand Dieskastr.		0.273	223.44	60.999	
335 Außenwandbekleidungen außen	A	Kalk-Zement Leichtputz	Außenputz	0.020	223.44	4.469	
331 Tragende Außenwände	B	Kalksandstein	Rohbau	0.240	223.44	53.626	
331 Tragende Außenwände		Kalk-Zementmörtel	Rohbau		223.44	11.172	
336 Außenwandbekleidungen innen	C	Innenputz Kalk-Gips	Innenputz	0.010	223.44	2.234	
336 Außenwandbekleidungen innen	D	Grundierung	Maler	0.001	223.44	0.223	
336 Außenwandbekleidungen innen	E	Malervlies	Maler	0.001	223.44	0.223	
336 Außenwandbekleidungen innen	F	Anstrich	Maler	0.001	223.44	0.223	

Figure 26. Example of external walls description in Building Element Catalogue. Source: woscim. (2025). woscim . <https://www.woscim.de/>

Woscim was developing the LCA Analysis for the project to achieve the QNG and DGNB certification system labels targeted by the developer. Therefore, it was important to ensure that the developed BIM model aligns with the requirements of the certification systems. It was decided to frame the scope of the building elements according to the DGNB and QNG guidelines for LCA analysis. Due to the limitation in time of the study, it was also agreed to apply these requirements to the architectural and structural elements only. The details on DGNB and QNG elements scope requirements are provide in Table 12. The list of elements included to the building model is provided in Annex A-1.

Table 12. DGNB and QNG LCA analysis element scope requirements (DGNB, 2025; QNG, 2025)

	DGNB	QNG
4. Parts of the Building Assessed	Complete Estimation Method - Materials that make up more than 1% of the total mass of the building. In total, the ignored materials/material groups must not make up more than 5% of the mass of the entire building. - The following applies to plastics and products made from renewable raw materials: The total primary energy demand (PE_{tot}) of the material is more than 2% of the total primary energy demand of the building (only construction, incl. production, maintenance and end-of-life). In total, the ignored materials/material groups must not make up more than 5% of the total primary energy demand of the building. - The following applies to coatings: The summer smog potential (POCP) is greater than 2% of the summer smog potential of the building. In total, the ignored materials/material groups must not make up more than 5% of the summer smog potential of the building.	- Cost Groups 300, 400 - Materials that make up more than 1% of the total mass of the building. In total, the ignored materials/material groups must not make up more than 5% of the mass of the entire building.

After the information was received and the scope was identified, the modelling in Autodesk Revit Software started. Due to the fact that BTK and 2D drawing were provided in German, the German Revit project template (BIM_Architektur_und_Ingenieurbau), while the element modelling was based on the Generic German Revit Family Library. Such an approach was chosen to achieve consistent terminology of semantic information. Once the template was set, the building elements were created with corresponding properties from the BTK: Number of the element, Name of technical system, physical dimensions (Figure 27). Material layers and thickness were input using Edit Assembly function in Revit (Figure 28).

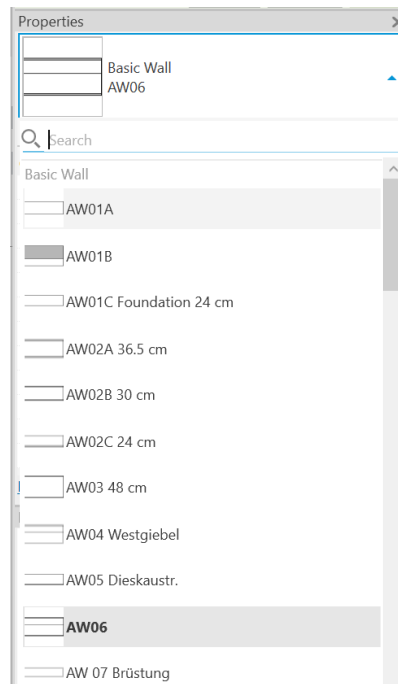


Figure 27. Example of project building elements in Revit

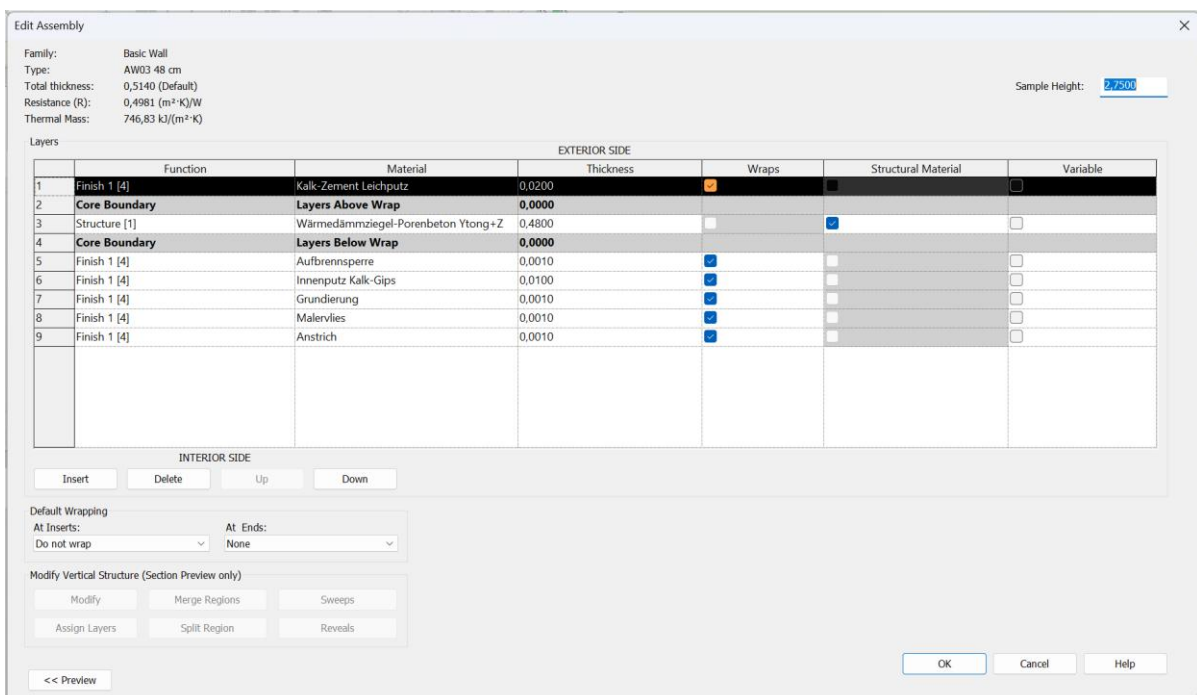


Figure 28. Example of material assembly of an external wall

With the help of the Autodesk Revit feature to import the 2D drawings to the model, the floor plans were imported and assigned to corresponding level as a reference for element placement (Figure 29). The process of the modelling of the 1st floor elements is illustrated in Figure 30.

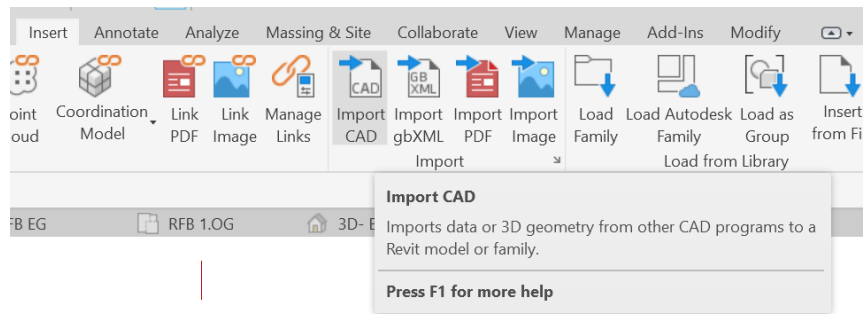


Figure 29. CAD file export feature in Revit

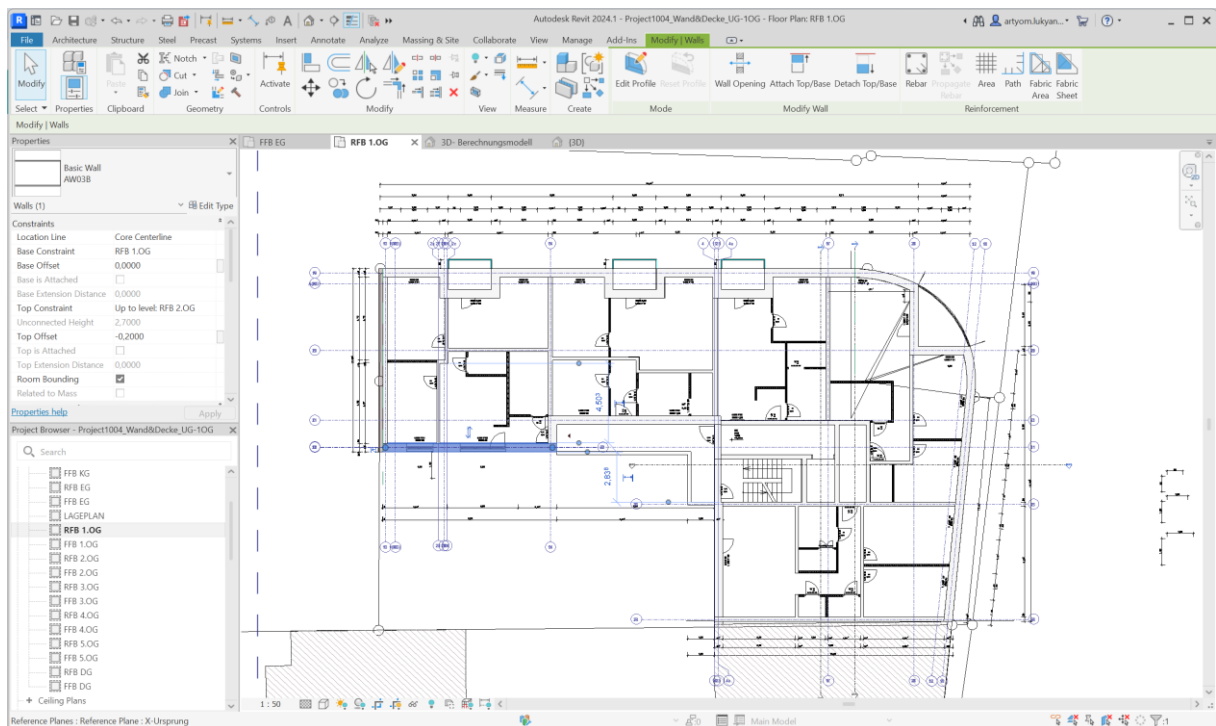


Figure 30. 1st floor modelling process based on imported CAD drawings

The resulted BIM model is illustrated in Figure 31, Figure 32, and Figure 33, which served as a base for further export and environmental assessment in CircularLCA software.

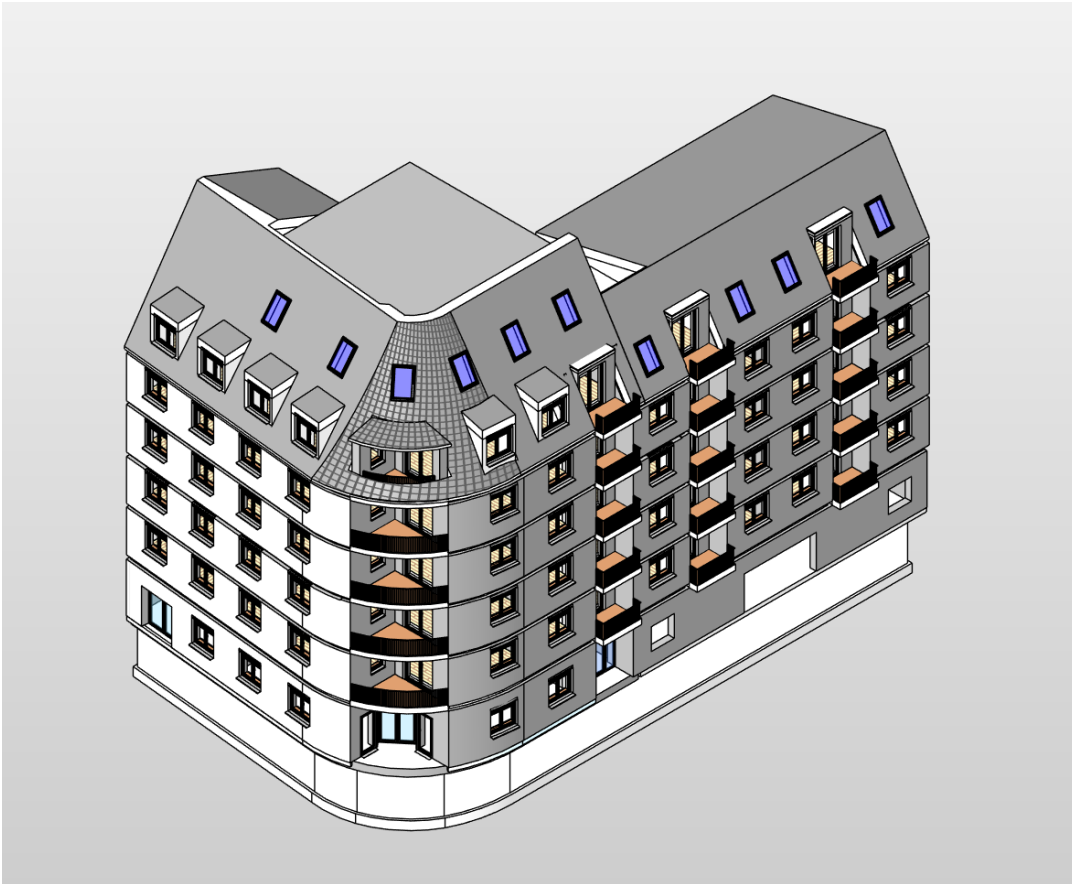


Figure 31. BIM model 3D view



Figure 32. BIM model floor plan view



Figure 33. BIM model elevation view

5.2.2. IFC MODEL SETUP AND EXPORT

To prepare the model for the export to the IFC format, the IFC export guidelines suggested by Concular were reviewed to evaluate if the BIM model and the export setup satisfy the data interpretation logic of the CircularLCA tool (Concular, 2025). The guideline covers such export aspects as the **types of data exported** to the LCA software, **the applicable IFC versions**, and **export instructions** for various BIM modelling software, including Revit.

According to the Concular guideline (Concular, 2025), the 5 groups of semantic data that are accepted and interpreted by the software were identified and described in Table 13. Since such information type as Material Flow and Pset_Concular are intended to evaluate the circularity of the elements, which is not included in the scope of the study, those types of information were excluded from further analysis.

Table 13. Types of data interpreted by CircularLCA software. Source: Concular

Type of data	Description
Identity Data	Basic identification information of a particular element, such as IFC Class and Element Name.
Base Quantities	The geometrical measurements of a particular element. The values are exported using the Quantity Set concept (with a Qto_ prefix), which are structured collections of quantity data.
Common Properties	The non-geometric properties that define various functions and characteristics of an element. They are exported using Common Property Sets (Pset_), which are available for most IFC entities. As an example, Pset_WallCommon contains properties like IsExternal (True/False), LoadBearing (True/False).
Material Information	The material composition of an element, including the name and the thickness. The data is exported through IfcMaterialDefinition entity.
Material Flow	The phase of an element related to the lifecycle (new, existing, demolish, temporary). This data is exported through the Status Common Property.
Pset_Concular	The custom property set developed by Concular, which defines the circularity properties of an element. Includes such properties as Reusability, Separability, Deconstruction and Preuse.

After the required data types were identified, each element was manually checked to reveal if it contains the relevant properties. If a parameter was not present or not properly assigned, the BIM model was adjusted in Revit. As an example, CircularLCA recommends to define the status of a wall, such as IsExternal and IsLoadBearing.

Another aspect of IFC export that is covered in the guideline is the supported IFC versions. In particular, the guideline provide recommendations on the selection of MVD and export of multi-layered elements. According to the guidelines, the following IFC versions and the characteristics are defined:

- **IFC 2x3 Coordination View (Official):** the multi-layered elements are properly exported to the software
- **IFC 4.0 Reference View (Official):** for a proper export of the multi-layered elements, the separation of the layers is necessary
- **IFC 4.0 Design Transfer View (Official):** the multi-layered elements are properly exported to the software

Together with the versions description, Concular provides the export setups for each IFC version described above (Figure 34). Each setup defines the rules that frame the elements and properties exported to the IFC. According to Concular, the primary factors that have to be considered during the export are the Model View Definition (MVD) and property sets. For the proper import to the IFC model, the base quantities and common properties must be exported, while the other properties (Revit Properties, User Defined Properties) are optional (Concular, 2025). Using these setups, the developed BIM model was exported to the corresponding IFC versions for further analysis. In case of IFC 4.0 DTV, the setup was not properly defined, therefore was adjusted manually.

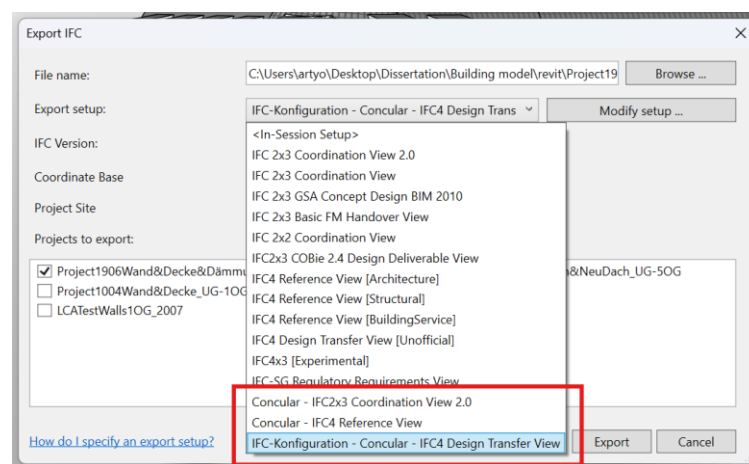


Figure 34. IFC export through Concular export setup

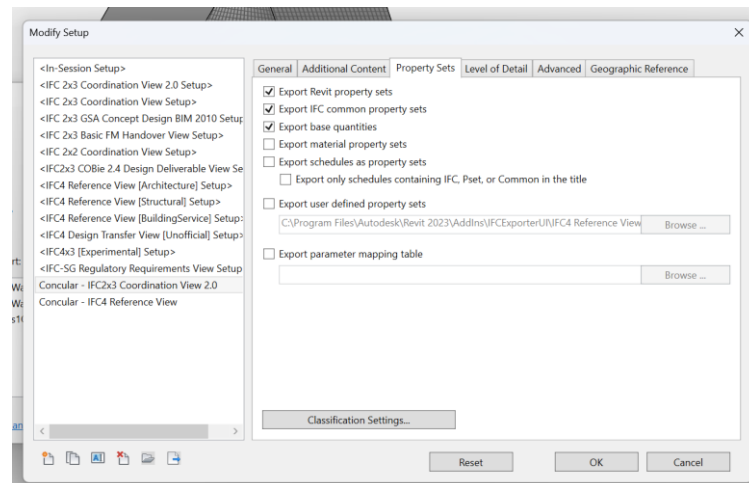


Figure 35. Property sets exported through Concular export setup

5.2.3. MODEL IMPORT TO SOLIBRI SOFTWARE

To ensure the data required for the LCA analysis in CircularLCA is present, consistent and complete in the IFC model, the model check was conducted using Solibri software. In the software, the checking rules for each data type (identity data, base quantities, common properties, material information) were

established for every element category. Figure 36 provides a list of the established rules and Figure 37 illustrates an example of the base quantities check for the wall elements.

▼ CircularLCA_IFCFileCheck		
§ Wall_BaseQuantitiesCheck	SOL/203/2.5	①
§ Wall_CommonPropertiesCheck	SOL/203/2.5	②
§ Wall_IdentityDataCheck	SOL/230/1.1	③
§ MaterialCheck	SOL/230/1.1	④
§ Column_BaseQuantitiesCheck	SOL/203/2.5	⑤
§ Column_IdentityDataCheck	SOL/230/1.1	⑥
§ Column_CommonPropertiesCheck	SOL/203/2.5	⑦
§ Slab_BaseQuantitiesCheck	SOL/203/2.5	⑧
§ Slab_CommonPropertiesCheck	SOL/203/2.5	⑨
§ Slab_IdentityDataCheck	SOL/230/1.1	⑩
§ Roof_BaseQuantitiesCheck	SOL/203/2.5	⑪
§ Roof_CommonPropertiesCheck	SOL/203/2.5	⑫
§ Roof_IdentityDataCheck	SOL/230/1.1	⑬
§ Windows_IdentityDataCheck	SOL/230/1.1	⑭
§ Windows_BaseQuantitiesCheck	SOL/203/2.5	⑮
§ Windows_CommonPropertiesCheck	SOL/203/2.5	⑯
§ Doors_IdentityDataCheck	SOL/230/1.1	⑰
§ Doors_BaseQuantitiesCheck	SOL/203/2.5	⑱
§ Doors_CommonPropertiesCheck	SOL/203/2.5	⑲
§ Ceiling_BaseQuantitiesCheck	SOL/203/2.5	⑳
§ Ceiling_IdentityDataCheck	SOL/230/1.1	㉑
§ Stairs_BaseQuantitiesCheck	SOL/203/2.5	㉒
§ Stairs_CommonPropertiesCheck	SOL/203/2.5	㉓
§ Stairs_IdentityDataCheck	SOL/230/1.1	㉔
§ Railing_BaseQuantitiesCheck	SOL/203/2.5	㉕
§ Railing_IdentityDataCheck	SOL/230/1.1	㉖

Figure 36. Solibri semantic data check rules

State	Component	Property	Operator	Value
Include	Wall			

Component	Property Set	Property	Value Exists	Value Conditions	Visualization
Wall	BaseQuantities	Height	Must exist	X > 0	
Wall	BaseQuantities	Width	Must exist	X > 0	
Wall	BaseQuantities	Length	Must exist	X > 0	
Wall	BaseQuantities	Volume	Must exist	X > 0	
Wall	BaseQuantities	Area	Must exist	X > 0	

Figure 37. Solibri wall base quantities check rule

5.2.4. MODEL IMPORT TO CIRCULARLCA SOFTWARE

Once the model was exported to the IFC format and checked in Solibri, the next step was to import the files to the CircularLCA software. For the purpose of this study, a new project in CircularLCA was created, where the general information (Name, Area, Type) were input. During the project creation, the software also allows to select the certification system to which the project is aimed to comply. In this case, DGNB and QNG certifications were selected (Figure 38).

After the project was set, the model was imported to the software through the project inventory interface, in which the model can be exported through IFC or Excel file (Figure 39). When the model was uploaded, the project information was observed, including the 3D model and a table with project elements and corresponding imported properties. The 3D view allowed to navigate and investigate individual components. Meanwhile, the tabular form enabled to display and group the elements according to any imported property, as well as label the environmental data, after which the environmental impacts are estimated automatically.

The figure shows two side-by-side screenshots of the 'Edit building' interface in CircularLCA. The left screenshot displays the 'General information' tab, which includes a sidebar with 'General information', 'Planned operation', 'Compliance settings', and 'Mapping Editor'. The main area contains a 'Drag and drop or Upload a file' section, a 'Name*' field with 'ATRIUM Parkblich BIM', an 'Address' search field, a 'Building Type' dropdown set to 'Multi family building', and two input fields for 'Gross floor area*' (3575.9 m²) and 'Net room area*' (2996.66 m²). At the bottom, there is a 'Planned operation' section and 'Delete building' and 'Update building' buttons. The right screenshot shows the 'Compliance settings' and 'Mapping Editor' tabs. The 'Compliance settings' tab includes a 'Desired certification*' dropdown set to 'QNG' and a 'Conformity*' dropdown set to 'A1'. Below these, there is a note about DIN EN 15804. The 'Mapping Editor' tab includes a 'Consider previous mappings' checkbox (checked) and a 'Run auto-mapping after file upload' checkbox (checked).

Figure 38. CircularLCA project creation

The figure shows a screenshot of the 'Material resources' section in the CircularLCA software. The 'Inventory' tab is selected, and the 'Upload data' button is highlighted. Below the button, there is a table with the following data:

File name	Type	Upload date	Uploaded by	Status	Mapping	Active file
LCATest_10G_2507_...	IFC	25.07.25 00:36	Artyom Lukyanenko	Mapping 64%	Map products	☐
LCATest_10G_2507_...	IFC	25.07.25 00:36	Artyom Lukyanenko	Mapping 65%	Map products	☐

Figure 39. CircularLCA model import

Mapping editor

Project2407_ifc2.3.ifc

1455 of 3512 objects are mapped

Help

Define rules

Done

3D view

Zoom to building



Tabular view

Grouped by: Material, Name

Filter +

Sorted by: Name

Info columns

Grouping columns				Info columns						
Number of objects	Name	Material	Volume (m³) Sum	Mass (kg) Sum	GWP (kg CO₂e) Sum	IFC Class Uniqueness	Width (m) Sum	IFC Global Uniqueness	Object-mapping	
☐	6	Basic Wall:AW04 Wn	Dämmung - weich	19,555	-	-	IfcWallStandardCas	0,960	Different	Search and map a building product
☐	6	Basic Wall:AW04 Wn	Mauerwerk - Kalksa	29,333	-	-	IfcWallStandardCas	1,440	Different	Search and map a building product
☐	6	Basic Wall:AW04 Wn	Plaster	0,183	-	-	IfcWallStandardCas	0,009	Different	Search and map a building product
☐	7	Basic Wall:AW05 Die	Anstrich	0,082	-	-	IfcWallStandardCas	0,007	Different	Search and map a building product
☐	7	Basic Wall:AW05 Die	Grundierung	0,082	-	-	IfcWallStandardCas	0,007	Different	Search and map a building product
☐	7	Basic Wall:AW05 Die	Innenputz Kalk-Gips	0,823	-	-	IfcWallStandardCas	0,070	Different	Search and map a building product
☐	7	Basic Wall:AW05 Die	Malervlies	0,082	-	-	IfcWallStandardCas	0,007	Different	Search and map a building product
☐	7	Basic Wall:AW05 Die	Mauerwerk - Kalksa	19,744	-	-	IfcWallStandardCas	1,680	Different	Search and map a building product

Figure 40. Model view in CircularLCA

5.2.5. PRELIMINARY DATA EVALUATION AND MAPPING

When the IFC models were checked in Solibri and imported to CircularLCA, the preliminary evaluation was conducted to determine the level of import consistency of the model data across the three IFC versions. To conduct a transparent and structured comparison an evaluation matrix was developed in Excel, which included the list of building elements and a ranking of data import quality for each data type (identity data, common properties, base quantities, material information). The quality for each element was labelled with the colour (red-not imported, orange – partially imported, green – fully imported). After the evaluation was completed for each element type, the final percentage of data quality for each type of information was estimated. Finally, the elements with data import issues were identified in Solibri 3D viewer to trace the root of the problem. The evaluation below will show the results of the data evaluation for the building elements included in the 1st floor (1.OG).

1) IFC 2x3 Coordination View 2.0

Overall, the export through IFC 2x3 shows a moderate level of data transfer consistency for identity, base quantities, and common properties, while most of the limitations were observed in material information. After the model import, it was identified that some of the building elements were not properly defined and resulted in data losses (Table 15). Such an issue was mostly observed in elements with multiple layers, particularly the walls.

Table 14. IFC 2x3 CV 2.0 lost data description

Element group	Lost data	Solibri – issue description	CircularLCA - issue description
Wall	Identity Information	Inconsistent Ifc Entity assignment	Inconsistent Ifc Entity assignment
Wall	Base Quantities	Lost element quantities-Height	Lost element quantities-Height
Wall	Material information		Lost material names and quantities
Windows	Material information	Lost material quantities	Lost material names and quantities
Doors	Material information	Lost material quantities	Lost material names and quantities
Stairs	Identity Data	Inconsistent Ifc Entity Assignment	Inconsistent Ifc Entity Assignment
Stairs	Base Quantities		Lost element quantities - Volume
Stairs	Material information	Lost material names and quantities	Lost material names and quantities

Table 15 provides an example of the evaluation matrix for the wall elements. The complete evaluation matrix for each IFC version is provided in Annex A.2. Table 16 provides the summary of data import quality for each element and data type. The following results were highlighted:

- 88.1% of the **Identity data** was fully imported and interpreted by the software. Partial data import was identified as 11.9%, mostly for multi-layered elements such as walls and stairs with inconsistent parameters such as IfcClass
- **Base Quantities** showed similar results, with 88.1% fully and 11.9% partially imported data. The data lost was mostly observed in wall elements, where some elements dimensions, such as wall height, were not exported correctly, with value of 0.
- **Common Properties**, such as IsExternal and LoadBearing were fully imported with the IFC model. However, the interpretation issues in the software were identified. For example, while the IsExternal property in Wall Common Properties was True, the wall "External" status in the information tab in the software was showing False.
- **Material Information** showed the lowest performance in data quality import, where less than half of the data (47.5%) was fully exported, with major partial and full data loss (45.8% and 6.8% respectively) for wall, stairs, doors and windows elements.

Table 15. Data import quality evaluation matrix example for wall elements

IFC 2x3 CV 2.0							
Nr	Element	Element (Eng)	Multi-layered	Identity Data	Base Quantities	Common Properties	Material Information
1	AR01A, Abstellräume KG, Trennwände	AR01A, Storage rooms KG, Partitions					
2	AW01A Außenwand UG (ohne Dämmung)	AW01A Exterior wall, basement (without insulation)					
3	AW02A Außenwand Garage Porenbeton 36	AW02A Exterior wall, garage, aerated concrete 36	+				
4	AW03 Außenwand Gasporenbeton	AW03 Exterior wall, aerated concrete	+				
5	AW04 Außenwand WDVS Westgiebel	AW04 Exterior wall, ETICS, west gable	+				
6	AW05 Außenwand Giebelwand Dieskastr.	AW05 Exterior wall, gable wall, Dieskastr.	+				
7	AW06 Lichtschacht UG	AW06 Light shaft, basement					
8	IW01A Kalksandsteinwand 24 cm - UG (mit Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (with insulation)	+				
9	IW01B Kalksandsteinwand 24 cm - UG (ohne Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (without insulation)	+				
10	IW02 Trockenbauwand 12,5 cm	IW02 Drywall, 12 cm	+				
11	IW04A Kalksandsteinwand 17,5 cm	IW04A Sand-lime brick wall, 17.5 cm	+				

■ not imported
■ partially imported
■ fully imported

Table 16. IFC 2x3 CV preliminary data quality import evaluation results

IFC 2x3 CV 2.0				
Elements	Identity Data	Base Quantities	Common Properties	Material Information
Walls	45.5%	45.5%	100.0%	45.5%
	54.5%	54.5%	0.0%	36.4%
	0.0%	0.0%	0.0%	18.2%
Columns	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Slabs	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Roof	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Windows	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
Doors	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
Floor cover	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Balcony	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Foundation	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Ceiling	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Stairs	0.0%	0.0%	100.0%	0.0%
	100.0%	100.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Railing	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Other	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Total	88.1%	88.1%	100.0%	47.5%
	11.9%	11.9%	0.0%	45.8%
	0.0%	0.0%	0.0%	6.8%

■ not imported
■ partially imported
■ fully imported

According to the evaluation matrix, the elements with limited and inconsistent data quality import were walls, openings, and stairs. As the wall elements caused the major part of data loss, the issue tracing for these elements was conducted. The issue of data import was identified in the BIM model, where the elements were joined with other objects, such as walls, floors, and ceiling, which resulted in different layers dimensions due to layers prioritization.

When walls were joined with the floors (Figure 41), some of the layers in the wall (Finishes) had changes in the dimensions (Height). Therefore, the uniformity of the wall element shape was disrupted, which resulted in data loss of material information (Material Name, Material Thickness), Base Quantities (Height) and inconsistent identity information (IfcClass). The similar issue was observed in the wall-to-wall joining, particularly when more than 2 walls were joined together. As a result, the uniformity of the wall due to the joining was disrupted (Figure 42) and similar data losses and inconsistency in material information, base quantities and identity information occurred.

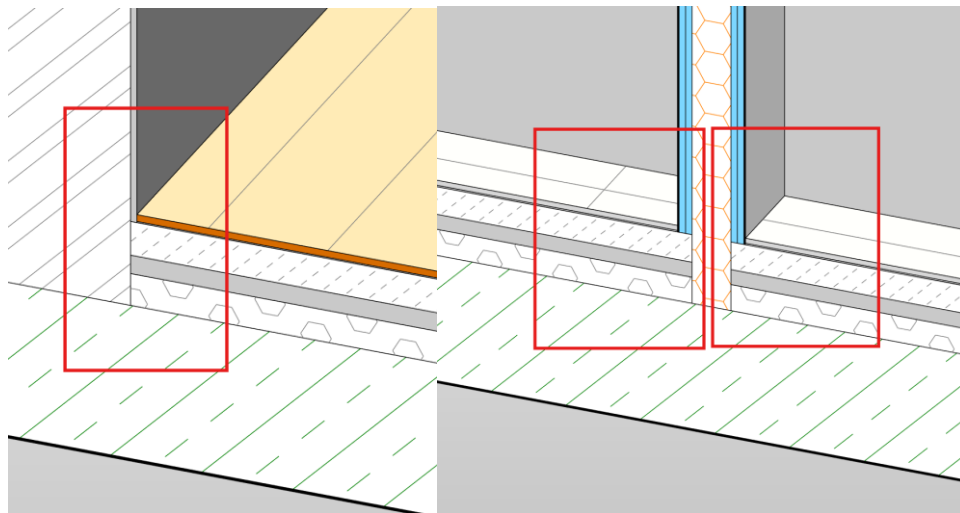


Figure 41. BIM model walls to floors intersection root cause

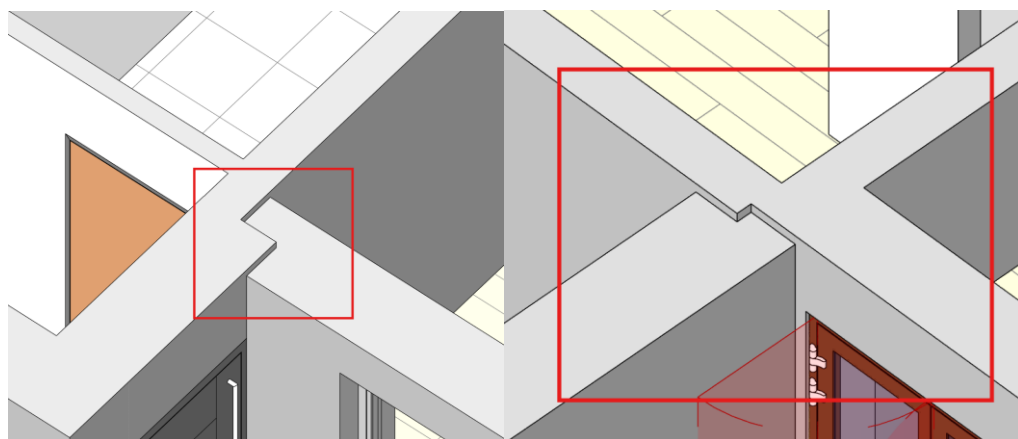


Figure 42. BIM model walls to walls intersection root cause

2) IFC 4 Reference View

Considering IFC 4 RV version, noticeable data losses were observed in all the data types. The issue was identified mostly in multi-layered elements (Table 17).

Table 17. IFC 4 RV data loss description

Element group	Lost data	Solibri – issue description	CircularLCA - issue description
Wall	Identity Information	Lost data – Element Name	Lost data – Element Name
Wall	Base Quantities	Inconsistent element quantities-Area, Volume	Inconsistent element quantities-Area, Volume
Wall	Common Properties	Lost data – “IsExternal”, “LoadBearing”	Lost data – “IsExternal”, “LoadBearing”
Roof	Identity Information	Lost data – Element Name	Lost data – Element Name
Roof	Base Quantities	Inconsistent element quantities-Area, Volume	Inconsistent element quantities-Area, Volume
Roof	Common Properties	Lost data – “IsExternal”	Lost data – “IsExternal”
Slab	Identity Information	Lost data – Element Name	Lost data – Element Name
Slab	Common Properties	Lost data – “LoadBearing”	Lost data – “LoadBearing”
Floor cover	Identity Information	Lost data – Element Name	Lost data – Element Name
Floor cover	Common Properties	Lost data – “LoadBearing”	Lost data – “LoadBearing”
Windows	Material information	Lost material quantities	Lost material names and quantities
Doors	Material information	Lost material quantities	Lost material names and quantities
Stairs	Identity Data	Inconsistent Ifc Entity Assignment	Inconsistent Ifc Entity Assignment
Stairs	Base Quantities		Lost element quantities - Volume
Stairs	Material information	Lost material names and quantities	Lost material names and quantities

According to Table 18, which provides details on preliminary data import quality evaluation results, the following results were identified:

- 57.6% of **Identity Data** was fully imported, while the other half (42.4%) had partial data losses for such elements as walls, slabs, floors, roof, balconies, foundation, ceiling, and stairs. Such data as Element Name and Family was not imported to the software.
- Most the geometrical data (81.4%) from the **Base Quantities** was correctly imported and interpreted, while 18.6% showed inconsistency in base quantities mostly for the wall elements.
- Similar to the identity data, 57.6% of **Common Properties** was partially imported with missing (LoadBearing) or incorrect data (IsExternal) for such elements as walls, slabs, floors, roof, balconies, foundation, ceiling, and stairs.
- More than half of the **Material Information** (59.3%) was fully imported and interpreted by the software, while 40.7% was completely missing for windows, doors, stairs and other category elements.

Table 18. IFC 4 RV preliminary data import quality evaluation results

IFC 4 RV				
Elements	Identity Data	Base Quantities	Common Properties	Material Information
Walls	27.3%	27.3%	27.3%	100.0%
	72.7%	72.7%	72.7%	0.0%
	0.0%	0.0%	0.0%	0.0%
Columns	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Slabs	0.0%	100.0%	0.0%	100.0%
	100.0%	0.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Roof	0.0%	0.0%	0.0%	100.0%
	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Windows	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Doors	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Floor cover	0.0%	100.0%	0.0%	100.0%
	100.0%	0.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Balcony	0.0%	100.0%	0.0%	100.0%
	100.0%	0.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Foundation	0.0%	100.0%	0.0%	100.0%
	100.0%	0.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Ceiling	0.0%	100.0%	0.0%	100.0%
	100.0%	0.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Stairs	0.0%	0.0%	0.0%	0.0%
	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Railing	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Other	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Total	57.6%	81.4%	57.6%	59.3%
	42.4%	18.6%	42.4%	0.0%
	0.0%	0.0%	0.0%	40.7%

■ not imported
■ partially imported
■ fully imported

Similarly to IFC 2x3 CV, this version experienced issues with data import quality for multi-layered elements, such as walls, openings, floors, slabs and stairs. For the wall elements. For the walls, floors and slabs elements, the root cause was identified in the separation of the building elements before the export. As multi-layered elements must be separated in Revit before the export to the IFC 4.0 RV, each separated layer became a Part with alternative identity data and common properties, which resulted in the loss of identity and common properties data previously assigned to the original element (Figure 43). Moreover, Revit was unable to separate the elements with irregular shapes, which made an element improper for the export. Another issue of inconsistent wall base quantities was identified in elements with openings (a wall with a hosted window). When separating the layers, some of them disregard existing opening in the element, which results in incorrect base quantities of an element (Figure 43).

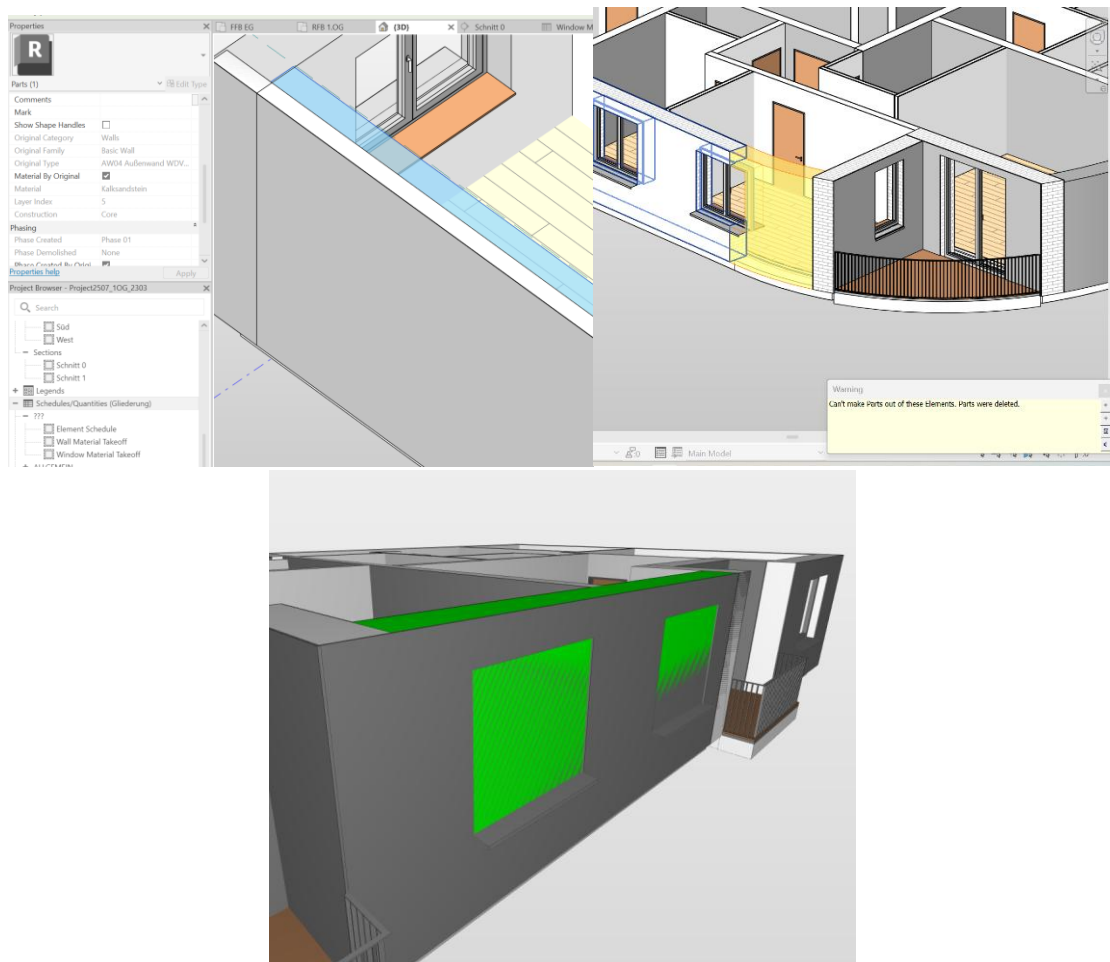


Figure 43. BIM walls separation root cause example

3) IFC 4.0 Design Transfer View

The IFC 4.0 DTV showed a similar performance to IFC2x3 CV, with moderate quality level for identity, base quantities, and common properties types of information. However, Material Information import showed a lower import quality with higher data losses (Table 19).

- **Identity Data and Base Quantities** were both fully exported in 88.1% of the cases and partially exported in 11.9%, due to similar limitations with multilayered construction elements.
- **Common Properties** were 100% imported, matching the performance of IFC 2x3 CV
- **Material Information** showed significant full (44.1%) and partial (8.5%) data loss, while only 47.5% were properly imported and interpreted by the software. The issue was mostly observed in multi-layered elements (Walls, Doors, Windows, Stairs), in which materials names and thickness were not defined or defined inconsistently.

Similarly to the IFC 2x3 CV, such multi-layered elements as walls, openings and stairs resulted in limited data import for identity, base quantities and material information. In addition, the root causes were also identified as joining method of the walls element in BIM for the walls, and limited IFC Schema for the openings. However, while IFC 2x3 CV could import the material information for the main profile of the opening, in IFC 4.0 MTV the material information was completely not defined, which resulted in higher data loss for this type of information.

Table 19. IFC 4.0 DTV preliminary data quality evaluation results

IFC 4 DTV				
Elements	Identity Data	Base Quantities	Common Properties	Material Information
Walls	45.5%	45.5%	100.0%	45.5%
	54.5%	54.5%	0.0%	36.4%
	0.0%	0.0%	0.0%	18.2%
Columns	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Slabs	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Roof	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Windows	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Doors	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Floor cover	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Balcony	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Foundation	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Ceiling	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Stairs	0.0%	0.0%	100.0%	0.0%
	100.0%	100.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Railing	100.0%	100.0%	100.0%	100.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
Other	100.0%	100.0%	100.0%	0.0%
	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	100.0%
Total	88.1%	88.1%	100.0%	47.5%
	11.9%	11.9%	0.0%	8.5%
	0.0%	0.0%	0.0%	44.1%

not imported
partially imported
fully imported

According to the results of the preliminary data quality import evaluation, all the three IFC versions had limited data consistency, and were not suitable for further analysis and mapping. Nevertheless, the mapping methods were analysed to identify if the model contains sufficient data to conduct the

automated mapping process. CircularLCA suggests 2 methods of automated data mapping, which are AI mapping and rule-based mapping. According to Concular (2025), AI mapping currently has limited capabilities to map the building elements with the environmental data correctly and is not recommended for the automated mapping process. Therefore, only the rule-based mapping was considered in this study.

Rule-based mapping is a beta feature that has been developing by Concular (Concular, 2025). The feature allows to create multiple rules for automated mapping based on the match between the model element and environmental product properties. The example of the rule development is illustrated in Figure 44. In the rule definition, it is possible to select the model element according to a particular property (1), and match the element property on the left with the environmental product on the right (2) using different functions (Is, Contains, Greater Than, Less Than). The feature enables the matching with such environmental product properties as Product Name, EPD Name, DIN KG 276, Material Name, Reference Unit and Tag. The elements in the initial BIM model did not include these properties, which would limit the application of this feature.

The screenshot shows the 'CircularLCA Ruleset editor window'. At the top right, there are 'Help' and 'Done' buttons. Below them, the rule is titled 'Wall' with an edit icon. The rule is defined by two conditions, numbered 1 and 2. Condition 1 is 'When' with a purple hexagon icon, 'Name' property, 'Contains' function, and 'Basic Wall' value. Condition 2 is 'And' with a purple hexagon icon, 'Material' property, 'Is' function, and 'Material Name' value. Both conditions have copy and delete icons. Below the conditions is a '+ Add further condition' button.

Condition	Operator	Property	Function	Value	Actions
1	When	Name	Contains	Basic Wall	Copy, Delete
2	And	Material	Is	Material Name	Copy, Delete

+ Add further condition

Figure 44. CircularLCA Ruleset editor window

5.2.6. BIM-MODEL EXPORT RULESET DEFINITION

To ensure the high quality of BIM model data import to the CircularLCA software, a tailored export ruleset is defined. The ruleset is based on the preliminary data quality evaluation and aims to address the issues defined during the evaluation. The structure of the ruleset is divided according to the stages of BIM model export, where each stage covers particular instructions and quality control measures to improve the compatibility of a BIM model with the CircularLCA tool. Table 20 provides an overview on the structure of the ruleset.

Table 20. BIM model export ruleset structure

Export stage	Rule	Attachment
Before the export	Select the appropriate IFC version	1. IFC versions comparison table for a BIM model export to CircularLCA
	Ensure the modelling requirements are satisfied	1. Modelling recommendations for a wall element
	Select the properties to be included to the model	1. Types of data interpreted by CircularLCA software table 2. Custom Property set Pset_CircularLCA
	Ensure the property values are allocated to the corresponding property sets	1. Elements' properties mapping according to the IFC 2x3 CV scheme
During Export	Apply an export setup provided by CircularLCA	
	Ensure the model properties are exported to the IFC	
After Export	Apply the model checking to ensure the required semantic data is properly exported and defined in the IFC model	1. Property export configuration file

1) Before the export

IFC Version Selection and Comparison

Before the model export, an IFC model relevant to the considered model should be selected. Therefore, a comparative analysis was undertaken for the IFC versions suggested by CircularLCA and is provided in Table 21. Each of the versions is considered in the context of integration with Revit and CircularLCA, where each workflow has specific advantages and limitations regarding the export of the semantic data, which are underscored in the comparison. The purpose of this rule is to support the user in applying the IFC version aligning with the project model and scope.

Table 21. IFC versions comparison for BIM model export to CircularLCA.

	IFC 2.3 TC1 Coordination View 2.0	IFC 4 ADD2 TC1 Reference View	IFC 4 ADD2 TC1 Design Transfer View
Status (buildingSMART, 2025)	Final	Final	Draft
MVD (buildingSMART, 2025)	Spatial and physical components for design coordination between architectural, structural, and building services (MEP) domains	Simplified geometric and relational representation of spatial and physical components to reference model information for design coordination between architectural, structural, and building services (MEP) domains	Advanced geometric and relational representation of spatial and physical components to enable the transfer of model information from one tool to another. Not a "round-trip" transfer, but a higher fidelity one-way transfer of data and responsibility.
Number of Property Sets (buildingSMART, 2025)	300+	600+	600+
Number of Entities (buildingSMART, 2025)	600+	800+	800+
Geometric Representation	Supports basic geometry, but can be less precise for complex shapes. This version struggles with geometry of joined elements, particularly with multi-layered structure. When an element (e.g.Wall) is joined to other elements (Wall, Slab, Floor, Ceiling), it needs to be ensured that the element shape is uniform and is not disrupted. Otherwise, data losses in material information, identity data,	Supports basic geometry, but can be less precise for complex shapes.	Supports basic geometry, but can be less precise for complex shapes. This version struggles with geometry of joined elements, particularly with multi-layered structure. When an element (e.g.Wall) is joined to other elements (Wall, Slab, Floor, Ceiling), it needs to be ensured that the element shape is uniform and is not disrupted. Otherwise, data losses in material information, identity

	and base quantities are observed.		data, and base quantities are observed.
Material Definition	Basic material definition. Provides the information regarding the Name and Dimensions. No custom material properties are interpreted.	Basic material definition. Provides the information regarding the Name and Dimensions. No custom material properties are interpreted.	Basic material definition. Provides the information regarding the Name and Dimensions. No custom material properties are interpreted.
Environmental Information Export	Lacks a dedicated, standardized structure for environmental data. Information must be added through custom property sets, making automated data extraction difficult for the LCA tool.	Includes specific Psets like Pset_EnvironmentalImpactIndicators, which provides standardized fields for Expected Service Life, Functional Unit Reference and other key environmental indicators.	Includes specific Psets like Pset_EnvironmentalImpactIndicators, which provides standardized fields for Expected Service Life, Functional Unit Reference and other key environmental indicators.
Multilayer Structure Support	When the geometrical representation of an element is uniform, support is robust and reliable. Multi-layered elements are exported using the IfcMaterialLayerSet entity, which accurately defines the material, thickness, and order of each layer. When the element's layers are not measured with thickness, the layers cannot be identified.	When layers are merged into a single geometric shape, this results in a loss of individual layer dimensions and definitions. When layers are exported as separate parts, the link to the original host element is lost, which results in identity and common properties data losses. In addition, the hosted elements (e.g. Window) may be ignored, resulting in incorrect layers quantities.	When the geometrical representation of an element is uniform, support is robust and reliable. Multi-layered elements are exported using the IfcMaterialLayerSet entity, which accurately defines the material, thickness, and order of each layer. When the element's layers are not measured with thickness, the layers cannot be identified.

Modelling recommendations

This rule is intended to ensure the BIM model compatibility and prevent the data loss due to element model during the IFC export.

Table 22. Modelling example recommendations for a wall element

IfcWall	
IFC2x3 Coordination view 2.0	
Recommendation	Description
Ensure a proper wall-to-wall joining	When joining walls at the same level, particularly multi-layered ones, it must be ensured that the object shape is solid and does not include any irregular cuts. Otherwise, elements must be unjoined.
Ensure a proper wall-to-floor joining	When joining walls to the floor element, particularly multi-layered ones, it must be ensured that the wall shape is solid and does not include any small or irregular cuts due to the connection of different layers (e.g. floor covering with wall finish). Otherwise, another method of profile adjustment has to be used or the elements must be unjoined.
Ensure a proper wall-to-ceiling joining	When joining walls to the roof element, particularly multi-layered ones, it must be ensured that the wall shape is solid and does not include any small or irregular cuts due to the connection of different layers (e.g. floor covering with wall finish). Otherwise, another method of profile adjustment has to be used or the elements must be unjoined.

Semantic information check

The goal of this rule is to ensure that all the required and relevant semantic information is included and assigned to the properties that are processed by the IFC model. Table 24 provides a list of the properties interpreted by the CircularLCA software with corresponding mapping in the IFC 2x3 CV scheme. The table also classifies the properties to required (green) and optional (yellow). In addition, the custom property set Pset_CircularLCA was created to ensure the alignment of the element properties with the environmental database in CircularLCA and facilitate the rule-based mapping process. The list and description of the custom property set is provided in Table 23.

Table 23. Custom Property set Pset_CircularLCA

Information	Revit Model Property	Description	Property type	Data type
KG – DIN 276	KG_DIN276	Classification code for cost groups (e.g., 300, 400)	Instant	Text
EPD Name	EPDName	Official name or reference of the Environmental Product Declaration.	Instant	Text
Element Tag	ElementTag	Unique tag to support automated mapping in CircularLCA or similar tools.	Instant	Text
CircularLCA Product Name	ProductName	Name of the product in CircularLCA environmental data database	Instant	Text

Table 24. Elements' properties mapping according to the IFC 2x3 CV scheme (buildingSMART, 2025)

Information type	Information	IFC entity	Property Set	Property	Attribute	Imported
Identity Information	Element Name	IfcWall			Name	
Identity Information	Global Id (GUID)	IfcWall			GlobalId	
Base Quantities	Element Dimensions	IfcElementQuantity			Length, Width, Height, Area, Volume	
Material Information	Material Names	IfcMaterial			Name	
Material Information	Multi-layered elements information	IfcMaterialLayerSet			LayerSetName, TotalThickness	
Common Properties	External Status	IfcWall	Pset_WallCommon	IsExternal		
Common Properties	Load Bearing Status	IfcWall	Pset_WallCommon	LoadBearing		
Custom Properties	KG DIN 276		Pset_CircularLCA	KG_DIN276		+
Custom Properties	EPD Name		Pset_CircularLCA	EPDName		+
Custom Properties	Element Tag		Pset_CircularLCA	ElementTag		+
Custom P3properties	CircularLCA Product Name		Pset_CircularLCA	ProductName		+

2) During the export

Once the model is prepared, these rules support the export process in Revit to ensure the consistent transfer of the BIM model information to the IFC file.

Export setup

Select the CircularLCA export setup according to the selected IFC version.

Ensure the property sets are exported

Base Quantities – “Export base quantities” box in the Property set export must be enabled

Common Properties – when desirable, “Export common properties” box in the Property set export must be enabled

Custom Properties – when desirable, “Export user-defined property set” box must be enabled and the predefined configuration file that specifies the property set and custom parameters must be uploaded. The configuration file is developed as a scope of this study

3) After the export

After the IFC file is exported, a model checking rule is included, where the presence and consistency of included properties is verified.

Model checking

To perform the verification, a Solibri software is used. In the software, the IFC model is uploaded and the custom ruleset “CircularLCA_IFCFileCheck”, which was developed as a part of this study, is applied to the model. In the ruleset, such information types as Identity Data, Base Quantities, Common Properties, Material Information and Custom Properties are verified, and the properties’ presence and consistency is evaluated. The overview of the Solibri ruleset is provided in Figure 45.

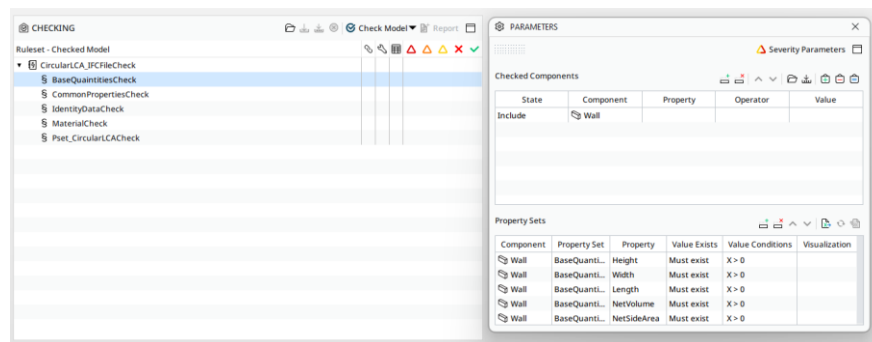


Figure 45. Solibri Ruleset overview

5.2.7. RULESET APPLICATION

To validate the effectiveness of the proposed export ruleset, it was applied to the case study building model. During the validation, the IFC 2x3 Coordination View 2.0 version was selected, as it provided comparatively higher levels of data import quality and aligns with the developed BIM model elements and shapes. In addition, only wall elements considered in the analysis due to the most occurring data transfer issues across all the 4 information types.

Before the export, the BIM model was adjusted according to the modelling recommendations specified in the ruleset. In particular, the multi-layered elements such as walls were reconfigured to establish proper geometric connections and when necessary, were unjoined to achieve element shape uniformity and avoid data losses. In addition, required project parameters were verified (identity data, material information, base quantities) and optional parameters (common properties, Pset_CircularLCA) were imported to the model. In case of multi-layered elements, where each element could have its separate value for the custom properties, such as EPD Name or Product Name, the custom properties were not assigned to the element. Moreover, since all the considered workflows were unable to export material property sets, the custom properties were also not assigned to different materials, and therefore were

disregarded for multi-layered elements. **During the export**, the model was exported again using the IFC 2x3 RV export setup provided by Concular. Together with enabling base quantities and common properties export, the property set file, defined in the ruleset, was applied to export the custom properties.

After the export, the exported IFC model was checked through the Solibri Software to ensure the presence and consistency of the properties included to the model. A custom model checking ruleset was applied in the software, and according to the results, illustrated in Figure 46, the model passed the checking and included all the necessary properties.

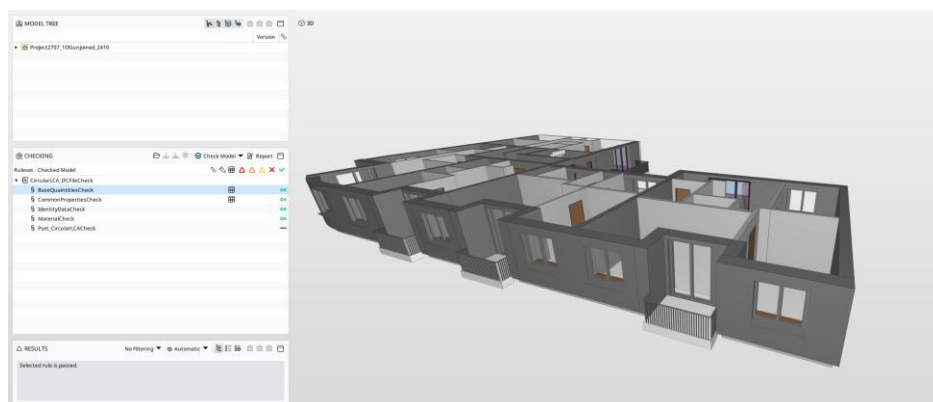


Figure 46. Solibri model checking results

5.2.8. FINAL DATA IMPORT QUALITY EVALUATION

After the model was verified, it was imported to the CircularLCA software to verify the data, and the Excel matrix for data import quality evaluation was applied. According to the results illustrated in Table 25, all the data for the wall elements was completely imported and interpreted, increasing the overall score of fully exported identity data, base quantities, and material information to 100%.

Table 25. IFC 2x3 CV final data import quality evaluation for wall elements

Nr	Element	Element (Eng)	Multi-layered	Identity Data	Base Quantities	Common Properties	Material Information
1	AR01A, Abstellräume KG, Trennwände	AR01A, Storage rooms KG, Partitions					
2	AW01A Außenwand UG (ohne Dämmung)	AW01A Exterior wall, basement (without insulation)					
3	AW02A Außenwand Garage Porenbeton 36	AW02A Exterior wall, garage, aerated concrete 36	+				
4	AW03 Außenwand Gasporenbeton	AW03 Exterior wall, aerated concrete	+				
5	AW04 Außenwand WDVS Westgiebel	AW04 Exterior wall, ETICS, west gable					
6	AW05 Außenwand Giebelwand Dieskastr.	AW05 Exterior wall, gable wall, Dieskastr.	+				
7	AW06 Lichtschacht UG	AW06 Light shaft, basement					
8	IW01A Kalksandsteinwand 24 cm - UG (mit Dämmung)	IW01B Sand-lime brick wall, 24 cm - basement (with insulation)	+				
9	IW01B Kalksandsteinwand 24 cm - UG (ohne Dämmung)	IW01B Sand-lime brick wall, 24 cm - basement (without insulation)	+				
10	IW02 Trockenbauwand 12,5 cm	IW02 Drywall, 12 cm	+				
11	IW04A Kalksandsteinwand 17,5 cm	IW04A Sand-lime brick wall, 17,5 cm	+				
Total Fully Exported				100.0%	100.0%	100.0%	100.0%
Total Partially Exported				0.0%	0.0%	0.0%	0.0%
Total Not Exported				0.0%	0.0%	0.0%	0.0%

■ not imported
■ partially imported
■ fully imported

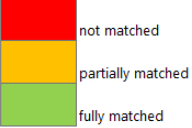
5.2.9. ENVIRONMENTAL DATA MAPPING

The final stage of the methodology application was to test the effectiveness of the proposed custom ruleset to support the rule-based mapping feature of CircularLCA software. The process evaluated if the imported custom data enables precise and automated linking between the model element and the environmental data. For the evaluation, the custom properties were assigned to the wall elements and the rule-based mapping was conducted

Table 26 illustrates the results of the data mapping comparison. According to the outcome, the ruleset proves the efficiency for the rule-based mapping for single-layer elements. However, due to the limitations of exporting custom material property sets to IFC, the applicability for the multi-layered elements is limited.

Table 26. Auto-mapping results for the model excluding (left) and including (right) custom property set

Nr	Element	Element (Eng)	Multi-layered	Rule-based mapping result
1	AR01A, Abstellräume KG, Trennwände	AR01A, Storage rooms KG, Partitions		
2	AW01A Außenwand UG (ohne Dämmung)	AW01A Exterior wall, basement (without insulation)		
3	AW02A Außenwand Garage Porenbeton 36	AW02A Exterior wall, garage, aerated concrete 36	+	
4	AW03 Außenwand Gasporenbeton	AW03 Exterior wall, aerated concrete	+	
5	AW04 Außenwand WDVS Westgiebel	AW04 Exterior wall, ETICS, west gable	+	
6	AW05 Außenwand Giebelwand Dieskastr.	AW05 Exterior wall, gable wall, Dieskastr.	+	
7	AW06 Lichtschacht UG	AW06 Light shaft, basement		
8	IW01A Kalksandsteinwand 24 cm - UG (mit Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (with insulation)	+	
9	IW01B Kalksandsteinwand 24 cm - UG (ohne Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (without insulation)	+	
10	IW02 Trockenbauwand 12,5 cm	IW02 Drywall, 12 cm	+	
11	IW04A Kalksandsteinwand 17,5 cm	IW04A Sand-lime brick wall, 17.5 cm	+	
Total fully matched				27.3%
Total partially matched				0.0%
Total not matched				72.7%



not matched
partially matched
fully matched

5.2.10. LIMITATIONS OF THE METHODOLOGY APPLICATION

During the application of the proposed methodology in the case study, several challenges and limitations were identified. These constraints occurred due to the real-world project environment as well as current maturity of the BIM-to-LCA data transfer workflow.

- Building model development

The critical limitation revealed during the development of a BIM-model was the fragmented nature of project information and data exchange. The application of multiple reference information (2D drawings and Building Element Catalogue) for the BIM-model development created significant constraint in defining element types, material layers and base quantities for the study. During the BIM modelling process, multiple data inconsistencies were identified, such as misalignment of the identity data between different versions and types of information, lack of cross-referencing, and mismatch of element compositions and quantities. Consequently, the modelling process required the introduction of manual interpretation and assumptions, creating the gap between the case study project and the developed BIM model. In addition, the lack of coordinated data exchange between the project teams from sustainability, design and development disciplines further contributed to the lower precision of the BIM

model. The issue was identified during the parallel updates and undocumented changes of information sources.

- Scope of ruleset development & application

The development and application of the export ruleset was limited to an IFC 2x3 CV 2.0 version only, as the developed model was not suitable for the data transfer through IFC 4.0 RV due to the challenges in separability of some of the building elements, while IFC 4.0 DTV had the lowest data transfer performance. In addition, the ruleset covered exclusively the wall elements due to the most occurring data loss issues across different information types. Although the applied approach showed its effectiveness in improving data consistency and reducing data losses, the disregard of other elements limits wider application of the developed ruleset. Other elements included to the model were not considered during the ruleset design and application, therefore may show different behaviour under the identical export configuration.

- Ruleset impact on element quantities

One of the rule of the modeling requirements included the modification of the wall element geometry to achieve the compatibility with a selected IFC version. Particularly, the elements were unjoined from adjacent components such as floors and ceilings. Although the proposed solution contributed to a complete consistency and transfer of the semantic model data, it also reduced the precision of the base quantities due to changes in the initial element geometry.

6

RESULTS AND DISCUSSION

6.1. WORKFLOW SHIFT TO BIM-BASED MODELLING AND ANALYSIS

Throughout the application of a BIM-based workflow for LCA, the transition from conventional project modelling and analysis data, which includes 2D drawings and Building Element Catalogue, to a BIM-based approach was observed. The study illustrated how the geometric information is created in a BIM model, and how the semantic information is enriched, structured, shared, and applied for further sustainability assessment at the project's construction stage. While the BIM-based workflow offered improvements in data consistency and availability, it also identified multiple practical and methodological challenges of conventional project information sources and their application for the BIM

model development in the context of Life Cycle Analysis and Green Building Ranking Systems (DGNB and QNG).

6.1.1. ADVANTAGES OF BIM MODELLING FOR LCA ANALYSIS

The BIM-based modelling in this study offered **automated quantities estimation** for the projects' materials and elements analysis. For each building element, quantities such as area, volume and thickness were provided and exported directly from the model developed in Revit. As material and element quantities were identified as required information for the LCA, the BIM ensured that the information input to the software represented the considered building project.

Another noticeable advantage of BIM-based project was the **centralized storage of geometrical and semantic information**. BIM offered to include and manage not only geometrical information, but also properties representing semantic information. The study showed that LCA analysis through the CircularLCA software is based on semantic data, such as element identity data and material information. Meanwhile, BIM allowed to input this information to the model, using a single file as a source information. In addition, custom sets of information were also embedded to the model elements, representing the references for the environmental data associated with an element, supporting automated environmental data labelling.

The recognized advantages of the BIM-based modelling approach underscored its potential value as a centralized and comprehensive data source for LCA analysis. By combining geometrical model with structured property data, the integration of BIM-modelling enhanced the precision of element quantities and the availability of element-specific information necessary for environmental impact assessment. Accordingly, BIM bridged the gap between different construction project building sources and sustainability evaluation through a single workflow.

6.1.2. CHALLENGES OF BIM MODELLING DEVELOPMENT

Despite the highlighted advantages of a BIM model for the LCA analysis, multiple challenges were observed during the model development process that underscore the real-world practical difficulties in data inconsistency and exchange.

Through the model development, the issue of **data inconsistency between different information sources** was observed. The original source of information for the BIM model development was received from two primary sources: 2D architectural drawings (in PDF and DWG format) and the Building Element Catalogue (Bauteilkatalog), which included definitions and physical properties of elements and their components. In the study, it was observed that these documents provided different identity information for the elements, lacked clear cross-referencing, and in some cases did not align on the composition or quantities of the elements. This required manual interpretation and created the risk of lower precision in project information for further export for environmental analysis.

Another significant challenge revealed during the BIM modelling process was **unstructured and asynchronous data exchange**. As the data sources were coordinated by different project teams of designing, sustainability evaluation, and project owner, the modelling stage was negatively affected by a lack of systematic communication and data exchange between the stakeholders. Updates to 2D drawing and building element catalogue were provided without intercommunication between the parties, resulting in overwork and inconsistencies.

The identified challenges highlighted inefficiencies in conventional construction project development, which hindered the switch of the project to the BIM-based approach. Insufficient precision of information and lack of structured collaboration limited the modelling process and the accuracy of the model data for further LCA analysis.

6.2. PRELIMINARY IFC IMPORT QUALITY EVALUATION RESULTS

The export of an initial model through an IFC model highlighted multiple challenges in transferring information from BIM to LCA tools using file-based exchange. While the study considered a BIM-based workflow as a method of data streamline improvement, the current stage of the file-based exchange complicated the development of a robust and complete data source for environmental analysis due to partial or full data losses. Moreover, the same BIM model experienced different export issues and produced data with different level of import quality depending on a building element and applied IFC version.

6.2.1. COMPARISON OF DATA IMPORT THROUGH DIFFERENT IFC SCHEMES

The preliminary import quality assessment revealed a moderate level of identity data transfer between the tools, which includes such information as Element Type and IfcClass. The results in Table 27 illustrates the performance of IFC 2x3 CV 2.0 and IFC 4.0 DTV in importing the identity data to the CircularLCA software, with 88.1% and 11.9% of the data fully and partially imported. In comparison, IFC 4.0 RV provided the data with lower import quality level of identity information, showing 42.4% of partial data loss. However, no complete data loss was observed in all 3 cases.

Table 27. Identity data import results comparison

	IFC 2x3 Coordination View 2.0	IFC 4.0 Reference View	IFC 4.0 Design Transfer View
Fully Imported	88.1%	57.6%	88.1%
Partially Imported	11.9%	42.4%	11.9%
Not Imported	0%	0%	0%

The evaluation of base quantities, which describe the quantities of building elements, showed a consistent pattern of data import quality across the IFC versions. As illustrated in Table 28, each version achieved a similar percentage of full and partially data import (88.1% and 11.9% respectively), without complete data loss. According to this outcome, base quantities were recognized as the most reliable imported information type, although partial data loss was still a challenge for a completely reliable and consistent data.

Table 28. Base quantities data import results comparison

	IFC 2x3 Coordination View 2.0	IFC 4.0 Reference View	IFC 4.0 Design Transfer View
Fully Imported	88.1%	81.4%	88.1%
Partially Imported	11.9%	28.6%	11.9%
Not Imported	0%	0%	0%

Common properties, which are a part of the IFC scheme and describe the element properties such as external/internal and load-bearing/not load-bearing, showed different patterns of data import qualities depending on the utilized IFC version. Both IFC 2x3 RV 2.0 and IFC 4.0 DTV resulted in complete transfer of common properties without data loss. Accordingly, these data schemes were fully capable of transferring the common element properties to the LCA software. Meanwhile, IFC 4.0 could achieve around a half of the complete common properties data import, with 42.4% of partially lost data.

Table 29. Common properties data import results comparison

	IFC 2x3 Coordination View 2.0	IFC 4.0 Reference View	IFC 4.0 Design Transfer View
Fully Imported	100.0%	57.6%	100.0%
Partially Imported	0.0%	42.4%	0.0%
Not Imported	0.0%	0.0%	0.0%

Comparing to the other types of information, data about material composition of the elements was identified as the least complete, experiencing the highest level of transfer inconsistency from the BIM model to the LCA software. As described in

Table 30, only IFC 4.0 RV version could exceed the 50% of complete data import. However, the other significant part of the data was lost completely. IFC 4.0 DTV showed the lowest performance of data transfer for material information, providing only 47.5% of complete data, while the major part of it was completely or partially lost (8.5% and 44.1% respectively). In case of IFC 2x3 CV 2.0, the lowest fraction of the data was entirely lost, which constituted 6.8%. Nevertheless, Only 47.5.9% of the data was transferred successfully, while 45.8% experienced partial inconsistency. Given that material information is the core data source for the LCA software to conduct the environmental analysis, the findings underscore the limitation of the IFC schemes to transfer a complete and reliable data necessary to evaluate a building's environmental performance.

Table 30. Material information data quality results

	IFC 2x3 Coordination View 2.0	IFC 4.0 Reference View	IFC 4.0 Design Transfer View
Fully Imported	47.5%	59.3%	47.5%
Partially Imported	45.8%	0.0%	8.5%
Not Imported	6.8%	40.7%	44.1%

The results across all the 3 workflow applications revealed inability of IFC based BIM-to-LCA approach to provide fully consistent data required for the LCA. While most of the information types (identity data, common properties, base quantities) did not experience complete data loss, the partial inconsistency of the substantial part of model data, as well as significant data losses in material information still created a barrier for further environmental data mapping and impact evaluation. This illustrated limited reliability of the proposed BIM-based framework in supporting the whole building environmental assessment. In

addition, these findings highlighted the need for standardised and informed export procedure to ensure the BIM model information is properly set, exported and transferred to the LCA software tool.

6.2.2. LIMITATIONS OF THE REVIT-IFC-CIRCULARLCA DATA TRANSFER

While IFC scheme is an intermediate stage in connecting the BIM and LCA software and transferring the data among them, the application of the Revit-IFC-CircularLCA workflow identified several limitations that affected the completeness and robustness of the imported data. The process of identifying the elements with most data losses and tracing of a root cause for the data losses across the three IFC versions revealed the three primary barriers for consistent and complete data transfer in the analysed workflow, which are lack of geometry support, material definition constraints, and limited support of multi-layered structures. The characteristics and common issues for each barrier were summarized and provided in Table 31.

During the application of the workflow through different IFC versions, limited geometry support of a BIM model was observed, particularly for multi-layered elements. This was identified as a consistent cause of data loss and disruption. In case of the data transfer from Revit to CircularLCA through IFC 2x3 CV 2.0 and IFC 4.0 DTV, the joining of different elements in Revit (e.g. wall-to-wall, wall-to-floor) lead to the disturbance of the shape uniformity due to the connection of multiple elements and layers. As a result, the inconsistent base quantities of elements were developed. In addition, this issue disrupted the definition of the material components of an element and transfer of the material information to the LCA software. When applying IFC 4.0 RV, which required the separation of multi-layered elements, the elements with irregular shapes (e.g. round wall) , openings and stairs were unable to be separated in Revit, and the embedded material information was not transferred.

When the workflow could support the element geometry, all of the three workflows were able to transfer the basic material information, which covered the material name and thickness. Nevertheless, in all the cases, the export of custom material properties was not achieved, limiting the BIM's functionality to enrich and contain model information. Therefore, the data enrichment and application of the custom parameters for mapping automation was limited to the elements with a single layer.

One of the major barriers for an effective application of the Revit-IFC-CircularLCA workflow was data transfer for multi-layered elements. In the IFC 2x3 CV 2.0 and IFC 4.0 DTV- based workflows, complete material information was transferred when the element geometry was uniform. In addition, only layers measured with thickness were able to be transferred and interpreted by the CircularLCA software. In case when the element composites were represented in Revit in volume or area, the material information was partially or completely lost. While applying IFC 4.0 RV to the workflow, the element layers were required to be separated before the export. However, due to the layer separation in Revit, noticeable data losses were observed in identity data and common properties initially assigned to the parent element. In addition, the workflow was unable to properly transfer the layers' dimensions of elements which were hosting other elements, such as openings.

Table 31. Revit-IFC-CircularLCA workflow limitations

Workflow	Geometry Support
Revit – IFC 2x3 CV 2.0 - CircularLCA	Supports basic geometry, but less precise for complex shapes. When the shape uniformity of an element is disturbed, particularly a multi-layered one, the data loss in base quantities and material information is experienced.

Revit – IFC 4.0 CV - CircularLCA	Supports basic geometry, but can be less precise for complex shapes. The elements with complex shapes cannot be separated and their data cannot be exported, which results in data loss of material information.
Revit – IFC 4.0 CV - CircularLCA	Supports basic geometry, but less precise for complex shapes. When the shape uniformity of an element is disturbed, particularly a multi-layered one, the data loss in base quantities and material information is experienced.
Workflow	Material Definition Support
Revit – IFC 2x3 CV 2.0 - CircularLCA	
Revit – IFC 4.0 CV - CircularLCA	Supports basic material definition, including the material names and dimensions. Does not allow to enrich and export custom material properties.
Revit – IFC 4.0 CV - CircularLCA	
Workflow	Multi-Layered Structure Support
Revit – IFC 2x3 CV 2.0 - CircularLCA	When the geometrical shape of an element is solid and uniform, the composition of the multiple layers is transferred, including the material names and thicknesses. When the material quantities are represented in area or volume, the material information is partially or completely lost.
Revit – IFC 4.0 CV - CircularLCA	When multiple layers are merged in one element, the material information is not supported, leading to complete material data loss. When material layers are separated, the identity data, common properties and base quantities can be partially or completely lost.
Revit – IFC 4.0 CV - CircularLCA	When the geometrical shape of an element is solid and uniform, the composition of the multiple layers is transferred, including the material names and thicknesses. When the material quantities are represented in area or volume, the material information is lost completely.

6.3. BIM MODEL EXPORT RULESET

6.3.1. EXPORT RULESET DEVELOPMENT

The results from the preliminary assessment of data import revealed that following the native Revit-to-IFC export procedure was insufficient to provide complete and consistent data for further LCA analysis in CircularLCA. The fragmented transfer of identity data, frequent loss of material layers information, and misinterpretation of base element quantities, especially in multi-layered wall elements, underscored the need for a more structured and informed export approach.

To address this limitation, a custom export ruleset was developed based on the observation patterns and results from the preliminary data import quality evaluation. The aim of the ruleset was to provide a structured step-by-step guideline to prevent the data losses in the BIM-IFC-CircularLCA export workflow. The defined rules were grouped to 3 primary stages before, during and after export, covering the processes of model adjustment, export setup, and model checking before the import to the LCA

software. In addition, the ruleset was able to classify the import information to the CircularLCA, pointing out the required data types and suggesting the custom data types to enrich the BIM model for a more effective and automated environmental data mapping and environmental analysis.

6.3.2. IMPACT OF THE RULESET TO THE DATA IMPORT QUALITY

The results of the export ruleset application justified the effectiveness of the informed and structured export methodology, achieving 100% complete data import across all the identified information types. The ruleset was able to prevent the data losses throughout the workflow application, providing a consistent and reliable data to the CircularLCA software. This outcome highlights the ruleset's efficiency in ensuring:

- Uniformity of elements' geometry by unjoining and remodelling problematic elements
- Proper semantic data allocation and enrichment of a BIM model through data mapping
- Complete model properties transfer through correctly configured export settings and model checking.

According to the achieved results, the BIM model export workflow to the LCA software through the IFC resulted in limited consistency of data import, while proper data export and management strategy allowed to increase the data completeness and prevent potential losses. Although IFC provided the standardized format of a BIM model export, differences in how modelling tools like Revit structured data and how LCA tools like CircularLCA interpreted the data increased the chance of data inconsistency and losses.

6.4. ENVIRONMENTAL DATA MAPPING

The final stage of the BIM-to-LCA workflow involved linking building elements to environmental data and evaluating the workflow's capabilities for automated data labelling. The CircularLCA software provided a feature of rule-based mapping, which was capable of link the model element with the environmental product based on the defined matching properties, such as material name, reference unit, EPD name, environmental product name and element tag. Although the software provided an opportunity to implement the automated data mapping through user-controlled and transparent approach, the study revealed the limitations of the considered BIM-based workflow due to insufficient data export capabilities.

The preliminary evaluation revealed that the initial model did not include sufficient data for the rule-based mapping and therefore was proposed to be enriched with the properties interpreted by CircularLCA for the rule-based mapping. Therefore, the export setup included the custom properties set to be assigned and exported with the model to the CircularLCA. While Revit provided an option to assign the custom property set to the element materials, the proposed workflow, which is based on the IFC open file export, was unable to export the material property set. Therefore, only single-layered elements were suitable for further rule-based mapping in the software. This revealed the limited application of the rule-based mapping in this study. For all other components, manual environmental data assignment remained necessary due to inability of the analysed BIM-based framework to provide sufficient data.

7

CONCLUSION

The primary focus of the study was the integration of Building Information Modelling and Life Cycle Assessment workflow by developing and applying a tailored and structured IFC export strategy for environmental performance assessment aligned with DGNB and QNG green building certification systems. By applying the BIM-LCA approach to the real-world construction project, the study illustrated the shift from conventional fragmented project modelling & environmental analysis to BIM-based workflow that enables more uniform data storage and transfer. In addition, the investigation proposed a structured and informed data transfer strategy that provide more consistent and reliable data for further environmental analysis. While technological and interoperability barriers still remain a challenge for a comprehensive BIM-LCA integration, the developed methodology contributes to the foundation of

more automated and efficient environmental evaluation and integration of BIM as a standard procedure for LCA data structuring and transfer.

The study demonstrated a noticeable fragmentation of conventional project information, highlighting such limitations as data inconsistency between different project inputs and lack of structured data exchange. Meanwhile the BIM model allowed to develop a centralized source of data that included both geometrical and semantic information. With more reliable quantity take-off estimations and enrichment of the geometrical elements with required and supporting semantic data, the BIM ability to enhance the availability and consistency of the data for further transfer to the LCA software was identified. However, a systematic and informed model setup and export methodology is required to ensure that the model contains the necessary information for LCA analysis through the professional tool.

Another crucial finding of the study was the inconsistent data transfer outcome of the BIM-LCA workflow through the IFC format exchange. The results revealed noticeable data losses in elements' identity data and base quantities, while the major data incompleteness was observed in the material information. In addition, varying data loss patterns were observed across different IFC versions, highlighting the limitation of IFC schemes to properly transfer the model data, particularly for multi-layered elements, as well as lack of interoperability between the IFC scheme and BIM & LCA software tools.

The integration of the BIM model export ruleset, which included the tailored rules for every step of the data transfer process, showed significant improvements in data import consistency and quality. The rules were focusing on adjustment and enrichment of the model elements, structured assignment of the element properties, and validation of the model export through the custom checking. After the application of the ruleset to the wall elements, 100% of the embedded data was completely transferred from the BIM model to the CircularLCA software. This level of imported information allowed further environmental data mapping and estimation of the environmental impact categories. This outcome underscores the importance of informed and structured data transfer methodology for achieving complete and reliable data import.

Finally, the study identified that the enrichment of the BIM model with supportive properties for environmental data mapping in CircularLCA did not achieve significant results. The proposed workflow was unable to transfer the custom properties of multi-layered elements, and only single-layered elements could be enriched and automatically mapped in the software. Therefore, the full potential of the automated data mapping remains constrained due to current limitations in interoperability and schemes of the BIM-IFC-LCA workflow.

Although the study methodology was able to provide a uniform data source and achieve a full consistency of data transfer across the different information types, several limitations are identified that can hinder the broader application of the workflow:

- The study considered the construction project at the construction stage only, when the project detailed information, such as building elements catalogue, was available
- The proposed export ruleset was based on one IFC version and applied to one building element with the most data loss issues.
- The study analysed the interoperability of particular BIM and LCA software, such as Revit and CircularLCA.
- The methodology could not provide sufficient support of multi-layered elements other than walls and slabs due to Revit-to-IFC export and scheme limitations.

Based on the identified limitations, the following recommendations for future research and development are proposed:

- Development of export strategies covering multiple architectural and technical building elements
- Investigation of IFC scheme modification and its interoperability with other BIM and LCA software to ensure more consistent data structuring and transfer.
- Integration of the circular economy aspects to the LCA workflow for evaluation of reuse potential, recyclability, and disassembly of building elements.
- Comparative studies across multiple LCA platforms to define a more comprehensive data export framework.
- Development of dynamic BIM-LCA approach to enhance environmental performance evaluation through different stages of the building life cycle.

8

REFERENCES

- Akbari, S., Sheikhhoshkar, M., Pour Rahimian, F., el Haouzi, H. B., Najafi, M., & Talebi, S. (2024). Sustainability and building information modelling: Integration, research gaps, and future directions. *Automation in Construction*, 163, 105420. <https://doi.org/10.1016/J.AUTCON.2024.105420>
- Alwan, Z., & Ilhan Jones, B. (2022). IFC-based embodied carbon benchmarking for early design analysis. *Automation in Construction*, 142, 104505. <https://doi.org/10.1016/J.AUTCON.2022.104505>
- Askar, R., Karaca, F., Salles, A., Lukyanenko, A., Cervantes Puma, G. C., Tavares, V., Khaidarova, A., Nadaždi, A., Pineda-Martos, R., Díaz-Cabrera, J. M., Honic, M., de Wolf, C., Cinar Resulogulari, E., Karatas, I., Gervásio, H., & Bragança, L. (2025). Driving the Built Environment Twin Transition: Synergising Circular

Economy and Digital Tools. In *Circular Economy Design and Management in the Built Environment* (pp. 459–505). https://doi.org/10.1007/978-3-031-73490-8_17

Autodesk. (2025a). *Autodesk Revit*. <https://www.autodesk.com/eu/products/revit/overview>

Autodesk. (2025b). *Levels of Development in BIM: Enabling coordination and collaboration*. <https://www.autodesk.com/solutions/bim-levels-of-development>

Bau-EPD. (2025). <https://www.bau-epd.at/en/>

Bongardt, A., & Torres, F. (2022). The European Green Deal: More than an Exit Strategy to the Pandemic Crisis, a Building Block of a Sustainable European Economic Model*. *Journal of Common Market Studies*, 60(1), 170–185. <https://doi.org/10.1111/jcms.13264>

Bonoli, A., Serrano-Bernardo, F., & Zanni, S. (2021). Sustainability in building and construction within the framework of circular cities and european new green deal. The contribution of concrete recycling. *Sustainability Switzerland*, 13(4), 1–16. <https://doi.org/10.3390/su13042139>

buildingSMART. (2024). *The Evolution of IFC: The path to IFC5*. <https://www.buildingsmart.es/2024/12/03/the-evolution-of-ifc-the-path-to-ifc5/>

buildingSMART. (2025). *Industry Foundation Classes (IFC)*. <https://www.buildingsmart.org/standards/bsi-standards/industry-foundation-classes/>

BuildLACCD. (2019). *LACCD Building Information Modeling Standards*.

Carvajal-Arango, D., Bahamón-Jaramillo, S., Aristizábal-Monsalve, P., Vásquez-Hernández, A., & Botero, L. F. B. (2019a). Relationships between lean and sustainable construction: Positive impacts of lean practices over sustainability during construction phase. *Journal of Cleaner Production*, 234, 1322–1337. <https://doi.org/10.1016/J.JCLEPRO.2019.05.216>

Carvajal-Arango, D., Bahamón-Jaramillo, S., Aristizábal-Monsalve, P., Vásquez-Hernández, A., & Botero, L. F. B. (2019b). Relationships between lean and sustainable construction: Positive impacts of lean practices over sustainability during construction phase. *Journal of Cleaner Production*, 234, 1322–1337. <https://doi.org/10.1016/J.JCLEPRO.2019.05.216>

Carvalho, J. G. R. O., Cecchin, D., de Azevedo, A. R. G., do Carmo, D. F., Paes, J. L., Ferraz, P. F. P., Hamacher, L. S., Costa, K. A., Rossi, G., & Bambi, G. (2025). Life cycle assessment (LCA) in construction materials – Review. *Agronomy Research*, 23(1), 293–321. <https://doi.org/10.15159/AR.25.041>

Chandrasekaran, V., & Dvarionienė, J. (2022). A Review of the Environmental Impact of Buildings with an Emphasis on Performance Assessment Tools and Their Incorporation of LCA. *Advances in Civil Engineering*, 2022(1), 9947920. <https://doi.org/10.1155/2022/9947920>

Charef, R., Emmitt, S., Alaka, H., & Fouchal, F. (2019). Building Information Modelling adoption in the European Union: An overview. *Journal of Building Engineering*, 25, 100777. <https://doi.org/10.1016/J.JOBE.2019.100777>

Chastas, P., Theodosiou, T., Kontoleon, K. J., & Bikas, D. (2018). Normalising and assessing carbon emissions in the building sector: A review on the embodied CO₂ emissions of residential buildings. *Building and Environment*, 130, 212–226. <https://doi.org/10.1016/J.BUILDENV.2017.12.032>

Cheng, B., Li, J., Tam, V. W. Y., Yang, M., & Chen, D. (2020). A BIM-LCA Approach for Estimating the Greenhouse Gas Emissions of Large-Scale Public Buildings: A Case Study. *Sustainability* 2020, Vol. 12, Page 685, 12(2), 685. <https://doi.org/10.3390/SU12020685>

Concular. (2025). *CircularLCA – Ökobilanzierung und Gebäuderessourcenpass – CircularLCA*. <https://circularlca.de/>

Construction Specifications Institute. (2025). *About OmniClass*.

Datta, S. D., Tayeh, B. A., Hakeem, I. Y., & Abu Aisheh, Y. I. (2023). Benefits and Barriers of Implementing Building Information Modeling Techniques for Sustainable Practices in the Construction Industry—A Comprehensive Review. In *Sustainability (Switzerland)* (Vol. 15, Issue 16). <https://doi.org/10.3390/su151612466>

del Rosario, P., Palumbo, E., & Traverso, M. (2021). Environmental Product Declarations as Data Source for the Environmental Assessment of Buildings in the Context of Level(s) and DGNB: How Feasible Is Their Adoption? *Sustainability* 2021, Vol. 13, Page 6143, 13(11), 6143. <https://doi.org/10.3390/SU13116143>

DGNB. (2025). *About the DGNB System* . <https://www.dgnb.de/en/certification/important-facts-about-dgnb-certification/about-the-dgnb-system>

DIN 276. (2018). *DIN 276:2018-12, Kosten im Bauwesen*. <https://doi.org/10.31030/2873248>

DIN EN 15978:2012-10, Nachhaltigkeit von Bauwerken - Bewertung der umweltbezogenen Qualität von Gebäuden - Berechnungsmethode; Deutsche Fassung EN_15978:2011. (2012). <https://doi.org/10.31030/1917049>

Dsilva, J., Zarmukhambetova, S., & Locke, J. (2023). Assessment of building materials in the construction sector: A case study using life cycle assessment approach to achieve the circular economy. *Heliyon*, 9(10), e20404. <https://doi.org/10.1016/J.HELIYON.2023.E20404/ASSET/E9AEC25A-DAC9-4A97-AFBA-2F67BA1C72CA/MAIN.ASSETS/GR6.JPG>

Durão, V., Costa, A. A., Silvestre, J. D., Mateus, R., Santos, R., & de Brito, J. (2020). Current Opportunities and Challenges in the Incorporation of the LCA Method in BIM. *The Open Construction & Building Technology Journal*, 14(1), 336–349. <https://doi.org/10.2174/1874836802014010336>,

EN 15804:2012+A2:2019 - Sustainability of construction works - Environmental product declarations -. (2019). https://standards.iteh.ai/catalog/standards/cen/c98127b4-8dc2-48a4-9338-3e1366b16669/en-15804-2012a2-2019?srsId=AfmBOor_dMB92sl5XaZP590oJwBDH9Zy9j6SYtYbXUhaKuqyWayyGI-Y

EPD Danmark. (2025). <https://www.epddanmark.dk/uk/about-epd-danmark/>

European Comission. (2024). *CONSTRUCTION INDUSTRIAL ECOSYSTEM*. <https://doi.org/10.2873/474024>

European Commission. (n.d.). *European Green Deal*. Retrieved June 14, 2025, from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

European Commission. (2023). *Transition Pathway for Construction*.

European data. (2025). <https://data.europa.eu/data/datasets/https-datos-gob-es-catalogo-ea0020951-opendap-es?locale=en>

Fawzy, S., Osman, A. I., Rooney, D. W., & Doran, J. (2020). Strategies for mitigation of climate change: a review. *Environmental Chemistry Letters*, 18(6), 2069–2094. <https://doi.org/10.1007/s10311-020-01059-w>

Feng, H., Sadiq, R., & Hewage, K. (2022). Exploring the current challenges and emerging approaches in whole building life cycle assessment. *Canadian Journal of Civil Engineering*, 49(2), 149–158. <https://doi.org/10.1139/CJCE-2020-0284/ASSET/IMAGES/CJCE-2020-0284TAB6.GIF>

- Figueiredo, K., Pierott, R., Hammad, A. W. A., & Haddad, A. (2021). Sustainable material choice for construction projects: A Life Cycle Sustainability Assessment framework based on BIM and Fuzzy-AHP. *Building and Environment*, 196, 107805. <https://doi.org/10.1016/J.BUILDENV.2021.107805>
- Fnais, A., Rezgui, Y., Petri, I., Beach, T., Yeung, J., Ghoroghi, A., & Kubicki, S. (2022). The application of life cycle assessment in buildings: challenges, and directions for future research. *The International Journal of Life Cycle Assessment* 2022 27:5, 27(5), 627–654. <https://doi.org/10.1007/S11367-022-02058-5>
- Grossarth, J. (2024). Nachhaltigkeit und Lebenszyklusbetrachtung im Bauwesen. *Bioökonomie Und Zirkulärwirtschaft Im Bauwesen*, 217–266. https://doi.org/10.1007/978-3-658-40198-6_7
- Guignone, G., Calmon, J. L., Vieira, D., & Bravo, A. (2023). BIM and LCA integration methodologies: A critical analysis and proposed guidelines. *Journal of Building Engineering*, 73, 106780. <https://doi.org/10.1016/J.JOBE.2023.106780>
- Hao, J. L., Cheng, B., Lu, W., Xu, J., Wang, J., Bu, W., & Guo, Z. (2020). Carbon emission reduction in prefabrication construction during materialization stage: A BIM-based life-cycle assessment approach. *Science of The Total Environment*, 723, 137870. <https://doi.org/10.1016/J.SCITOTENV.2020.137870>
- Hauke, B., & Hein, H. L. (2024). Ökobilanzierung im Bauwesen. *Bautechnik*, 101(1), 29–39. <https://doi.org/10.1002/BATE.202300100>
- Horn, R., Ebertshäuser, S., di Bari, R., Jorgji, O., Traunspurger, R., & von Both, P. (2020). The BIM2LCA Approach: An Industry Foundation Classes (IFC)-Based Interface to Integrate Life Cycle Assessment in Integral Planning. *Sustainability* 2020, Vol. 12, Page 6558, 12(16), 6558. <https://doi.org/10.3390/SU12166558>
- Inies. (2025). <https://www.inies.fr/en/inies-and-its-data/who-are-we/>
- Innovative UK. (2017). *Creating a Digital Built Britain: what you need to know*. <https://www.gov.uk/guidance/creating-a-digital-built-britain-what-you-need-to-know>
- Institut Bauen und Umwelt e.V. (2025). <https://ibu-epd.com/en/ibu-data-start/>
- ISO. (2018). *ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles*.
- ISO - ISO 14000 family — Environmental management. (n.d.). Retrieved July 11, 2025, from <https://www.iso.org/standards/popular/iso-14000-family>
- ISO 14040:2006 - Environmental management — Life cycle assessment — Principles and framework. (2006). <https://www.iso.org/standard/37456.html>
- ISO 14044:2006 - Environmental management — Life cycle assessment — Requirements and guidelines. (2006). <https://www.iso.org/standard/38498.html>
- Kumar, D., Maurya, K. K., Mandal, S. K., Mir, B. A., Nurdawati, A., & Al-Ghamdi, S. G. (2025). Life Cycle Assessment in the Early Design Phase of Buildings: Strategies, Tools, and Future Directions. *Buildings*, 15(10), 1612. <https://doi.org/10.3390/BUILDINGS15101612/S1>
- Larsen, V. G., Tollin, N., Sattrup, P. A., Birkved, M., & Holmboe, T. (2022). What are the challenges in assessing circular economy for the built environment? A literature review on integrating LCA, LCC and S-LCA in life cycle sustainability assessment, LCSA. *Journal of Building Engineering*, 50, 104203. <https://doi.org/10.1016/J.JOBE.2022.104203>

- Li, Y., Zhao, X., Liu, C., & Zhang, Z. (2025). Applications of Digital Technologies in Promoting Sustainable Construction Practices: A Literature Review. *Sustainability Switzerland*, 17(2). <https://doi.org/10.3390/su17020487>
- Lima, L., Trindade, E., Alencar, L., Alencar, M., & Silva, L. (2021a). Sustainability in the construction industry: A systematic review of the literature. *Journal of Cleaner Production*, 289, 125730. <https://doi.org/10.1016/J.JCLEPRO.2020.125730>
- Lima, L., Trindade, E., Alencar, L., Alencar, M., & Silva, L. (2021b). Sustainability in the construction industry: A systematic review of the literature. *Journal of Cleaner Production*, 289, 125730. <https://doi.org/10.1016/J.JCLEPRO.2020.125730>
- Lu, K., Jiang, X., Tam, V. W. Y., Li, M., Wang, H., Xia, B., & Chen, Q. (2019). Development of a Carbon Emissions Analysis Framework Using Building Information Modeling and Life Cycle Assessment for the Construction of Hospital Projects. *Sustainability 2019*, Vol. 11, Page 6274, 11(22), 6274. <https://doi.org/10.3390/SU11226274>
- Mitera-Kielbasa, E., & Zima, K. (2024). BIM Policy Trends in Europe: Insights from a Multi-Stage Analysis. *Applied Sciences 2024*, Vol. 14, Page 4363, 14(11), 4363. <https://doi.org/10.3390/APP14114363>
- Najjar, M. K., Figueiredo, K., Evangelista, A. C. J., Hammad, A. W. A., Tam, V. W. Y., & Haddad, A. (2022). Life cycle assessment methodology integrated with BIM as a decision-making tool at early-stages of building design. *International Journal of Construction Management*, 22(4), 541–555. <https://doi.org/10.1080/15623599.2019.1637098;WGROU:STRING:PUBLICATION>
- ÖKOBAUDAT. (2025). <https://www.oekobaudat.de/en.html>
- Palumbo, E., Soust-Verdaguer, B., Llatas, C., & Traverso, M. (2020a). How to Obtain Accurate Environmental Impacts at Early Design Stages in BIM When Using Environmental Product Declaration. A Method to Support Decision-Making. *Sustainability 2020*, Vol. 12, Page 6927, 12(17), 6927. <https://doi.org/10.3390/SU12176927>
- Palumbo, E., Soust-Verdaguer, B., Llatas, C., & Traverso, M. (2020b). How to Obtain Accurate Environmental Impacts at Early Design Stages in BIM When Using Environmental Product Declaration. A Method to Support Decision-Making. *Sustainability 2020*, Vol. 12, Page 6927, 12(17), 6927. <https://doi.org/10.3390/SU12176927>
- Palumbo, E., Soust-Verdaguer, B., Llatas, C., & Traverso, M. (2022). Implications of the building system boundary definition to conduct an LCA. A case study comparison of two frameworks for assessing building sustainability: DGNB and Level(s). *E3S Web of Conferences*, 349, 04015. <https://doi.org/10.1051/E3SCONF/202234904015>
- Panteli, C., Polycarpou, K., Morsink-Georgalli, F. Z., Stasiuliene, L., Pupeikis, D., Jurelionis, A., & Fokaides, P. A. (2020). Overview of BIM integration into the Construction Sector in European Member States and European Union Acquis. *IOP Conference Series: Earth and Environmental Science*, 410(1), 012073. <https://doi.org/10.1088/1755-1315/410/1/012073>
- Picardo, A., Soltero, V. M., & Peralta, E. (2023). Life Cycle Assessment of Sustainable Road Networks: Current State and Future Directions. *Buildings 2023*, Vol. 13, Page 2648, 13(10), 2648. <https://doi.org/10.3390/BUILDINGS13102648>
- QNG. (2025). *QNG Certification*. <https://www.qng.info/en/qng-certification/#>

- Richardson, K., Bendtsen, J., Nogués-Bravo, D., Steffen, W., Lucht, W., Donges, J. F., Drüke, M., von Bloh, W., Feulner, G., Gerten, D., Porkka, M., & Virkki, V. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, 9(37). <https://doi.org/10.1126/sciadv.adh2458>
- Sachs, J. D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six Transformations to achieve the Sustainable Development Goals. *Nature Sustainability*, 2(9), 805–814. <https://doi.org/10.1038/s41893-019-0352-9>
- Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers* (3rd ed.).
- Safari, K., & AzariJafari, H. (2021). Challenges and opportunities for integrating BIM and LCA: Methodological choices and framework development. *Sustainable Cities and Society*, 67, 102728. <https://doi.org/10.1016/J.SCS.2021.102728>
- Sartori, T., Drogemuller, R., Omrani, S., & Lamari, F. (2021a). A schematic framework for Life Cycle Assessment (LCA) and Green Building Rating System (GBRS). *Journal of Building Engineering*, 38, 102180. <https://doi.org/10.1016/J.JOBE.2021.102180>
- Sartori, T., Drogemuller, R., Omrani, S., & Lamari, F. (2021b). A schematic framework for Life Cycle Assessment (LCA) and Green Building Rating System (GBRS). *Journal of Building Engineering*, 38, 102180. <https://doi.org/10.1016/J.JOBE.2021.102180>
- Säynäjoki, A., Heinonen, J., Junnila, S., -, al, Zahra, E., Manish, M., Baltrusaitis, J., Pagnon, F., Mathern, A., & Ek, K. (2020). A review of online sources of open-access life cycle assessment data for the construction sector. *IOP Conference Series: Earth and Environmental Science*, 588(4), 042051. <https://doi.org/10.1088/1755-1315/588/4/042051>
- Solibri. (2023). *Level of Information*. <https://help-inside.solibri.com/hc/en-us/articles/10919113065367-Level-of-Information>
- Soust-Verdaguer, B., Llatas, C., García-Martínez, A., & Gómez de Cózar, J. C. (2018). BIM-Based LCA Method to Analyze Envelope Alternatives of Single-Family Houses: Case Study in Uruguay. *Journal of Architectural Engineering*, 24(3). [https://doi.org/10.1061/\(ASCE\)AE.1943-5568.0000303](https://doi.org/10.1061/(ASCE)AE.1943-5568.0000303)
- Su, D., Ren, Z., Wu, Y., Su, D., Wu, Y., & Ren, Z. (2020). Guidelines for Selection of Life Cycle Impact Assessment Software Tools. *Sustainable Product Development*, 57–70. https://doi.org/10.1007/978-3-030-39149-2_4
- Takano, A., Winter, S., Hughes, M., & Linkosalmi, L. (2014). Comparison of life cycle assessment databases: A case study on building assessment. *Building and Environment*, 79, 20–30. <https://doi.org/10.1016/J.BUILDENV.2014.04.025>
- Theißen, S., Höper, J., Drzymalla, J., Wimmer, R., Markova, S., Meins-Becker, A., & Lambertz, M. (2020). Using Open BIM and IFC to Enable a Comprehensive Consideration of Building Services within a Whole-Building LCA. *Sustainability*, 12(14), 5644. <https://doi.org/10.3390/su12145644>
- Theißen, S., Höper, J., Wimmer, R., Zibell, M., Meins-Becker, A., Rössig, S., Goi-towski, S., & Lambertz, M. (2020). BIM integrated automation of whole building life cycle assessment using German LCA data base ÖKOBAUDAT and Industry Foundation Classes. *IOP Conference Series: Earth and Environmental Science*, 588(3), 032025. <https://doi.org/10.1088/1755-1315/588/3/032025>
- UN Climate Change. (n.d.). *Paris Agreement*.

- UNDP. (n.d.). *Sustainable Development Goals*. Retrieved June 14, 2025, from <https://www.undp.org/sustainable-development-goals>
- Vijayan, D. S., Devarajan, P., Sivasuriyan, A., Stefańska, A., Koda, E., Jakimiuk, A., Vaverková, M. D., Winkler, J., Duarte, C. C., & Corticos, N. D. (2023). A State of Review on Instigating Resources and Technological Sustainable Approaches in Green Construction. In *Sustainability (Switzerland)* (Vol. 15, Issue 8). MDPI. <https://doi.org/10.3390/su15086751>
- Watts, N., Beagley, J., Coleman, S., Kelman, I., McGushin, A., Romanello, M., Costello, A., Hamilton, I., Hsu, S.-C., Kennard, H., Taylor, J., & Triñanes, J. (2021). The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *Lancet*, 397(10269), 129–170. [https://doi.org/10.1016/S0140-6736\(20\)32290-X](https://doi.org/10.1016/S0140-6736(20)32290-X)
- Wiesneth, B. (2022). *BIM-Monitor 2022/23: Is Germany Ready for Digitization in Construction?* <https://www.dreso.com/de/en/news/details/bim-monitor-2022-23-is-germany-ready-for-digitization-in-construction>
- woscim. (2025). *woscim* . <https://www.woscim.de/>
- Xu, J., Teng, Y., Pan, W., & Zhang, Y. (2022). BIM-integrated LCA to automate embodied carbon assessment of prefabricated buildings. *Journal of Cleaner Production*, 374, 133894. <https://doi.org/10.1016/J.JCLEPRO.2022.133894>

A

ANNEXES

A.1 – Detailed elements schedule of a modelled building (woscim)

Walls							
Element Name (Ger)				Element Name (Eng)		Width (m)	Area (m²)
AR01A, Abstellräume KG, Trennwände				AR01A, Storage rooms KG, Partitions		0.05	293.92
AW01A	Außenwand	UG (ohne Dämmung)	AW01A Exterior wall, basement (without insulation)			0.3	282.45
AW02A	Außenwand	Garage Porenbeton 36,5 cm	AW02A Exterior wall, garage, aerated concrete 36			0.405	144.19
AW02B	Außenwand	Garage Kalksandstein 30 cm	AW03 Exterior wall, aerated concrete			0.34	16.01
AW03 Außenwand Gasporenbeton			AW04 Exterior wall, ETICS, west gable			0.514	846.21
AW04 Außenwand WDVS Westgiebel			AW05 Exterior wall, gable wall, Dieskaustr.			0.403	131.79
AW05	Außenwand	Giebelwand Dieskaustr.	AW06 Light shaft, basement			0.253	186.99
AW06 Lichtsschacht UG			IW01B Sand-lime brick wall, 24 cm – basement (with insulation)			0.3	33.37
IW01A Kalksandsteinwand 24 cm - UG (mit Dämmung)			IW01B Sand-lime brick wall, 24 cm – basement (without insulation)			0.38	59.25
IW01B Kalksandsteinwand 24 cm - UG (ohne Dämmung)			IW02 Drywall, 12 cm			0.26	1151.6
IW02 Trockenbauwand 12,5 cm			IW04A Sand-lime brick wall, 17.5 cm			0.131	879.9
IW04 Kalksandsteinwand 17,5 cm			AR01A, Storage rooms KG, Partitions		0.201	501.48	
Columns							
Element Name (Ger)			Element Name (Eng)		Count		
IW03 Stahlbetonstütze D 30 cm			IW03 Reinforced concrete column D 30 cm			13	
IW03A Stahlbetonstütze 24cm x 24 cm			IW03A Reinforced concrete column 24x24 cm			2	

IW03B Stahlbetonstütze	25 cm x 90 cm	IW03B Reinforced column	25x90 cm	concrete	2
IW03C Stahlbetonstütze	35 cm x 80 cm	IW03C Reinforced column	35x80 cm	concrete	1
IW03D Stahlbetonstütze	EG 30 cm x 80 cm	IW03D Reinforced column	30x80 cm	concrete	1
IW03E Stahlbetonstütze	EG 30 cm x 40 cm	IW03D Reinforced column	30x40 cm	concrete	1

Slabs

Element Name (Ger)	Element Name (Eng)	Core Thickness (m)	Area (m ²)
DE01 Decke UG zu EG	DE01 Slab basement to ground floor	0.25	193.42
DE02 Decke EG zu 1.OG	DE02 Slab ground floor to 1st floor	0.25	432.62
DE02.1 Decke EG zu 1.OG über Garage	DE02.1 Slab ground floor to 1st floor over Garage	0.25	233.05
DE03 Decke 1.OG zu 2.OG	DE03 Slab 1st floor to 2nd floor	0.2	411.83
DE04 Decke 2.OG zu 3.OG	DE04 Slab 2nd floor to 3rd floor	0.2	411.83
DE05 Decke 3.OG zu 4.OG	DE05 Slab 3rd floor to 4th floor	0.2	411.96
DE06 Decke 4.OG zu 5.OG	DE06 Slab 4th floor to 5th floor	0.2	411.83
DE07 Decke 5.OG zu DG	DE07 Slab 5th floor to attic	0.2	347.3

Roof

Element Name (Ger)	Element Name (Eng)	Core Thickness (m)	Area (m ²)
DA03 Flachdach Hauptdach	DA03 Flat roof	0.503	115.99
DA04 Schrägdach	DA04 Pitched roof	0.493	457.89

Windows

Element Name (Ger)	Element Name (Eng)	Count
Fenster 5. OG, 1.00x1.65 m	Window 5th floor 1.00 x 1.65 m	10
FF02A Fenster 1.-4. OG, 1.50x1.65 m	FF02A Window 1st-4th floor, 1.50x1.65x0.485	63
FF02C Fenster 1.20x0.80 m	FF02C Window 1.20x0.80	16
FF02D Fenster 1.-4. OG, 1.00x1.65 m	FF02D Window 1st-4th floor, 1.00x1.65x0.485	5

Doors			
Element Name (Ger)	Element Name (Eng)	Count	
AR01B, Abstellräume KG, Türen Abstellräume	AR01B, Storage rooms KG, Doors Storage rooms	26	
AT01A, Außentür opak (Alu + Glas), Hauseingangstür	AT01A, opaque exterior door (aluminum + glass), front door	1	
AT01B, Außentür opak (Alu + Glas), Gewerbe 1	AT01B, opaque exterior door (aluminum + glass), commercial 1	1	
AT01C, Außentür opak (Alu + Glas), Gewerbe 2	AT01C, opaque exterior door (aluminum + glass), commercial 2	1	
AT01D Außentür Typ 1, Innenhof- Eingang + Eingang-Hausflur	AT01D exterior door type 1, courtyard entrance + entrance hallway	1	
AT01E, Außentür Typ 2, Innenhof-TH	AT01E, exterior door type 2, courtyard TH	1	
AT01F Außentür Typ 2	AT01F Exterior door type 2	6	
AT01G DG Laubengang- Diele DG T 04	AT01G DG Balcony - Hallway DG T 04	4	
AT01J Außentür Typ 1	AT01J Exterior door type 1	5	
IT01A WE Innentüren 860/2110/125 mm	IT01A WE Interior doors 860/2110/125	86	
IT02A WE-Eingangstüren Holz 985/2110/270 mm	IT02A WE Entrance doors wood 985/2110/270 mm	26	
IT02B WE-Eingangstüren Alu 985/2110/270 mm	IT02B WE entrance doors, aluminum, 985/2110/270 mm	10	
IT03A Stahltüren 875/2125 mm	IT03A Steel doors 875/2125 mm	5	
IT03B Stahltüren 885/2135 mm	IT03B Steel doors 885/2135 mm	1	
Balkontür 2.6 x 2.55 m	Balcony door 2.6 x 2.55 m	11	
Balkontür 1-4.OG 1.75 x 2.55 m	Balcony door 1-4.OG 1.75 x 2.55 m	15	
Balkontür 1-4.OG 2 x 2.55 m	Balcony door 1-4.OG 2 x 2.55 m	5	
Balkontür EG 1.00 x 2,25 m	Balcony door EG 1.00 x 2,25 m	2	
Floor cover			
Element Name (Ger)	Element Name (Eng)	Thickness (m)	Area (m ²)
DB01 Deckenbelag Fliesen	DB 01 Floor covering tiles	0.15	237.93
DB02 Deckenbelag Parkett	DB 02 Floor covering parquet	0.15	1495.66

Balcony						
Element Name (Ger)		Element Name (Eng)			Thickness (m)	Area (m²)
DB03 Deckenbelag Laubengänge		DB03 Floor covering outer circulation			0.35	102.63
DB04 Deckenbelag Balkone		DB04 Floor covering balconies			0.35	155.28
Foundation						
Element Name (Ger)		Element Name (Eng)			Thickness (m)	Area (m²)
GR01 Gründung		GR01 Foundation			0.55	466.07
Ceiling						
Element Name (Ger)		Element Name (Eng)			Area (m²)	
DE06 Unterhangdecke (Gewerbe / Bäder / HWR / WC / Flur)		DE06 Suspended ceiling			662.78	
Stairs						
Element Name (Ger)		Element Name (Eng)			Count	
TT01 Treppe		TT01 Stairs			1	
Railing						
Element Name (Ger)		Element Name (Eng)			Length (m)	
AW07 Brüstung Laubengänge		AW07 Parapet Outer Circulation			66.51	
BR01 Brüstung		BR01 Parapet			142.086	
Other						
Element Name (Ger)		Element Name (Eng)			Count	
FF03A Sonnenschutz Fenster		FF03A Window shutters			62	

A.2 – Detailed data import quality evaluation matrix

IFC 2X3 CV 2.0						
Element	Element (Eng)	Multi-layered	ID	BQ	CP	MI
Walls						
AR01A, Abstellräume KG, Trennwände	AR01A, Storage rooms KG, Partitions					

AW01A Außenwand UG (ohne Dämmung)	AW01A Exterior wall, basement (without insulation)			
AW02A Außenwand Garage Porenbeton 36	AW02A Exterior wall, garage, aerated concrete 36	+		
AW03 Außenwand Gasporenbeton	AW03 Exterior wall, aerated concrete	+		
AW04 Außenwand WDVS Westgiebel	AW04 Exterior wall, ETICS, west gable	+		
AW05 Außenwand Giebelwand Dieskaustr.	AW05 Exterior wall, gable wall, Dieskaustr.	+		
AW06 Lichtsschacht UG	AW06 Light shaft, basement			
IW01A Kalksandsteinwand 24 cm - UG (mit Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (with insulation)	+		
IW01B Kalksandsteinwand 24 cm - UG (ohne Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (without insulation)	+		
IW02 Trockenbauwand 12,5 cm	IW02 Drywall, 12 cm	+		
IW04A Kalksandsteinwand 17,5 cm	IW04A Sand-lime brick wall, 17.5 cm	+		
Columns				
IW03 Stahlbetonstütze D 30 cm	IW03 Reinforced concrete column D 30 cm			
IW03A Stahlbetonstütze 24cm x 24 cm	IW03A Reinforced concrete column 24x24 cm			
IW03B Stahlbetonstütze 25 cm x 90 cm	IW03B Reinforced concrete column 25x90 cm			

IW03C Stahlbetonstütze 35 cm x 80 cm	IW03C Reinforced concrete column 35x80 cm		
IW03D Stahlbetonstütze EG 30 cm x 80 cm	IW03D Reinforced concrete column 30x80 cm		
IW03E Stahlbetonstütze EG 30 cm x 40 cm	IW03D Reinforced concrete column 30x40 cm		
Slabs			
DE01 Decke UG zu EG	DE01 Slab basement to ground floor +		
DE02 Decke EG zu 1.OG	DE02 Slab ground floor to 1st floor +		
DE02.1 Decke EG zu 1.OG über Garage	DE02.1 Slab ground floor to 1st floor over Garage +		
DE03 Decke 1.OG zu 2.OG	DE03 Slab 1st floor to 2nd floor +		
DE04 Decke 2.OG zu 3.OG	DE04 Slab 2nd floor to 3rd floor +		
DE05 Decke 3.OG zu 4.OG	DE05 Slab 3rd floor to 4th floor +		
DE06 Decke 4.OG zu 5.OG	DE06 Slab 4th floor to 5th floor +		
DE07 Decke 5.OG zu DG	DE07 Slab 5th floor to attic +		
Roof			
DA03 Flachdach Hauptdach	DA03 Flat roof +		
DA04 Schrägdach	DA04 Pitched roof +		
Window			
Fenster 5. OG, 1.00x1.65 m	Window 5th floor 1.00 x 1.65 m +		
FF02A Fenster 1.-4. OG, 1.50x1.65 m	FF02A Window 1st-4th floor, 1.50x1.65x0.485 +		

FF02C Fenster 1.20x0.80 m	FF02C Window 1.20x0.80	+		
FF02D Fenster 1.-4. OG, 1.00x1.65 m	FF02D Window 1st-4th floor, 1.00x1.65x0.485	+		
Door				
Balkontür 1-4.OG 1	Balcony door 1st-4th floor 1	+		
Balkontür 1-4.OG 2 x 2.55	Balcony door 1st-4th floor 2 x 2.55 m	+		
Balkontür 2.6x2.55	Balcony door 2.6x2.55 m	+		
Balkontür EG 1.00 x 2,25	Balcony door ground floor 1.00 x 2.55 m	+		
AR01B, Abstellräume KG, Türen Abstellräume	AR01B, Storage rooms KG, Doors Storage rooms	+		
AT01A, Außentür opak (Alu + Glas), Hauseingangstür	AT01A, opaque exterior door (aluminum + glass), front door	+		
AT01B, Außentür opak (Alu + Glas), Gewerbe 1	AT01B, opaque exterior door (aluminum + glass), commercial 1	+		
AT01C, Außentür opak (Alu + Glas), Gewerbe 2	AT01C, opaque exterior door (aluminum + glass), commercial 2	+		
AT01D Außentür Typ 1, Innenhof-Eingang + Eingang-Hausflur	AT01D exterior door type 1, courtyard entrance + entrance hallway	+		
AT01E, Außentür Typ 2, Innenhof-TH	AT01E, exterior door type 2, courtyard TH	+		
AT01F Außentür Typ 2	AT01F Exterior door type 2	+		
AT01G DG Laubengang- Diele DG T 04	AT01G DG Balcony - Hallway DG T 04	+		
AT01J Außentür Typ 1	AT01J Exterior door type 1	+		

IT01A WE Innentüren 860/2110/125 mm	IT01A WE Interior doors 860/2110/125	+		
IT02A WE- Eingangstüren Holz 985/2110/270 mm	IT02A WE Entrance doors wood 985/2110/270 mm	+		
IT02B WE- Eingangstüren Alu 985/2110/270 mm	IT02B WE entrance doors, aluminum, 985/2110/270 mm			
IT03A Stahltüren 875/2125 mm	IT03A Steel doors 875/2125 mm	+		
IT03B Stahltüren 885/2135 mm	IT03B Steel doors 885/2135 mm	+		
Floor cover				
DB01 Deckenbelag Fliesen	DB 01 Floor covering tiles	+		
DB02 Deckenbelag Parkett	DB 02 Floor covering parquet	+		
Balcony				
DB03 Deckenbelag Laubengänge	DB03 Floor covering outer circulation	+		
DB04 Deckenbelag Balkone	DB04 Floor covering balconies	+		
Foundation				
GR01 Gründung	GR01 Foundation	+		
Ceiling				
DE06 Unterhangdecke (Gewerbe / Bäder / HWR / WC / Flur)	DE06 Suspended ceiling	+		
Stairs				
TT01 Treppe	TT01 Stairs	+		
Railing				
AW07 Brüstung Laubengänge	AW07 Parapet Outer Circulation			
BR01 Brüstung	BR01 Parapet			
Other				

FF03A Sonnenschutz Fenster	FF03A Window shutters				
Total Fully Exported		88.1%	88.1%	100.0%	47.5%
Total Partially Exported		11.9%	11.9%	0.0%	45.8%
Total Not Exported		0.0%	0.0%	0.0%	6.8%

IFC 4.0 RV						
Element	Element (Eng)	Multi-layered	ID	BQ	CP	MI
Walls						
AR01A, Abstellräume KG, Trennwände	AR01A, Storage rooms KG, Partitions					
AW01A Außenwand UG (ohne Dämmung)	AW01A Exterior wall, basement (without insulation)					
AW02A Außenwand Garage Porenbeton 36	AW02A Exterior wall, garage, aerated concrete 36	+				
AW03 Außenwand Gasporenbeton	AW03 Exterior wall, aerated concrete	+				
AW04 Außenwand WDVS Westgiebel	AW04 Exterior wall, ETICS, west gable	+				
AW05 Außenwand Giebelwand Dieskaustr.	AW05 Exterior wall, gable wall, Dieskaustr.	+				
AW06 Lichtsschacht UG	AW06 Light shaft, basement					
IW01A Kalksandsteinwand 24 cm - UG (mit Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (with insulation)	+				
IW01B Kalksandsteinwand 24 cm - UG (ohne Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (without insulation)	+				

IW02 Trockenbauwand 12,5 cm	IW02 Drywall, 12 cm	+				
IW04A Kalksandsteinwand 17,5 cm	IW04A Sand-lime brick wall, 17.5 cm	+				
Columns						
IW03 Stahlbetonstütze D 30 cm	IW03 Reinforced concrete column D 30 cm					
IW03A Stahlbetonstütze 24cm x 24 cm	IW03A Reinforced concrete column 24x24 cm					
IW03B Stahlbetonstütze 25 cm x 90 cm	IW03B Reinforced concrete column 25x90 cm					
IW03C Stahlbetonstütze 35 cm x 80 cm	IW03C Reinforced concrete column 35x80 cm					
IW03D Stahlbetonstütze EG 30 cm x 80 cm	IW03D Reinforced concrete column 30x80 cm					
IW03E Stahlbetonstütze EG 30 cm x 40 cm	IW03D Reinforced concrete column 30x40 cm					
Slabs						
DE01 Decke UG zu EG	DE01 Slab basement to ground floor	+				
DE02 Decke EG zu 1.OG	DE02 Slab ground floor to 1st floor	+				
DE02.1 Decke EG zu 1.OG über Garage	DE02.1 Slab ground floor to 1st floor over Garage	+				
DE03 Decke 1.OG zu 2.OG	DE03 Slab 1st floor to 2nd floor	+				
DE04 Decke 2.OG zu 3.OG	DE04 Slab 2nd floor to 3rd floor	+				
DE05 Decke 3.OG zu 4.OG	DE05 Slab 3rd floor to 4th floor	+				

DE06 Decke 4.OG zu 5.OG	DE06 Slab 4th floor to 5th floor	+				
DE07 Decke 5.OG zu DG	DE07 Slab 5th floor to attic	+				
Roof						
DA03 Flachdach Hauptdach	DA03 Flat roof	+				
DA04 Schrägdach	DA04 Pitched roof	+				
Window						
Fenster 5. OG, 1.00x1.65 m	Window 5th floor 1.00 x 1.65 m	+				
FF02A Fenster 1.-4. OG, 1.50x1.65 m	FF02A Window 1st-4th floor, 1.50x1.65x0.485	+				
FF02C Fenster 1.20x0.80 m	FF02C Window 1.20x0.80	+				
FF02D Fenster 1.-4. OG, 1.00x1.65 m	FF02D Window 1st-4th floor, 1.00x1.65x0.485	+				
Door						
Balkontür 1-4.OG 1	Balcony door 1st-4th floor 1	+				
Balkontür 1-4.OG 2 x 2.55	Balcony door 1st-4th floor 2 x 2.55 m	+				
Balkontür 2.6x2.55	Balcony door 2.6x2.55 m	+				
Balkontür EG 1.00 x 2,25	Balcony door ground floor 1.00 x 2.55 m	+				
AR01B, Abstellräume KG, Türen Abstellräume	AR01B, Storage rooms KG, Doors Storage rooms	+				
AT01A, Außentür opak (Alu + Glas), Hauseingangstür	AT01A, opaque exterior door (aluminum + glass), front door	+				
AT01B, Außentür opak (Alu + Glas), Gewerbe 1	AT01B, opaque exterior door (aluminum + glass), commercial 1	+				

AT01C, Außentür opak (Alu + Glas), Gewerbe 2	AT01C, opaque exterior door (aluminum + glass), commercial 2	+				
AT01D Außentür Typ 1, Innenhof-Eingang + Eingang-Hausflur	AT01D exterior door type 1, courtyard entrance + entrance hallway	+				
AT01E, Außentür Typ 2, Innenhof-TH	AT01E, exterior door type 2, courtyard TH	+				
AT01F Außentür Typ 2	AT01F Exterior door type 2	+				
AT01G DG Laubengang- Diele DG T 04	AT01G DG Balcony - Hallway DG T 04	+				
AT01J Außentür Typ 1	AT01J Exterior door type 1	+				
IT01A WE Innentüren 860/2110/125 mm	IT01A WE Interior doors 860/2110/125	+				
IT02A WE- Eingangstüren Holz 985/2110/270 mm	IT02A WE Entrance doors wood 985/2110/270 mm	+				
IT02B WE- Eingangstüren Alu 985/2110/270 mm	IT02B WE entrance doors, aluminum, 985/2110/270 mm					
IT03A Stahltüren 875/2125 mm	IT03A Steel doors 875/2125 mm	+				
IT03B Stahltüren 885/2135 mm	IT03B Steel doors 885/2135 mm	+				
Floor cover						
DB01 Deckenbelag Fliesen	DB 01 Floor covering tiles	+				
DB02 Deckenbelag Parkett	DB 02 Floor covering parquet	+				
Balcony						

DB03 Deckenbelag Laubengänge	DB03 Floor covering outer circulation	+				
DB04 Deckenbelag Balkone	DB04 Floor covering balconies	+				
Foundation						
GR01 Gründung	GR01 Foundation	+				
Ceiling						
DE06 Unterhangdecke (Gewerbe / Bäder / HWR / WC / Flur)	DE06 Suspended ceiling	+				
Stair						
TT01 Treppe	TT01 Stairs	+				
Railing						
AW07 Brüstung Laubengänge	AW07 Parapet Outer Circulation					
BR01 Brüstung	BR01 Parapet					
Other						
FF03A Sonnenschutz Fenster	FF03A Window shutters					
Total Fully Exported			57.6%	81.4%	57.6%	59.3%
Total Partially Exported			42.4%	18.6%	42.4%	0.0%
Total Not Exported			0.0%	0.0%	0.0%	40.7%

IFC 4.0 DTV						
Element	Element (Eng)	Multi-layered	ID	BQ	CP	MI
Walls						
AR01A, Abstellräume KG, Trennwände	AR01A, Storage rooms KG, Partitions					
AW01A Außenwand UG (ohne Dämmung)	AW01A Exterior wall, basement (without insulation)					

AW02A Außenwand Garage Porenbeton 36	AW02A Exterior wall, garage, aerated concrete 36	+			
AW03 Außenwand Gasporenbeton	AW03 Exterior wall, aerated concrete	+			
AW04 Außenwand WDVS Westgiebel	AW04 Exterior wall, ETICS, west gable	+			
AW05 Außenwand Giebelwand Dieskaustr.	AW05 Exterior wall, gable wall, Dieskaustr.	+			
AW06 Lichtsschacht UG	AW06 Light shaft, basement				
IW01A Kalksandsteinwand 24 cm - UG (mit Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (with insulation)	+			
IW01B Kalksandsteinwand 24 cm - UG (ohne Dämmung)	IW01B Sand-lime brick wall, 24 cm – basement (without insulation)	+			
IW02 Trockenbauwand 12,5 cm	IW02 Drywall, 12 cm	+			
IW04A Kalksandsteinwand 17,5 cm	IW04A Sand-lime brick wall, 17.5 cm	+			
Columns					
IW03 Stahlbetonstütze D 30 cm	IW03 Reinforced concrete column D 30 cm				
IW03A Stahlbetonstütze 24cm x 24 cm	IW03A Reinforced concrete column 24x24 cm				
IW03B Stahlbetonstütze 25 cm x 90 cm	IW03B Reinforced concrete column 25x90 cm				
IW03C Stahlbetonstütze 35 cm x 80 cm	IW03C Reinforced concrete column 35x80 cm				

IW03D Stahlbetonstütze EG 30 cm x 80 cm	IW03D Reinforced concrete column 30x80 cm		
IW03E Stahlbetonstütze EG 30 cm x 40 cm	IW03D Reinforced concrete column 30x40 cm		
Slabs			
DE01 Decke UG zu EG	DE01 Slab basement to ground floor	+	
DE02 Decke EG zu 1.OG	DE02 Slab ground floor to 1st floor	+	
DE02.1 Decke EG zu 1.OG über Garage	DE02.1 Slab ground floor to 1st floor over Garage	+	
DE03 Decke 1.OG zu 2.OG	DE03 Slab 1st floor to 2nd floor	+	
DE04 Decke 2.OG zu 3.OG	DE04 Slab 2nd floor to 3rd floor	+	
DE05 Decke 3.OG zu 4.OG	DE05 Slab 3rd floor to 4th floor	+	
DE06 Decke 4.OG zu 5.OG	DE06 Slab 4th floor to 5th floor	+	
DE07 Decke 5.OG zu DG	DE07 Slab 5th floor to attic	+	
Roof			
DA03 Flachdach Hauptdach	DA03 Flat roof	+	
DA04 Schrägdach	DA04 Pitched roof	+	
Windows			
Fenster 5. OG, 1.00x1.65 m	Window 5th floor 1.00 x 1.65 m	+	
FF02A Fenster 1.-4. OG, 1.50x1.65 m	FF02A Window 1st-4th floor, 1.50x1.65x0.485	+	
FF02C Fenster 1.20x0.80 m	FF02C Window 1.20x0.80	+	
FF02D Fenster 1.-4. OG, 1.00x1.65 m	FF02D Window 1st-4th floor, 1.00x1.65x0.485	+	

Doors				
Balkontür 1-4.OG 1	Balcony door 1st-4th floor 1	+		
Balkontür 1-4.OG 2 x 2.55	Balcony door 1st-4th floor 2 x 2.55 m	+		
Balkontür 2.6x2.55	Balcony door 2.6x2.55 m	+		
Balkontür EG 1.00 x 2,25	Balcony door ground floor 1.00 x 2.55 m	+		
AR01B, Abstellräume KG, Türen Abstellräume	AR01B, Storage rooms KG, Doors Storage rooms	+		
AT01A, Außentür opak (Alu + Glas), Hauseingangstür	AT01A, opaque exterior door (aluminum + glass), front door	+		
AT01B, Außentür opak (Alu + Glas), Gewerbe 1	AT01B, opaque exterior door (aluminum + glass), commercial 1	+		
AT01C, Außentür opak (Alu + Glas), Gewerbe 2	AT01C, opaque exterior door (aluminum + glass), commercial 2	+		
AT01D Außentür Typ 1, Innenhof-Eingang + Eingang-Hausflur	AT01D exterior door type 1, courtyard entrance + entrance hallway	+		
AT01E, Außentür Typ 2, Innenhof-TH	AT01E, exterior door type 2, courtyard TH	+		
AT01F Außentür Typ 2	AT01F Exterior door type 2	+		
AT01G DG Laubengang- Diele DG T 04	AT01G DG Balcony - Hallway DG T 04	+		
AT01J Außentür Typ 1	AT01J Exterior door type 1	+		
IT01A WE Innentüren 860/2110/125 mm	IT01A WE Interior doors 860/2110/125	+		
IT02A WE-Eingangstüren Holz 985/2110/270 mm	IT02A WE Entrance doors wood 985/2110/270 mm	+		

IT02B WE- Eingangstüren Alu 985/2110/270 mm	IT02B WE entrance doors, aluminum, 985/2110/270 mm				
IT03A Stahltüren 875/2125 mm	IT03A Steel doors 875/2125 mm	+			
IT03B Stahltüren 885/2135 mm	IT03B Steel doors 885/2135 mm	+			
Floor cover					
DB01 Deckenbelag Fliesen	DB 01 Floor covering tiles	+			
DB02 Deckenbelag Parkett	DB 02 Floor covering parquet	+			
Balcony					
DB03 Deckenbelag Laubengänge	DB03 Floor covering outer circulation	+			
DB04 Deckenbelag Balkone	DB04 Floor covering balconies	+			
Foundation					
GR01 Gründung	GR01 Foundation	+			
Ceiling					
DE06 Unterhangdecke (Gewerbe / Bäder / HWR / WC / Flur)	DE06 Suspended ceiling	+			
Stairs					
TT01 Treppe	TT01 Stairs	+			
Railing					
AW07 Brüstung Laubengänge	AW07 Parapet Outer Circulation				
BR01 Brüstung	BR01 Parapet				
Other					
FF03A Sonnenschutz Fenster	FF03A Window shutters				
Total Fully Exported			88.1%	88.1%	100.0%
Total Partially Exported			11.9%	11.9%	0.0%
Total Not Exported			0.0%	0.0%	44.1%