



Polytechnic of Turin

Department of Structural, Building and Geotechnical Engineering (DISEG)

Master's Degree Program
in **Civil Engineering**

BIM-LCA Approach to Carbon Footprint Reduction in Building Envelope Insulations: A Residential Case Study in Chieri, Turin

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March 2026

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To my parents, who never limited my dreams.

To myself, whose perseverance sustained me.

Acknowledgement

This work, titled “BIM-LCA Approach to Carbon Footprint Reduction in Building Envelope Insulations: A Residential Case Study in Chieri, Turin”.

I warmly thank my supervisor, Prof. Anna Osello, and my co-supervisor, Prof. Matteo Del Giudice, for their invaluable guidance, constructive feedback, and continuous encouragement throughout the preparation of this thesis.

I also wish to thank the studio where I carried out my internship, together with my tutor, for their valuable support and contribution to this project, and I extend my gratitude to all my colleagues who supported me.

My gratitude extends as well to all those who, in different ways, have supported me throughout this journey.

Finally, I express my heartfelt thanks to my family for their constant encouragement, patience, and unconditional support, which have sustained me during this journey.

Ringraziamenti

Il presente lavoro, dal titolo “Approccio BIM-LCA per la riduzione dell’impronta di carbonio negli isolamenti dell’involucro edilizio: caso studio residenziale a Chieri, Torino”.

Desidero esprimere la mia più sincera gratitudine alla mia relatrice, la Prof.ssa Anna Osello, e al mio correlatore, il Prof. Matteo Del Giudice, per la loro guida preziosa, i suggerimenti costruttivi e l’incoraggiamento costante durante la preparazione di questa tesi.

Rivolgo inoltre un sentito ringraziamento allo studio presso il quale ho svolto il mio tirocinio e alla mia tutor, per il loro prezioso supporto e contributo a questo progetto.

La mia riconoscenza si estende anche a tutte le persone che, in modi diversi, mi hanno sostenuto lungo questo percorso.

Infine, desidero ringraziare di cuore la mia famiglia e i miei amici per il loro costante incoraggiamento, la pazienza e il sostegno incondizionato, che mi hanno sostenuta durante questo cammino.

Abstract

This thesis presents a Building Information Modeling–Life Cycle Assessment (BIM–LCA) approach for evaluating and reducing the embodied carbon of building envelope insulation, demonstrated through a residential case study in Chieri, Turin. The research addresses the challenge of accurately assessing Global Warming Potential (GWP) in historical buildings with irregular geometries, where precise quantity take-off is essential for reliable environmental calculations.

The methodology involved generating a high-fidelity BIM model from point cloud data, ensuring accurate representation of irregular walls through “Model In-Place” tools. Two drawing approaches for insulation layers were tested: integrating insulation into the wall assembly and modeling it as a separate wall component. The latter proved more suitable for LCA, enabling precise isolation of insulation quantities, easier Environmental Product Declaration (EPD) assignment, and straightforward scenario testing for different thicknesses and materials.

Two LCA tools—Tally and One Click LCA—were applied to assess insulation materials (Expanded Polystyrene and Multipor Xella) across life-cycle stages, following EN 15804 standards. Tally provided streamlined integration within Revit for rapid analysis, while One Click LCA delivered detailed stage-by-stage outputs. The comparative results revealed differences in GWP values due to variations in databases and calculation methods, with EPS consistently exhibiting higher embodied carbon than Multipor.

To enhance the usability of results, a Dynamo scripting workflow was developed to import GWP values from Excel into the BIM model as shared parameters. Color-coded visualizations were then applied to highlight high-impact elements, supporting transparent communication and informed decision-making.

The findings confirm that most environmental impacts occur in the usage stage (B2-B5) and that insulation choice plays a critical role in reducing embodied carbon for renovation projects. The study demonstrates that combining precise modeling, an effective drawing methodology, LCA tool outputs, and BIM-based visualization offers a practical and replicable workflow for low-carbon design.

Future research should extend this approach to bio-based and recyclable insulation materials, such as paper-based products, to explore further opportunities for circular, low-impact building solutions.

Keywords

Global Warming Potential, Carbon Footprint Reduction, Environmental Impact Assessment, BIM-LCA Approach, building information modeling (BIM), , life Cycle Assessment (LCA), Life Cycle Assessment tools, One Click LCA, Tally, Dynamo, Sustainability.

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RESEARCH QUESTIONS

1. How can BIM-LCA workflows (Tally, One Click LCA) improve the accuracy and efficiency of embodied carbon assessment for building envelope insulation systems compared to conventional methods?
(Focus: Advantages of BIM-LCA approach over manual calculations.)
2. What are the key discrepancies between Tally (native Revit plugin) and One Click LCA (cloud-based) in quantifying Global Warming Potential (GWP) for insulation materials and how do these differences impact design decisions?
(Focus: Tool comparison, database variations, and user workflow implications.)
3. How does automating GWP value assignment and visualization in Revit via Dynamo scripting enhance transparency and decision-making in low-carbon design processes?
(Focus: Role of automation in reducing human error and improving stakeholder communication.)

Methodology

4. How does BIM with LCA tools (Tally and One Click LCA) improve the accuracy and efficiency of carbon footprint assessment for building envelope insulation systems?
(Focus: Workflow advantages, data interoperability, and limitations of BIM-LCA approach.)
5. What are the critical challenges in aligning BIM models (Revit) with LCA system boundaries (e.g., cradle-to-gate vs. cradle-to-grave) for insulation materials?
(Focus: Data granularity, LOD/LOI requirements, and boundary condition mismatches.)

Tool Comparison & Validation

6. How do the results of Tally and One Click LCA differ when assessing the same building envelope insulation system, and what factors drive these discrepancies?
(Focus: Database differences, calculation methodologies, and user input requirements.)

7. What are the strengths and limitations of Tally (native Revit plugin) vs. One Click LCA (cloud-based) for optimizing insulation material selection in early design stages?
(Focus: Usability, automation, and flexibility for iterative design.)

Methodology

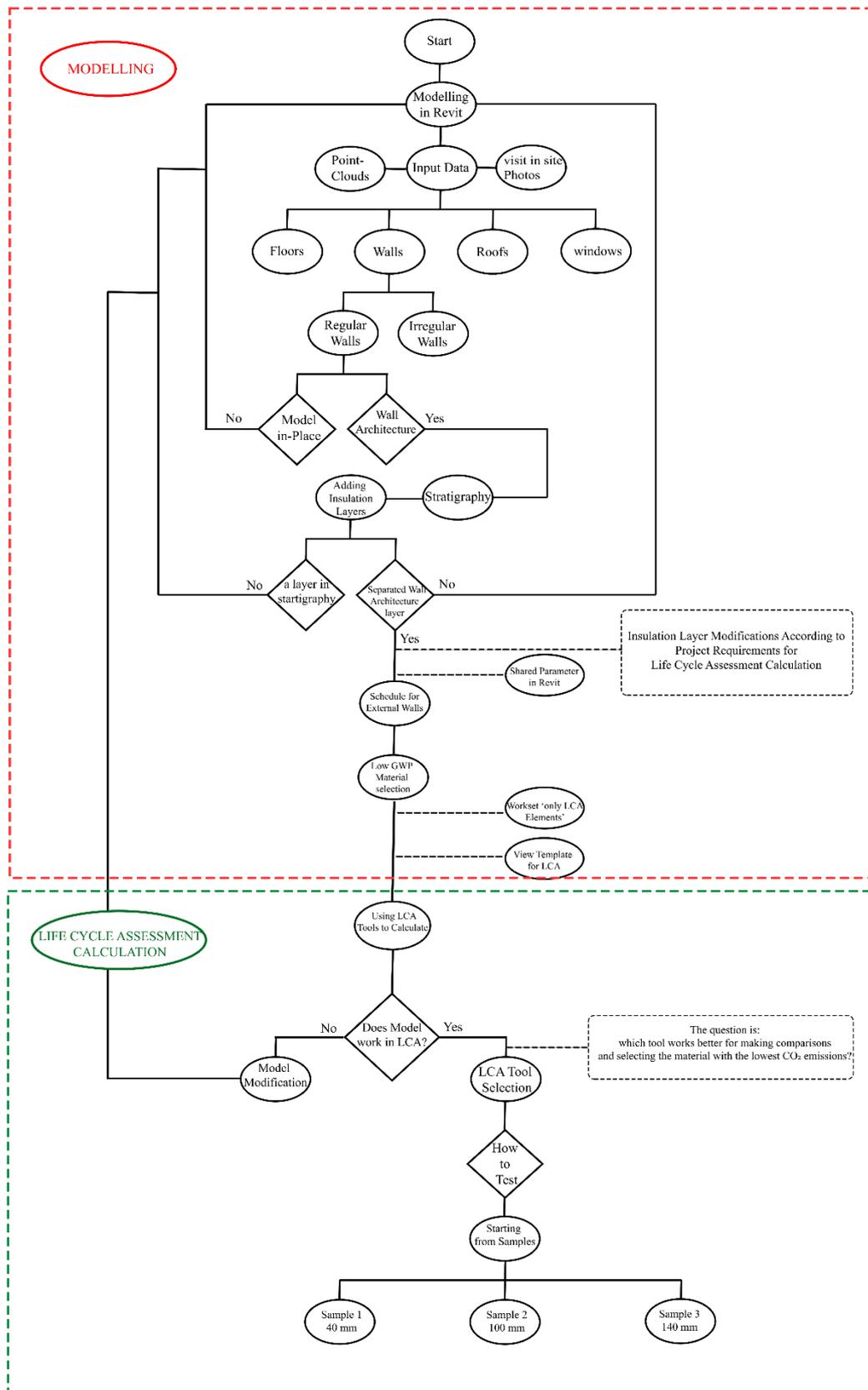


Figure 1: Methodology

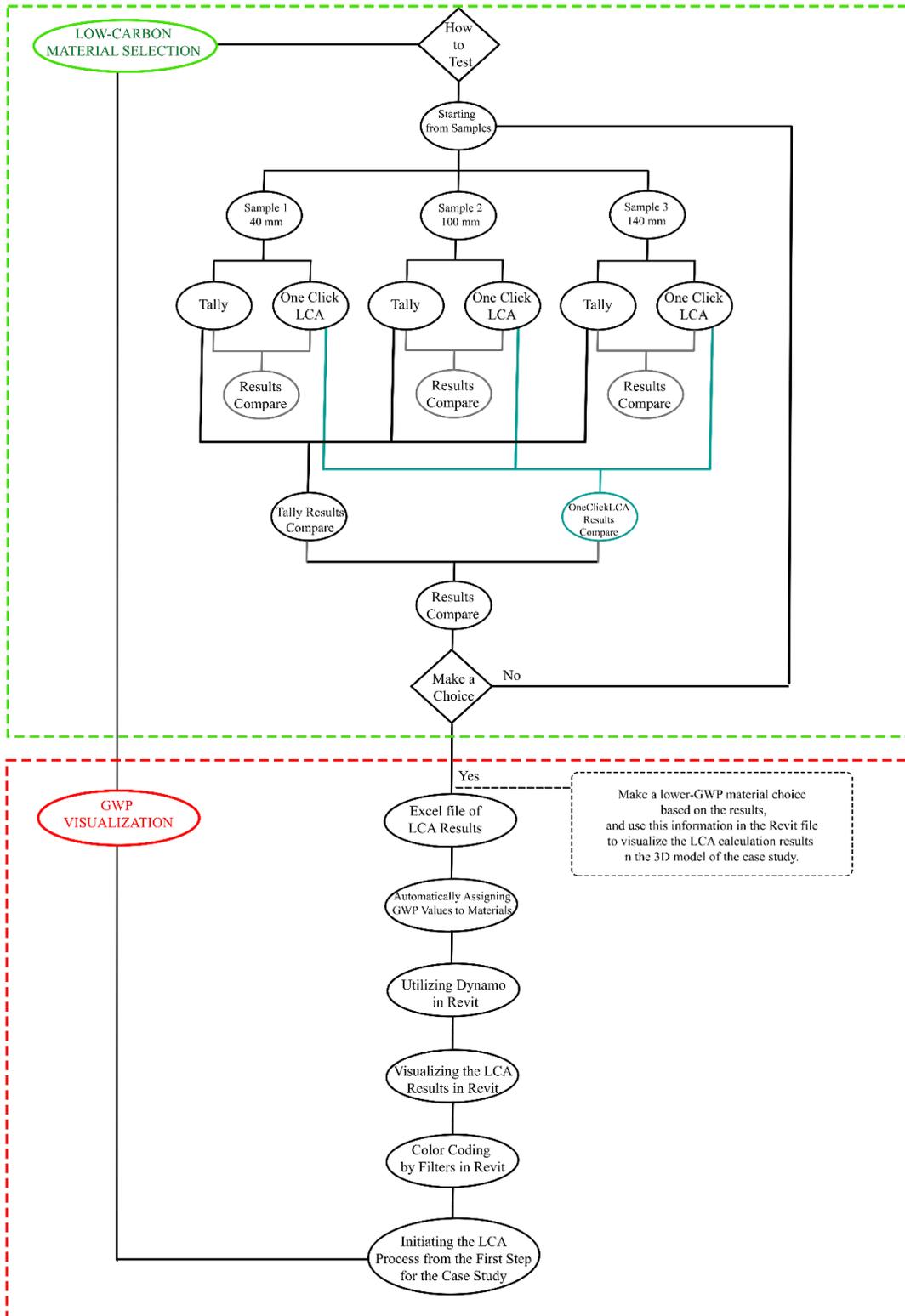


Figure 2: Methodology

Chapter 1: Introduction

The building and construction sector is responsible for approximately 39% of global carbon dioxide (CO₂) emissions, with 28% arising from operational energy use and 11% from the production and transport of construction materials (United Nations Environment Program [UNEP], 2022). In Europe, buildings account for 36% of CO₂ emissions and 40% of total energy consumption (European Commission, 2020). In the United States, buildings are responsible for 40% of material use, 38% of CO₂ emissions, and 30% of waste output (US Environmental Protection Agency, 2021). These statistics underscore the urgent need for the building industry to adopt strategies that minimize both operational and embodied carbon.

Sustainable architecture seeks to address these challenges by considering not only energy efficiency but also factors such as water use, material durability, recyclability, indoor environmental quality, and the overall life cycle impact of construction materials. To objectively evaluate and improve the sustainability of buildings, standardized frameworks and certifications—such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method)—have been developed. These systems provide comprehensive criteria for assessing the environmental performance of buildings (US Green Building Council, 2023, Building Research Establishment, 2023).

A key methodology for quantifying the environmental impacts of buildings is Life Cycle Assessment (LCA). LCA enables designers and stakeholders to analyze the entire life cycle of building materials—from raw material extraction through manufacturing, transportation, use, and end-of-life disposal—offering a data-driven basis for making greener material choices and reducing a building's overall carbon footprint (ISO, 2006; European Committee for Standardization, 2019).

This thesis focuses on optimizing the environmental performance of a residential building envelope in Chieri, Turin, by integrating Building Information Modeling (BIM) with LCA tools. The research aims to demonstrate how digital workflows, material selection, and local resource utilization can significantly reduce embodied carbon, contributing to a more sustainable built environment.

Global Warming Potential

Global Warming Potential (GWP) in the context of buildings is an indicator that quantifies the total greenhouse gas emissions—expressed as CO₂ equivalents—associated with a building throughout its entire life cycle, from raw material extraction ("cradle") to demolition and material recovery ("grave") (REHVA, 2024; Level(s), 2021). This includes embodied carbon emissions from manufacturing, transportation, construction, and end-of-life processes, as well as operational emissions during the building's use phase (WorldGBC, 2024).

The calculation of life cycle GWP follows standardized methodologies such as ISO 14067 and EN 15978, which define the life cycle stages and system boundaries for assessment. The assessment typically covers a reference period of around 50 years to capture the building's full environmental impact (REHVA, 2024; SEAI, 2025). The life cycle modules include production (A1–A3), construction (A4–A5), use (B1–B7), end-of-life (C1–C4), and benefits beyond the system boundary (D), each contributing to the total GWP (WorldGBC, 2024; EU Buildings Directive, 2024).

As buildings become more energy-efficient, reducing operational emissions, embodied carbon—especially emissions occurring early in the building's life—constitutes a larger share of the total GWP, highlighting the importance of design strategies that minimize material impacts and facilitate reuse and recycling at end-of-life (WorldGBC, 2024; Anavitor, 2024).

Policy frameworks in the EU, such as the recast Energy Performance of Buildings Directive (EPBD), mandate the calculation and disclosure of life cycle GWP for new buildings, aiming to reduce carbon emissions and promote circular economy principles in construction (EU Buildings Directive, 2024; WorldGBC, 2024). National methodologies, like Ireland's Lifecycle GWP Calculation Methodology, align with these standards and require reporting for larger new buildings starting in 2028 (SEAI, 2025).

In summary, life cycle GWP is a comprehensive metric essential for assessing and reducing the climate impact of buildings by accounting for all greenhouse gas emissions across their full life span.

Whole Life Carbon and Embodied Carbon

The discussion of whole life carbon, life cycle stages, and the use of EN 15978 as a reference standard for building life cycle assessment (LCA) is based on the European standard EN 15978.

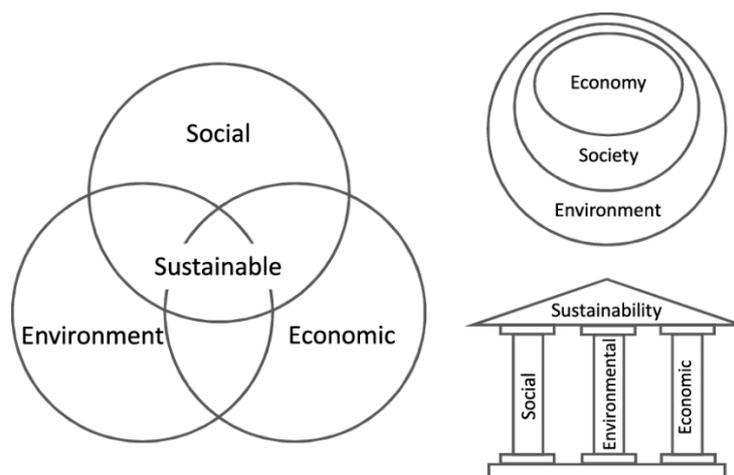
This standard is widely recognized in the construction and sustainability sectors for assessing the environmental performance of buildings throughout their life cycles, structuring the LCA into modules that cover production, construction, use, and end-of-life stages (BRE Global Ltd., 2018; RICS, 2018).

The definition and explanation of embodied carbon, including its calculation and significance, also directly reference EN 15978 and are supported by industry guidance such as the Royal Institution of Chartered Surveyors' (RICS) "Whole Life Carbon Assessment for the Built Environment". These documents clarify how embodied carbon is measured and why it is critical in evaluating the total environmental impact of buildings (RICS, 2018).

The specific breakdown of life cycle modules (A1–A5, B1–B7, C1–C4, D) and their relevance to embodied and whole life carbon calculations is visually represented in diagrams adapted from EN 15978, as seen in the provided image and in guides from organizations such as the UK Green Building Council (UKGBC) (UKGBC, 2023).

Background on Sustainability and the Three Pillars

The explanation of sustainability as encompassing environmental, social, and economic dimensions—the "three pillars"—is a well-established conceptual model in sustainability science. The Venn diagram shown in the image directly references this model, which has been discussed extensively in academic literature (Purvis, Mao, & Robinson, 2019).



*Figure 3: Three pillars of sustainability: in search of conceptual origins.
(Purvis, Mao, & Robinson, 2019, Sustainability Science)*

The importance of integrating sustainability into architectural design is highlighted by Thiebat (2019), reflecting current academic and professional thinking about the responsibilities of

architects in addressing the whole life cycle of buildings and their impacts on society and the environment.

The detailed explanations of each pillar (environmental, social, economic) and their interconnections are based on foundational sustainability literature and are reflected in professional guidance documents such as the RIBA Sustainable Outcomes Guide and academic reviews (Purvis et al., 2019; Thiebat, 2019).

Introduction of BIM Methodology

Building Information Modeling (BIM) has revolutionized the architecture, engineering, and construction (AEC) industry by enabling data-driven design, collaboration, and project management. Autodesk Revit is one of the leading BIM software solutions, offering parametric modeling, automated documentation, and interdisciplinary coordination to enhance efficiency in building design and construction

Building Information Modeling (BIM) is a digital process that enables the creation, management, and sharing of comprehensive building data throughout a project's life cycle. BIM is not just a 3D modeling tool; it is a collaborative methodology that integrates geometry, spatial relationships, geographic information, and a wide range of data attributes—such as material properties, environmental impacts, and cost information—into a single, coordinated model (ISO, 2018). BIM implementation is guided by international standards such as ISO 19650, which defines the organization and digitization of information about buildings and civil engineering works, including building information modeling (ISO, 2018). Additionally, the Level of Development (LOD) framework, as outlined by the BIMForum, specifies the degree of detail and reliability of BIM elements at different project stages, facilitating clear communication among stakeholders (BIMForum, 2021).

BIM and Sustainability

Recent research highlights BIM's crucial role in supporting sustainability assessments, especially when integrated with Life Cycle Assessment (LCA) methodologies. For example, Sustainability of Building Materials: Embodied Energy and Embodied Carbon of Masonry emphasize the importance of data granularity and modeling accuracy—such as Level of Information (LOI) and LOD 300-400—before conducting LCA. This ensures that material quantities and properties are sufficiently detailed for reliable environmental impact calculations

(Sustainability of Building Materials: Embodied Energy and Embodied Carbon of Masonry, 2023).

BIM models at LOD 300–400 provide the detail needed for trustworthy quantity take-offs and environmental analysis, as demonstrated in the thesis *A residential building project in Turin/Italy, design optimization in the light of low carbon materials: environmental impact assessment using LCA methodology* (2022). Here, BIM-based quantity take-off and Bill of Materials (BoM) extraction are used to align material data with LCA system boundaries, supporting both baseline and optimized design comparisons.

Introduction of Life Cycle Assessment (LCA) Methodology

Life Cycle Assessment (LCA) is a standardized methodology for evaluating the environmental impacts associated with all stages of a product's life, from raw material extraction through production, use, and end-of-life disposal. In the context of building sustainability, LCA provides a scientific basis for comparing materials and design alternatives by quantifying indicators such as global warming potential (GWP), ozone depletion potential (ODP), acidification potential (AP), eutrophication potential (EP), and primary energy demand (Michalak, Czernik, Marcinek, & Michałowski, 2020)

The LCA process is typically structured according to international standards such as EN 15804 and CEN TC 350, which define the scope and key phases of assessment (same). These phases include:

- **Product stage (cradle-to-gate):** Extraction and processing of raw materials, transport, and manufacturing (A1–A3 modules).
- **Construction process stage:** Transport to site and installation (A4–A5).
- **Use stage:** Operation, maintenance, and repair (B1–B7).
- **End-of-life stage:** Deconstruction, waste processing, and disposal (C1–C4).

For example, in *Environmental burdens of External Thermal Insulation Systems* (2024), the LCA of external thermal insulation systems (ETICS) is carried out for both expanded polystyrene (EPS) and mineral wool (MW), focusing on the cradle-to-gate impacts (A1–A3) in accordance with EN 15804. Environmental indicators are calculated per square meter of insulation for several thicknesses, allowing for direct comparison of material choices and their environmental burdens. Similarly, *New technical solutions for energy efficient*

buildings (2024) evaluate the Xella Multipor mineral foam board using cradle-to-gate LCA, reporting on embodied carbon and energy demand as key sustainability metrics.

Dynamic approaches to LCA, as discussed by Sohn et al. (2017), further enhanced the methodology by considering changes in the energy mix and building operation over time. This allows for more accurate modeling of climate impacts and optimal material choices, especially as energy systems decarbonize (Sohn et al., 2017).

The practical implementation of LCA in building design is increasingly supported by digital tools such as One Click LCA, which integrates with BIM platforms like Revit. These tools automate the extraction of material quantities and link them to verified environmental product declarations (EPDs) and LCA databases, streamlining the assessment process and improving accuracy (One Click LCA, 2024). The typical workflow involves:

- **Defining the goal and scope:** Selecting the building components and life cycle stages to be assessed.
- **Inventory analysis:** Collecting data on material quantities and environmental profiles.
- **Impact assessment:** Calculating environmental indicators such as GWP, ODP, AP, and EP.
- **Interpretation:** Comparing results and informing material selection and design optimization.

By integrating LCA into the BIM environment, as demonstrated in the referenced studies and supported by One Click LCA, designers and engineers can make informed decisions to enhance the sustainability of building envelopes—such as for residential retrofits in Chieri, Turin.

Life Cycle Assessment is defined in ISO 144044 (ISO, 2006) as a method to analyze the environmental impacts and aspects of the produced and consumed materials widely throughout their life cycles or in a particular period of time. LCA can be used for the decision-making process, improvements in production and usability of the materials. Improvements provided by the LCA analysis for the buildings in the decision-making process are considerably significant since it allows the designers to have environmentally better design solutions by considering the estimated impacts at the end. LCA methodology is designed to contain different phases of the project to examine the material and assure the overall process. (Köseci, 2018)

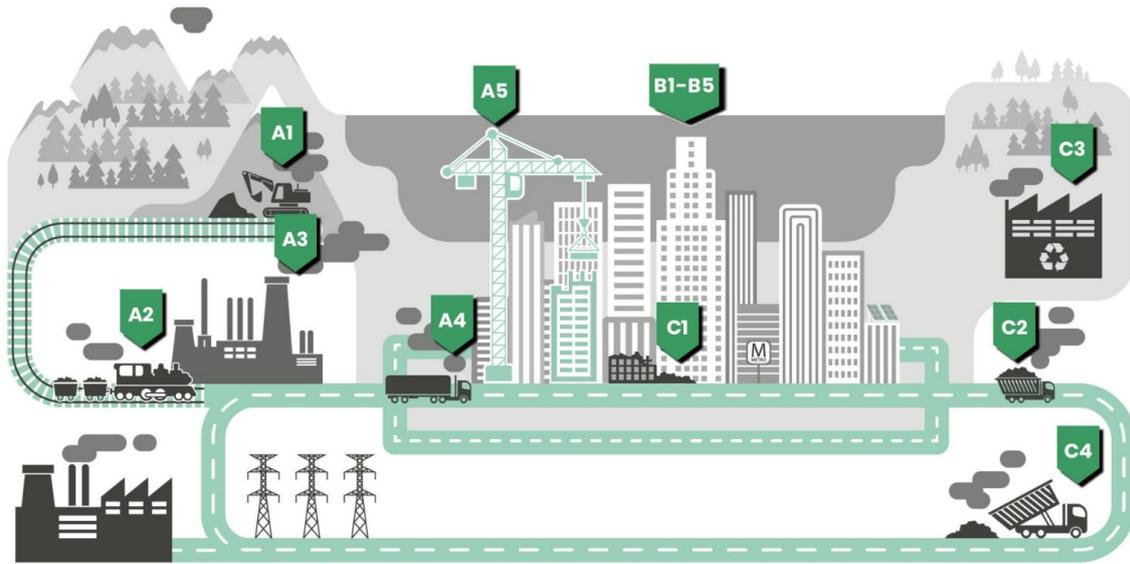
Life Cycle Assessment (LCA) is a methodology for assessing the environmental impact of products and is used in several certification systems (GBRS), including LEED BREEM. Backes et al. show that several countries, including the Netherlands, France, Sweden, Denmark, and Finland, are introducing policies to mandate LCA for new buildings. The “design phase”, due to its high degree of flexibility in compositional and technological choices, provides a significant opportunity to guide the selection of low-impact materials. (Bolognesi et al., 2025)

European research and policy efforts are increasingly focusing on evaluating embodied energy in construction materials throughout their life cycles. In this context, there is a growing need for tools and methodologies that enable greater control and verification of sustainability performance. It is precisely within this framework that the integration of Building Information Modeling (BIM) and Life Cycle Assessment (LCA) emerges as a valuable opportunity to automate, streamline, and enhance the reliability of environmental assessments from the early design stages. (same)

For Dalla Mora et al, the use of BIM allows the integration of complex information cohesively, providing accelerated LCA analyses. (Lima, Duarte, Exenberger, Fröch, & Flora, 2024) According to Guignone et al, it is important that impact assessment takes place from the very beginning of project design even if it is an estimate. The assessment process must occur throughout the project life cycle, allowing for up-to-date decision-making. In the same vein, advocated the need for the use of BIM–LCA not only at a specific stage but also during project development as an integrated decision-making tool, considering the entire design process and the evolution of available information. (Bolognesi et al., 2025)

Life Cycle Stages

Based on one click LCA official site, building life cycle stages are the different periods of a building’s lifetime. For instance: raw material harvesting, manufacturing of products, use phase of the building, end of life. In the European markets, the building life cycle stages are defined by EN 15978 and EN 15804 standards, which can be included in LCAs.



A1 - A3 Product stage

- A1 Raw material extraction
- A2 Transport to manufacturing site
- A3 Manufacturing

A4 - A5 Construction stage

- A4 Transport to construction site
- A5 Installation / Assembly

B1-B5 Use stage

- B1 Use
- B2 Maintenance
- B3 Repair
- B4 Replacement
- B5 Refurbishment

C1 - C4 End of life stage

- C1 Deconstruction & demolition
- C2 Transport
- C3 Waste processing
- C4 Disposal

Figure 4. Sources of embodied carbon across construction lifecycle (<https://www.oneclicklca.com/>)

The following graph lists all life cycle stages according to EN standards:

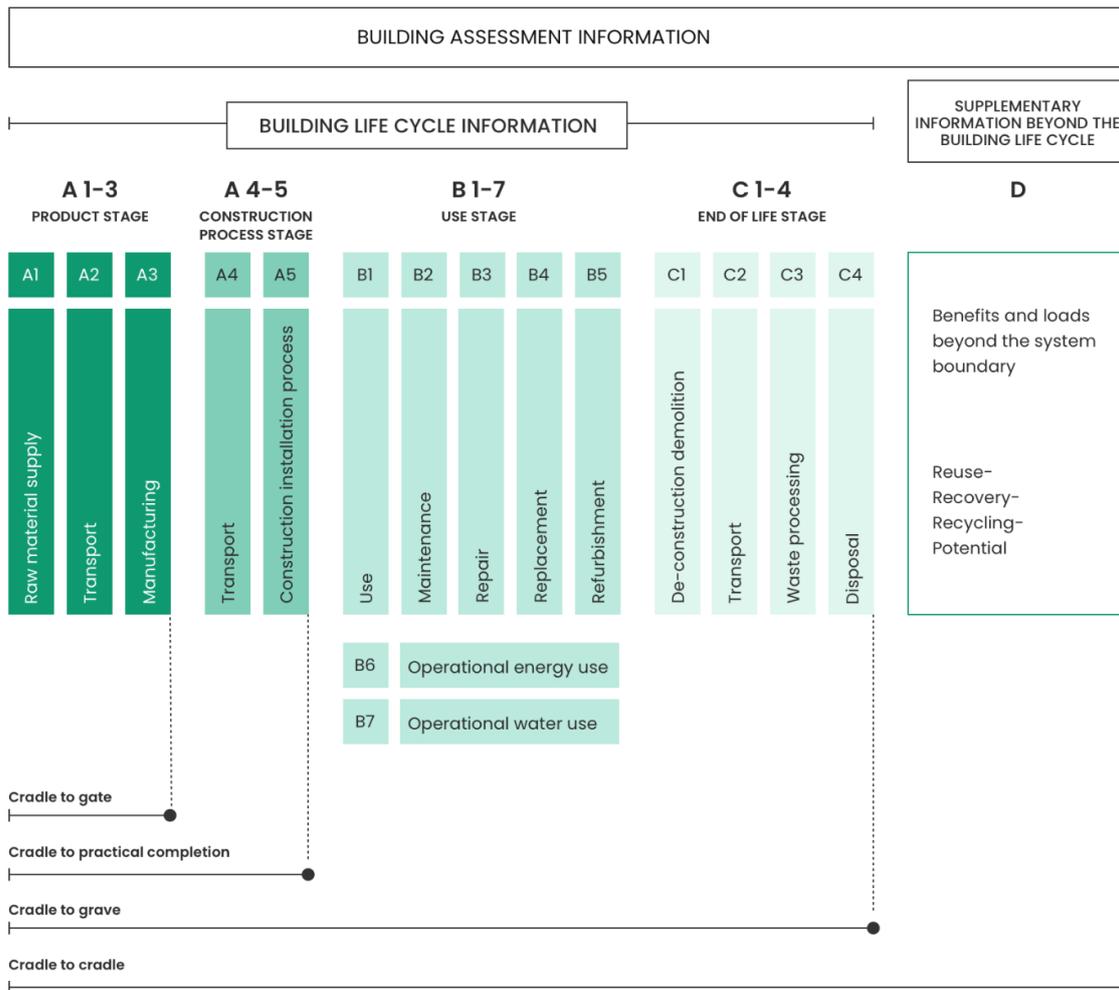


Figure 5: Figure x. Building Assessment Information (<https://www.oneclicklca.com/>)

A full list of possible life-cycle stages includes:

- **A0:** Pre-construction work including non-physical activities associated with the design of the asset (Used in the UK only)
- **A1:** Raw material extraction and processing, processing of secondary material input (e.g. recycling processes)
- **A2:** Transport to the manufacturer
- **A3:** Manufacturing

Module A1, A2, and A3 may be declared as one aggregate module A1-A3. All stages include the provision of all materials, products, and energy, as well as waste processing up to the end-of-waste state or disposal of final residues during the product stage. The assessment takes only the building and its parts into account, but not furniture or appliances, for example.

- **A4:** Transport to the building site
- **A5:** Installation into the building.

Stages A4 and A5 include all impacts and aspects related to any losses during this construction process stage (i.e. production, transport, and waste processing, and disposal of the lost products and materials).

- **B1:** Use or application of the installed product
- **B2:** Maintenance
- **B3:** Repair
- **B4:** Replacement
- **B5:** Refurbishment
- **B6:** Operational energy use (e.g. operation of the heating system and other building-related installed services);
- **B7:** Operational water use
- **B8:** Operational transport of users and goods to the building during the operation of the building (NS3720, PAS2080 and EN-17472 only)
- **B9:** User utilisation (PAS2080 only)

Stages B6 and B7 also include provision and transport of all materials, products, as well as energy and water provisions, waste processing up to the end-of-waste state or disposal of final residues during this part of the use stage.

- **C1:** De-construction, demolition
- **C2:** Transport to waste processing
- **C3:** Waste processing for reuse, recovery and/or recycling
- **C4:** Disposal

All C stages include provision and transport, provision of all materials, products and related energy and water use.

- **D:** Reuse, recovery and/or recycling potentials, expressed as net impacts and benefits

Different life cycle stages are either mandatory or optional for a different scope of LCA. In product level assessments only modules A1 to A3 are mandatory under EN 15804+A1, while all other phases are optional. This will change with EN 15804+A2 where A1-A3 and C1-C4 will become mandatory for most products. In building level calculations (for instance according to EN 15978) the idea is to consider all the meaningful impacts over the lifetime of the building. However, different certifications and calculation systems may limit the modules calculated.

Integration of BIM and LCA

The integration of Life Cycle Assessment (LCA) into Building Information Modeling (BIM) processes is becoming increasingly important for enhancing the environmental performance of construction projects. (Bolognesi et al., 2025) This scoping review examines how LCA methods and environmental data are currently integrated into BIM workflows, focusing on automation, data standardization, and visualization strategies.

As illustrated in Figure 6, Zimmermann et al. (2021, pp. 7–9) identify five principal workflows for linking BIM data with LCA tools:

1. **Enriched BIM models**, where environmental data are directly embedded into BIM objects;
2. **Quantity take-off**, in which material quantities are extracted from BIM and imported into LCA software via a bill of quantities (BoQ);
3. **Geometry import**, where the BIM model is exported (e.g., in IFC format) for use in LCA tools;
4. **Intermediate viewers**, which act as connectors between BIM software and LCA platforms; and
5. **LCA plug-ins**, where LCA tools are directly embedded into BIM environments.

These workflows represent varying degrees of automation and interoperability, with plug-ins and enriched BIM models enabling tighter integration but also requiring higher data quality and consistency (Zimmermann et al., 2021, pp. 7–9).

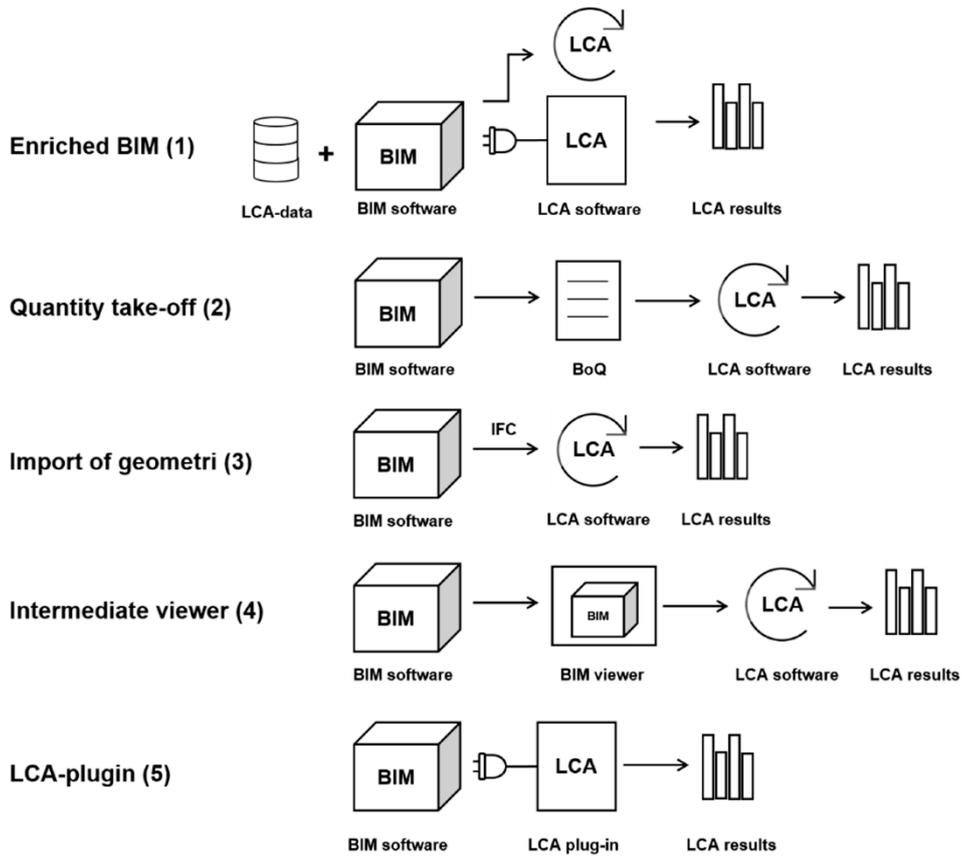


Figure 6. Possible workflows for integrating BIM and LCA, including enriched BIM models, quantity take-off, geometry import, intermediate BIM viewers, and LCA plug-ins. Reproduced from Zimmermann et al. (2021, p. 8), © 2021 by the authors, distributed under the terms of the Creative Commons Attribution (CC BY) license

Chapter 2: Methodology

This diagram illustrates a workflow for BIM (Building Information Modelling) and LCA (Life Cycle Assessment) approaches to evaluate environmental impacts of construction materials — especially insulation.

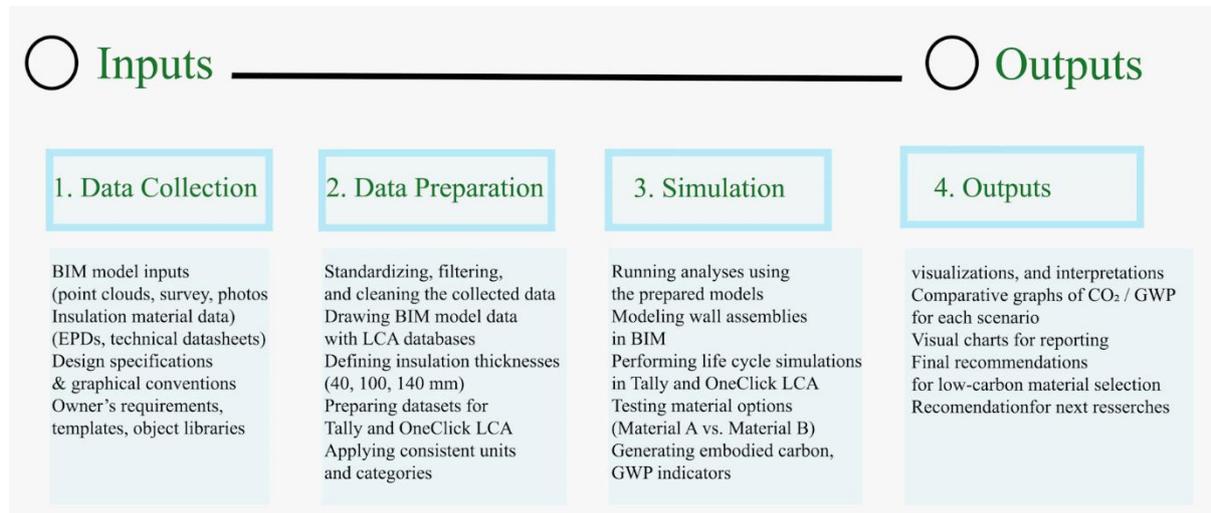


Figure 7. workflow for BIM-LCA approach

It's structured in four sequential stages between inputs and outputs:

1. Data Collection

- Gathering raw data: BIM inputs (point clouds, surveys, photos), insulation material data (EPDs, datasheets), design specs, owner requirements, templates, and object libraries.
- This stage ensures all necessary information is available before analysis.

2. Data Preparation

- Cleaning and standardizing the data collected.
- Linking BIM models with LCA databases.
- Defining insulation thicknesses (e.g., 40, 100, 140 mm).
- Preparing datasets for tools like Tally and OneClick LCA, applying consistent units and categories.
- This stage ensures comparability and reliability of later simulations.

3. Simulation

- Running analyses in BIM and LCA software.
- Modeling wall assemblies, testing alternative materials.
- Performing life cycle simulations to estimate embodied carbon and GWP (Global Warming Potential) indicators.

4. Outputs

- Producing results: visualizations, comparative CO₂/GWP graphs, reporting charts.
- Delivering recommendations for low-carbon material selection.
- Providing suggestions for future research.

In the Italian regulatory framework, the UNI 11337-4:2017 standard introduces a structured definition of the Level of Development (LOD) by distinguishing between two complementary components: the **Level of Geometry (LOG)**, which refers to the graphical attributes of objects, and the **Level of Information (LOI)**, which refers to the alphanumeric, non-geometric data associated with them. Together, LOG and LOI define the LOD of BIM objects and determine the quality and reliability of the digital information produced. As illustrated in Pavan (2017), the integration of geometric and alphanumeric attributes enables the generation of various outputs—such as graphical models, 2D integrations, calculations, tabular reports, and images—ensuring a coherent digital information flow throughout the project lifecycle. This dual-component approach underlines the Italian contribution to clarifying and operationalizing LOD concepts within BIM practices. (Figure 8)

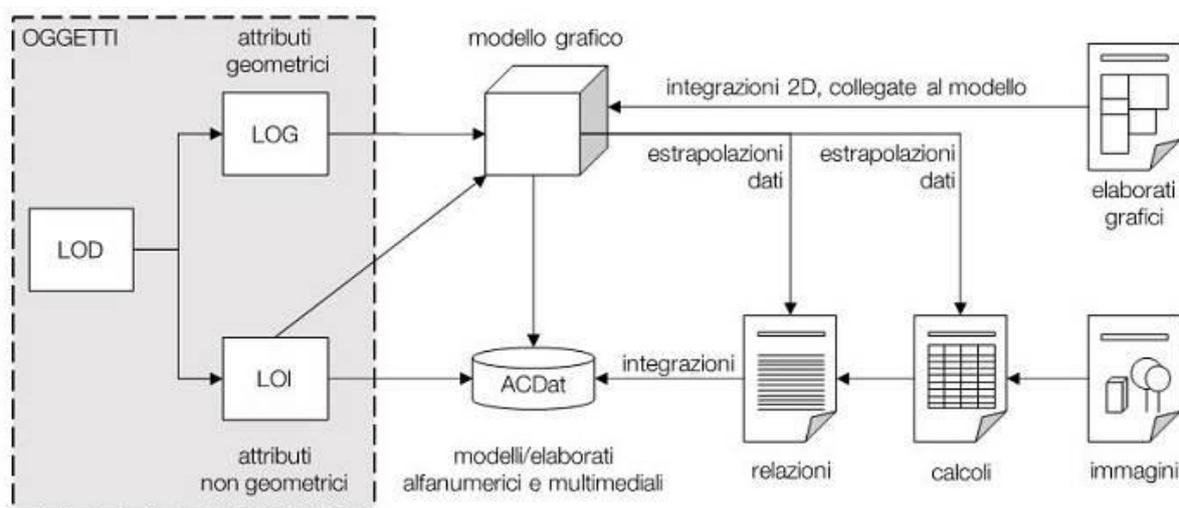


Figure 8. Data flows in the digital process through LOD of BIM objects (Pavan, 2017).

In recent studies, the distinction between *Level of Detail/Development (LOD)* and *Level of Information (LOI)* in BIM-LCA workflows has been refined, with emphasis on how both geometry and information completeness impact environmental assessment accuracy. For instance, *BIM-Led LCA: Feasibility of Improving Life Cycle Assessment through Building Information Modelling during the Building Design Process* (Cavalliere, 2019; Politecnico di Bari) proposes a method to conduct LCA continuously through all design phases by integrating BIM elements with LCA parameters, using different LCA databases aligned with the LOD of model elements. This method highlights that when geometric fidelity and information completeness increase through the project phases, GWP estimation becomes more reliable.

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Similarly, *BIM-based LCA: workflow applied to a raw earth version of the bioclimatic greenhouse of Trompone* (Ait Hadda, 2021; Politecnico di Torino) investigates model requirements for BIM-LCA workflows and finds that ensuring accurate geometry (for envelope components in particular) and defining non-geometric attributes (material properties, environmental data) are essential to produce credible assessments. [Webthesis](#)

Another useful study is *Key Parameters Featuring BIM-LCA Integration in Buildings* (Dalla Mora, 2020), which reviews BIM-LCA integration in the last decade and finds as recurring critical factors the geometric detail of building elements, and the non-geometric data completeness (material type, environmental attributes) required by LCA tools. The paper argues that many workflows fail or produce high uncertainty when LOI is incomplete—even if the geometry is detailed. [MDPI](#)

Based on these works, in this study the BIM model is developed to at least a level of geometric detail comparable to LOD 300, particularly for wall envelope components, enabling reliable extraction of material quantities. At the same time, LOI is ensured by attaching material type, thickness, density, and where available, product-specific environmental data (such as from EPDs) to each element. This approach follows recent literature which shows that combining accurate geometry with comprehensive information content is necessary to reduce uncertainty in LCA outcomes in building envelope retrofits.

According to Del Giudice and Iacono (2020), algorithmic workflows enable more consistent graphic standards in BIM. This articulated series of operations would make it possible to obtain, as a product, the improvement of the so-called Level of Geometry (LOG) as well as the addition of various elements of detail that would help to understand the more advanced project phases, as well as the improvement of the Level of Information (LOI) (fig. x). Depending on the BIM authoring application used to perform these operations, different subsets of representation settings may be required, whether they are based either on certain graphic filters, or on the addition of components and annotations, or on automatic or manual compilation of various properties of the elements.

As illustrated in Figure 9 (Del Giudice & Iacono, 2020), the level of detail in BIM models includes both graphical and alphanumeric components.

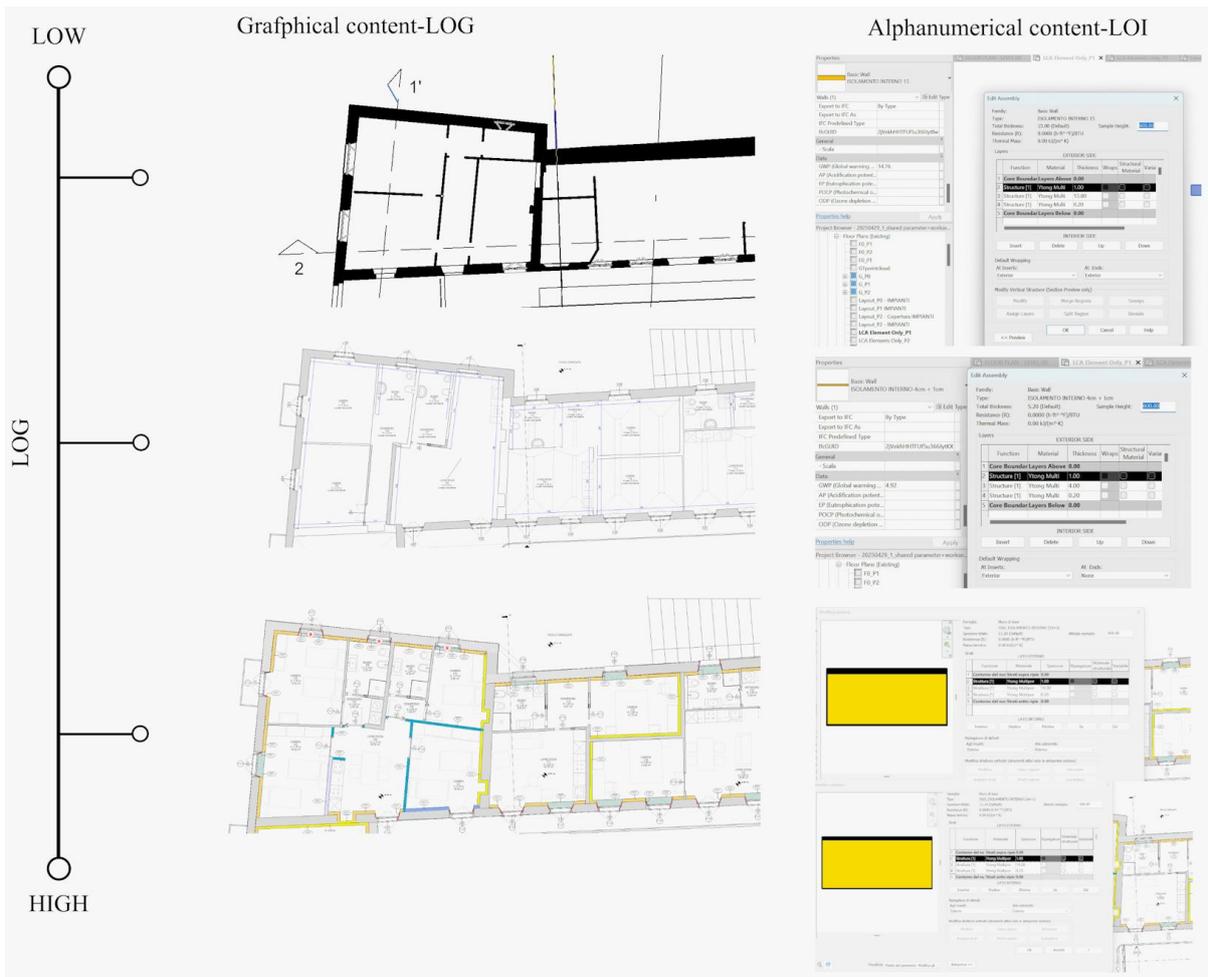


Figure 9. Example of graphic and alphanumerical contents of the LOD. Adapted from Algorithmic approach for the application of graphic standards in the BIM environment by M. Del Giudice & E. Iacono, 2020, *Disegno – Journal of the Italian Association of*

Level of Information Needed (LOIN)

According to Barbero, Vergri, Ugliotti, Del Giudice, Osello, and Manzone (2021), different meanings have been used in the international BIM context to indicate the “Level of Definition” by which information must be entered into a BIM model. The American Institute of Architects (AIA) first proposed LOD definition as Level of Detail, which later evolved into Level of Development [6]. In the UK, the PAS 1192- 2 introduced the differentiation between the geometric Level of Development (LOD) and the alphanumerical one. It has split the LOD between the Level of Geometry (LOG) and the Level of Information (LOI). Italian norm defines instead the Level of Development (LOD) for each object to be inserted within the BIM model, mentioning the double definition of LOG and LOI. Nowadays, the International Standard Organization (ISO) seeks to standardize this definition internationally with ISO 19650-1:2019 standard by introducing the concept of the “level of information need” concerning the specific BIM uses. Regarding the distinction between geometric and

alphanumeric content, the ISO suggests that the granularity of alphanumeric information should be at least as important as that of geometric information.

Work Approach – Selection of Environmental Indicators

To improve the accuracy and transparency of Life Cycle Assessment (LCA) calculations within the Revit model, key environmental performance indicators are incorporated as shared parameters linked to material properties. The selection of these indicators follows internationally recognized standards and frameworks, primarily based on the **International EPD System** and the **EN 15804** standard, as well as specific product data from the **Institut Bauen und Umwelt (IBU)** and **Xella's Multipor insulation** product information.

The indicators included are:

- **Global Warming Potential (GWP)**, divided into four components as prescribed by the General Programme Instructions (GPI 4.0) of the International EPD System:
 - GWP-fossil
 - GWP-biogenic
 - GWP-land use and land use change (LULUC)
 - GWP-total (sum of the above three)
- **Ozone Depletion Potential (ODP)**, which quantifies the potential contribution to the depletion of the stratospheric ozone layer.
- **Acidification Potential (AP)**, measuring the potential to cause acid rain and acidification of ecosystems.
- **Eutrophication Potential (EP)**, assessing the potential to cause nutrient enrichment in water bodies and soils.
- **Photochemical Ozone Creation Potential (POCP)**, indicating the potential for ground-level ozone (smog) formation.

These indicators are consistent with the mandatory environmental impact categories defined in the **EPD system** and are supported by data available from the **IBU database**, **Xella's Multipor product documentation**, and supplemented by the **GaBi database** for life cycle inventory data.

Environmental Indicator	Unit	Description
GWP-fossil	kg CO ₂ -eq/m ³	Greenhouse gas emissions from fossil sources
GWP-biogenic	kg CO ₂ -eq/m ³	Greenhouse gas emissions/removals from biogenic sources
GWP-land use and land use change (LULUC)	kg CO ₂ -eq/m ³	Emissions related to land use and land use change
GWP-total	kg CO ₂ -eq/m ³	Total global warming potential (sum of above)
Ozone Depletion Potential (ODP)	kg CFC-11 eq/m ³	Potential to degrade the ozone layer
Acidification Potential (AP)	kg SO ₂ -eq/m ³	Potential to cause acidification
Eutrophication Potential (EP)	kg PO ₄ ³⁻ -eq/m ³	Potential to cause eutrophication
Photochemical Ozone Creation Potential (POCP)	kg C ₂ H ₄ eq/m ³	Potential for photochemical smog formation

Table 1.Environmental Indicators Incorporated as Shared Parameters in Revit

LCA Tools: Tally and One Click LCA

For the development of the methodology, it is necessary to select an LCA plugin to use for calculating the GWP parameter of the elements. Among all the plugins available on the market, two were selected: **Tally** and **One Click LCA**.

The integration of Life Cycle Assessment (LCA) into Building Information Modeling (BIM) workflows has been significantly advanced by the development of specialized plugins and software tools. Among the most widely used and recognized LCA plugins for the construction sector are **Tally** and **One Click LCA**, both of which enable practitioners to assess the environmental performance of building materials and assemblies directly within BIM environments such as Autodesk Revit.

Tally

Tally is a Revit-integrated LCA tool developed by Kieran Timberlake and now maintained by Building Transparency. It allows users to perform whole-building LCA by linking material quantities from the Revit model to environmental impact data sourced from the US LCI Database and Ecoinvent. Tally operates within the Revit environment, enabling real-time feedback on the environmental impacts of design decisions-including global warming potential (GWP), acidification, eutrophication, and other key LCA indicators-across different building elements and assemblies.

Key features of Tally include:

- Seamless integration with Revit’s take-off material and scheduling functions.
- The ability to assign environmental profiles to modeled elements and track impacts as the design evolves.
- Reporting results according to established LCA standards (such as EN 15804 and ISO 14044).
- Export of LCA results for documentation and comparison.

Tally is particularly useful in early design phases, where rapid feedback on material choices can inform sustainable decision-making without requiring extensive manual data entry or external modeling (Building Transparency, 2024).

One Click LCA

One Click LCA is a cloud-based software that enables comprehensive Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and carbon footprint analysis. Integrated with certifications such as LEED, this tool is widely adopted in architecture and construction (One Click LCA for Autodesk® Revit, n.d.; Life-cycle costing | carbon assessments, n.d.).

To use it in Autodesk Revit, users must download the *One Click LCA Revit plugin* from the Autodesk App Store and log in via their One Click LCA account—trial, student, or full “Expert” license is required. Within Revit, the plugin reads building materials and geometry, automatically mapping items to the software’s extensive LCA database. Authenticated users can obtain results directly within Revit under the “LCA in Revit” option; otherwise, results are accessed via the “LCA in Cloud” option (One Click LCA for Autodesk® Revit, n.d.; Life-cycle assessment from Revit, n.d.).

Workflow Overview:

1. Create an account on One Click LCA’s website, enter license credentials.
2. In Revit, launch the plugin and choose either:
 - LCA in Revit – run the assessment within Revit’s interface; or
 - LCA in Cloud – export quantities to the online platform. The plugin captures material names, quantities, categories, and geometry directly from the model (One Click LCA Integration for Autodesk Revit, n.d.; Life-cycle assessment from Revit, n.d.).
3. Automatic mapping identifies materials, though manual adjustments are recommended for accuracy (Integration for Autodesk Revit, n.d.).
4. With Expert-level licensing, environmental impact results are viewable in Revit. Other license types must review results on the cloud platform (One Click LCA for Autodesk® Revit, n.d.).
5. After export, the cloud interface compiles a detailed PDF and Excel report, with options for customizing output fields such as project phase, model filters, grouping, mapping controls, and plausibility checks (Integration for Autodesk Revit, n.d.; One Click LCA for Autodesk® Revit, n.d.).

Use of Tally Plugin in Revit for Life Cycle Assessment (LCA)

- Activation of Tally within Revit

To initiate the Tally plugin within the Revit environment, the user accesses the Add-Ins tab and activates Tally. This prepares the software for LCA configuration by linking the BIM

model with environmental data. Upon activation, the user navigates to the material mapping interface, where materials defined in Revit are associated with corresponding environmental profiles (Autodesk App Store, 2023).

- Material Mapping with Tally

Material mapping is a critical step where each Revit material is linked to Life Cycle Inventory (LCI) datasets embedded within Tally, primarily sourced from the GaBi database. For proprietary or uncommon materials, custom environmental profiles can be created using third-party Environmental Product Declarations (EPDs). This ensures a comprehensive and accurate environmental data linkage necessary for subsequent LCA computations (Kieran Timberlake, 2024).

- Configuration and Execution of LCA

Users define impact assessment parameters by selecting relevant categories such as Global Warming Potential (GWP), Embodied Energy, and Ozone Depletion. Tally then performs the LCA simulation, calculating the environmental impacts of building components, such as insulation materials, typically expressed per unit area (e.g., kg CO_{2e}/m²). The output provides quantified environmental impact results, enabling comparative evaluation of materials and design options (Autodesk App Store, 2023).

In summary, the Tally plugin integrates seamlessly with Revit, enabling designers to embed comprehensive environmental data into BIM models and perform detailed LCA directly within the design environment. Its workflow—from activation and material mapping to impact assessment and scenario analysis—supports sustainable design practices by providing real-time feedback on the environmental consequences of material and design choices.

Tool Selection Decision Flowchart

The decision-making process is summarized in Figure 10, which visually breaks down the rationale for choosing Tally over One Click LCA and OpenLCA.

Tool Selection Decision Flowchart

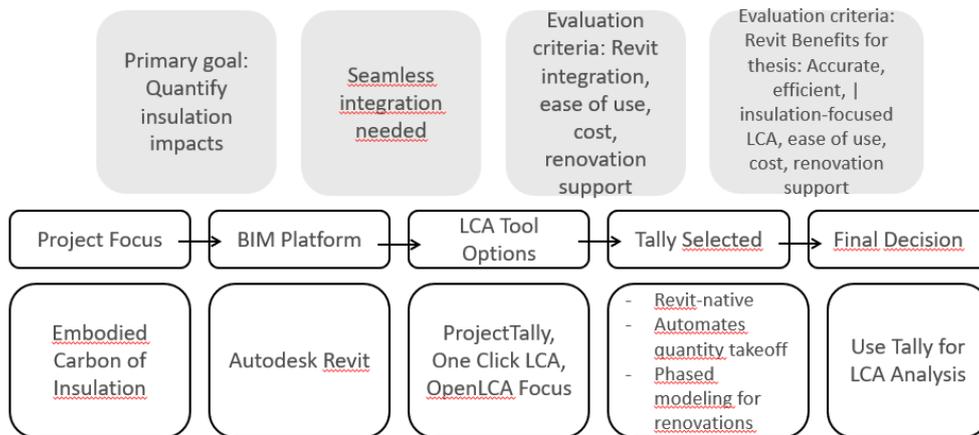


Figure 10. Tool Selection Decision Flowchart

As seen, Tally was chosen for its Revit integration, automation capabilities, and support for phased modeling in renovation projects and **the results for each stage divided**.

Process Map

Typically, the information flow required for conducting LCA with BIM as the source of quantifiable data follows a structured sequence. It originates from the 3D model generated in Revit®, undergoes interpretation by the OCL plugin within the Revit® environment, and is subsequently exported to the OCL cloud-based platform. This cloud version offers a more user-friendly interface, providing users with the capability to establish connections with datasets from diverse sources, including EPDs. Following this data integration, a comprehensive understanding of the overall information flow can be achieved, as shown in Figure 3. (Lima, Duarte, Exenberger, Fröch, & Flora, 2024)

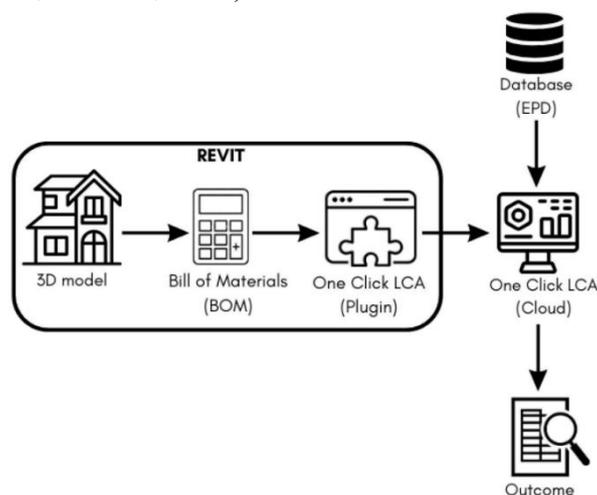


Figure 11. From “Integrating BIM-LCA to Enhance Sustainability Assessments of Constructions” by M. S. S. Lima, S. Duarte, H. Exenberger, G. Fröch, & M. Flora, 2024, *Sustainability*, 16(3), Article 1172 (<https://doi.org/10.3390/su16031172>).

By utilizing the Revit® plugin, project information is automatically transferred to the online version of OCL. There, the information is mapped to generate a carbon-emissions report. Both the plugin and online versions allow users to adjust certain settings to cluster or divide elements based on their level of detail. Additionally, it is possible to modify the functional unit of each material to optimize the mapping process.

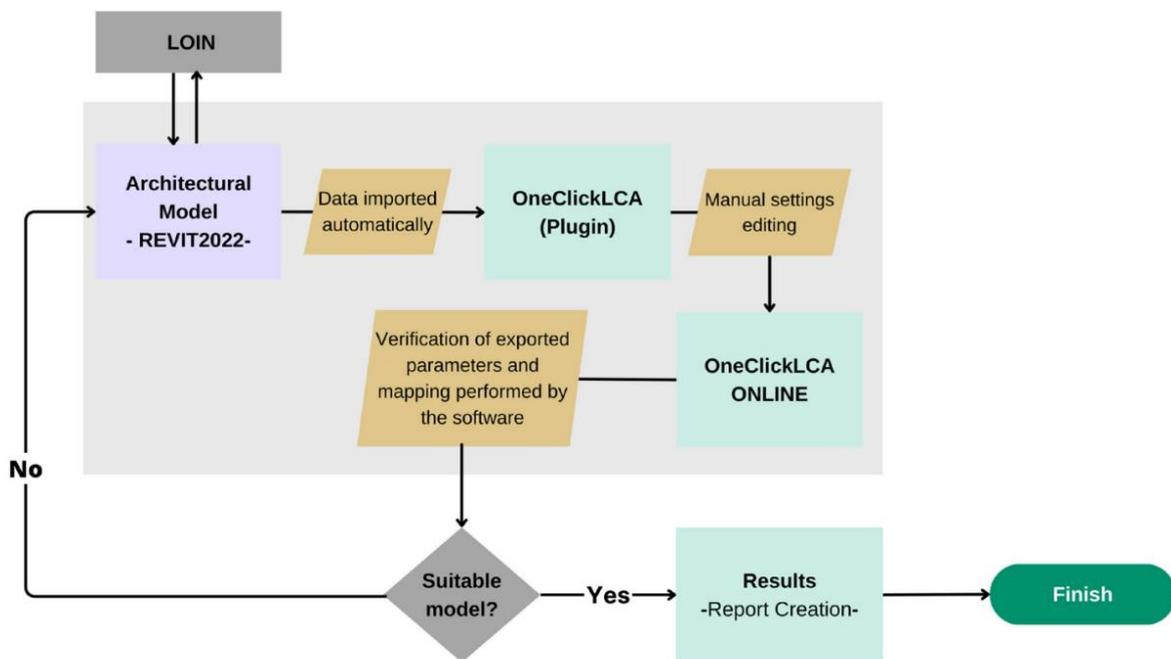


Figure 12. Workflow process mapping. From “Integrating BIM-LCA to Enhance Sustainability Assessments of Constructions” by M. S. S. Lima, S. Duarte, H. Exenberger, G. Fröch, & M. Flora, 2024, *Sustainability*, 16(3), Article 1172 (<https://doi.org/10.3390/su16031172>). Copyright 2024 by the authors. Distributed under the Creative Commons Attribution (CC BY) license.

Scope and Limitations of LCA Add-in Tools

One Click LCA and Tally have been selected as the LCA add-in tools to perform the BIM-based LCA study of the case project. To conduct an empirical study, the LCA add-in tools were plugged into the Revit Model, thus an integrated BIM-based LCA process can take place. First LCA application has been run through One Click LCA and followed by Tally as the second LCA application. The methodological framework can be seen in Figure 7. The 21 obtained quantitative results from both add-in tools were compared based on the quantified LCA modules in each impact category, the contribution

ratios of each module in GWP impact category, and contribution of material types to GWP impact category in [A1-A3] LCA module at last. (Köseci, 2018)

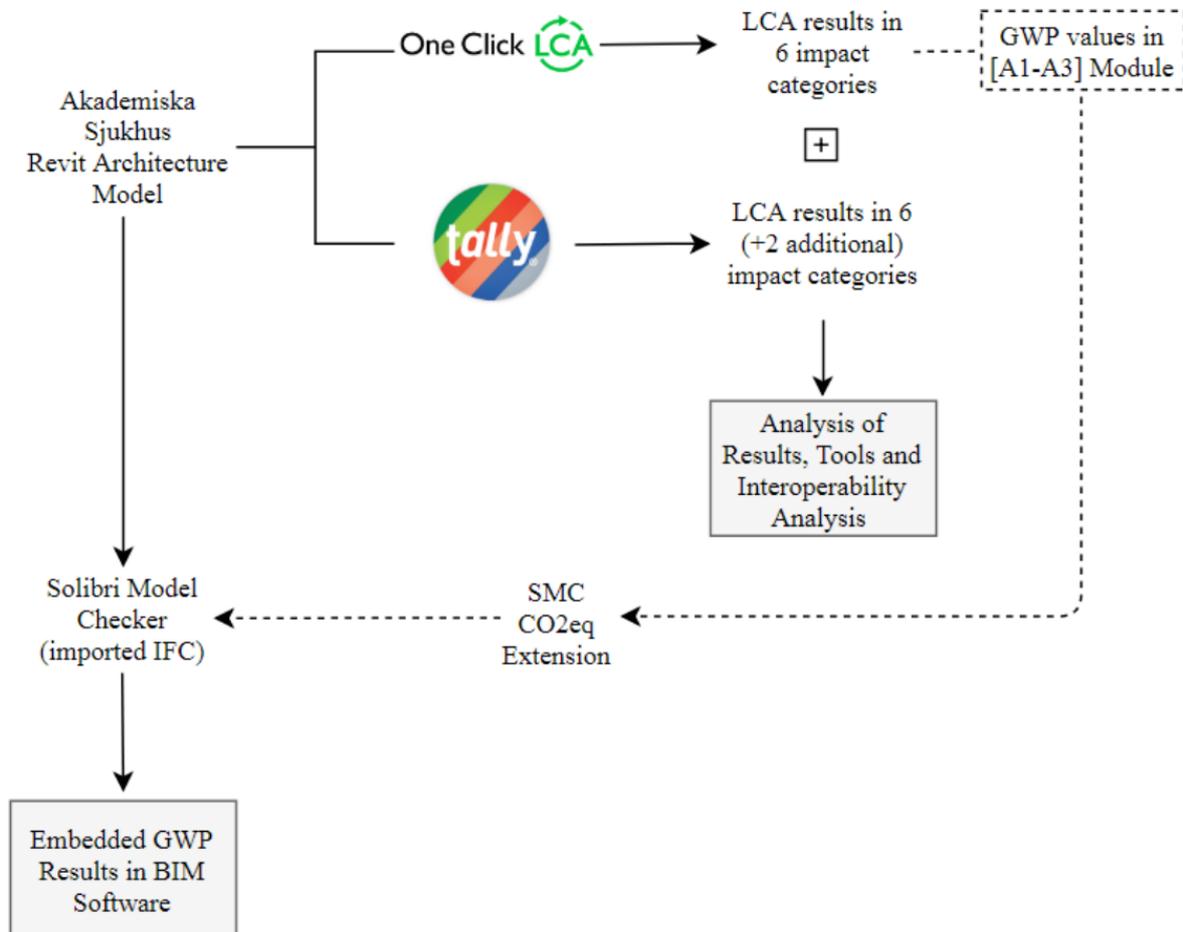


Figure 13. Methodological framework in general.

From “Integrated life cycle assessment (LCA) to building information modelling (BIM): Interoperability in the BIM-based LCA processes and analysis of BIM-based LCA results and tools” by F. C. Köseci, 2018 (Master’s thesis, KTH Royal Institute of Technology), p. 43. Copyright 2018 by F. C. Köseci. Reproduced with permission.

Test of Comparison between the Plugins Tally and One Click LCA through Case Study

To determine the most suitable plugin for a **BIM–LCA integration workflow**, a comparative test was conducted using a **simple case study model**. The model consisted of three walls, each constructed from different thicknesses and two different materials, including 40mm, 100 mm, 140 mm and two different materials Multipor M3 and External polystyrene.

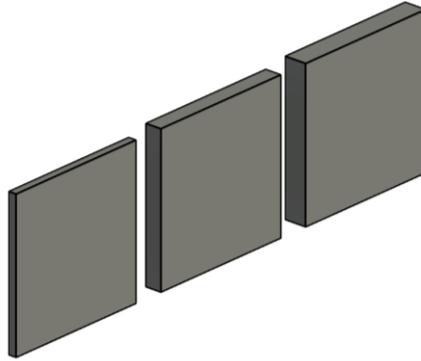


Figure 14. samples of insulation layers

The walls were modeled on Revit and LCA analysis was performed first using the plugin Tally and then the One Click LCA plugin. The methodology of the two plugins is similar but with different results which we will see in the following steps.

First Step: BIM-LCA Approach Strategy for Samples

BIM-LCA Approach Strategy for Samples: Tally

Starting from the calculation of LCA for samples with the Tally plugin, the LCA software collects impacts for each category (which in my case is wall). If you notice that the walls or even a specific material used in the wall, are making a high percentage of emissions composed of other building parts, the area considered a ‘hotspot’.

In my case, since it is a renovation case, in the light of minor renovation, the structures, external walls, which are building envelopes and a big part of the building are fixed, so what it can help to reduce environmental impact in this case could be more insulation layers of the building envelope and openings. Since they have already replaced some years ago, the owner is not convinced to pay for them again, so, at the end insulation layers of external walls are the main part possible to have impacts more on the environment. Apart from that, humidity is the main factor contributing to the deterioration of interior building elements which are visible in photos of internal spaces.

Mapping in Tally

- Since Multipor doors don’t exist in Tally material mapping, the nearest feature (Mineral Wool) is used here: select “**Mineral Wool Board – High Density**” in Tally if available.
- This aligns with typical densities of 115–140 kg/m³ and λ around 0.034–0.036 W/m·K.

Tally Steps

After installing the Tally plugin in Revit, the Add-in tab is visible; then, by pressing the Tally icon, mapping materials are started. (Figure 15)

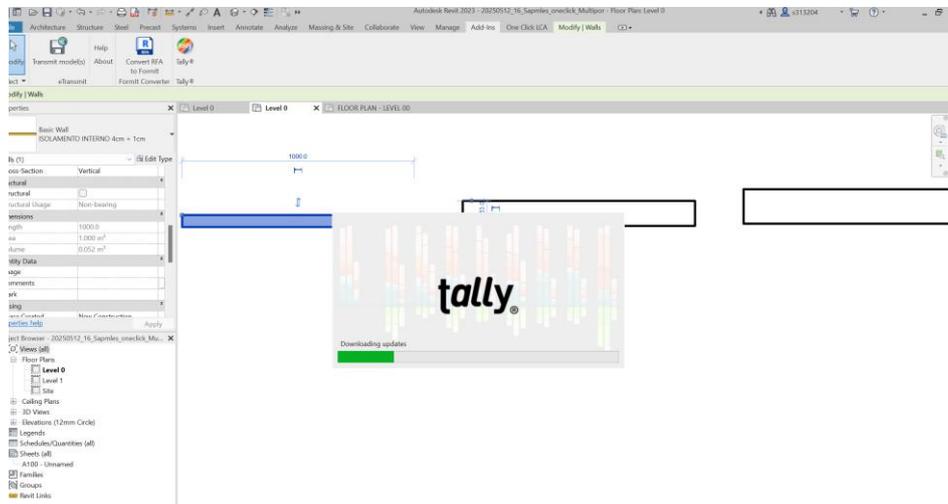


Figure 15. Installing Tally plugin

Then, the Tally options can be seen, which are different based on the goal of using this plugin. In my case, full building study option works, since it gives me the opportunity to select the category of my focus, which in this project is called 'LCA Only Elements'; also, phase is selectable. (figure 16)

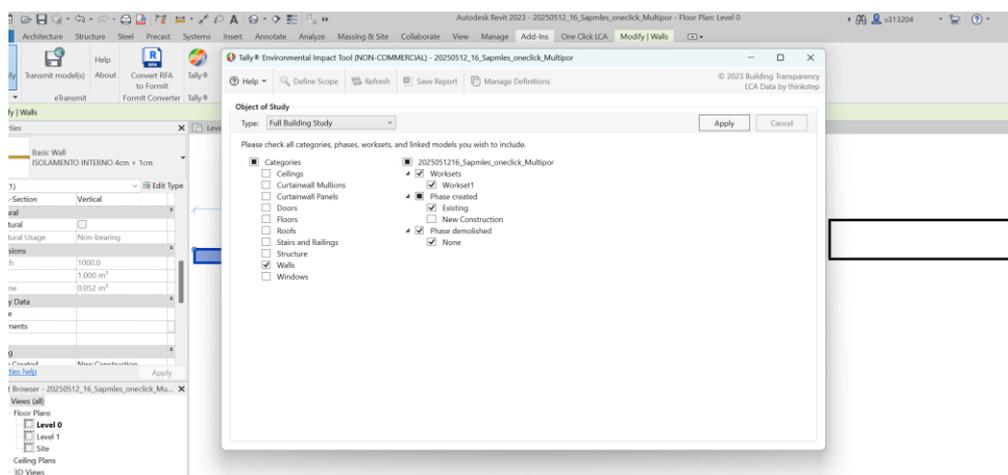


Figure 16. Categories in Tally plugin

By applying the selection, the category of walls is visible which by clicking on every item in the list, the materials could be selected, then the years of considering to Life Cycle Assessment and the details of material is chosen. (figure 17)

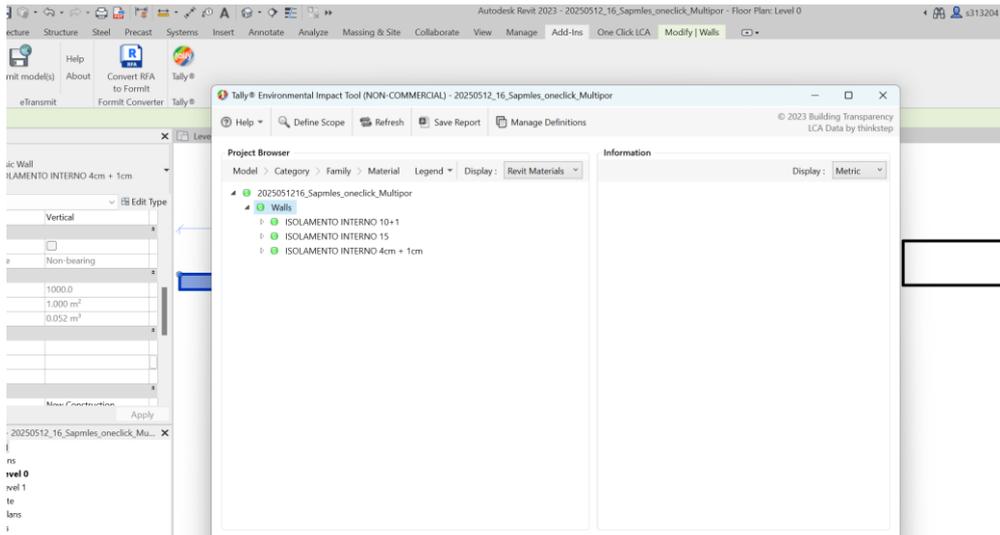


Figure 17. Categories in Revit seen in Tally plugin

As shown, mineral wool with these details is selected which is the closest one to Multipor (figure 12), and there is also possibility to edit the materials. (figure 18)

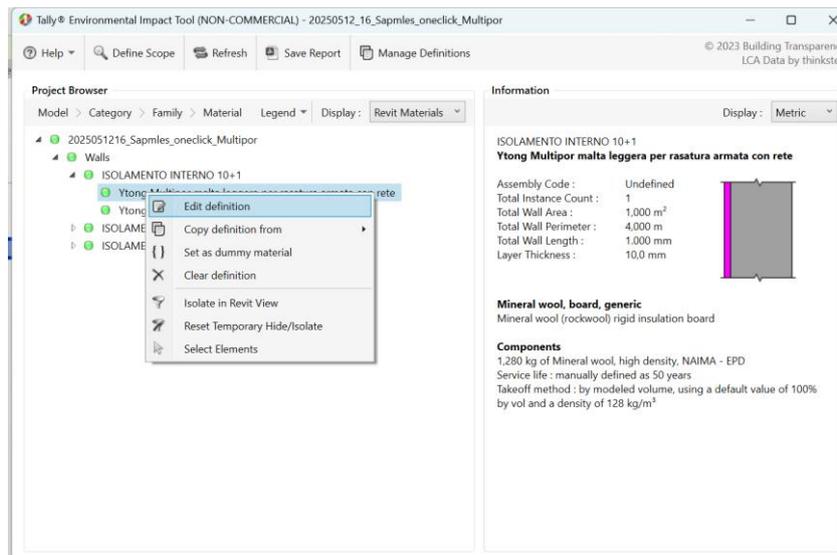


Figure 18. Material Mapping in Tally plugin

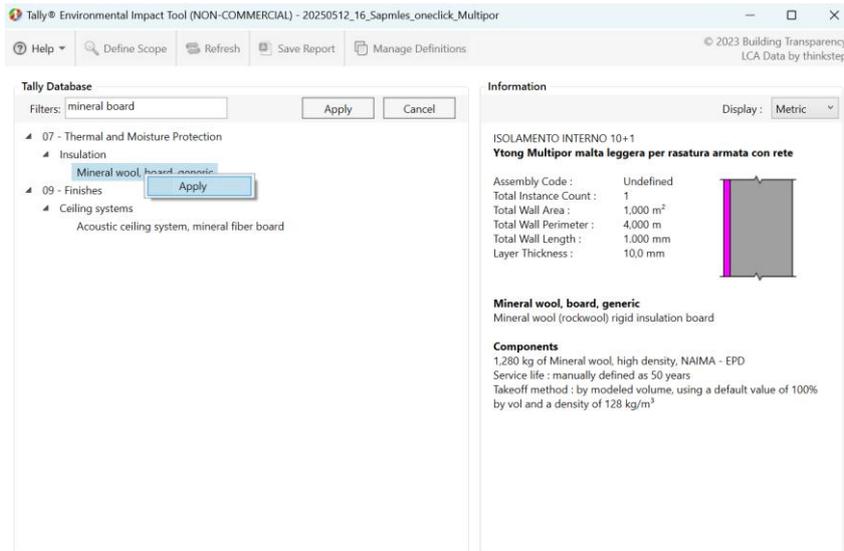


Figure 19. Tally database

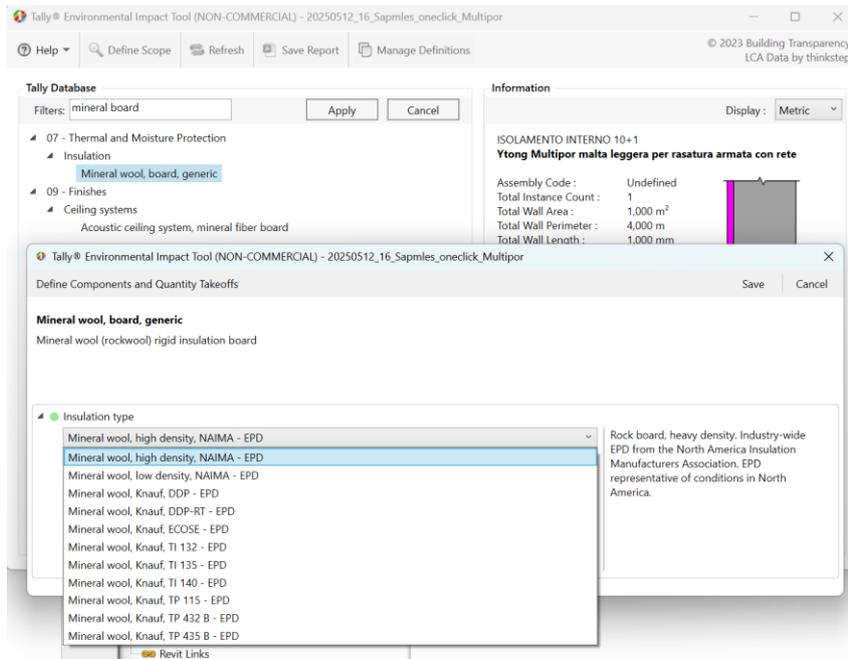


Figure 20. Apply material in Tally

After finding the material by searching in Filters or finding by category, then apply, at the end of the process, a window opens with the Report information, transportation Impacts and Output summaries. The Excel part has issues, but they are working on solving the problem based on the supporter reply.

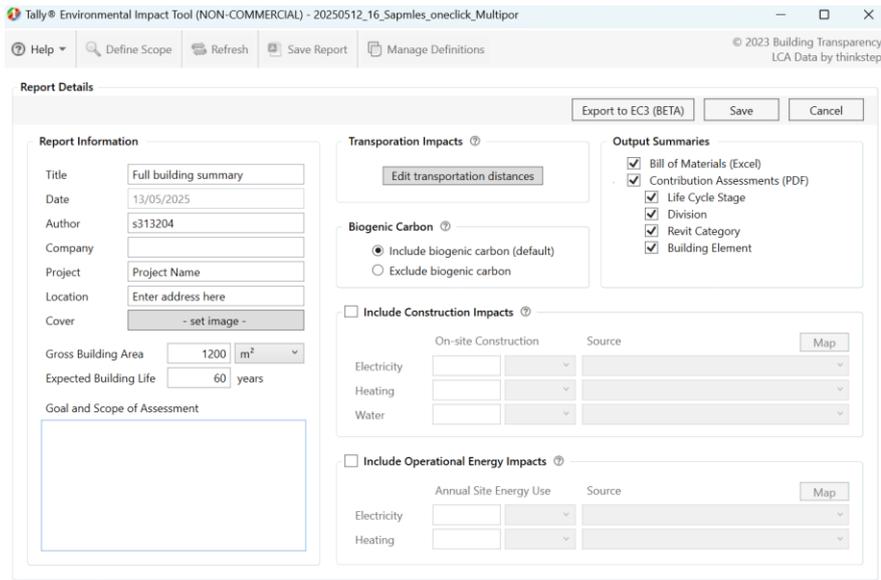


Figure 21. Report details on Tally plugin

After all, the results based on the Tally, for each sample including 40 mm, 100 mm and 140 mm for Mineral wool material are provided below.

Report Summary

It reports totals for key environmental indicators—such as Global Warming Potential (27.139 kg CO₂eq) and Primary Energy Demand (350,564 MJ)—broken down by life cycle stages.

Report Summary

Created with Tally

Non-commercial Version 2023.09.13.01

Goal and Scope of Assessment

LCA_Sample1_40 mm_EPS

Author s313204
Company studio 74
Date 13/05/2025

Project Chieri Project
Location Enter address here
Gross Area 1200 m²
Building Life 60 years

Boundaries Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO ₂ eq)	4,068	0,08851	4,212	0,05491	0
Acidification (kg SO ₂ eq)	0,007251	4,102E-004	0,008528	8,674E-004	0
Eutrophication (kg Neq)	4,405E-004	3,340E-005	8,047E-004	3,307E-004	0
Smog Formation (kg O ₃ eq)	0,1947	0,01355	0,2155	0,007276	0
Ozone Depletion (kg CFC-11eq)	1,672E-010	3,032E-015	1,672E-010	1,010E-014	0
Primary Energy (MJ)	117,7	1,287	119,9	0,941	0
Non-renewable Energy (MJ)	116,6	1,256	118,7	0,8798	0
Renewable Energy (MJ)	1,106	0,03113	1,199	0,06203	0
Environmental Impacts / Area					
Global Warming (kg CO ₂ eq/m ²)	0,00339	7,376E-005	0,00351	4,576E-005	0
Acidification (kg SO ₂ eq/m ²)	6,042E-006	3,418E-007	7,107E-006	7,228E-007	0
Eutrophication (kg Neq/m ²)	3,671E-007	2,783E-008	6,705E-007	2,756E-007	0
Smog Formation (kg O ₃ eq/m ²)	1,622E-004	1,129E-005	1,796E-004	6,063E-006	0
Ozone Depletion (kg CFC-11eq/m ²)	1,394E-013	2,526E-018	1,394E-013	8,414E-018	0
Primary Energy (MJ/m ²)	0,09807	0,001073	0,09993	7,842E-004	0
Non-renewable Energy (MJ/m ²)	0,09714	0,001047	0,09892	7,332E-004	0
Renewable Energy (MJ/m ²)	9,214E-004	2,594E-005	9,991E-004	5,169E-005	0

Figure 22. Report summary of Tally Plugin

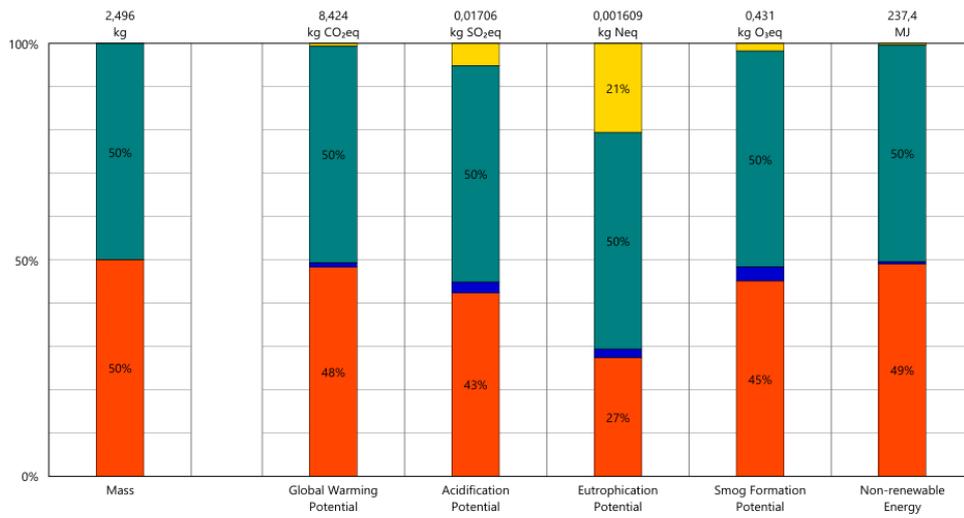
Results per Life Cycle Stage

This section quantifies impacts across stages A1–A3 (Product), A4 (Transport), B2–B5 (Use), C2–C4 (End-of-Life), and D (Benefits beyond system boundary). It reveals that:

- Most impacts (~97%) occur in the Product stage, especially Global Warming and energy usage.
- End-of-life and transport have relatively minor contributions.

This helps prioritize which stages are environmentally dominant.

Results per Life Cycle Stage



Legend

- Life Cycle Stages
- Product [A1-A3]
 - Transportation [A4]
 - Maintenance and Replacement [B2-B5]
 - End of Life [C2-C4]
 - Module D [D]

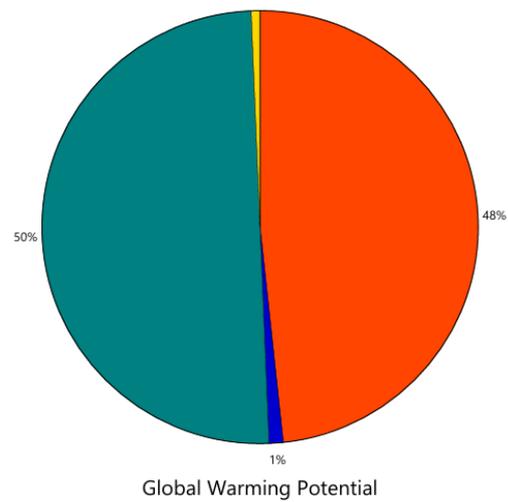


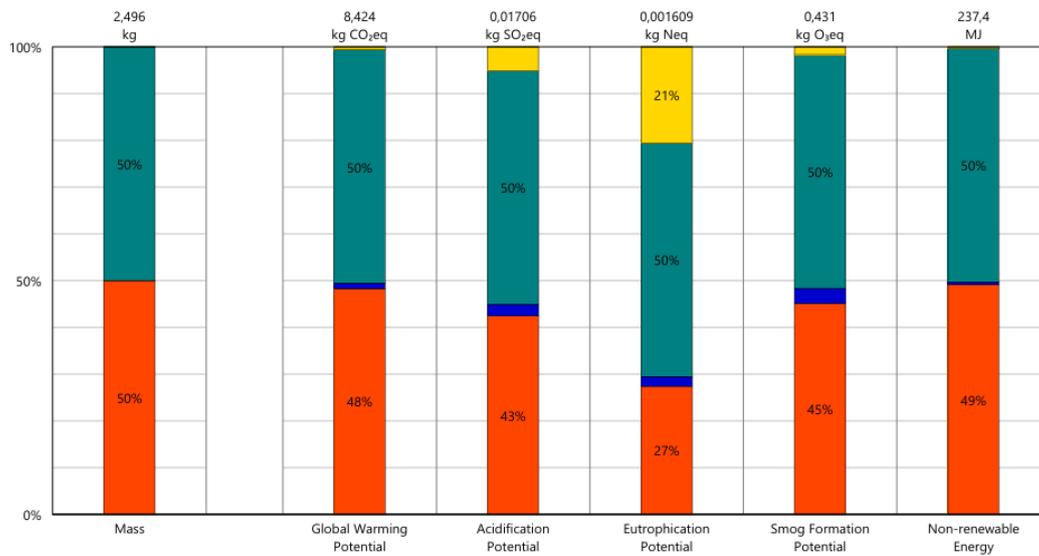
Figure 23. Results per Life Cycle Stage

Results of Life Cycle Stage

Here, results are organized:

- Division 07 – Thermal and Moisture Protection is the dominant contributor in all stages.
- The breakdown shows how insulation systems (e.g. EPS and mineral wool) drive emissions.

Results per Life Cycle Stage, itemized by Division



Legend

- Product [A1-A3]
 - 07 - Thermal and Moisture Protection
- Transportation [A4]
 - 07 - Thermal and Moisture Protection
- Maintenance and Replacement [B2-B5]
 - 07 - Thermal and Moisture Protection
- End of Life [C2-C4]
 - 07 - Thermal and Moisture Protection
- Module D [D]
 - 07 - Thermal and Moisture Protection

Figure 24. Results by Division and Life Cycle Stage

Results by Division and Life Cycle Stage

Here, results are organized:

- Division 07 – Thermal and Moisture Protection is the dominant contributor in all stages.
- The breakdown shows how insulation systems (e.g. EPS and mineral wool) drive emissions.

Results per Division

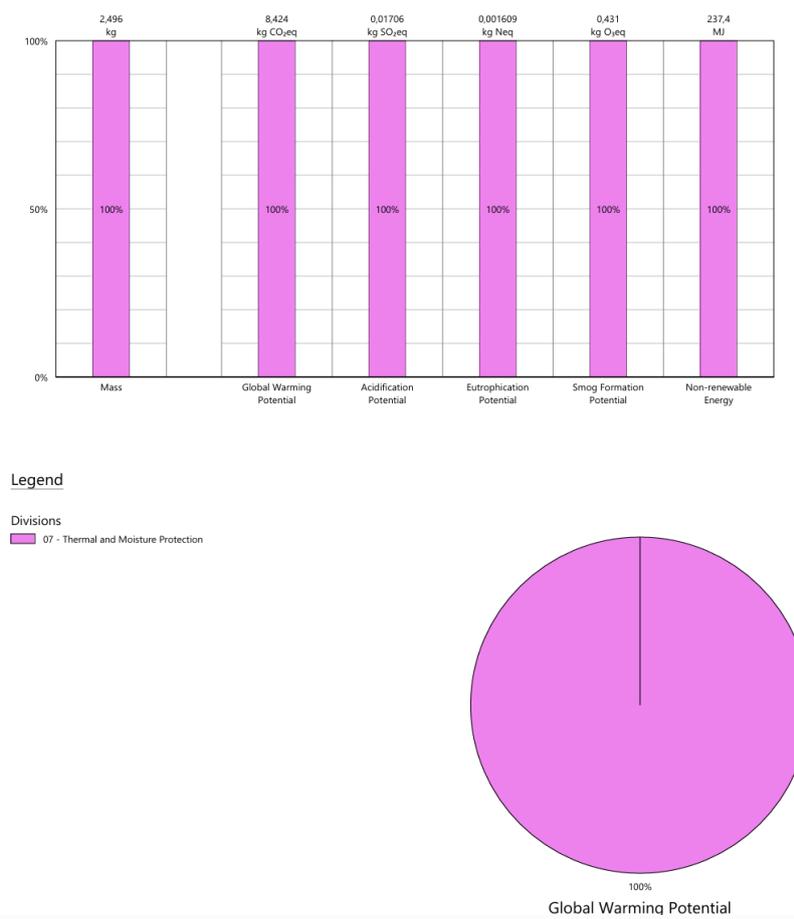


Figure 25. Results by Division and Life Cycle Stage

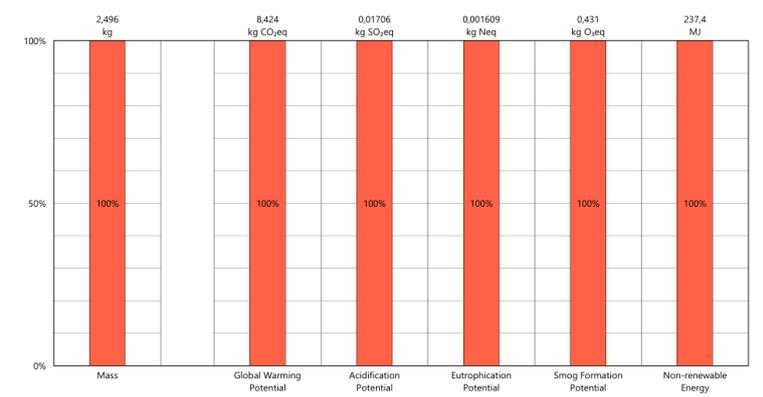
Results by Material and Revit Category

EPS and mineral wool are assessed for them:

- CO₂ emissions
- Energy use
- Smog/ozone formation

It identifies which materials and design families (like internal insulation types) have the highest impact, allowing targeted sustainability interventions.

Results per Revit Category



Legend

Revit Categories
■ Walls

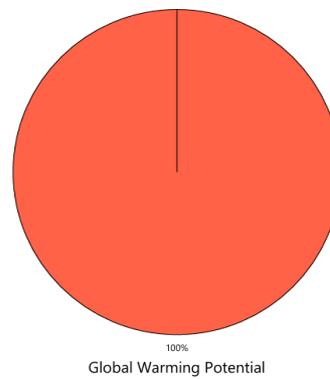


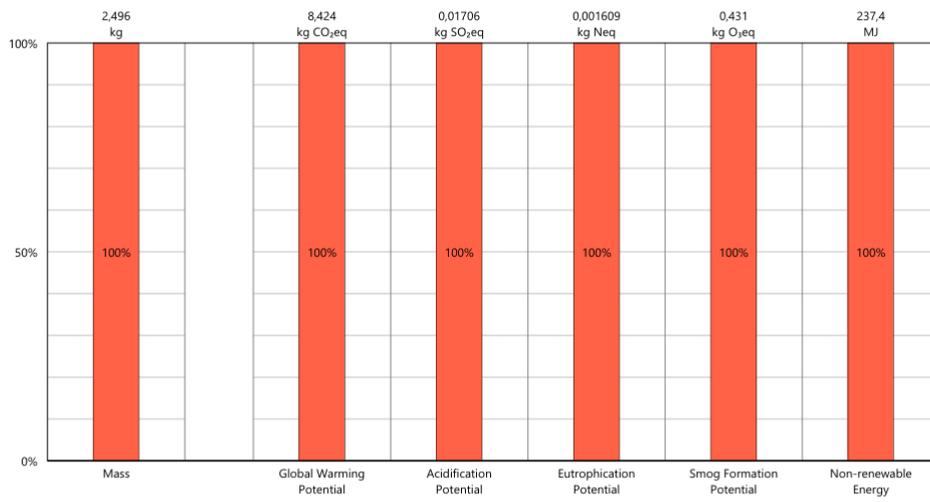
Figure 26. Results by Material and Revit Category

Results by Revit Family and Building Element

Focuses on:

- Specific families like IS01 to IS06 insulation systems used across the building.
- Contributions of each to environmental metrics.

Results per Revit Category, itemized by Family



Legend

Walls

ISOLAMENTO INTERNO 4cm + 1cm

Figure 27. Results by Revit Family and Building Element

Calculation Methodology

LIFE CYCLE ASSESSMENT METHODS

The following provides a description of terms and methods associated with the use of Tally to conduct life cycle assessment for construction works and construction products. Tally methodology is consistent with LCA standards ISO 14040-14044, ISO 21930:2017, ISO 21931:2010, EN 15804:2012, and EN 15978:2011. For more information about LCA, please refer to these standards or visit www.choosetally.com.

Studied objects

The life cycle assessment (LCA) results reported represent an analysis of a single building, multiple buildings, or a comparative analysis of two or more building design options. The assessment may represent the complete architectural, structural, and finish systems of the building(s) or a subset of those systems. This may be used to compare the relative environmental impacts associated with building components or for comparative study with one or more reference buildings. Design options may represent a full or partial building across various stages of the design process, or they may represent multiple schemes of a full or partial building that are being compared to one another across a range of evaluation criteria.

Functional unit and reference unit

A functional unit is the quantified performance of a product, building, or system that defines the object of the study. The functional unit of a single building should include the building type (e.g. office, factory), relevant technical and functional requirements (e.g. regulatory requirements, energy performance), pattern of use (e.g. occupancy, usable floor area), and the required service life. For a design option comparison of a partial building, the functional unit is the complete set of building systems or products that perform a given function. It is the responsibility of the modeler to assure that reference buildings or design options are functionally equivalent in terms of scope and relevant performance. The expected life of the building has a default value of 60 years and can be modified by the modeler.

The reference unit is the full collection of processes and materials required to produce a building or portion thereof and is quantified according to the given goal and scope of the assessment over the full life of the building. If construction impacts are included in the assessment, the reference unit also includes the energy, water, and fuel consumed on the building site during construction. If operational energy is included in the assessment, the reference unit includes the electrical and thermal energy consumed on site over the life of the building.

Data source

Tally utilizes a custom designed LCA database that combines material attributes, assembly details, and architectural specifications with environmental impact data resulting from the collaboration between KieranTimberlake and thinkstep. LCA modeling was conducted in GaBi 8.5 using GaBi 2018 databases and in accordance with [GaBi databases and modeling principles](#).

The data used are intended to represent the US and the year 2017. Where representative data were unavailable, proxy data were used. The datasets used, their geographic region, and year of reference are listed for each entry. An effort was made to choose proxy datasets that are technologically consistent with the relevant entry.

Data quality and uncertainty

Uncertainty in results can stem from both the data used and their application. Data quality is judged by: its measured, calculated, or estimated precision; its completeness, such as unreported emissions; its consistency, or degree of uniformity of the methodology applied on a study serving as a data source; and geographical, temporal, and technological representativeness. The [GaBi LCI databases](#) have been used in LCA models worldwide in both industrial and scientific applications. These LCI databases have additionally been used both as internal and critically reviewed and published studies. Uncertainty introduced by the use of proxy data is reduced by using technologically, geographically, and/or temporally similar data. It is the responsibility of the modeler to appropriately apply the predefined material entries to the building under study.

System boundaries and delimitations

The analysis accounts for the full cradle to grave life cycle of the design options studied across all life cycle stages, including material manufacturing, maintenance and replacement, and eventual end of life. Optionally, the construction impacts and operational energy of the building can be included within the scope. Product stage impacts are excluded for materials and components indicated as existing or salvaged by the modeler. The modeler defines whether the boundary includes or excludes the flow of biogenic carbon, which is the carbon absorbed and generated by biological sources (e.g. trees, algae) rather than from fossil resources.

Architectural materials and assemblies include all materials required for the product's manufacturing and use including hardware, sealants, adhesives, coatings, and finishing. The materials are included up to a 1% cut-off factor by mass except for known materials that have high environmental impacts at low levels. In these cases, a 1% cut-off was implemented by impact.

Figure 28. Tally report

Calculation Methodology

LIFE CYCLE STAGES

The following describes the scope and system boundaries used to define each stage of the life cycle of a building or building product, from raw material acquisition to final disposal. For products listed in Tally as Environmental Product Declarations (EPD), the full life cycle impacts are included, even if the published EPD only includes the Product stage [A1-A3].

Product [EN 15978 A1 - A3]

This encompasses the full manufacturing stage, including raw material extraction and processing, intermediate transportation, and final manufacturing and assembly. The product stage scope is listed for each entry, detailing any specific inclusions or exclusions that fall outside of the cradle to gate scope. Infrastructure (buildings and machinery) required for the manufacturing and assembly of building materials are not included and are considered outside the scope of assessment.

Transportation [EN 15978 A4]

This counts transportation from the manufacturer to the building site during the construction stage and can be modified by the modeler.

Construction Installation [EN 15978 A5] (Optional)

This includes the anticipated or measured energy and water consumed on-site during the construction installation process, as specified by the modeler.

Maintenance and Replacement [EN 15978 B2-B5]

This encompasses the replacement of materials in accordance with their expected service life. This includes the end of life treatment of the existing products as well as the cradle to gate manufacturing and transportation to site of the replacement products. The service life is specified separately for each product. Refurbishment of materials marked as existing or salvaged by the modeler is also included.

Operational Energy [EN 15978 B6] (Optional)

This is based on the anticipated or measured energy and natural gas consumed at the building site over the lifetime of the building, as indicated by the modeler.

End of Life [EN 15978 C2-C4]

This includes the relevant material collection rates for recycling, processing requirements for recycled materials, incineration rates, and landfilling rates. The impacts associated with landfilling are based on average material properties, such as plastic waste, biodegradable waste, or inert material. Stage C2 encompasses the transport from the construction site to end-of-life treatment based on national averages. Stages C3-C4 account for waste processing and disposal, i.e., impacts associated with landfilling or incineration.

Module D [EN 15978 D]

This accounts for reuse potentials that fall beyond the system boundary, such as energy recovery and recycling of materials. Along with processing requirements, the recycling of materials is modeled using an avoided burden approach, where the burden of primary material production is allocated to the subsequent life cycle based on the quantity of recovered secondary material. Incineration of materials includes credit for average US energy recovery rates.

PRODUCT	CONSTRUCTION	USE	END-OF-LIFE	MODULE D
A1. Extraction A2. Transport (to factory) A3. Manufacturing	A4. Transport (to site) A5. Construction Installation	B1. Use B2. Maintenance B3. Repair B4. Replacement B5. Refurbishment B6. Operational energy B7. Operational water	C1. Demolition C2. Transport (to disposal) C3. Waste processing C4. Disposal	D. Benefits and loads beyond the system boundary from: 1. Reuse 2. Recycling 3. Energy recovery

Life-Cycle Stages as defined by EN 15978. Processes included in Tally modeling scope are shown in bold. Italics indicate optional processes.

Figure 29. Tally report

Then, this process was repeated for the second Sample with a thickness of 100 mm. Below are the results from the Tally report PDF.

Report Summary

Created with Tally

Non-commercial Version 2023.09.13.01

Goal and Scope of Assessment

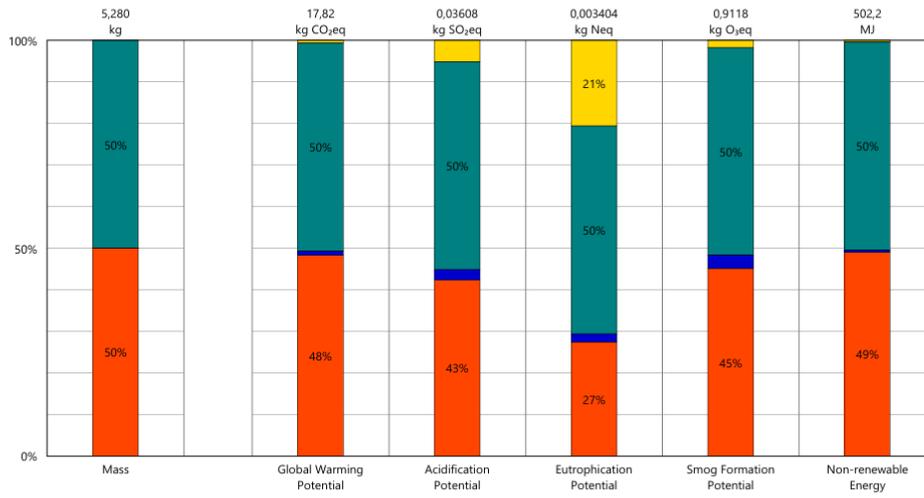
LCA_Sample2_100 mm_EPS

Author	s313204
Company	Studio 74
Date	13/05/2025
Project	Chieri Project
Location	Enter address here
Gross Area	1200 m ²
Building Life	60 years
Boundaries	Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO ₂ eq)	8,606	0,1872	8,910	0,1162	0
Acidification (kg SO ₂ eq)	0,01534	8,676E-004	0,01804	0,001835	0
Eutrophication (kg Neq)	9,319E-004	7,064E-005	0,001702	6,996E-004	0
Smog Formation (kg O ₃ eq)	0,4118	0,02867	0,4559	0,01539	0
Ozone Depletion (kg CFC-11eq)	3,538E-010	6,413E-015	3,538E-010	2,136E-014	0
Primary Energy (MJ)	249,0	2,723	253,7	1,991	0
Non-renewable Energy (MJ)	246,6	2,658	251,1	1,861	0
Renewable Energy (MJ)	2,339	0,06584	2,536	0,1312	0
Environmental Impacts / Area					
Global Warming (kg CO ₂ eq/m ²)	0,007172	1,560E-004	0,007425	9,680E-005	0
Acidification (kg SO ₂ eq/m ²)	1,278E-005	7,230E-007	1,503E-005	1,529E-006	0
Eutrophication (kg Neq/m ²)	7,766E-007	5,887E-008	1,418E-006	5,830E-007	0
Smog Formation (kg O ₃ eq/m ²)	3,432E-004	2,389E-005	3,799E-004	1,283E-005	0
Ozone Depletion (kg CFC-11eq/m ²)	2,948E-013	5,344E-018	2,948E-013	1,780E-017	0
Primary Energy (MJ/m ²)	0,2075	0,002269	0,2114	0,001659	0
Non-renewable Energy (MJ/m ²)	0,2055	0,002215	0,2092	0,001551	0
Renewable Energy (MJ/m ²)	0,001949	5,487E-005	0,002113	1,093E-004	0

Figure 30. Report summary

Results per Life Cycle Stage



Legend

- Life Cycle Stages
- Product [A1-A3]
 - Transportation [A4]
 - Maintenance and Replacement [B2-B5]
 - End of Life [C2-C4]
 - Module D [D]

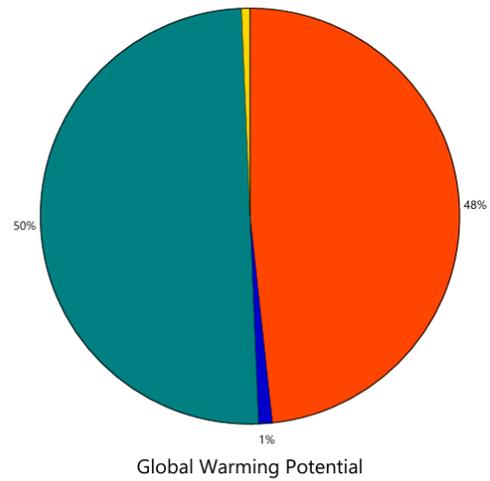
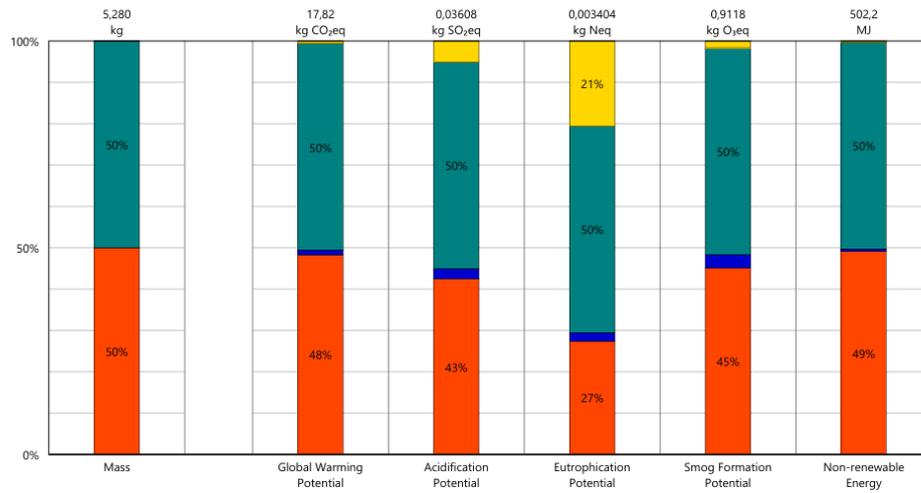


Figure 31. Results per Life Cycle Stage

Results per Life Cycle Stage, itemized by Division

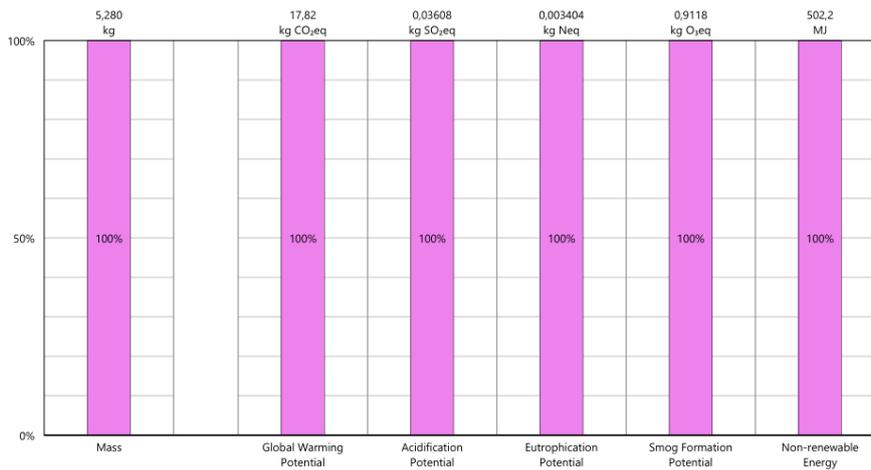


Legend

- Product [A1-A3]
 - 07 - Thermal and Moisture Protection
- Transportation [A4]
 - 07 - Thermal and Moisture Protection
- Maintenance and Replacement [B2-B5]
 - 07 - Thermal and Moisture Protection
- End of Life [C2-C4]
 - 07 - Thermal and Moisture Protection
- Module D [D]
 - 07 - Thermal and Moisture Protection

Figure 32. Results by Division and Life Cycle Stage

Results per Division, itemized by Material

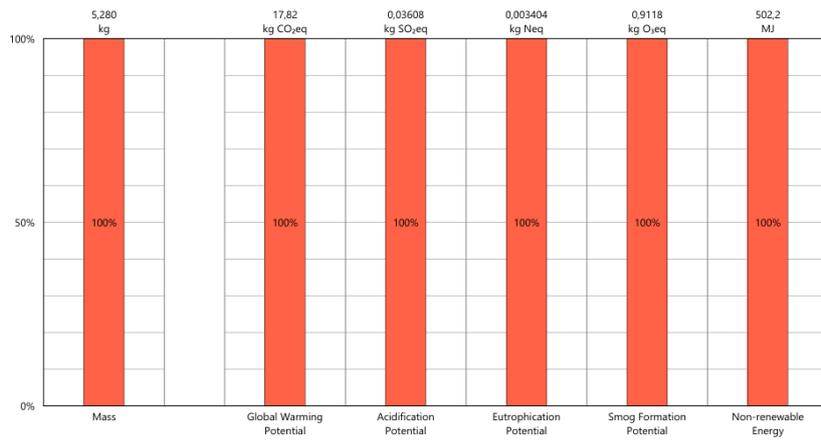


Legend

- 07 - Thermal and Moisture Protection
 - Expanded polystyrene (EPS) board

Figure 33. Results by Division and Life Cycle Stage

Results per Revit Category



Legend

Revit Categories
■ Walls

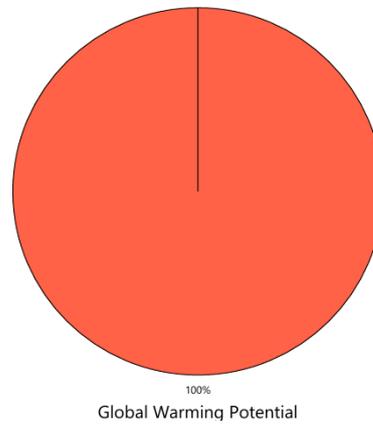
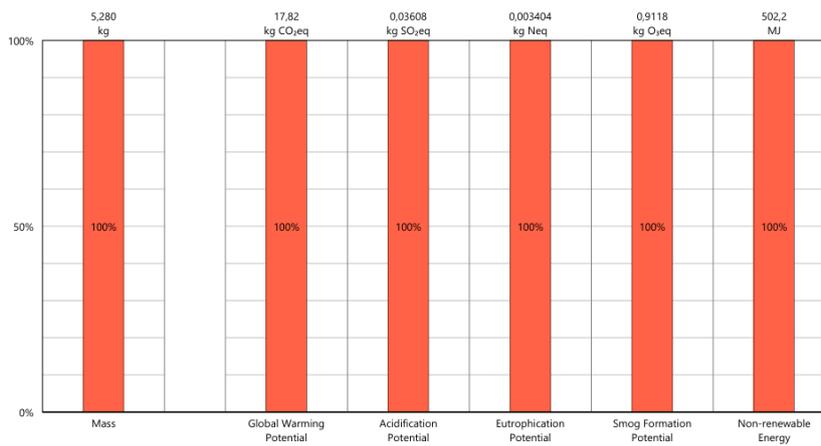


Figure 34. Results by Material and Revit Category

Results per Revit Category, itemized by Family



Legend

Walls
■ ISOLAMENTO INTERNO 10+1

Figure 35. Results by Revit Family and Building Element

Then, for the third sample with a thickness of 140 mm, the results are provided in the Tally report PDF.

Report Summary

Created with Tally

Non-commercial Version 2023.09.13.01

Goal and Scope of Assessment

LCA_Samplw3_140 mm Thickness_ EPS

Author s313204
Company Studio 74
Date 13/05/2025

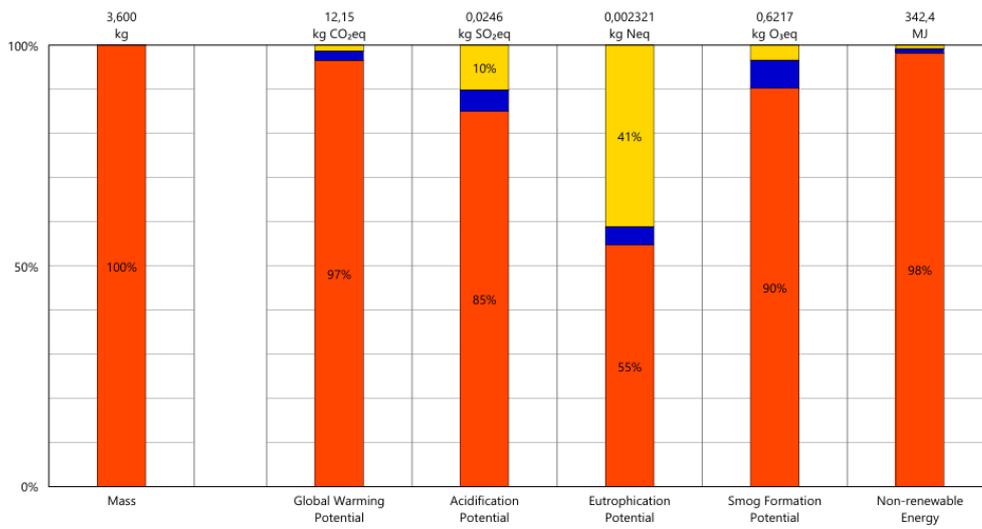
Project Chieri Project
Location Enter address here
Gross Area 1200 m²
Building Life 50 years

Boundaries Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO ₂ eq)	11,74	0,2553	0	0,1584	0
Acidification (kg SO ₂ eq)	0,02092	0,001183	0	0,002502	0
Eutrophication (kg Neq)	0,001271	9,633E-005	0	9,540E-004	0
Smog Formation (kg O ₃ eq)	0,5616	0,03909	0	0,02099	0
Ozone Depletion (kg CFC-11eq)	4,824E-010	8,745E-015	0	2,912E-014	0
Primary Energy (MJ)	339,5	3,713	0	2,714	0
Non-renewable Energy (MJ)	336,2	3,624	0	2,538	0
Renewable Energy (MJ)	3,190	0,08979	0	0,1789	0
Environmental Impacts / Area					
Global Warming (kg CO ₂ eq/m ²)	0,00978	2,128E-004	0	1,320E-004	0
Acidification (kg SO ₂ eq/m ²)	1,743E-005	9,859E-007	0	2,085E-006	0
Eutrophication (kg Neq/m ²)	1,059E-006	8,028E-008	0	7,950E-007	0
Smog Formation (kg O ₃ eq/m ²)	4,680E-004	3,258E-005	0	1,749E-005	0
Ozone Depletion (kg CFC-11eq/m ²)	4,020E-013	7,287E-018	0	2,427E-017	0
Primary Energy (MJ/m ²)	0,2829	0,003094	0	0,002262	0
Non-renewable Energy (MJ/m ²)	0,2802	0,00302	0	0,002115	0
Renewable Energy (MJ/m ²)	0,002658	7,482E-005	0	1,491E-004	0

Figure 36. Report summary

Results per Life Cycle Stage



Legend

Life Cycle Stages

- Product [A1-A3]
- Transportation [A4]
- Maintenance and Replacement [B2-B5]
- End of Life [C2-C4]
- Module D [D]

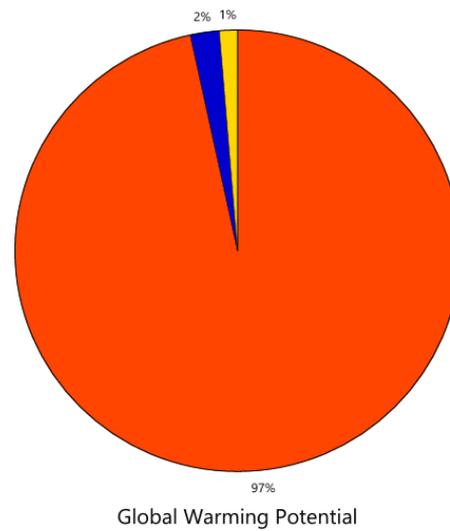
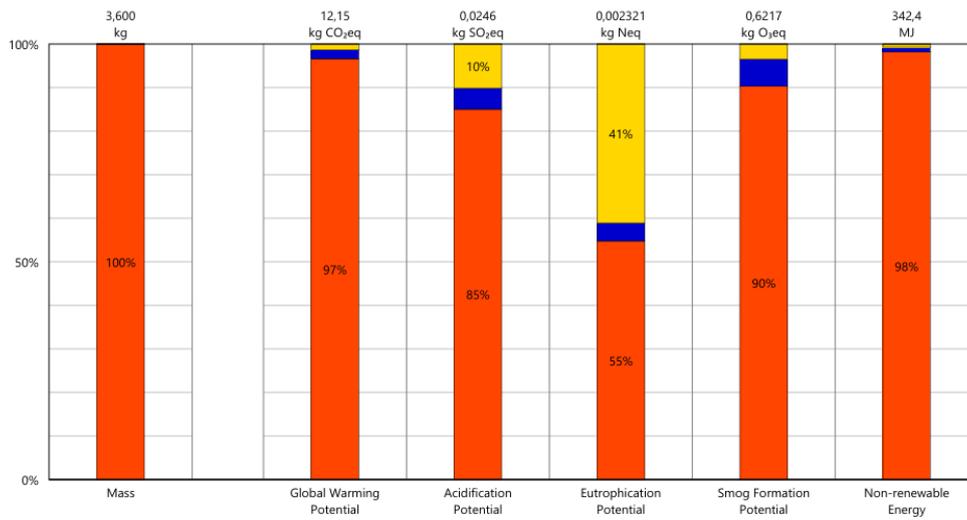


Figure 37. Results per Life Cycle Stage

Results per Life Cycle Stage, itemized by Division



Legend

Product [A1-A3]

07 - Thermal and Moisture Protection

Transportation [A4]

07 - Thermal and Moisture Protection

Maintenance and Replacement [B2-B5]

07 - Thermal and Moisture Protection

End of Life [C2-C4]

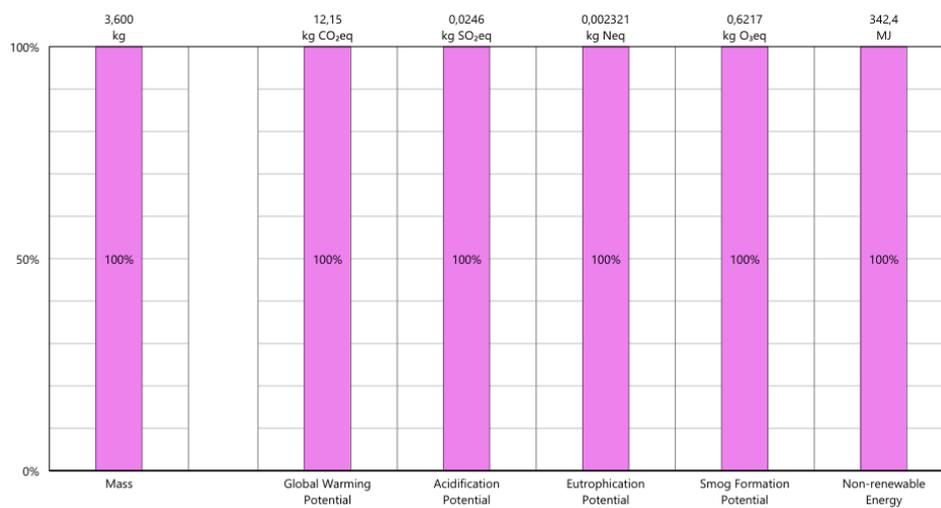
07 - Thermal and Moisture Protection

Module D [D]

07 - Thermal and Moisture Protection

Figure 38. Results by Division and Life Cycle Stage

Results per Division, itemized by Material



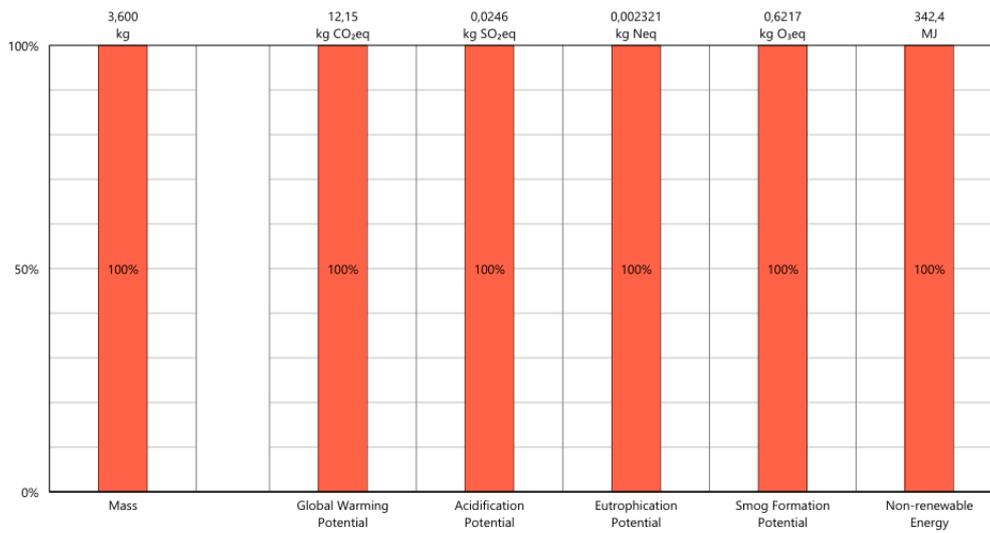
Legend

07 - Thermal and Moisture Protection

Expanded polystyrene (EPS), board

Figure 39. Results by Division and Life Cycle Stage

Results per Revit Category, itemized by Family



Legend

Walls
■ ISOLAMENTO INTERNO 15

Figure 40. Results by Material and Revit Category

At the end of the analysis for the three EPS samples, I repeated the entire process for the Multipor Xella material. To keep this section concise, only the summary results are presented here. However, the results from Tally for each sample have been compared in the following, and separate comparisons have also been made with the results from One Click LCA for each material. Finally, the outcomes for each material have been compared from the perspective of the Tally results versus One Click LCA, which will be discussed. Therefore, in this part, I will continue with the summary report from Tally only.

This figure presents the LCA summary for mineral wool insulation, showing environmental impacts.

Report Summary

Created with Tally

Non-commercial Version 2023.09.13.01

Goal and Scope of Assessment

Sample 1_ Mineral Wool

Author	s313204
Company	studio 74
Date	05/05/2025
Project	Project Name
Location	Enter address here
Gross Area	1200 m ²
Building Life	60 years
Boundaries	Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO ₂ eq)	24,22	0,1322	24,97	0,6195	0
Acidification (kg SO ₂ eq)	0,1732	6,127E-004	0,1767	0,002858	0
Eutrophication (kg Neq)	0,002957	4,989E-005	0,003152	1,450E-004	0
Smog Formation (kg O ₃ eq)	0,7814	0,02025	0,8584	0,05674	0
Ozone Depletion (kg CFC-11eq)	6,632E-007	4,529E-015	6,632E-007	1,139E-013	0
Primary Energy (MJ)	298,5	1,923	311,0	10,62	0
Non-renewable Energy (MJ)	285,8	1,877	297,6	9,926	0
Renewable Energy (MJ)	13,50	0,0465	14,25	0,6998	0
Environmental Impacts / Area					
Global Warming (kg CO ₂ eq/m ²)	0,02018	1,102E-004	0,02081	5,163E-004	0
Acidification (kg SO ₂ eq/m ²)	1,443E-004	5,106E-007	1,472E-004	2,382E-006	0
Eutrophication (kg Neq/m ²)	2,464E-006	4,157E-008	2,626E-006	1,209E-007	0
Smog Formation (kg O ₃ eq/m ²)	6,512E-004	1,687E-005	7,154E-004	4,729E-005	0
Ozone Depletion (kg CFC-11eq/m ²)	5,526E-010	3,774E-018	5,526E-010	9,492E-017	0
Primary Energy (MJ/m ²)	0,2487	0,001602	0,2592	0,008847	0
Non-renewable Energy (MJ/m ²)	0,2382	0,001564	0,248	0,008272	0
Renewable Energy (MJ/m ²)	0,01125	3,875E-005	0,01187	5,831E-004	0

Figure 41. Report summary of sample one with Mineral wool material

Report Summary

Created with Tally

Non-commercial Version 2023.09.13.01

Goal and Scope of Assessment

Sample 2_Mineral Wool

Author s313204
Company studio 74
Date 05/05/2025

Project Project Name
Location Enter address here
Gross Area 1200 m²
Building Life 60 years

Boundaries Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO ₂ eq)	24,22	0,1322	24,97	0,6195	0
Acidification (kg SO ₂ eq)	0,1732	6,127E-004	0,1767	0,002858	0
Eutrophication (kg Neq)	0,002957	4,989E-005	0,003152	1,450E-004	0
Smog Formation (kg O ₃ eq)	0,7814	0,02025	0,8584	0,05674	0
Ozone Depletion (kg CFC-11eq)	6,632E-007	4,529E-015	6,632E-007	1,139E-013	0
Primary Energy (MJ)	298,5	1,923	311,0	10,62	0
Non-renewable Energy (MJ)	285,8	1,877	297,6	9,926	0
Renewable Energy (MJ)	13,50	0,0465	14,25	0,6998	0
Environmental Impacts / Area					
Global Warming (kg CO ₂ eq/m ²)	0,02018	1,102E-004	0,02081	5,163E-004	0
Acidification (kg SO ₂ eq/m ²)	1,443E-004	5,106E-007	1,472E-004	2,382E-006	0
Eutrophication (kg Neq/m ²)	2,464E-006	4,157E-008	2,626E-006	1,209E-007	0
Smog Formation (kg O ₃ eq/m ²)	6,512E-004	1,687E-005	7,154E-004	4,729E-005	0
Ozone Depletion (kg CFC-11eq/m ²)	5,526E-010	3,774E-018	5,526E-010	9,492E-017	0
Primary Energy (MJ/m ²)	0,2487	0,001602	0,2592	0,008847	0
Non-renewable Energy (MJ/m ²)	0,2382	0,001564	0,248	0,008272	0
Renewable Energy (MJ/m ²)	0,01125	3,875E-005	0,01187	5,831E-004	0

Figure 42. Report summary of second sample with Mineral wool material

Report Summary

Created with Tally

Non-commercial Version 2023.09.13.01

Goal and Scope of Assessment

Sample 3_Mineral Wool

Author s313204
Company studio 74
Date 05/05/2025

Project Project Name
Location Enter address here
Gross Area 1200 m²
Building Life 60 years

Boundaries Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO ₂ eq)	11,45	0,06251	11,80	0,2929	0
Acidification (kg SO ₂ eq)	0,08187	2,896E-004	0,08351	0,001351	0
Eutrophication (kg Neq)	0,001398	2,358E-005	0,00149	6,856E-005	0
Smog Formation (kg O ₃ eq)	0,3694	0,009571	0,4058	0,02682	0
Ozone Depletion (kg CFC-11eq)	3,135E-007	2,141E-015	3,135E-007	5,385E-014	0
Primary Energy (MJ)	141,1	0,909	147,0	5,019	0
Non-renewable Energy (MJ)	135,1	0,8872	140,7	4,692	0
Renewable Energy (MJ)	6,383	0,02198	6,736	0,3308	0
Environmental Impacts / Area					
Global Warming (kg CO ₂ eq/m ²)	0,00954	5,209E-005	0,009836	2,441E-004	0
Acidification (kg SO ₂ eq/m ²)	6,822E-005	2,414E-007	6,959E-005	1,126E-006	0
Eutrophication (kg Neq/m ²)	1,165E-006	1,965E-008	1,242E-006	5,713E-008	0
Smog Formation (kg O ₃ eq/m ²)	3,078E-004	7,976E-006	3,382E-004	2,235E-005	0
Ozone Depletion (kg CFC-11eq/m ²)	2,612E-010	1,784E-018	2,612E-010	4,487E-017	0
Primary Energy (MJ/m ²)	0,1176	7,575E-004	0,1225	0,004182	0
Non-renewable Energy (MJ/m ²)	0,1126	7,394E-004	0,1172	0,00391	0
Renewable Energy (MJ/m ²)	0,005319	1,832E-005	0,005613	2,757E-004	0

Figure 43. Report summary of third sample with Mineral wool material

BIM-LCA Integration Strategy for Samples: One Click LCA

The steps for calculating the Life Cycle Assessment (LCA) of Multipor Xella insulation include the following:

First, after installing One Click LCA, a new tab appears in Revit. Then, by selecting 'LCA in Cloud', it will proceed to the 'Settings' tab, where the scope is set to 'Building'. (Figure 44)

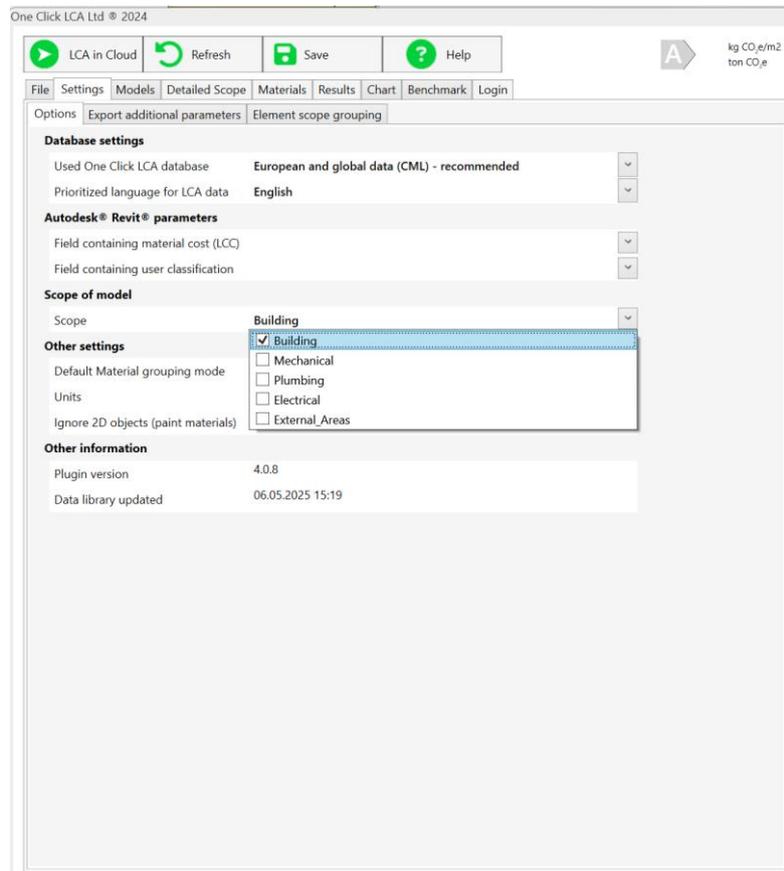


Figure 44. One Click LCA

Then, in the Material tab, the database selected is One Click LCA. The category is set to Insulation, and the type is Generic. The next step is to search for the selected material for assessment and assign it to external elements in the wall category. (figure 45)

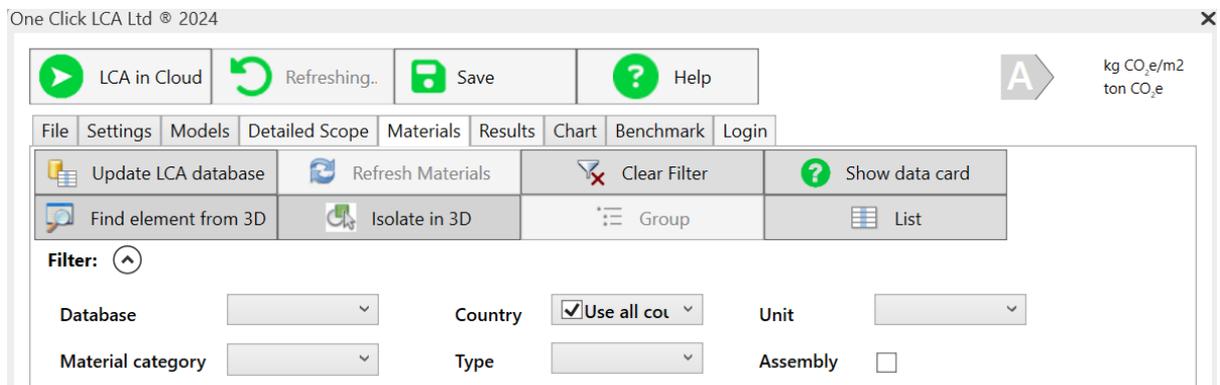
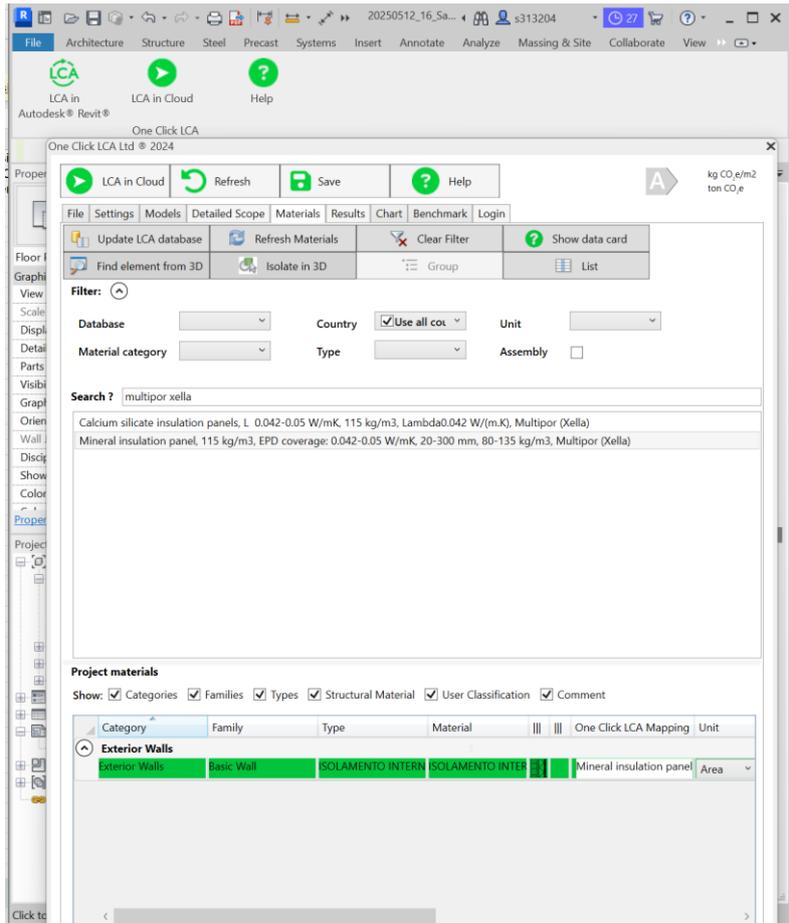


Figure 45. Material mapping in One Click LCA

Next, continue with LCA in the cloud by setting the information for the Chieri project and then proceed to review the results. (figure 45)

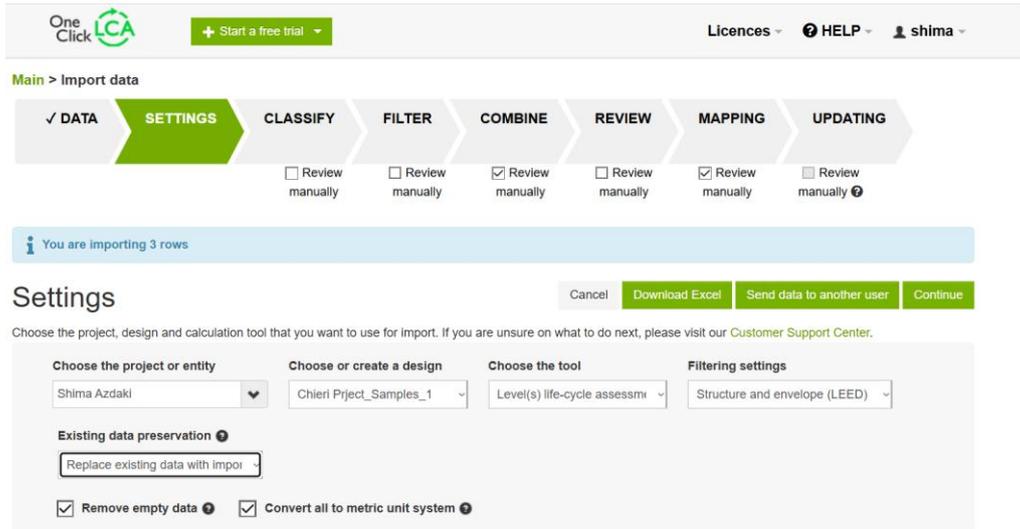
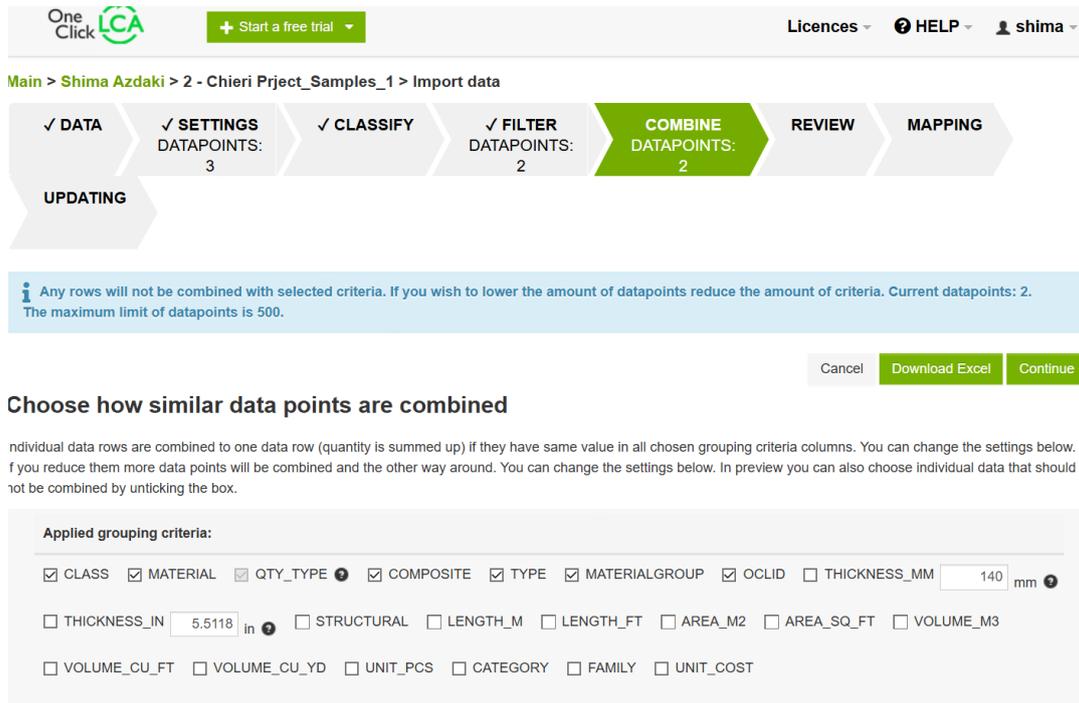


Figure 46. One Click LCA setting

These results are for Sample 3, which is an external wall with a 140 mm thickness, 1 m² area made of Multipor Xella material. Therefore, thickness in mm and thickness in inch is written here. (Figure 47)



One Click LCA Licences ▾ HELP ▾ shima ▾

+ Start a free trial ▾

Main > Shima Azdaki > 2 - Chieri Prject_Samples_1 > Import data

✓ DATA

✓ SETTINGS
DATAPOINTS:
3

✓ CLASSIFY

✓ FILTER
DATAPOINTS:
2

✓ COMBINE

✓ REVIEW
DATAPOINTS:
2

MAPPING
DATAPOINTS:
2 + 0

UPDATING

MAPPING

Results Cancel Download Excel Save new mappings ⚠ Continue

Material	Country	Data source	Type	Upstream	CO2e	Unit	Standard
Insulation x ▾	Italy x ▾	One Click ... x ▾	Filter: ▾	G... x ▾	Filter: ▾	Filter: ▾	EN 15804 +A1 (CML) x

?

Datasets are automatically identified by the software if similar data was mapped previously. Existing mappings are used in the following order of priority: your own mappings, mappings of your organisation, mappings in same country, and all mappings (to add system mappings, full name, and reset defaults from splitting data). Mappings take into consideration also other properties of the imported dataset, for example its classification. You can change mappings you wish. Changes will be automatically memorized.

Unidentified, unquantified or composite materials are not imported, unless you map them to resources. Units will be converted automatically if necessary.

> ✓ Identified data: 2 / 100 % of volume

Figure 47. One Click LCA combined DataPoints

At the end, the results show that the source is (EN 15804+A1) Level(s). As seen, the CO₂ emission for this example is 17 kg CO₂e, and the embodied carbon benchmark is green, indicating a low or zero impact. (Figure 48)

Chieri Prject_Samples_1 - Level(s) life-cycle assessment (EN15804 +A1) **Level(s)** Project basic information

Commercial usage is forbidden. One Click LCA Student (International) Business + Carbon Designer 3D, EDUCATION, shima azdaki 12.05.2025 13:32

CO₂ 6 kg CO₂e **0** kg CO₂e / m² / year **286 €** Social cost of carbon

Carbon Heroes Benchmark

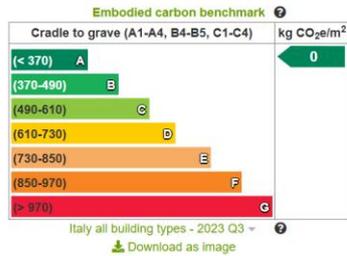


Figure 48. sample one Results of One Click LCA

As seen, in this phase it is possible to export the results to Excel. (Figure 49)

One Click LCA - LCA...

One Click LCA + Start a free trial Licences HELP shima

Main > Shima Azdaki > Chieri Prject_Samples_1 > Level(s) life-cycle assessment (EN15804 +A1) Back Input data Compare designs Compare data (1) More actions

Chieri Prject_Samples_1 - Level(s) life-cycle assessment (EN15804 +A1) **Level(s)**

Project basic information

Commercial usage is forbidden. One Click LCA Student (International) Business + Carbon Designer 3D, EDUCATION, shima azdaki 12.05.2025 14:...

CO₂ 17 kg CO₂e **0** kg CO₂e / m² / year **825 €** Social cost of carbon

Carbon Heroes Benchmark

- Reports
 - One Click LCA result rep
 - Generate Word report
 - Data sources
- Downloads & Sharing
 - Send data to another use
- Formatting & Settings
 - Scientific numbers
 - Decimal numbers
 - Remove formatting
- Print
- Help

Figure 49. Life Cycle Assessment Results

The results include different stages for all the factors of LCA in detail. (figure 50)

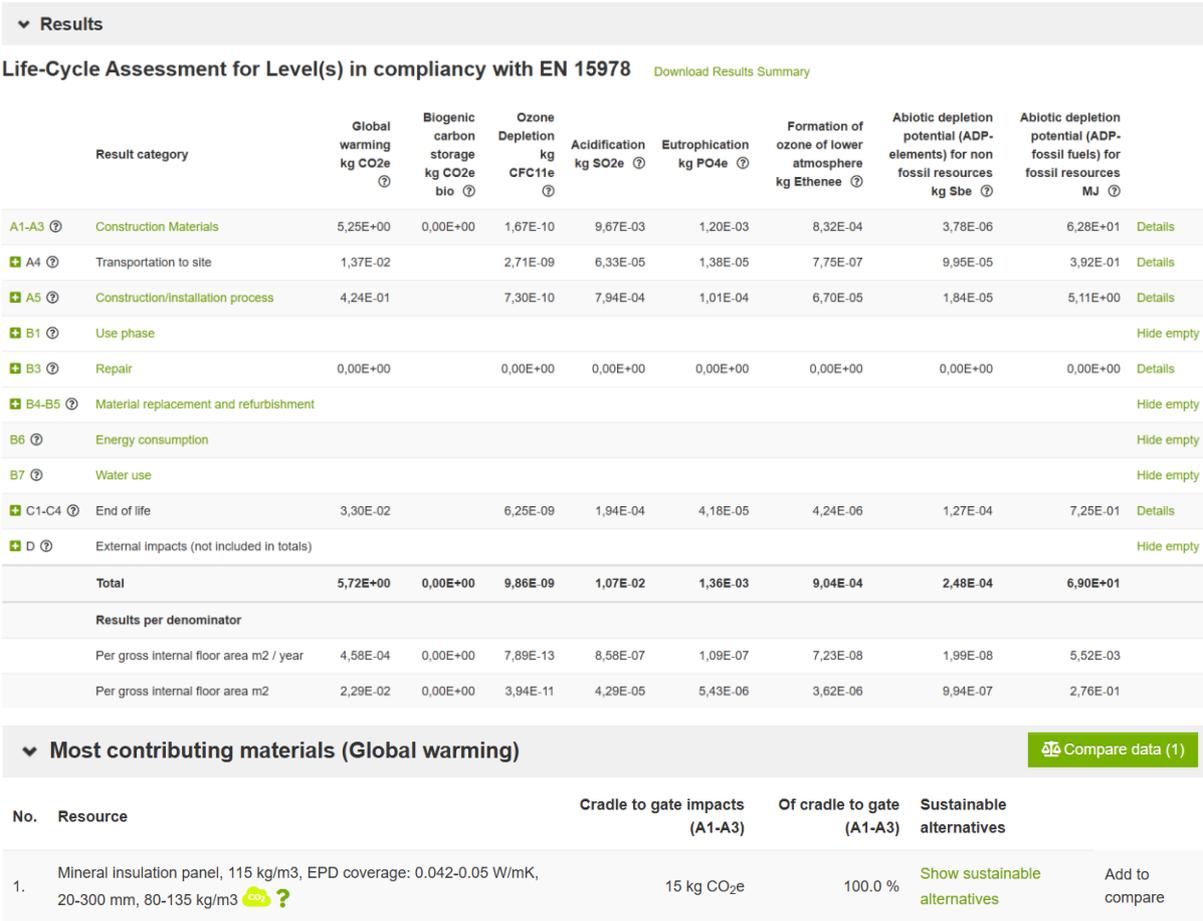


Figure 50. Results summary of One Click LCA

In continuing, it is seen the Life-cycle overview of Global Warming. (Figure 51)

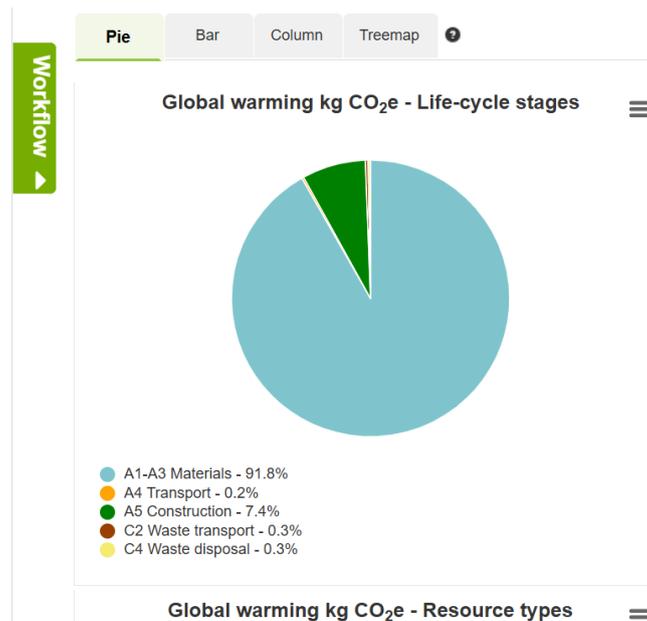


Figure 51. Pie chart Results of One Click LCA

In addition, for EPS (Expanded Polystyrene), follow the same steps for the sample 1, thickness 40 mm, and 1 m² area.

The material used is EPS insulation panels for roofs, with a thermal conductivity (λ) of 0.035 W/m·K, as specified in the Environmental Product Declaration (EPD) valid for the range 0.034–0.035 W/m·K. The panels have a thermal resistance (R) of 5.70 m²·K/W, a thickness of 200 mm, a weight of 4.50 kg/m², and a density of 22.5 kg/m³. They are classified with a fire resistance rating of Class E and correspond to the PRB Thermi Toit TH34 and PRB Thermi Toit TH35 products (Produits de Revêtement du Bâtiment).

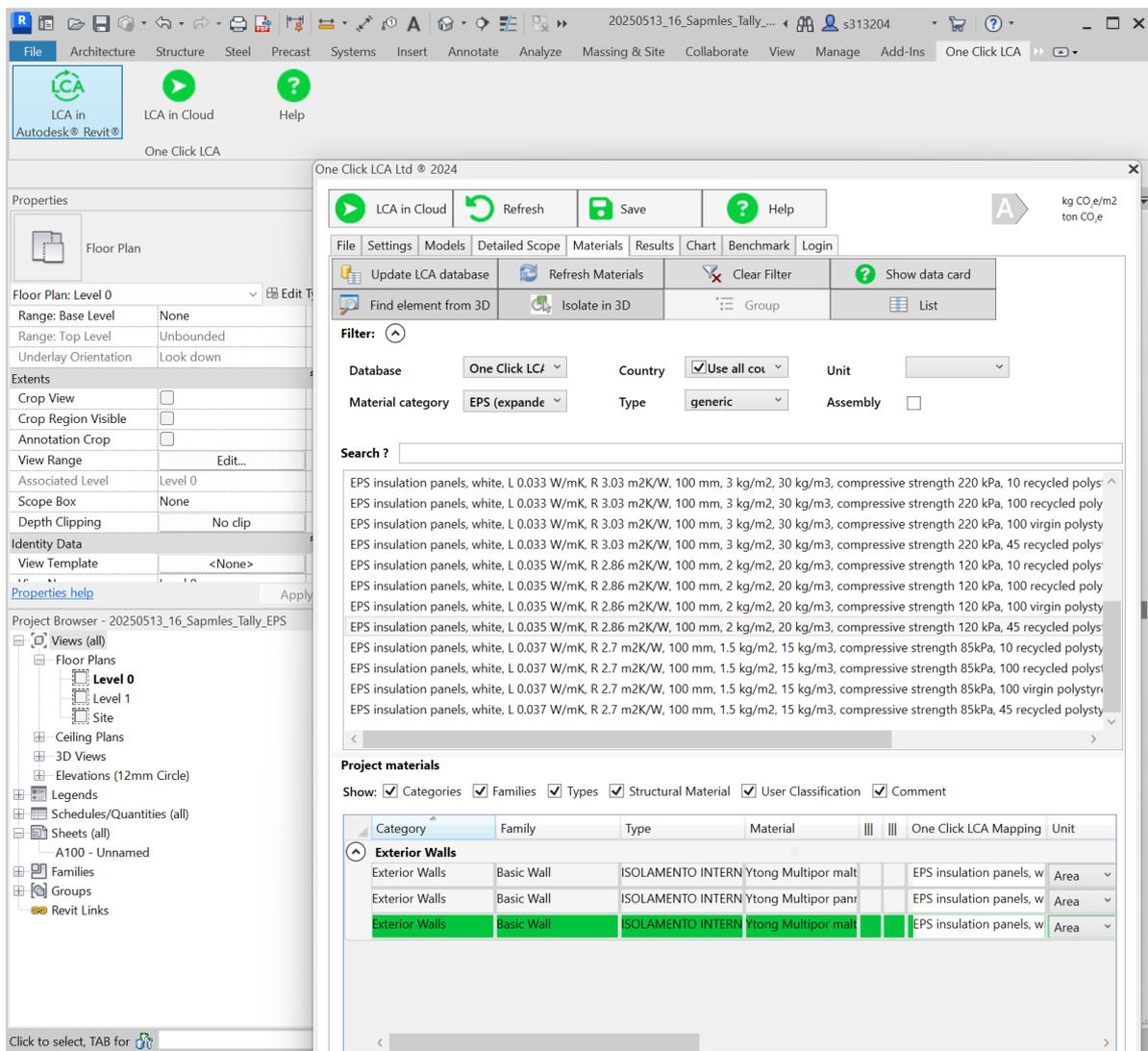
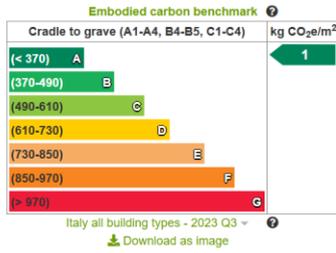


Figure 52. Material Mapping of One Click LCA

Carbon Heroes Benchmark



Life-Cycle Assessment for Level(s) in compliancy with EN 15978

Result category	Global warming kg CO ₂ e	Biogenic carbon storage kg CO ₂ e bio	Ozone Depletion kg CFC11e	Acidification kg SO ₂ e	Eutrophication kg PO ₄ e	Formation of ozone of lower atmosphere kg Ethenee	Abiotic depletion potential (ADP-elements) for non fossil resources kg Sbe	Abiotic depletion potential (ADP-fossil fuels) for fossil resources MJ
A1-A3 Construction Materials	2,29E+02	0,00E+00	4,52E-06	7,81E-01	6,36E-02	1,30E+00	1,02E-04	4,66E+03
A4 Transportation to site	9,44E-01		1,87E-07	4,35E-03	9,47E-04	5,32E-05	6,84E-03	2,69E+01
A5 Construction/installation process	1,40E+01		3,37E-07	3,41E-02	2,99E-03	5,21E-02	3,47E-04	1,96E+02
B1 Use phase								
B3 Repair	0,00E+00		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B4-B5 Material replacement and refurbishment	0,00E+00		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B6 Energy consumption								
B7 Water use								
C1-C4 End of life	1,19E+02		3,71E-06	6,79E-02	1,01E-02	4,68E-03	1,72E-03	1,98E+02
D External impacts (not included in totals)	-8,35E+01		-1,01E-05	-1,89E-01	-5,85E-02	-1,83E-02	-7,96E-06	-1,12E+03
Total	3,63E+02	0,00E+00	8,75E-06	8,87E-01	7,77E-02	1,36E+00	9,01E-03	5,09E+03
Results per denominator								
Per gross internal floor area m ² / year								
Per gross internal floor area m ²	1,45E+00	0,00E+00	3,50E-08	3,55E-03	3,11E-04	5,42E-03	3,60E-05	2,03E+01

Figure 53. Results of One Click LCA in compliance with EN 15978

Indicators describing the usage of primary energy and water

Result category	Use of renewable primary energy resources as raw materials MJ	Total use of primary energy ex. raw materials MJ	Total use of renewable primary energy MJ	Total use of non renewable primary energy MJ	Use of net fresh water m ³
A1-A3 Construction Materials	1,16E-01	2,67E+03	5,76E+01	5,14E+03	3,02E+00
A4 Transport to the building site	0,00E+00	2,69E+01	4,42E-02	2,68E+01	0,00E+00
A5 Construction/installation process	4,63E-03	1,17E+02	2,96E+00	2,15E+02	2,61E-01
B1 Use phase					
B3 Repair	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B4-B5 Material replacement and refurbishment	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B6 Energy consumption					
B7 Water use					
C1-C4 End of life	0,00E+00	2,30E+02	1,63E+01	2,14E+02	3,51E+00
D External impacts (not included in totals)	0,00E+00	-1,68E+03	-5,66E+02	-1,16E+03	-2,16E-01
Total	1,21E-01	3,05E+03	7,70E+01	5,59E+03	6,79E+00
Results per denominator					
Per gross internal floor area m ² / year					
Per gross internal floor area m ²	4,82E-04	1,22E+01	3,08E-01	2,24E+01	2,71E-02

Figure 54. Results of One Click LCA

Global warming kg CO₂e - Life-cycle stages

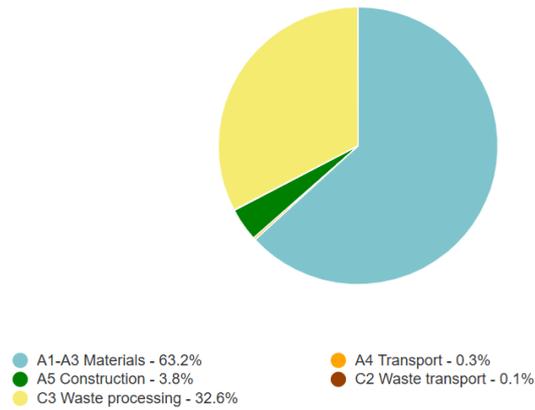


Figure 55. Pie chart Results of One Click LCA

Starting the same steps for the second sample:

The thickness of the sample is 100 mm, and the material type is the same.

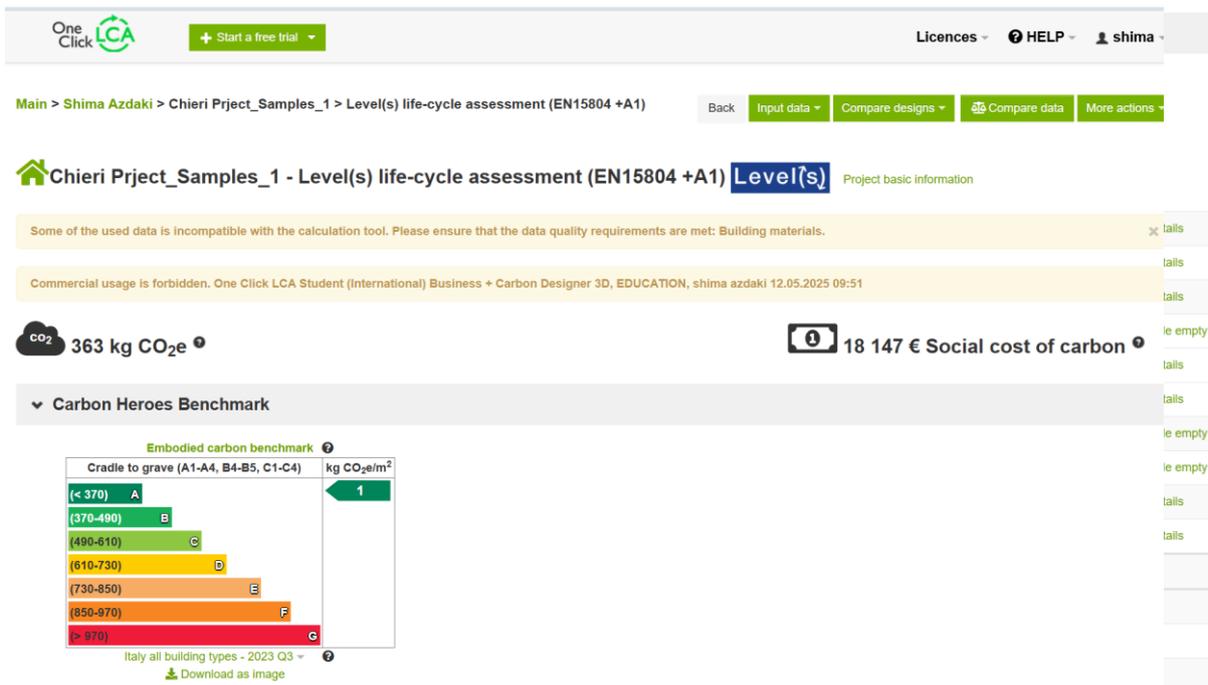


Figure 56. Results of One Click LCA

Indicators describing the usage of primary energy and water [Download Results Summary](#)

Result category	Use of renewable primary energy resources as raw materials MJ	Total use of primary energy ex. raw materials MJ	Total use of renewable primary energy MJ	Total use of non renewable primary energy MJ	Use of net fresh water m3
A1-A3	1,16E-01	2,67E+03	5,76E+01	5,14E+03	3,02E+00
A4	0,00E+00	2,69E+01	4,42E-02	2,68E+01	0,00E+00
A5	4,63E-03	1,17E+02	2,96E+00	2,15E+02	2,61E-01
B1					
B3	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B4-B5	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B6					
B7					
C1-C4	0,00E+00	2,30E+02	1,63E+01	2,14E+02	3,51E+00
D	0,00E+00	-1,68E+03	-5,66E+02	-1,16E+03	-2,16E-01
Total	1,21E-01	3,05E+03	7,70E+01	5,59E+03	6,79E+00
Results per denominator					
Per gross internal floor area m2 / year					
Per gross internal floor area m2	4,82E-04	1,22E+01	3,08E-01	2,24E+01	2,71E-02

Figure 57. Results of One Click LCA

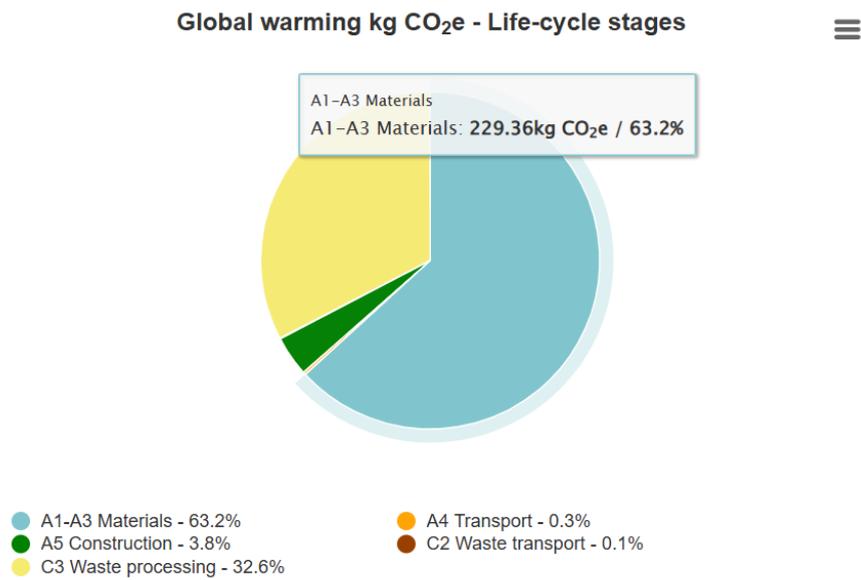


Figure 58. Pie chart Results of One Click LCA

Repeating steps for third sample:

The thickness is 140 mm, and the material type is the same.

Chieri Prjct_Samples_1 - Level(s) life-cycle assessment (EN15804 +A1) **Level(s)** Project basic information

Some of the used data is incompatible with the calculation tool. Please ensure that the data quality requirements are met: Building materials.

Commercial usage is forbidden. One Click LCA Student (International) Business + Carbon Designer 3D, EDUCATION, shima azdaki 12.05.2025 09:56

CO₂ 363 kg CO₂e

18 147 € Social cost of carbon

Carbon Heroes Benchmark

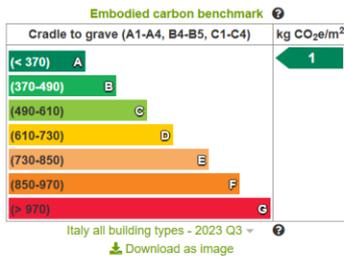


Figure 59. Results of One Click LCA

Results

Life-Cycle Assessment for Level(s) in compliancy with EN 15978 [Download Results Summary](#)

Result category	Global warming kg CO ₂ e	Biogenic carbon storage kg CO ₂ e bio	Ozone Depletion kg CFC11e	Acidification kg SO ₂ e	Eutrophication kg PO ₄ e	Formation of ozone of lower atmosphere kg Ethenee	Abiotic depletion potential (ADP-elements) for non fossil resources kg Sbe	Abiotic depletion potential (ADP-fossil fuels) for fossil resources MJ
A1-A3 Construction Materials	2,29E+02	0,00E+00	4,52E-06	7,81E-01	6,36E-02	1,30E+00	1,02E-04	4,66E+03
A4 Transportation to site	9,44E-01		1,87E-07	4,35E-03	9,47E-04	5,32E-05	6,84E-03	2,69E+01
A5 Construction/installation process	1,40E+01		3,37E-07	3,41E-02	2,99E-03	5,21E-02	3,47E-04	1,96E+02
B1 Use phase								Hide empty
B3 Repair	0,00E+00		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B4-B5 Material replacement and refurbishment	0,00E+00		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B6 Energy consumption								Hide empty
B7 Water use								Hide empty
C1-C4 End of life	1,19E+02		3,71E-06	6,79E-02	1,01E-02	4,68E-03	1,72E-03	1,98E+02
D External impacts (not included in totals)	-8,35E+01		-1,01E-05	-1,89E-01	-5,85E-02	-1,83E-02	-7,96E-06	-1,12E+03
Total	3,63E+02	0,00E+00	8,75E-06	8,87E-01	7,77E-02	1,36E+00	9,01E-03	5,09E+03
Results per denominator								
Per gross internal floor area m2 / year								
Per gross internal floor area m2	1,45E+00	0,00E+00	3,50E-08	3,55E-03	3,11E-04	5,42E-03	3,60E-05	2,03E+01

Figure 60. Results of One Click LCA

Indicators describing the usage of primary energy and water [Download Results Summary](#)

Result category	Use of renewable primary energy resources as raw materials MJ	Total use of primary energy ex. raw materials MJ	Total use of renewable primary energy MJ	Total use of non renewable primary energy MJ	Use of net fresh water m3
A1-A3 ② Construction Materials	1,16E-01	2,67E+03	5,76E+01	5,14E+03	3,02E+00 Details
A4 ② Transport to the building site	0,00E+00	2,69E+01	4,42E-02	2,68E+01	0,00E+00 Details
A5 ② Construction/installation process	4,63E-03	1,17E+02	2,96E+00	2,15E+02	2,61E-01 Details
B1 ② Use phase					Hide empty
B3 ② Repair	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00 Details
B4-B5 ② Material replacement and refurbishment	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00 Details
B6 ② Energy consumption					Hide empty
B7 ② Water use					Hide empty
C1-C4 ② End of life	0,00E+00	2,30E+02	1,63E+01	2,14E+02	3,51E+00 Details
D ② External impacts (not included in totals)	0,00E+00	-1,68E+03	-5,66E+02	-1,16E+03	-2,16E-01 Details
Total	1,21E-01	3,05E+03	7,70E+01	5,59E+03	6,79E+00
Results per denominator					
Per gross internal floor area m2 / year					
Per gross internal floor area m2	4,82E-04	1,22E+01	3,08E-01	2,24E+01	2,71E-02

Figure 61. Results of One Click LCA

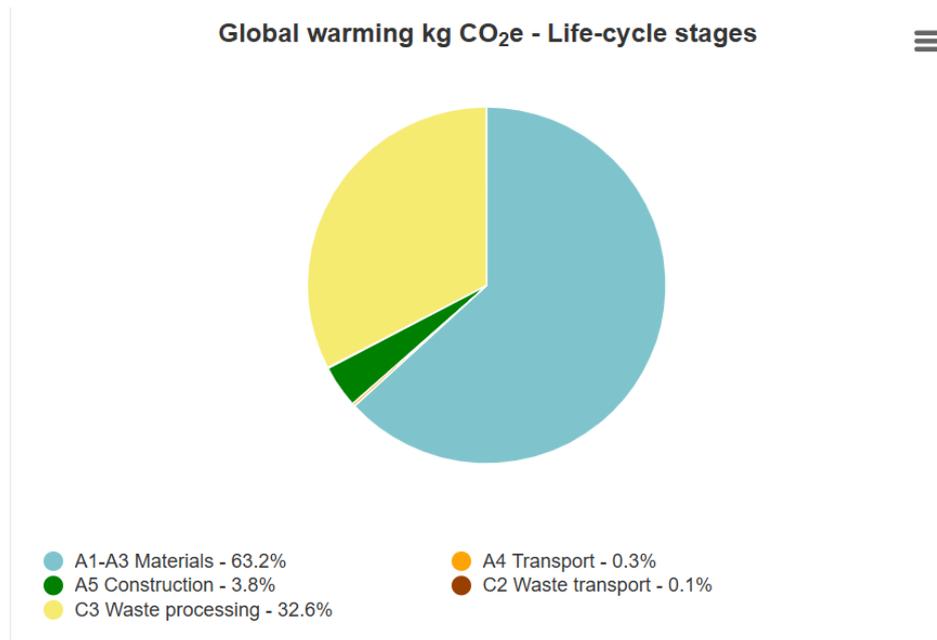


Figure 62. Pie chart Results of One Click LCA

Life-cycle impacts by stage as stacked columns

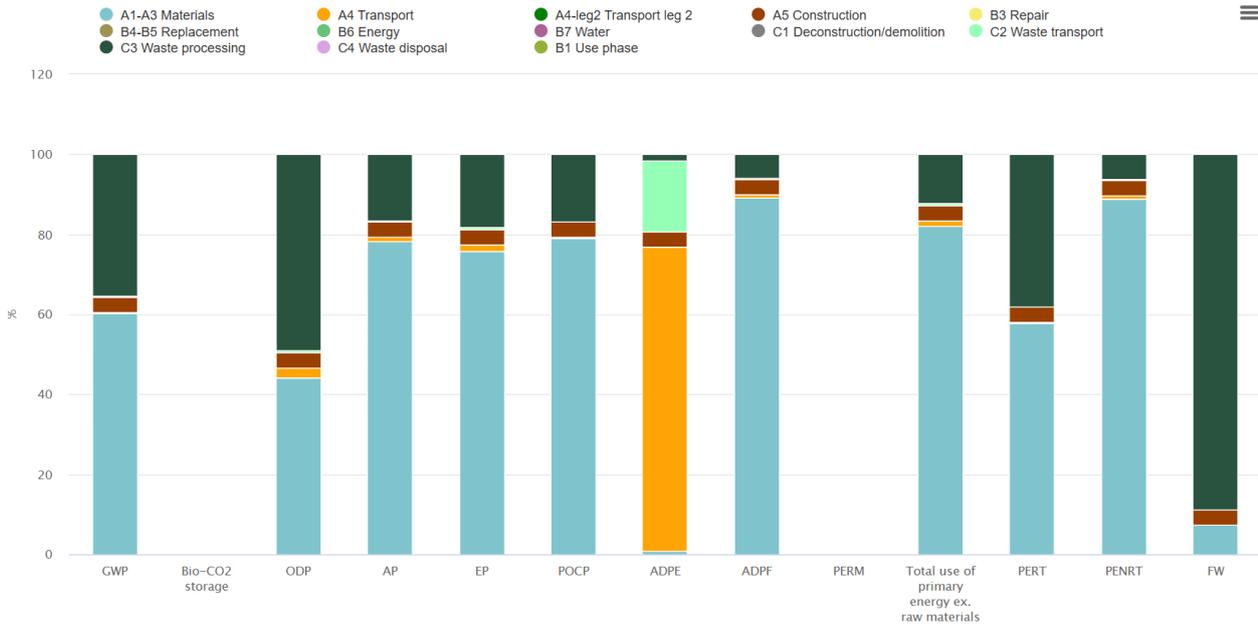


Figure 63. Bar chart Results of One Click LCA

Results of the Case Study by One Click LCA Plug-in

One Click LCA computed the data and gives an output, which is then examined to make sure that proper information has been given. This has given confirmation about the correctness of the plugin setting process.

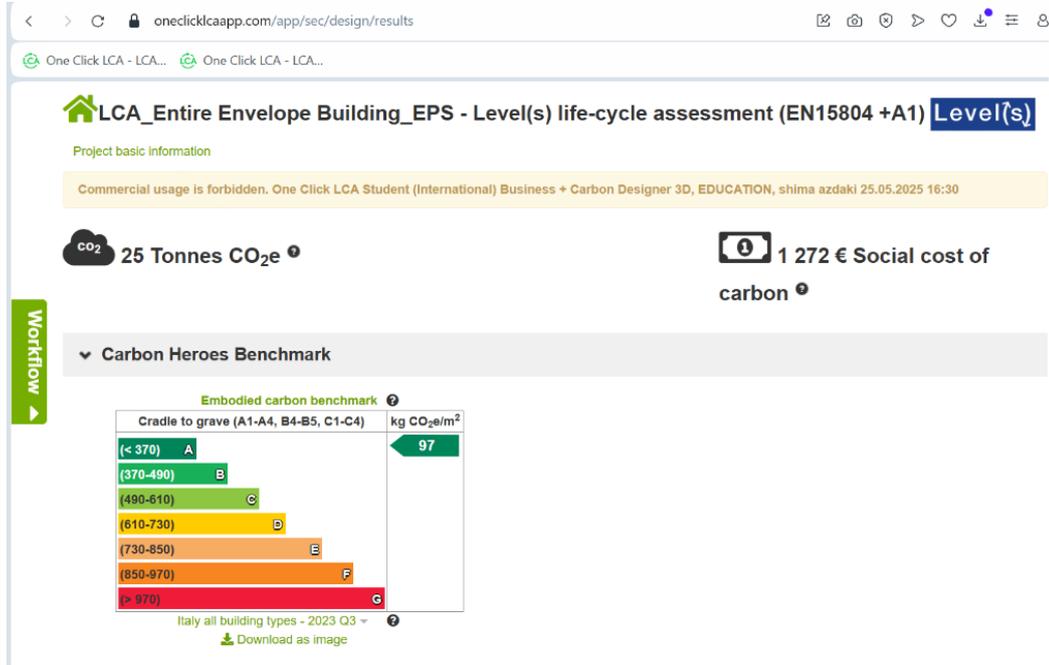


Figure 64. Output of One Click LCA plugin

The screenshot displays the following table:

Result category	Global warming kg CO ₂ e	Biogenic carbon storage kg CO ₂ e bio	Ozone Depletion kg CFC11e	Acidification kg SO ₂ e	Eutrophication kg PO ₄ e	Formation of ozone of lower atmosphere kg Ethenee	Abiotic depletion potential (ADP-elements) for non fossil resources kg Sbe	Abiotic depletion potential (ADP-fossil fuels) for fossil resources MJ
A1-A3 Construction Materials	1,81E+04	0,00E+00	7,83E+00	3,74E+01	5,51E+00	3,28E+00	1,08E+00	2,34E+05
A4 Transportation to site	8,20E+01		1,62E-05	3,78E-01	8,23E-02	4,62E-03	5,94E-01	2,34E+03
A5 Construction/installation process	1,26E+03		5,87E-01	2,46E+00	3,79E-01	2,18E-01	1,69E-01	1,34E+04
B1 Use phase								
B3 Repair	0,00E+00		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B4-B5 Material replacement and refurbishment	0,00E+00		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
B6 Energy consumption								
B7 Water use								
C1-C4 End of life	5,98E+03		2,03E-04	3,84E+00	6,02E-01	2,39E-01	7,70E-01	1,26E+04
D External Impacts (not included in totals)	-8,11E+03		-5,96E-04	-2,95E+01	-5,25E+00	-3,96E+00	-2,96E-02	-1,11E+05
Total	2,54E+04	0,00E+00	8,42E+00	4,41E+01	6,57E+00	3,74E+00	2,62E+00	2,62E+05

Results per denominator:

Per gross internal floor area m ² / year	Per gross internal floor area m ²
Global warming kg CO ₂ e	1,02E+02
Biogenic carbon storage kg CO ₂ e bio	0,00E+00
Ozone Depletion kg CFC11e	3,37E-02
Acidification kg SO ₂ e	1,76E-01
Eutrophication kg PO ₄ e	2,63E-02
Formation of ozone of lower atmosphere kg Ethenee	1,50E-02
Abiotic depletion potential (ADP-elements) for non fossil resources kg Sbe	1,05E-02
Abiotic depletion potential (ADP-fossil fuels) for fossil resources MJ	1,05E+03

Figure 65. Output of One Click LCA plugin

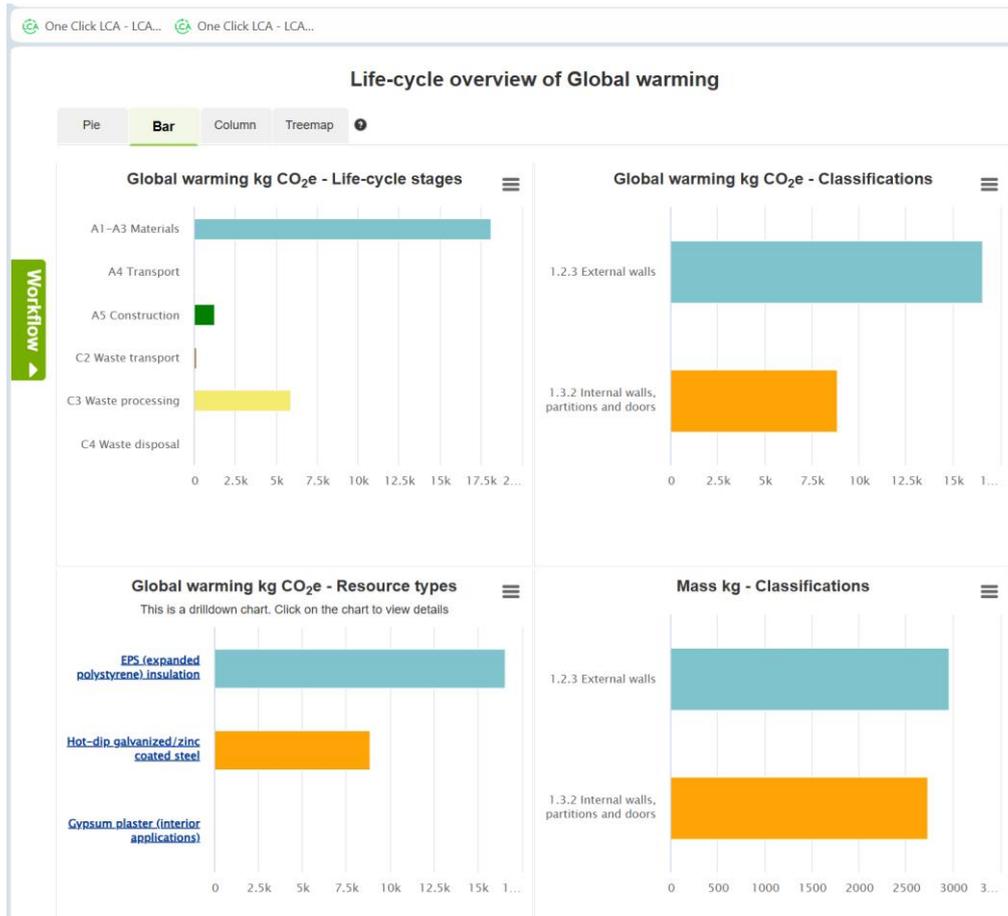


Figure 66. Output of One Click LCA plugin

onedickcaapp.com/app/sec/design/results

One Click LCA - LCA...

Global warming kg CO₂e - Life-cycle stages | Global warming kg CO₂e - Classifications | Global warming kg CO₂e - Resource types | Mass kg - Classifications

Data sources

Sources

Resource name	Technical specification	Product	Manufacturer	EPD program	EPD number	Environment Data Source	Standard	Verification	Year	Country	Upstream database	Density	Product Category Rules (PCR)	Notes about PCR	Performance ranking	Download EPD
EPS insulation panels, white	L= 0.035 W/mK, R= 2.66 m ² K/W, 100 mm, 2 kg/m ² , 20 kg/m ³ , compressive strength 120 kPa, 45% recycled polystyrene, Lambda=0.035 W/(m.K)	One Click LCA	One Click LCA	One Click LCA	-	One Click LCA	EN15804+A1, EN15804+A2	Internally verified	2023	LOCAL	One Click LCA		EN15804+A1, EN15804+A2	-	CO2 CML: 281 / 522 See full ranking	
Expanded galvanized steel sheets	7850 kg/m ³	Bredrene	Midthaug AS	EPD Norge	NEPD-2684-1384-NO	EPD Støkkmetall I varmforzinket utførelse	EN15804+A1	Internally verified	2021	norway	ecoinvent	7850.0	NPCR 013: 2019 Part B for Steel and aluminum construction products	Only with EN15804	CO2 CML: 467 / 672 See full ranking	Download EPD
Gypsum plaster, for mechanical application and fire protection	10 mm, 4 kg/m ² , bulk density: 480 kg/m ³	Igniver	Saint-Gobain PPC Italia Spa,	International EPD System	S-P-01688	EPD Gyproc Igniver	EN15804+A1	Third-party verified (as per ISO 14026)	2020	italy	ecoinvent		PCR 2012:01 Construction products and Construction services, ver 2.3	Only with EN15804	CO2 CML: 206 / 372 See full ranking	Download EPD

Figure 67. Output of One Click LCA plugin

As mentioned before, it is possible to export the results in Excel format, divided by stages. (figure 68)

Entity users	Project name	Design name	Indicator name				
1 shima azdaki	Shima Azdaki	2 - Chien Prject_Samples_1	Level(s) life-cycle assessment (EN15804 +A1)				
3 Section	Result category	Global warming kg CO2e	Biogenic carbon storage kg CO2e bio	Ozone Depletion kg CFC11e	Acidification kg SO2e	Eutrophication kg PO4e	Formation of ozone of lower atmosphere kg
4 A1-A3	Construction Materials	3,69E+00	0,00E+00	5,99E-08	5,69E-03	7,45E-04	
5 A4	Transportation to site	1,71E-02		3,38E-09	7,89E-05	1,72E-05	
6 A4	Transport to the building site	1,71E-02		3,38E-09	7,89E-05	1,72E-05	
7 A4-leg2	Transportation to site - leg 2						
8 A5	Construction/installation process	2,33E-01		5,22E-09	2,80E-04	3,78E-05	
9 A5a	Site operations & site waste handling						
10 A5b	Site waste transportation						
11 A5c	Construction site - material wastage - materials	1,48E-01		2,40E-09	2,28E-04	2,98E-05	
12 A5d	Construction site - material wastage - transport	8,85E-04		1,35E-10	3,15E-06	6,87E-07	
13 A5e	Construction site - material wastage - waste	8,81E-02	0,00E+00	2,69E-09	4,92E-05	7,34E-06	
14 A5m-waste	Construction site - material use on site - waste						
15 B1	Use phase						
16 B1-a	Refrigerant annual leakages						
17 B1-b	Refrigerant loss, equipment replacement						
18 B1-c	Refrigerant loss, equipment end of life						
19 B1-d	Carbonisation						
20 B1-e	Vegetation withdrawal of carbon						
21 B3	Repair	0,00E+00		0,00E+00	0,00E+00	0,00E+00	
22 B3a	Repair - materials	0,00E+00		0,00E+00	0,00E+00	0,00E+00	
23 B3b	Repair - transport	0,00E+00		0,00E+00	0,00E+00	0,00E+00	
24 B3c	Repair - waste	0,00E+00		0,00E+00	0,00E+00	0,00E+00	
25 B4-B5	Material replacement and refurbishment		0,00E+00	0,00E+00	0,00E+00	0,00E+00	
26 B4-B5a	Material replacement - materials						
27 B4-B5b	Material replacement - transport						
28 B4-B5b-leg2	Material replacement - transport leg 2						
29 B4-B5c	Material replacement - waste						
30 B6	Energy consumption						
31 B7	Water use						
32 C1-C4	End of life	2,15E+00		6,73E-08	1,23E-03	1,83E-04	
33 C1	Deconstruction/demolition						
34 C2	Waste transport	3,98E-03		7,87E-10	1,83E-05	4,00E-06	
35 C3	Waste processing	2,15E+00		6,65E-08	1,21E-03	1,79E-04	
36 C4	Waste disposal						
37 D	External impacts (not included in totals)	-8,33E-01		-1,01E-07	-1,88E-03	-5,83E-04	
38 D	Installed Materials - benefit	-8,01E-01	0,00E+00	-9,69E-08	-1,81E-03	-5,81E-04	
39 A5-benefit	Construction site - material wastage - benefit	-3,20E-02	0,00E+00	-3,88E-09	-7,24E-05	-2,24E-05	
40 A5m-benefit	Construction site - material use - benefit						
41 B3-benefit	Repair - benefit	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	
42 B4-B5-benefit	Material replacement - benefit						
43 D2	Exported energy (not included in totals)						

Figure 68. Output of One Click LCA plugin for entire Envelope building

Note- Section D (External impacts)- the negative numbers here (e.g., -3.98E-03 for Global Warming kg CO2e) indicate the environmental benefit from recycling or energy recovery of EPS insulation at the end of its life.

Visualization of Results

Following the workflow, the next step would be deciding based on the results and then following steps for Dynamo—which is written in details in the second step—in next season. Here are the following steps for each example.

Start from the List Prepared with Tally Results in Excel File

Starting from the list prepared with the Tally results in an Excel file. First, the information from the LCA calculation tools into an Excel files is collected, as shown in the picture.

Type of Category	Sum of AP (kg SO2 eq)	Sum of EP (kg N eq)	Sum of GWP (kg CO2 eq)	Sum of ODP (kg CFC-11 eq)	Sum of POCP (kg O3 eq)
ISOLAMENTO INTERNO 4cm	0,01706	0,001609	8,424	1,672E-10	0,431
ISOLAMENTO INTERNO 10	0,03608	0,003404	17,82	3,538E-10	0,9118
ISOLAMENTO INTERNO 15	0,0246	0,002321	12,15	4,824E-10	0,6217

Figure 69. Excel file prepared for Dynamo

Then, Dynamo continued with the Excel file and the 'GWP' factor was added as a Shared Parameter through the Manage tab, assigned to the Wall category specifically for insulation layers, and then included as a Project Parameter.

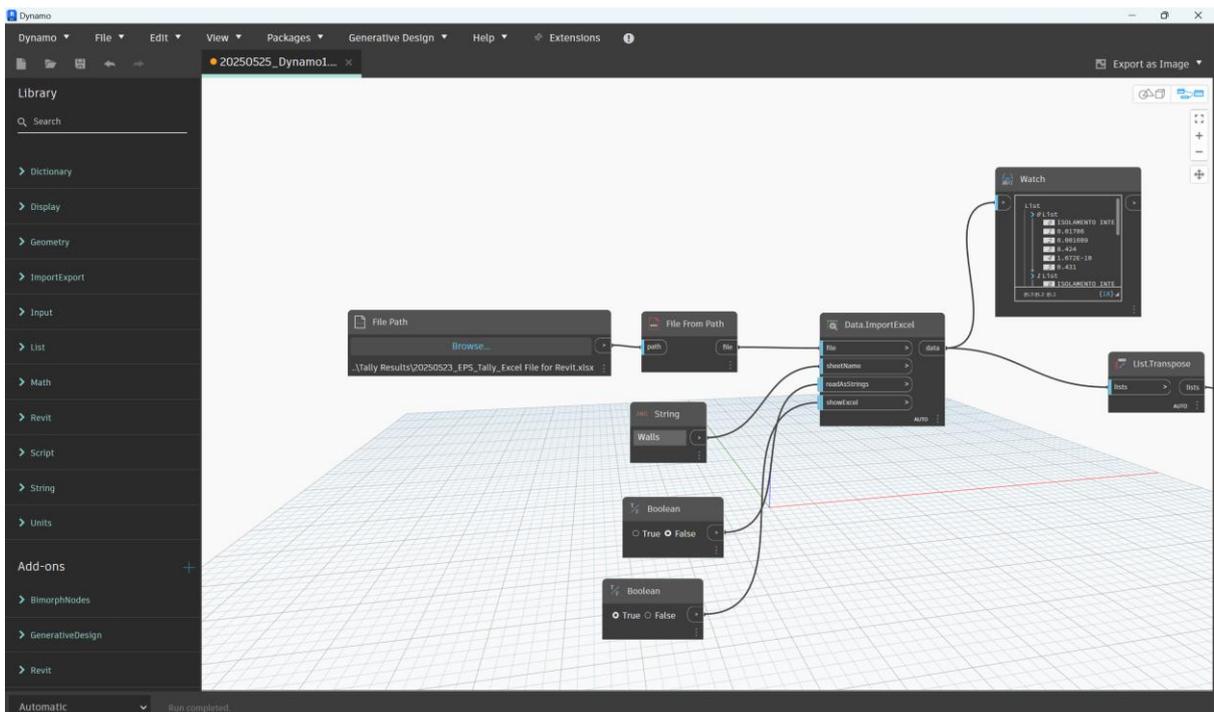


Figure 70. Dynamo

The 'GWP' factor was added as a Shared Parameter through the Manage tab, assigned to the Wall category specifically for insulation layers, and then included as a Project Parameter.

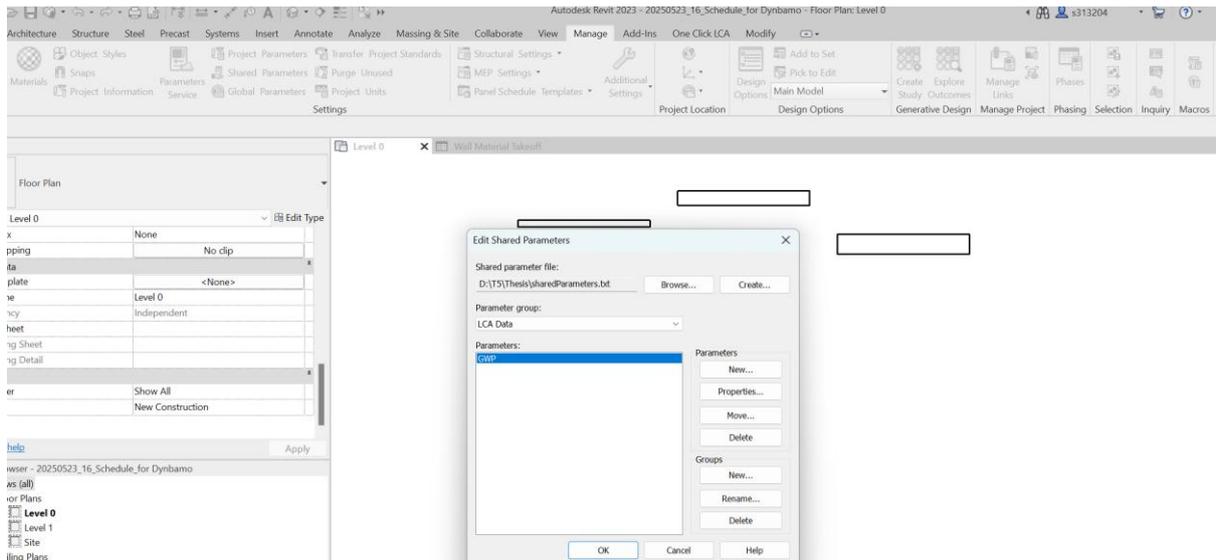


Figure 71. Shared parameter

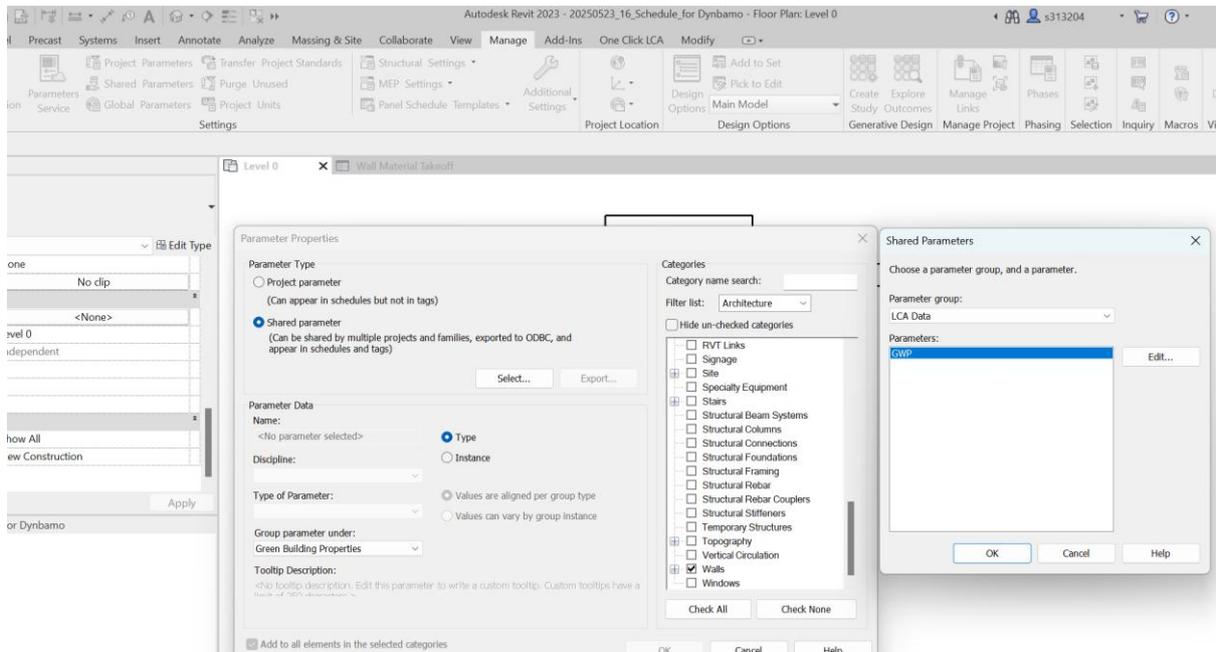


Figure 72. Shared parameter category selection

As shown, the 'GWP' factor is now visible in the Edit Type Properties, and the specific GWP value is displayed for each element.

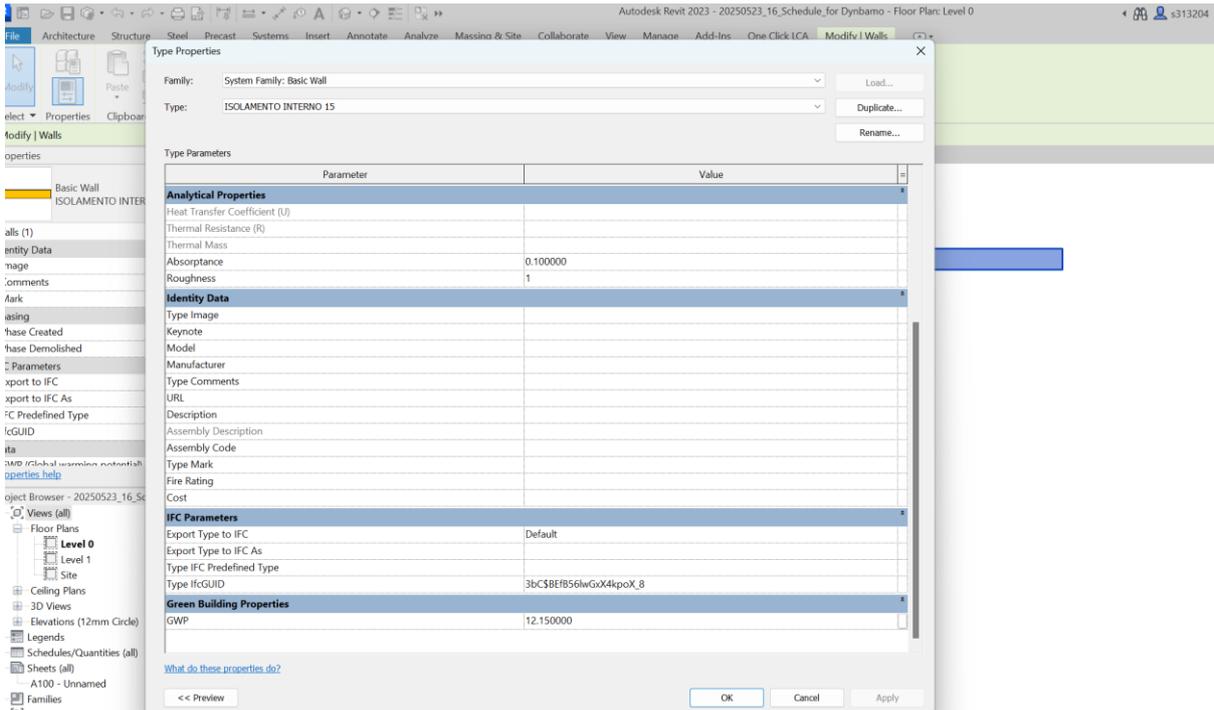


Figure 73. Assignment of GWP values in the Type Parameters

Filters for colors

As seen in these screenshots, some filters have been set for the wall category from the View tab.

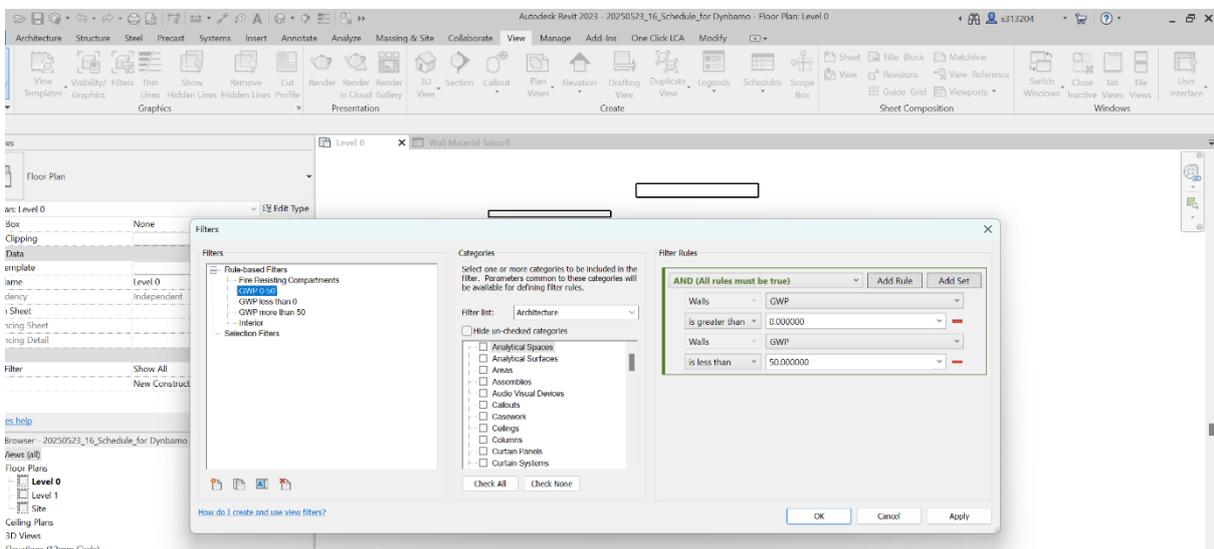


Figure 74. View tab and filter rules

Then, colors were set in the Manage tab based on the specific amount of GWP associated with each element. (figure 74)

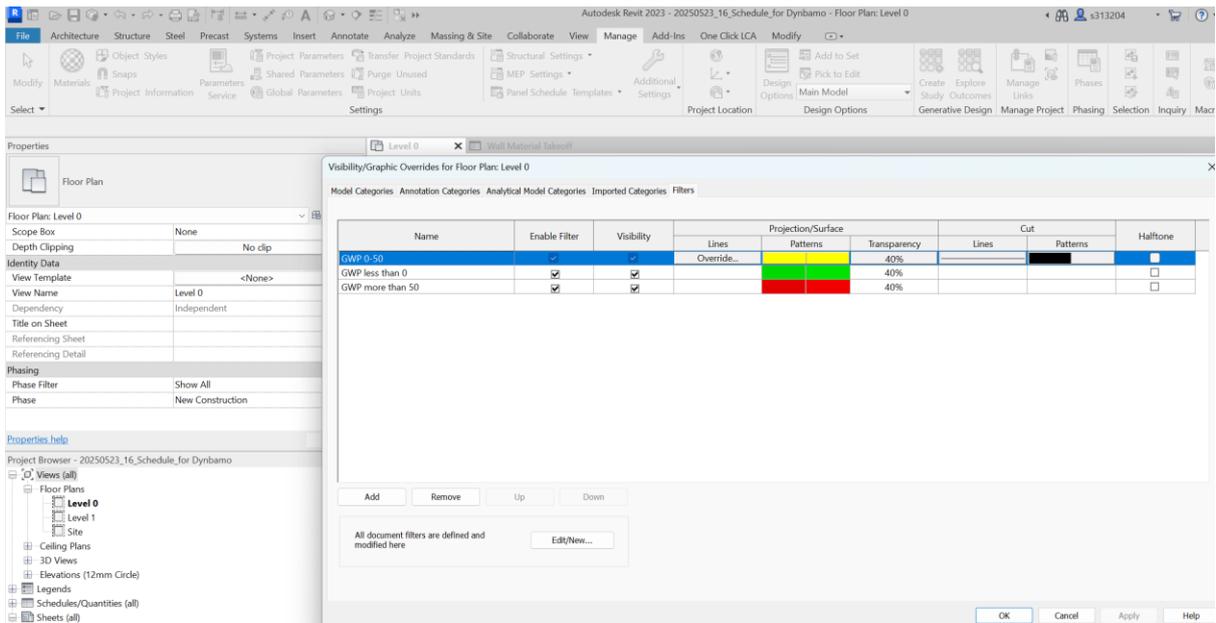


Figure 75. Color-coding of “GWP” factor

The process continues in Dynamo, and in the final Revit visualization, elements are color-coded based on their respective GWP values, which differ according to each element's area and thickness.

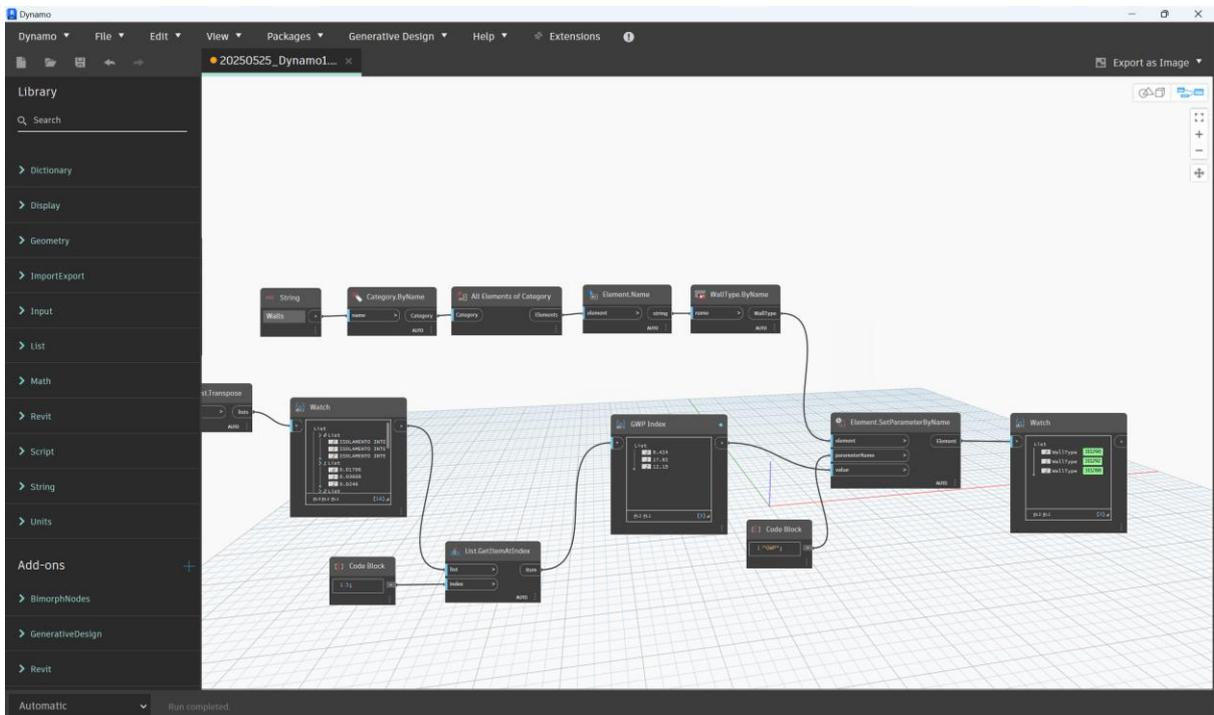


Figure 76. Dynamo

This is how it is seen in Revit.

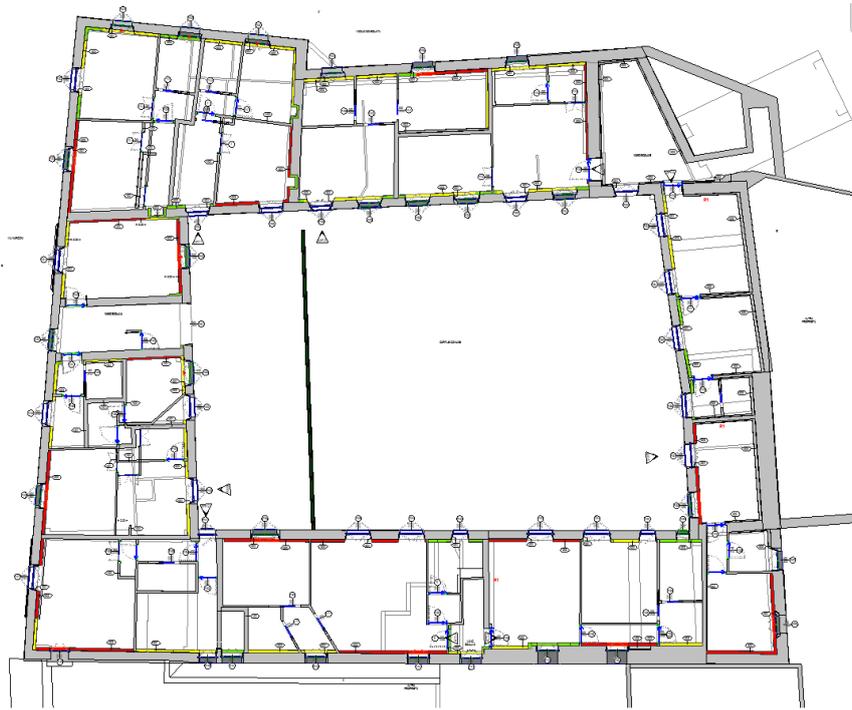


Figure 77. Color-coded Revit view showing GWP distribution across building elements.

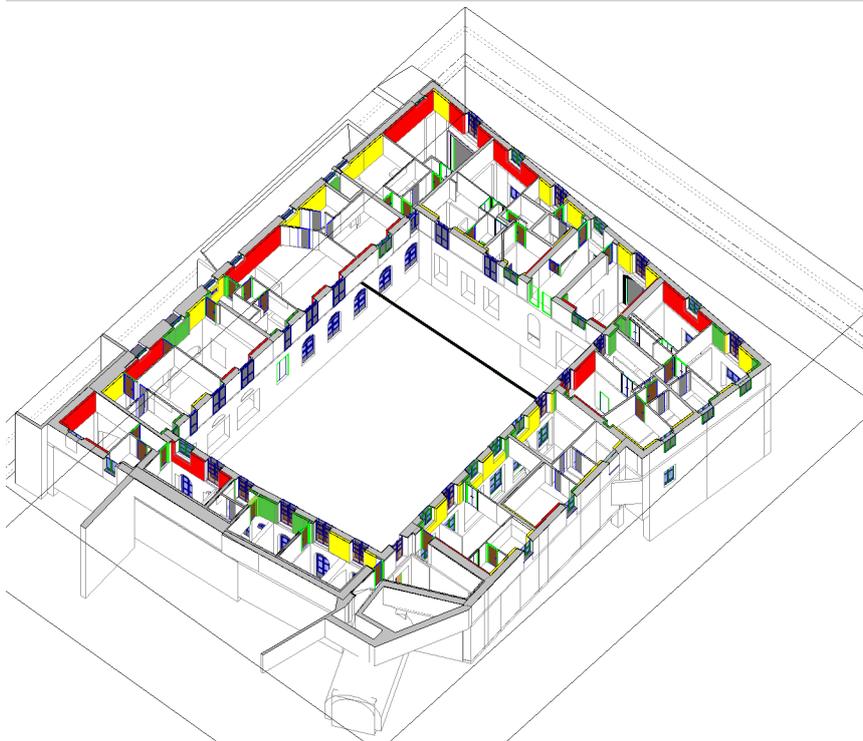


Figure 78. Color-coded Revit view showing GWP distribution across building elements.

Second step: BIM-LCA approach strategy for Case Study - Chieri Project

Presentation of the Chieri project modeled in Revit

1. BIM Model Creation from Point Cloud Data

A detailed BIM model of the existing building was generated using point cloud data obtained through laser scanning.

- **Uploading and Aligning Point Cloud Data:** The point cloud data was imported into Revit and aligned with the project's origin point to ensure spatial accuracy.

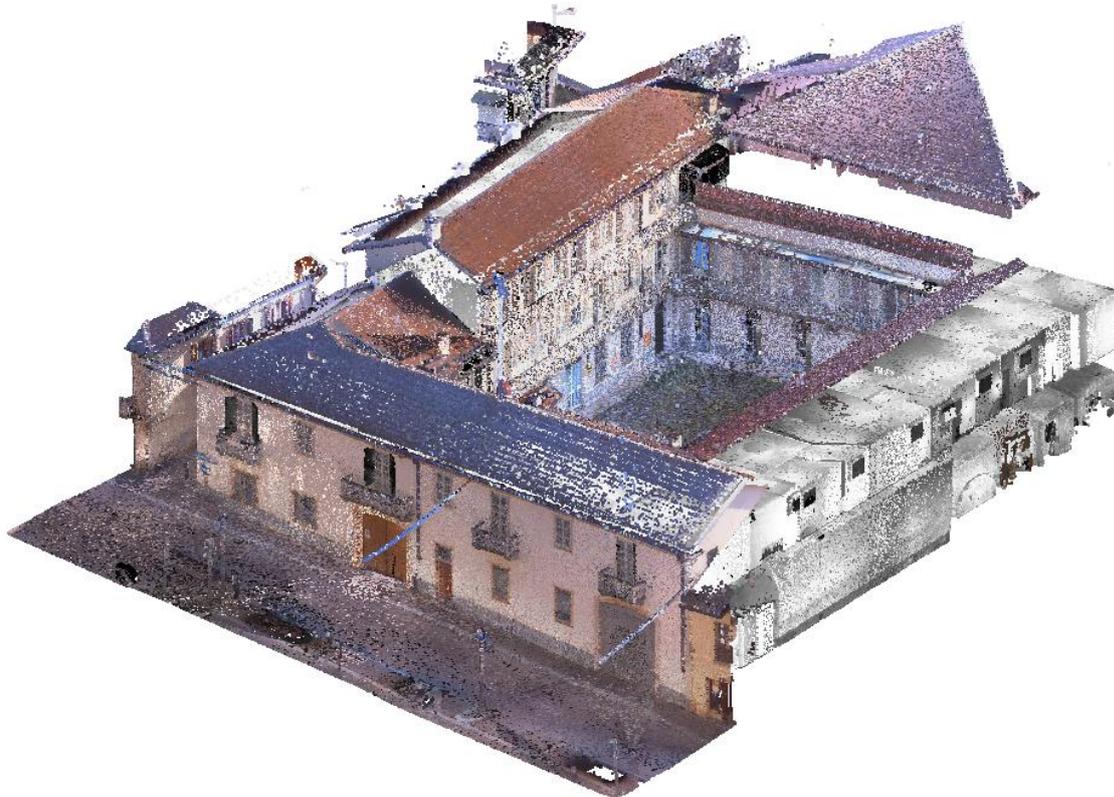


Figure 79. Point clouds of Chieri Project

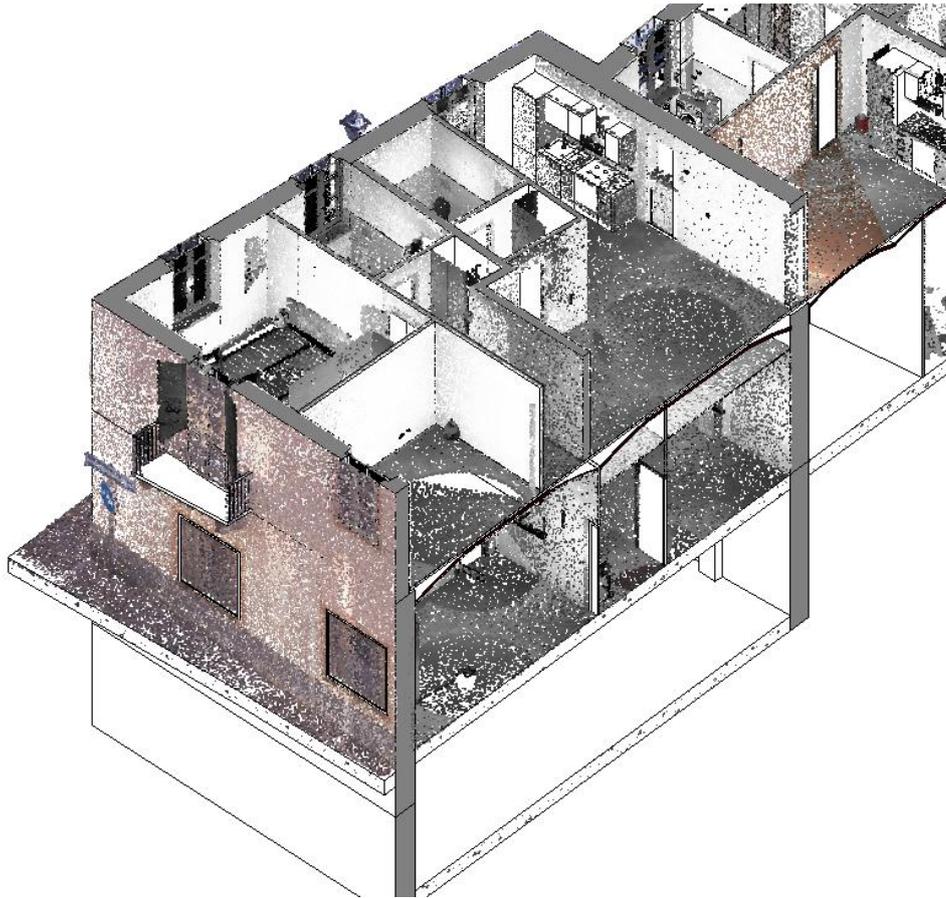


Figure 80. Point clouds of Chieri Project in section

- **Establishing Levels:** Levels corresponding to the point cloud data were established to maintain consistency across the model.
- **Modeling Walls Using the "Model In-Place" Option:** To achieve high accuracy, particularly in representing the irregular walls characteristic of historical buildings, the "Model In-Place" tool was utilized. This allowed for precise modeling of complex wall shapes and features, a crucial step in maintaining accuracy for LCA purposes (Smith, 2020). Voids were created within the walls to represent openings (windows, doors). A phased approach enabled separation of components, facilitating detailed analysis.

2. Modeling Insulation Options

The thesis evaluates two primary approaches for integrating insulation into the existing building model. This choice is driven by the need to accurately represent both the existing structure and the proposed insulation retrofit while also enabling effective LCA analysis.

Approach 1: Drawing External Walls with Separate Insulation Layer

- **Methodology:** External walls were created using standard architectural wall types. A separate wall element was then added adjacent to the first, composed solely of insulation material (e.g., Multipor M3).
- **Sustainability Considerations:** This approach accurately represents a common renovation scenario where insulation is added to an existing external wall (Stephan and Crawford, 2019). It enables clear tracking of the insulation material's environmental impact separately from the existing wall structure and simplifies LCA by providing a clear boundary for analysis.
- **Challenges:** Requires careful data management to ensure that the insulation layer is correctly associated with the existing wall in the model. It may also lead to slight inaccuracies if the insulation layer is not perfectly aligned with the existing wall geometry.



Figure 81. Revit Plan

Approach 2: Drawing Walls with Integrated Layers

- **Methodology:** Each wall component, including bricks and insulation (e.g., Multipor M3), was modeled as part of a single wall element.

- **Sustainability Considerations:** This approach integrates all wall components, facilitating the assessment of the overall environmental impact of the wall system (Murphy et al., 2018). It allows for the optimization of material selection and thickness based on performance criteria and LCA considerations.
- **Challenges:** Managing complex wall assemblies with multiple layers can be challenging, especially for irregular geometries. This approach demands precise data on material properties and quantities for accurate LCA results.

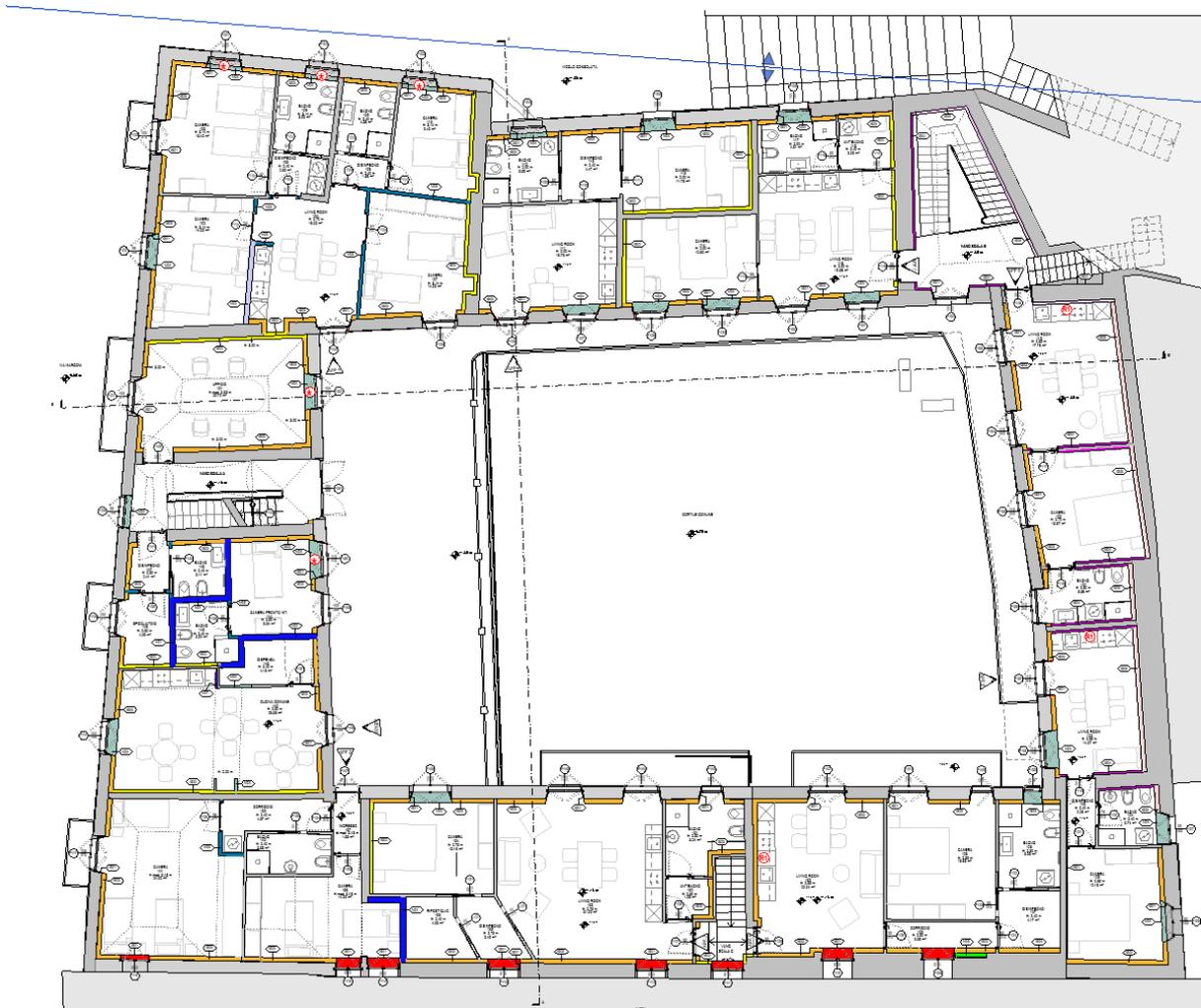


Figure 82. Revit Plan- walls category First Floor

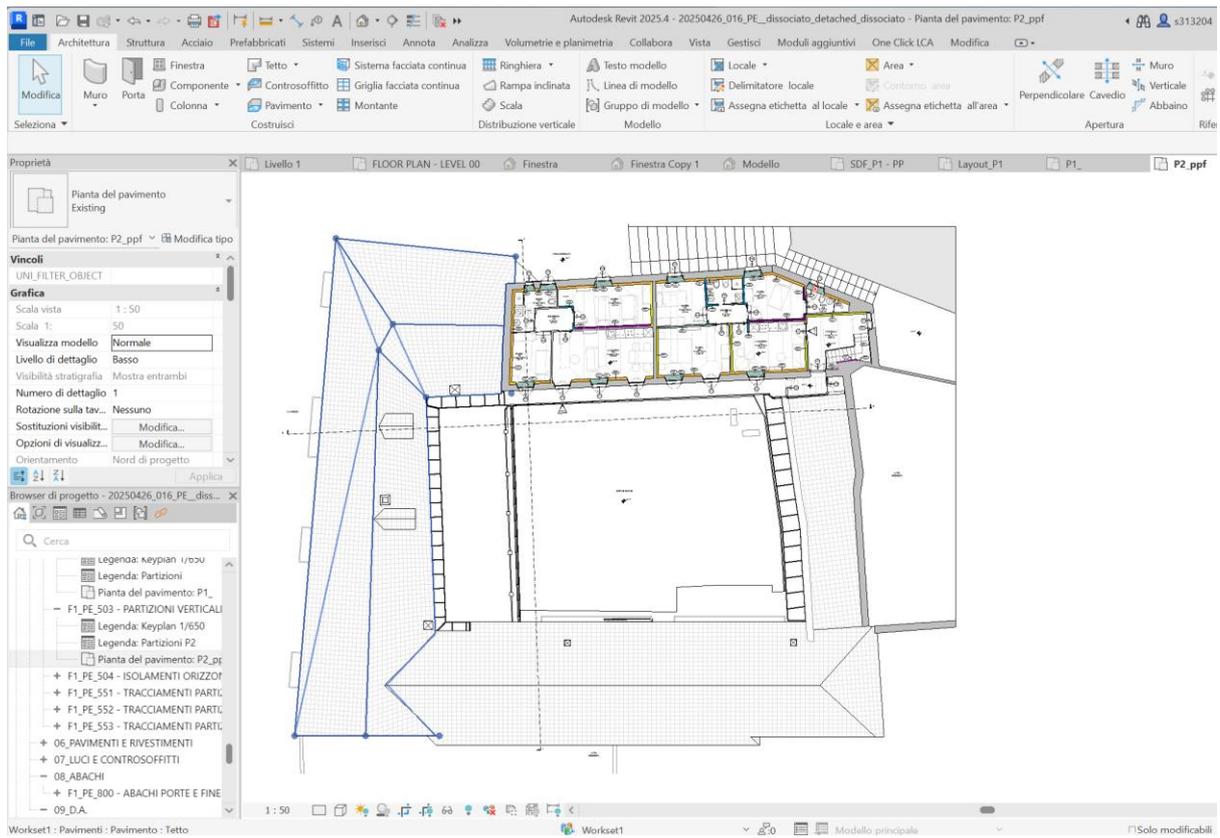


Figure 83. Revit Plan- walls category Second Floor

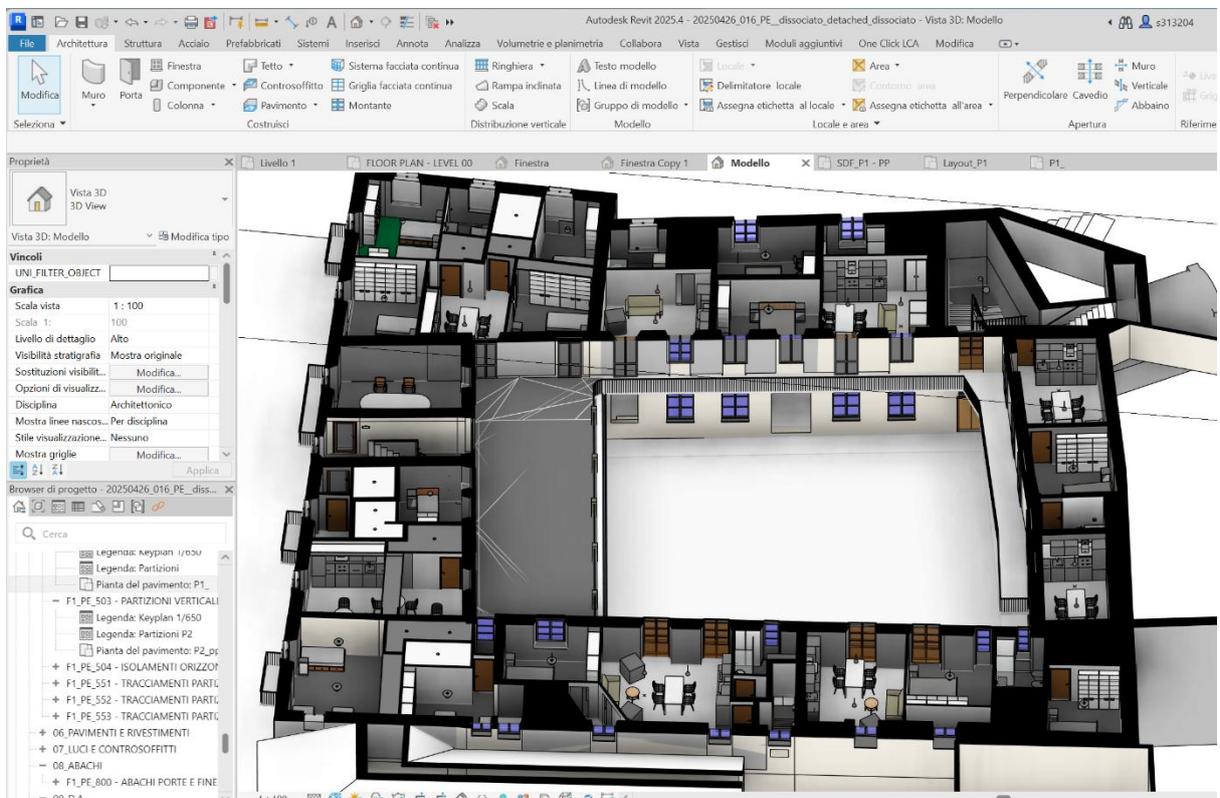


Figure 84. 3D Walls in Revit

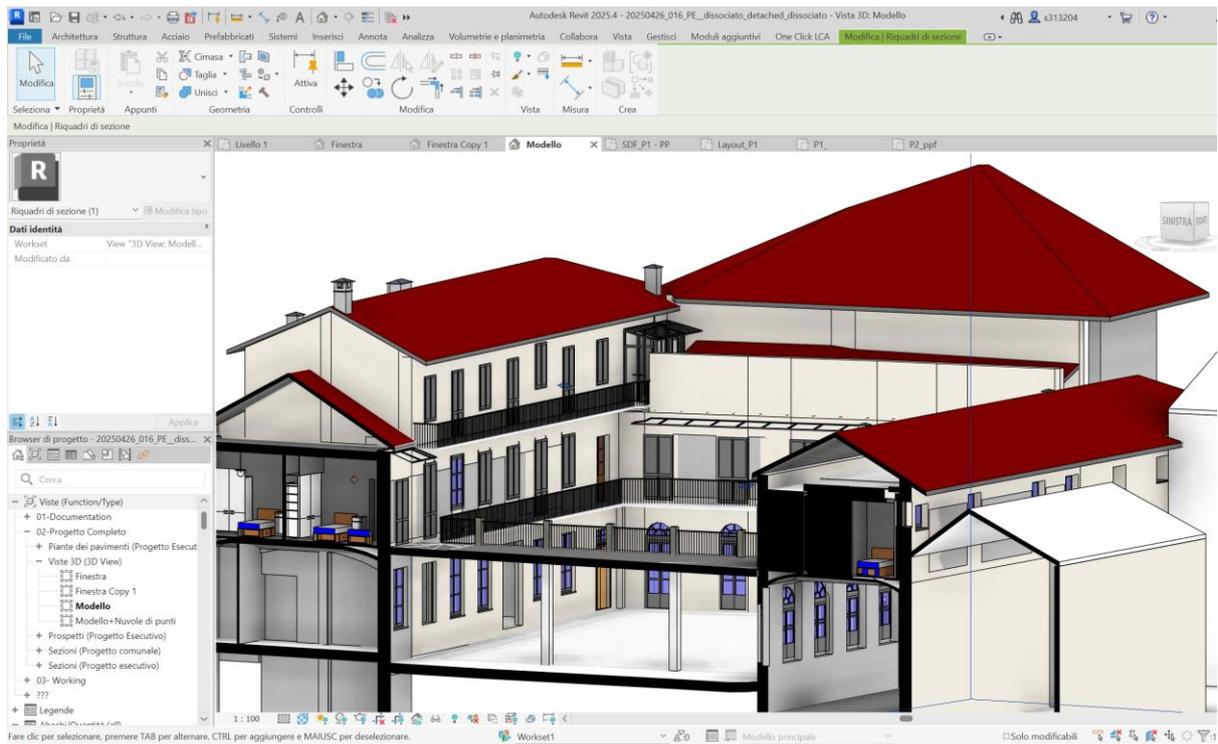


Figure 85. 3D Walls in Revit

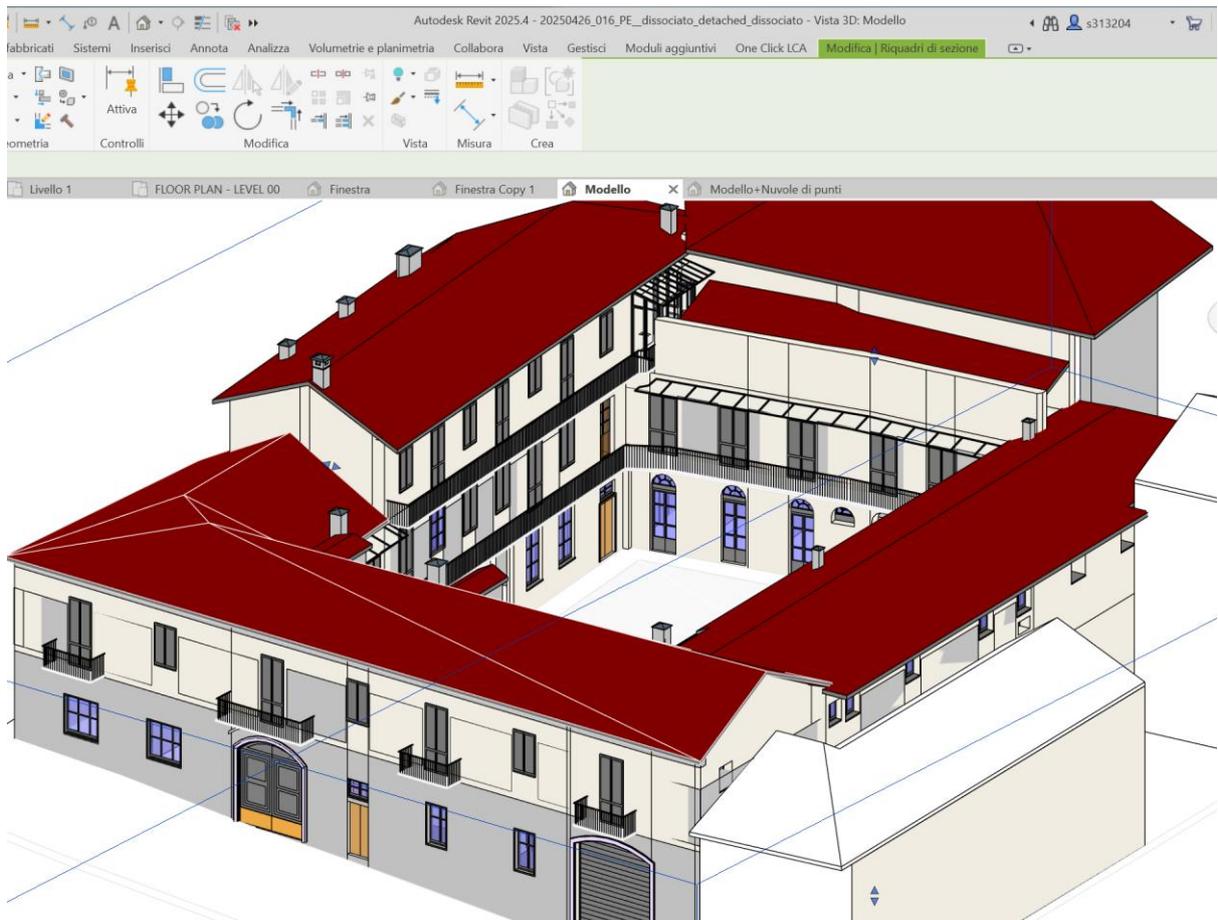


Figure 86. 3D Walls in Revit

Generally, drawing each wall component separately in a BIM model can significantly enhance the overall sustainability analysis of a building for the following reasons:

- **Accurate Material Quantification**

Modeling each wall component individually allows for precise quantification of materials used. This enables accurate assessment of material-related environmental impacts, such as embodied energy and carbon emissions.

- **Detailed Life Cycle Assessment (LCA)**

With each component modeled separately, LCA can be conducted more accurately, including evaluation of the environmental impacts of each material throughout its lifecycle. This approach facilitates a comprehensive understanding of the building's overall environmental footprint and helps identify areas for improvement.

- **Optimization of Material Selection**

Analyzing each component individually allows designers to optimize material selection based on environmental performance criteria. This supports the choice of materials with lower environmental impacts, such as recycled materials or those with lower embodied carbon.

- **Waste Reduction and Recycling**

Accurate material tracking facilitates, better waste management and potential recycling strategies. This reduces waste during construction and demolition phases, promoting a more circular economic approach.

- **Enhanced Collaboration and Decision-Making**

Clear visualization of each component supports better communication among stakeholders. This ensures that all parties are aligned on sustainability goals and strategies, leading to more effective decision-making.

- **Compliance with Sustainability Standards**

Detailed component modeling aids in demonstrating compliance with sustainability standards and certifications (e.g., LEED, BREEAM). This helps ensure that the building meets or exceeds sustainability benchmarks, enhancing its market value and reputation.

By modeling each wall component separately, a more detailed and accurate sustainability analysis can be conducted, which is crucial for achieving environmental goals in building design and construction.

Modeling Windows and Doors

Accurate modeling of windows and doors was essential for the project. The methodology included:

- **Initial Approach:** Initially, predefined Revit window families were attempted. However, this method was insufficient due to the diversity of window and door types in the building.
- **Revised Methodology:** Windows and doors were modeled based on point cloud data and historical catalogs (around 2015, the year of the last renovation). Site photographs were used for verification.

Non-Destructive Modeling of Wall Stratigraphy

A non-destructive approach was used to model the existing wall stratigraphy without altering the original structure.

- **Initial Approach:** Standard wall tools were used to model stratigraphy and thickness. However, this method was unsuitable for irregular walls.
- **Revised Approach:** The main portion of the walls was modeled using architectural wall tools. Irregular sections were merged with column components, which automatically adopted the material properties of the outermost wall layer. This allowed for the representation of both irregular geometries and wall stratigraphy simultaneously.

Edit assembly

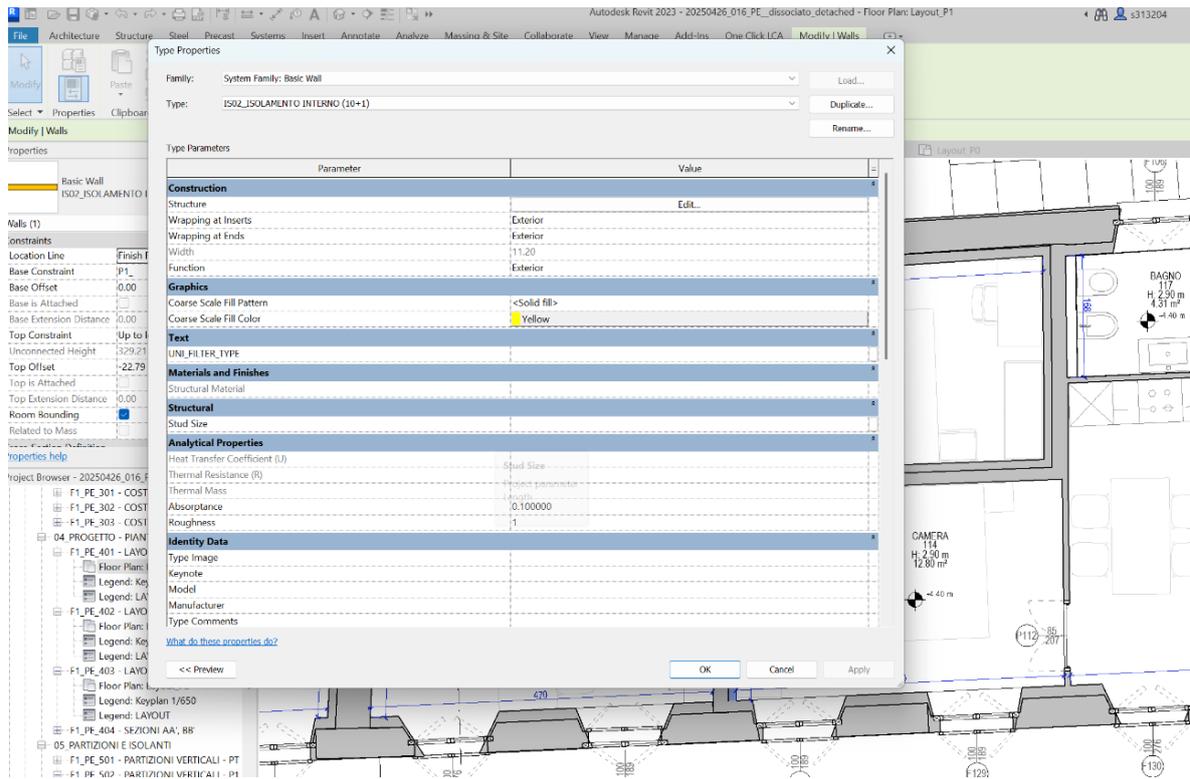


Figure 87. Edit assembly

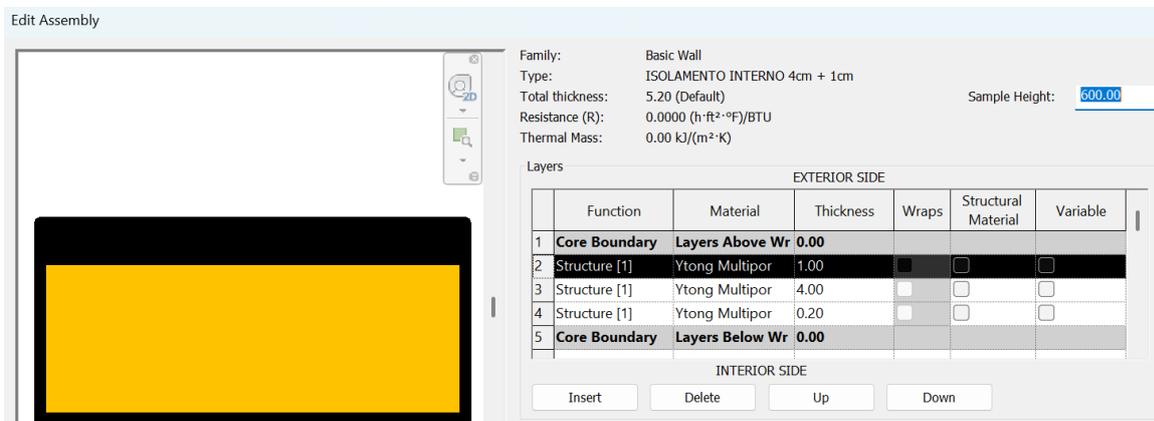


Figure 88. Edit assembly

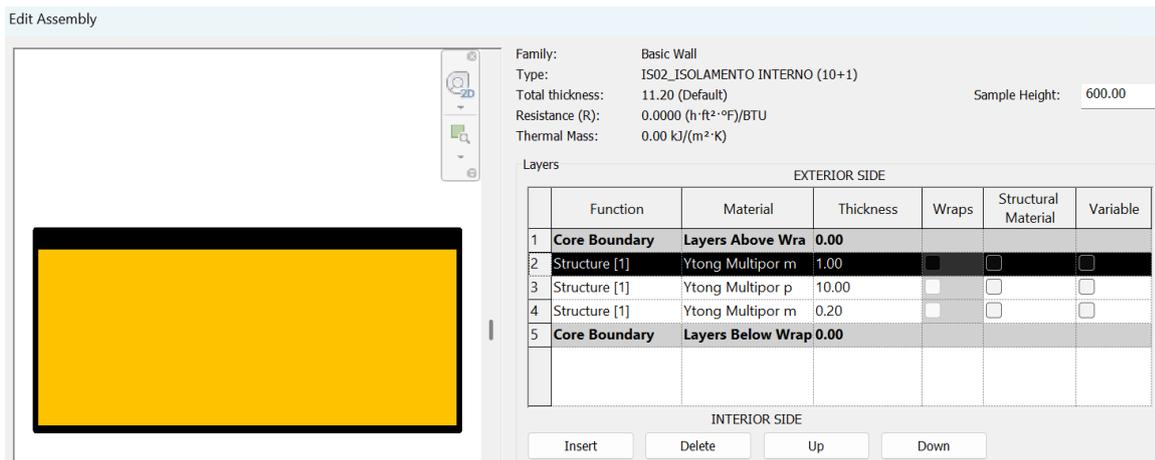


Figure 89. Edit assembly

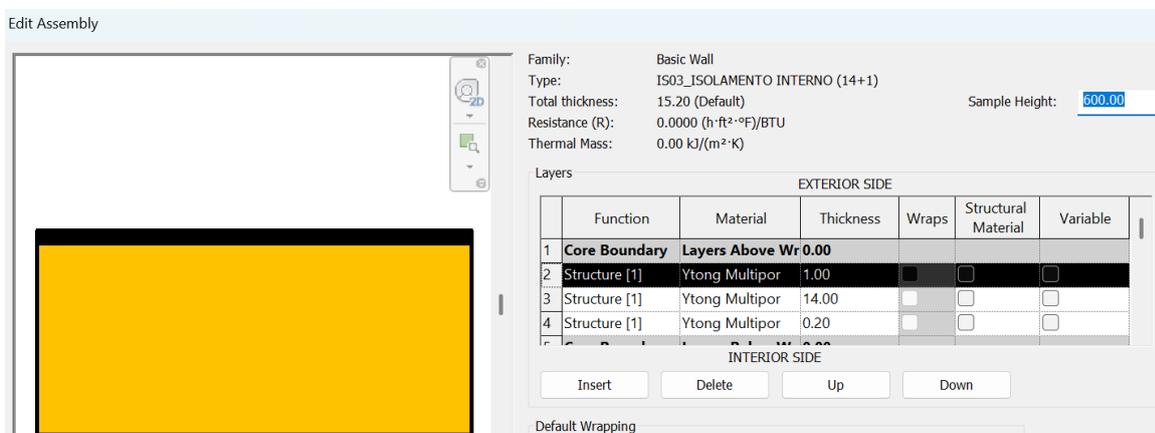


Figure 90. Edit assembly

Workflow for Preparing Revit Model for LCA Analysis

Since I am working on the main Revit file, which includes all necessary elements for a real project, and since my focus for calculating the Life Cycle Assessment (LCA) is specifically on external elements, I needed to set up a new Workset called ‘**Tally LCA Elements Only**’. The goal was to isolate the external elements — including walls, doors, windows, and roofs — for the LCA calculation.

Here are the steps I followed:

1. Create a New Workset

I created a new Workset named ‘**Tally LCA Elements Only**’ to isolate the external elements.

2. Select External Walls

Using the **Filter** tool, I selected all the walls. Then, I manually **unselected the internal walls** to ensure that only the external walls were included.

3.Assign to Workset:

After selecting the external walls, I assigned them to the newly created Workset 'Tally LCA Elements Only' using the Properties palette.

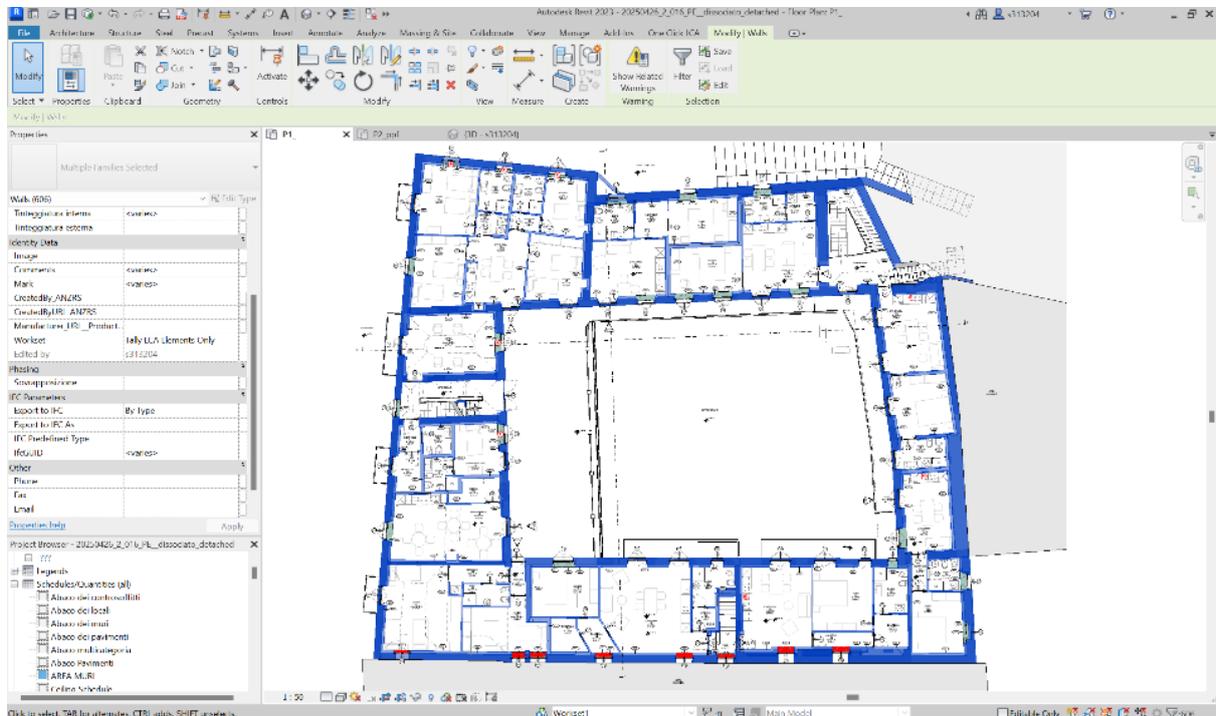


Figure 91. Workset 'only LCA Elements' _ First floor Plan

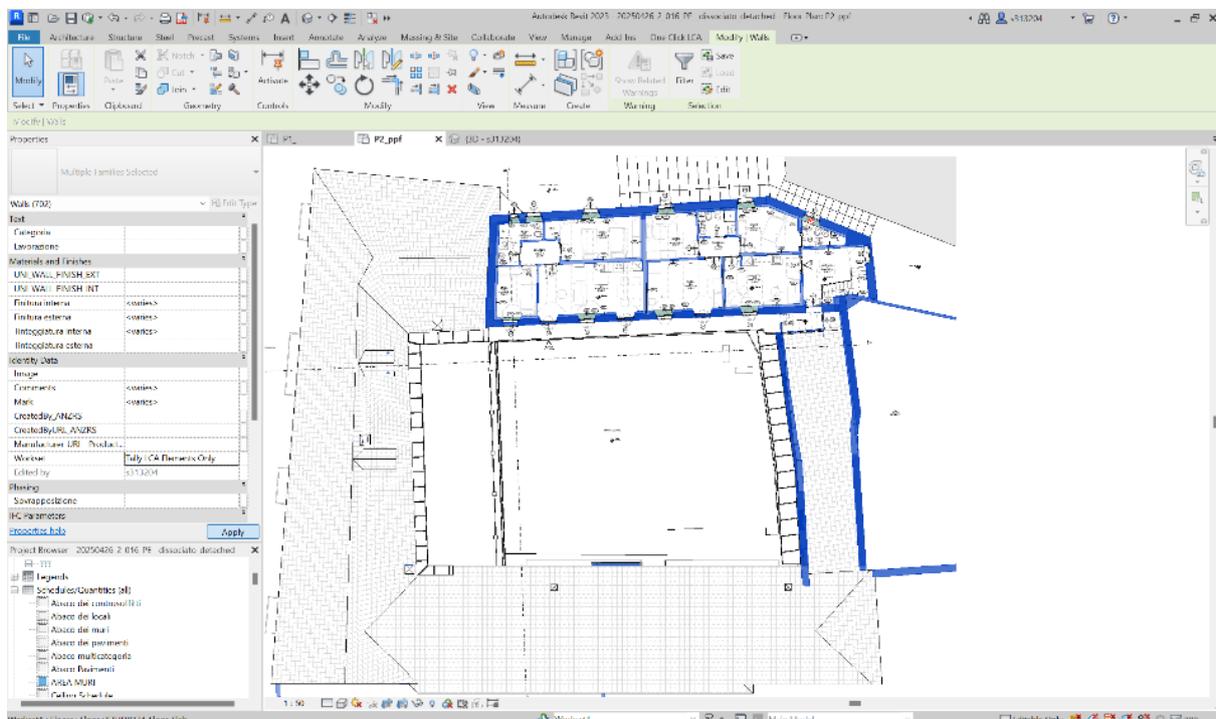


Figure 92. Workset 'only LCA Elements' _ Second floor

4.Verification of Accuracy

To ensure the accuracy of the selection, elements are reviewed by checking their Type Properties and confirmed that only the external elements were included. Also graphic overrides (such as temporary color changes) are used to visually validate that only the relevant elements were part of the Workset.

By following these steps, it is ensured that only the external elements necessary for the LCA calculation were included in the view used for Tally.

To prepare the Revit model for Life Cycle Assessment (LCA) calculations, specific steps were undertaken to isolate only the external elements (walls, doors, and windows) that contribute to the building envelope. The objective was to create a clean, manageable view showing only the relevant components, and to add parameters necessary for LCA factor assignment.

The following methodology was applied:

Creation of a Dedicated View Template for LCA Elements

Step 1 — Duplicate the Base View

A copy of the existing first floor plan was created to preserve the original view and provide a safe working environment. This was achieved by right-clicking on the first floor plan in the Project Browser and selecting **Duplicate View** → **Duplicate**. The new view was renamed "**LCA Elements Only – 1st Floor**".

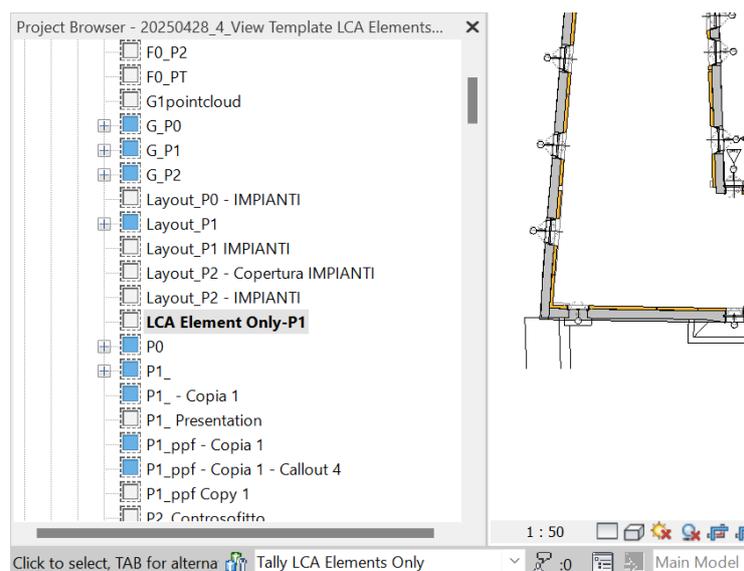


Figure 93. View template

Step 2 — Control Workset Visibility

In the duplicated view, the **Visibility/Graphics Overrides** (shortcut: **VV** or **VG**) were accessed.

Under the **Worksets** tab, all work sets were turned off except the work set named “**LCA Elements Only**”, which had been previously created to contain only external walls, external doors, and external windows. This ensured that only elements belonging to this specific work set remained visible in the view.

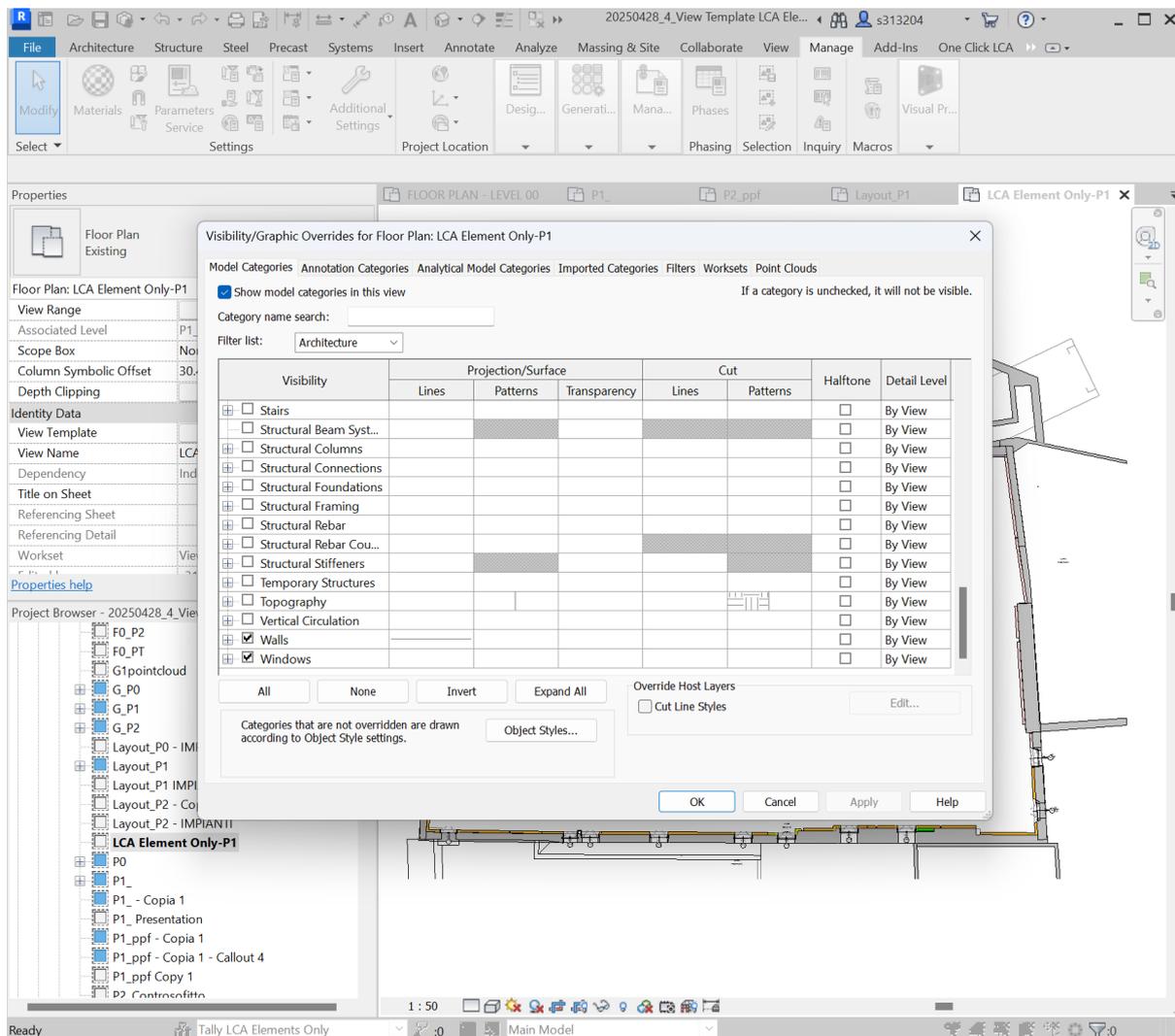


Figure 94. Workset Visibility

Step 3 — Additional Category Clean-Up (Optional)

Further refinement was carried out by turning off irrelevant model categories (e.g., Furniture, Plumbing Fixtures, Generic Models) in the same Visibility/Graphics dialog. This step was optional but highly beneficial in improving the clarity and focus of the view.

Step 4 — Creation of a View Template

Once the view was correctly filtered, a view template was created using the command **View Tab → View Templates → Create Template from Current View**. The template was named **"VT - LCA Elements Only"** and configured to lock the visibility settings, ensuring consistency when applied to other views.

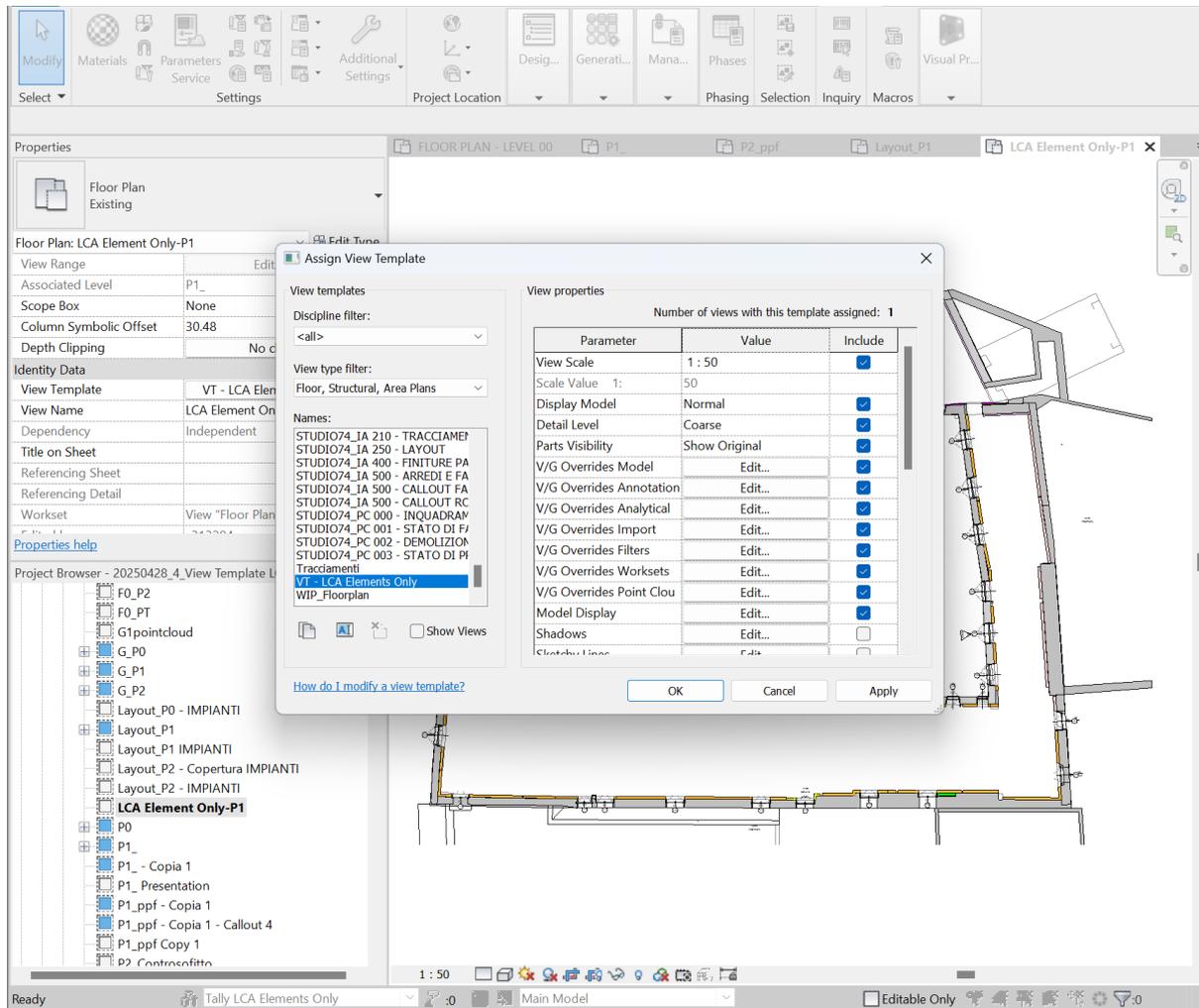


Figure 95. View template in Revit

Step 5 — Customization of the View Template Settings

The view template editor was used to verify and adjust settings:

- **Worksets:** Only the “LCA Elements Only” workset was set to visible.
- **Model Categories:** Non-relevant categories were hidden as needed.
- **Filters:** Optional filters could be added for further element control.

Step 6 — Application of the View Template

The view template was applied to other relevant plan or section views using the Properties palette. This enabled the reuse of the cleaned visibility setup without manual repetition.

BIM-LCA integration strategy for Case Study: Tally

Extension from Sample Analysis to Whole-Building Assessment

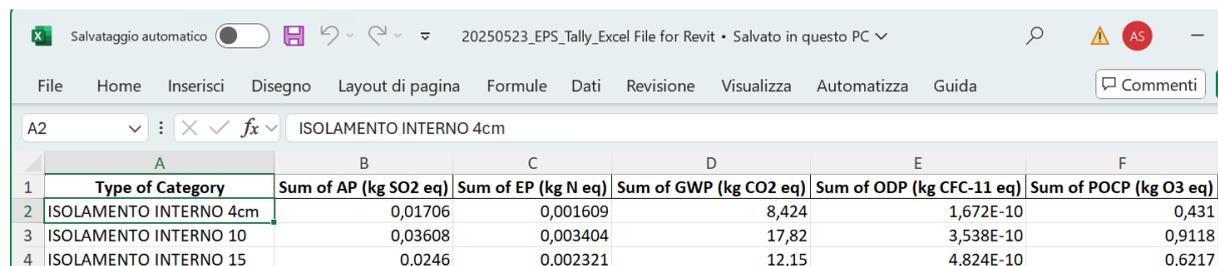
Following the initial comparative analysis of sample wall assemblies, the BIM-LCA integration workflow was systematically extended to the entire building model. The process began with material mapping in Autodesk Revit, ensuring that all relevant building elements were assigned accurate material definitions in alignment with the requirements of the Tally plugin.

Material Mapping and LCA Computation

After completing the material mapping, a full building Life Cycle Assessment (LCA) was conducted using the Tally plugin. Due to known limitations in Tally's Excel export functionality—where the report is sometimes empty and only a PDF output is available—LCA results were standardized by considering a reference area of 1 m² for all building elements. This approach ensured consistency and comparability across all components.

Data Export and Dynamo Integration

The LCA results generated by Tally were exported to an Excel file. This file included key environmental impact indicators such as Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Acidification Potential (AP), Eutrophication Potential (EP), and Photochemical Ozone Creation Potential (POCP), along with corresponding Revit Element IDs.



	A	B	C	D	E	F
1	Type of Category	Sum of AP (kg SO2 eq)	Sum of EP (kg N eq)	Sum of GWP (kg CO2 eq)	Sum of ODP (kg CFC-11 eq)	Sum of POCP (kg O3 eq)
2	ISOLAMENTO INTERNO 4cm	0,01706	0,001609	8,424	1,672E-10	0,431
3	ISOLAMENTO INTERNO 10	0,03608	0,003404	17,82	3,538E-10	0,9118
4	ISOLAMENTO INTERNO 15	0,0246	0,002321	12,15	4,824E-10	0,6217

Figure 96. Excel file prepared for Dynamo (EPS results by Tally)

To automate the integration of these results into the BIM environment, a Dynamo script was developed. The script reads the Excel data, matches each result to the appropriate Revit element using its unique Element ID, and assigns the environmental impact values to custom parameters within the Revit model. This automated workflow minimizes manual data entry, reduces the risk of errors, and enables rapid updates if design changes occur.

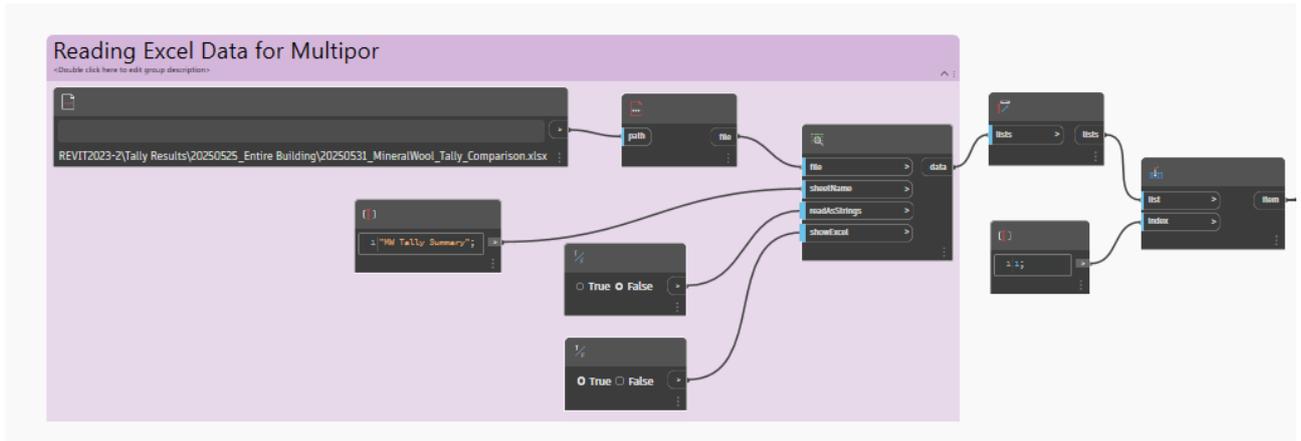


Figure 97. Dynamo workflow for importing LCA results from Excel to Revit for Multipor Xella

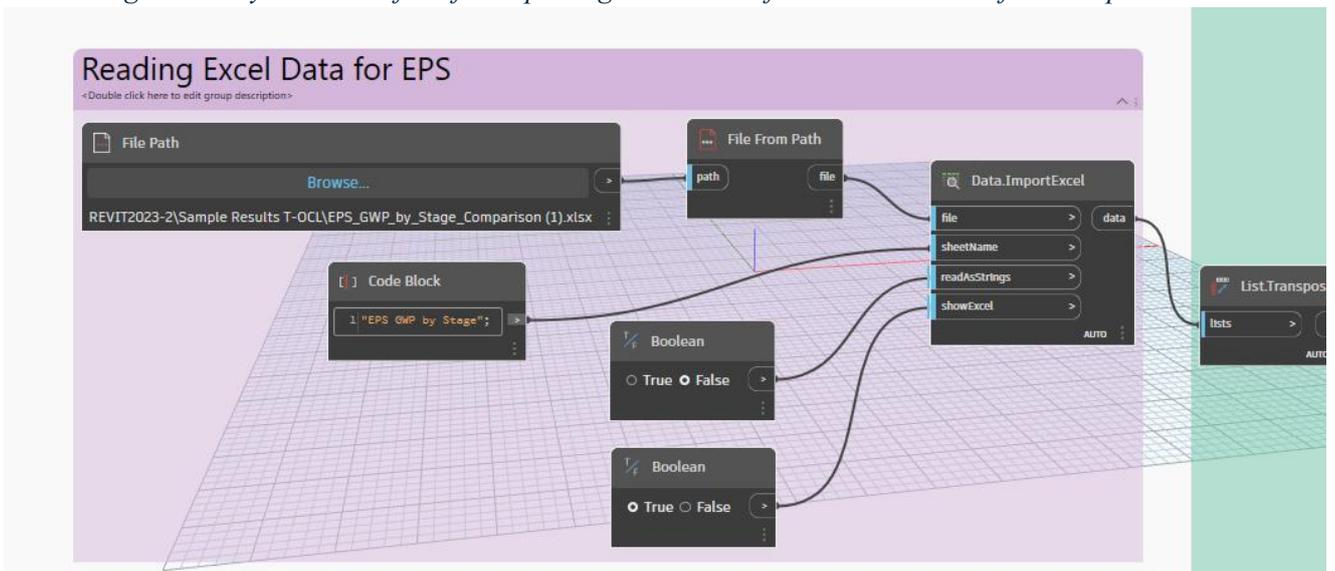


Figure 98. Dynamo workflow for importing LCA results from Excel to Revit for EPS.

Visualization and Result Capture in Revit

Once the environmental impact data was assigned to the building elements, Revit's visualization tools were used to create color-coded views and schedules. These visualizations highlight the spatial distribution of environmental impacts across the building envelope, making it possible to identify components with higher carbon footprints or other environmental burdens.

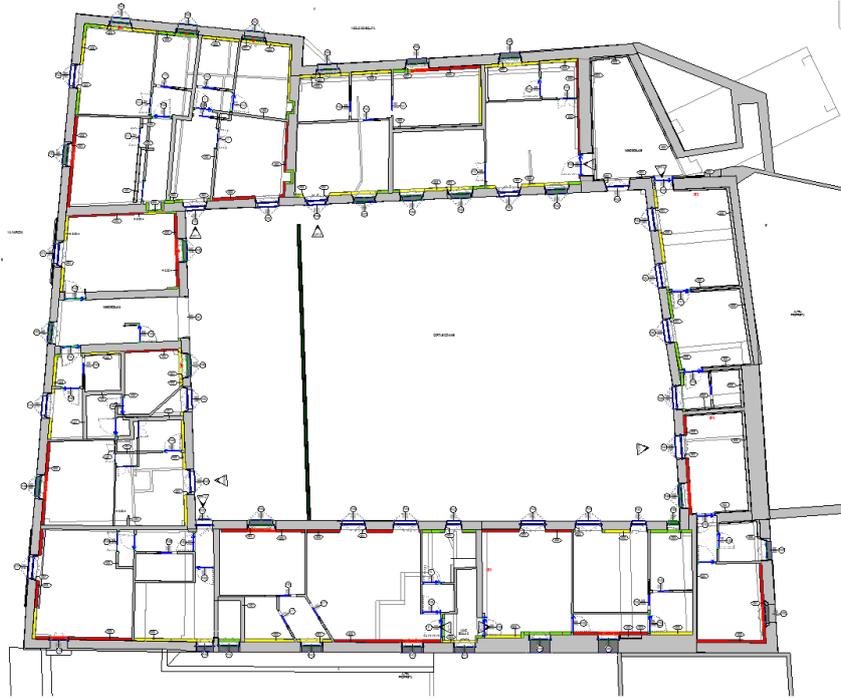


Figure 99. Color-coded Revit view showing GWP distribution across building elements

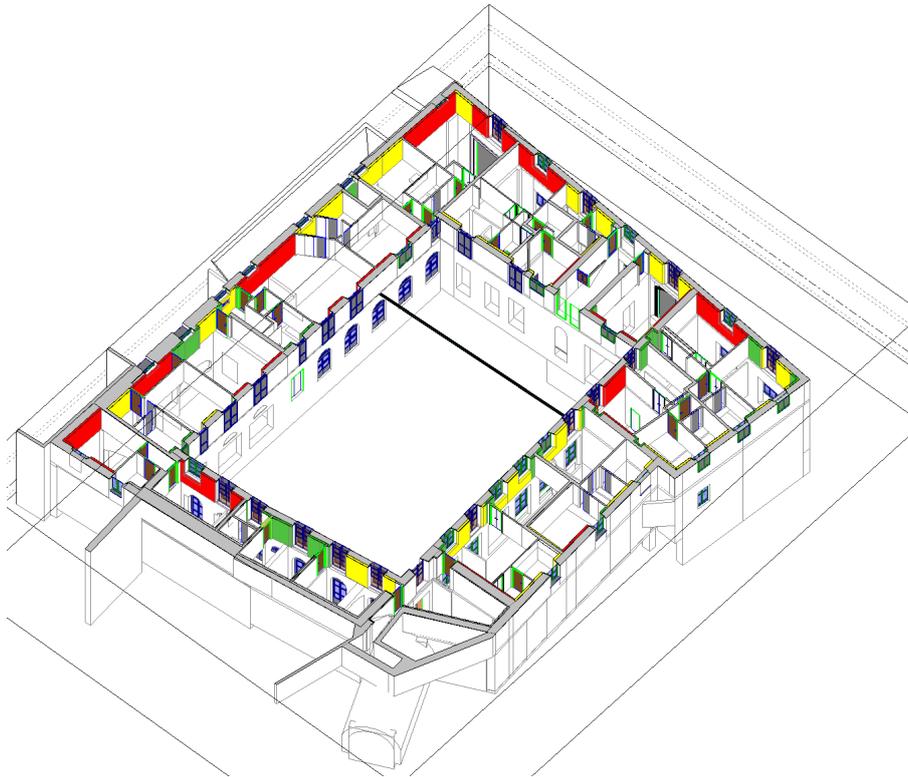


Figure 100. Color-coded Revit view showing GWP distribution across building elements.

Summary of Results

The results, as shown in the results captures, provide a comprehensive overview of the building's environmental performance. This workflow demonstrates the effectiveness of integrating LCA data into the BIM environment, supporting evidence-based decision-making for sustainable design at both the component and whole-building levels.

Dynamo Workflow for Importing Data from Excel to Revit

Strategy for whole Building Envelope

After computing the LCA GWP index for insulation walls through the One Click LCA plugin for Revit, it is needed to import the data into the Revit project.

To do so, we needed to select which walls were going to be edited with the new GWP value, creating a “blocks flow” to be able to select which GWP value had to be added in which insulation wall depending on its thickness and its area and finally reading the data from the Excel file to perform the importing operation.

All this process needed to be executed for two different materials, so two (almost) identical Dynamo files were created at the end.

Let's see the process in detail.

Step 1 – Extracting Valid Geometry Walls

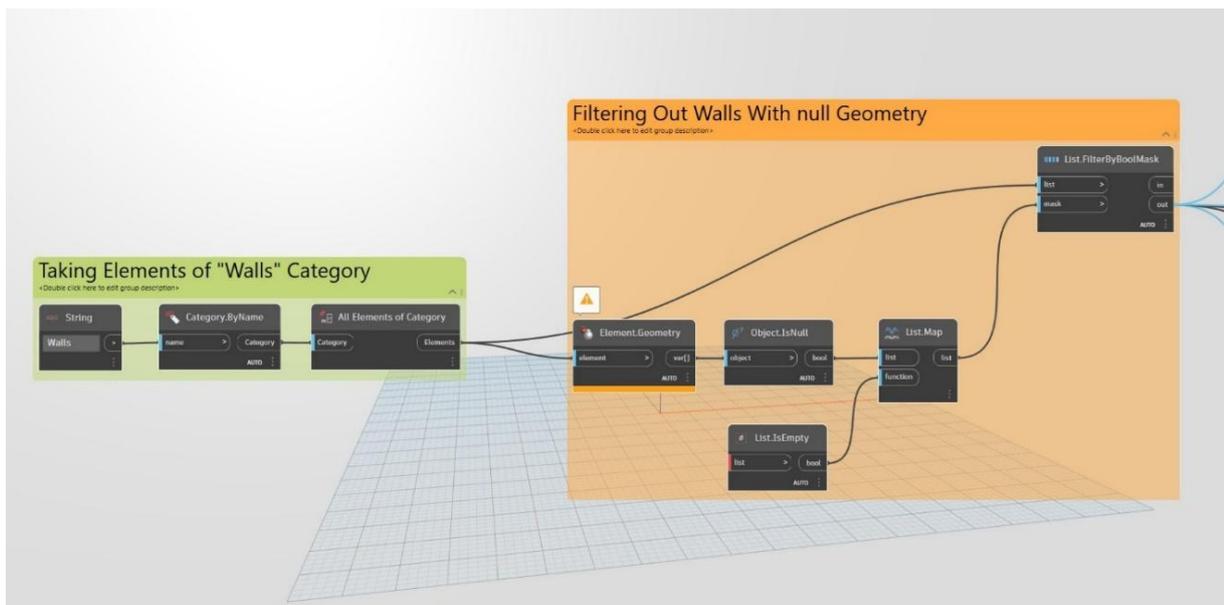


Figure 101. Dynamo in Revit

The first step is required to get all the elements of the required category (green group). It has three blocks here:

1. String Block – Used to specify the name of the category we need (“Walls” in our case).
2. Category By Name Block – Used to get a specific category based on the given string (“Walls”).
3. All Elements of Category Block – Used to get every instance of the given category (extracted from the previous block).

The planned next step was splitting the obtained Elements of Category “Walls” into two different lists (one for each thickness). So, we used this block to compute the Geometry of every Element:

- Element.Geometry Block – Used to get the geometry of every Element from the Elements list (obtained at the previous step).

Note – Regardless of whether the geometry is defined or not, the length of the list obtained at this step is the same as the length of the Elements list given as input in this block.

However, extracting the Geometry returned a *Warning*, which meant there had to be some issues during the Geometry extraction of one or more Elements in the input list: it is needed to remove those elements. To do so, there are used four blocks:

1. Object.IsNotNull Block – Used to get which Geometry is *null*. It returns a list (same length as the input) of Booleans (*True* or *False*), in which the n^{th} element is *True* if the n^{th} Element is *null*, *False* otherwise.

The output of this last step didn’t return any *True* value, so the problem should’ve been somewhere else. Perhaps, using a *Watch* block, we noticed that some of the list elements obtained from the Element.Geometry block were *empty*. So, we tried to filter out those elements from the list.

2. List.Map Block – Used to map every element of an input list with a specific function.

Note – In other words, we take every element of the input list and we test it using the specified function (List.IsEmpty Block in this case, which returns *True* if the given element is Empty).

At the end, we’ll have a list of Booleans, which tells if the n^{th} is empty or not.

3. List.IsEmpty Block – Used as input function for the List.Map Block.

- List.FilterByBoolMask Block – After getting which Wall Elements returned empty geometry, we used this block to remove the problematic ones, giving the Wall Elements list and the Boolean list obtained at the previous step as input.

Note – In other words, we take the n^{th} of the Wall Elements input list and we keep it only if the n^{th} element in the Booleans input list is *False*.

In this step, there is a ‘ready to use list’ of Wall Elements which has been divided into two parts: one containing 14cm thickness Insulation Walls only and the other containing 10cm thickness Insulation Walls only.

Step 2 – Dividing the List based on the Insulation Thickness

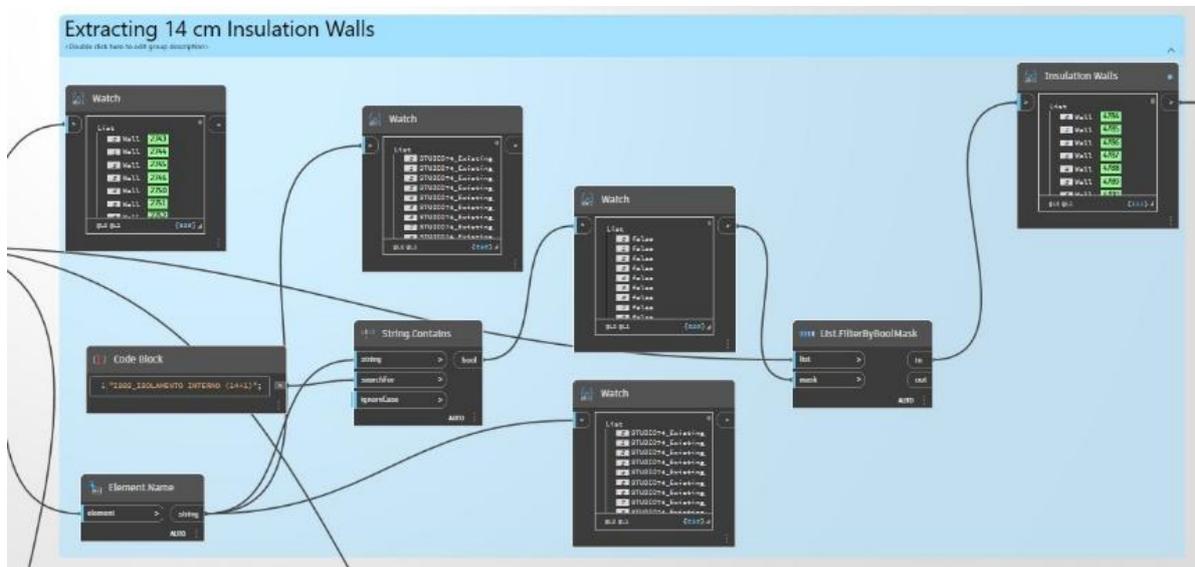


Figure 102. Dynamo in Revit

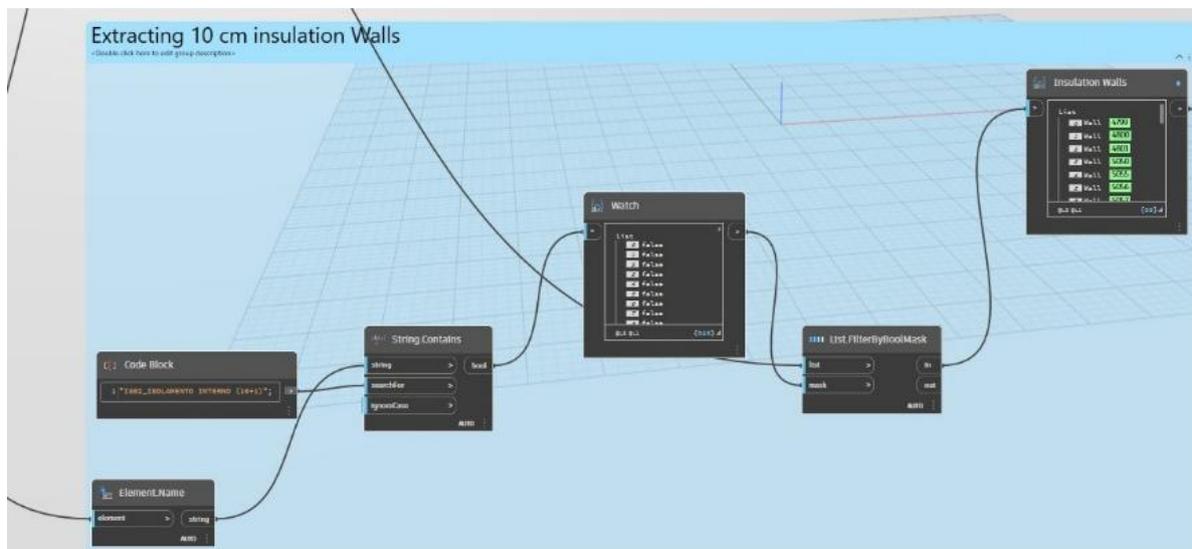


Figure 103. Dynamo in Revit

To distinguish between the types of Walls we needed to edit and their respective thicknesses, it has used four blocks (excluding Watch Blocks):

1. Element.Name Block – Used to get the name of the n^{th} elements of the Wall Elements obtained at the previous step.
2. Code Block – Used to specify the Wall name we needed to filter (we could use a String Block again but that's fine anyways).
3. String.Contains Block – Use to get if the n^{th} element of the Names list obtained at the previous step contains the input string (defined with the Code Block) or not.

Again, the obtained list at this step is a Booleans list which can be used to filter out the Wall Elements we don't need.

4. List.FilterByBoolMask Block – After getting which Wall Elements contains the inputted string in the name, we used this block to remove the ones that didn't contain it, giving the Wall Elements list and the Boolean list obtained at the previous step as input.

This process has been performed two times in parallel to create two different lists, each containing the list of Insulation Wall Elements of 10cm thickness and 14cm thickness respectively.

Step 3 – Extracting the Area of Insulation Wall Elements from the two Lists

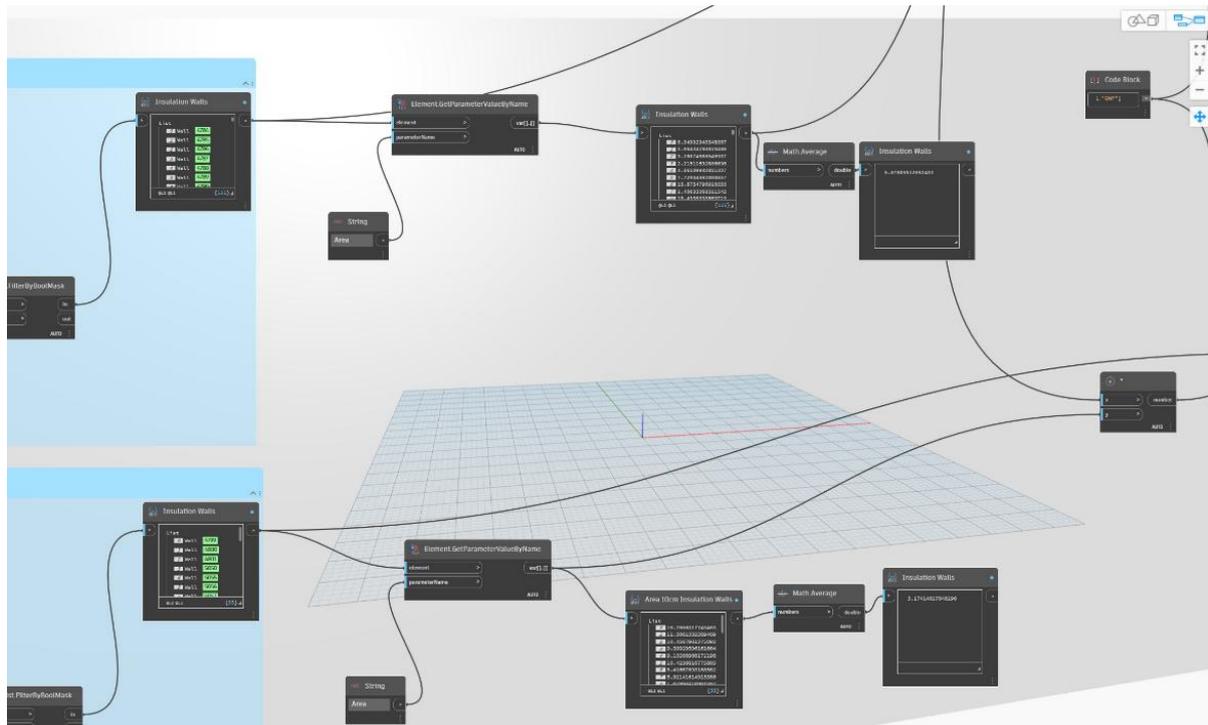


Figure 104. Dynamo in Revit

Before editing the selected Wall instances, we need to define the GWP value which needs to be imported in each of them.

The formula tells that the GWP value has to be defined as:

$$GWP = Base\ GWP \cdot Wall\ Area$$

where *Base GWP* is selected based on the Insulation Wall thickness.

So, we needed to extract the Area parameter from each Wall instance from the two lists separately; to do so, we used 2 blocks:

1. String Block – Used to specify the parameter name of each Wall instance.
2. Element.GetParameterByName Block – Used to get the numerical value of the specified parameter for every Wall instance. This returns a list of float numbers, defining the area of the nth Wall instance.

For helping with further analysis, we used another block to get the average of all the areas obtained at this step (Math.Average Block).

Step 4 – Reading and Analyzing the Excel Data

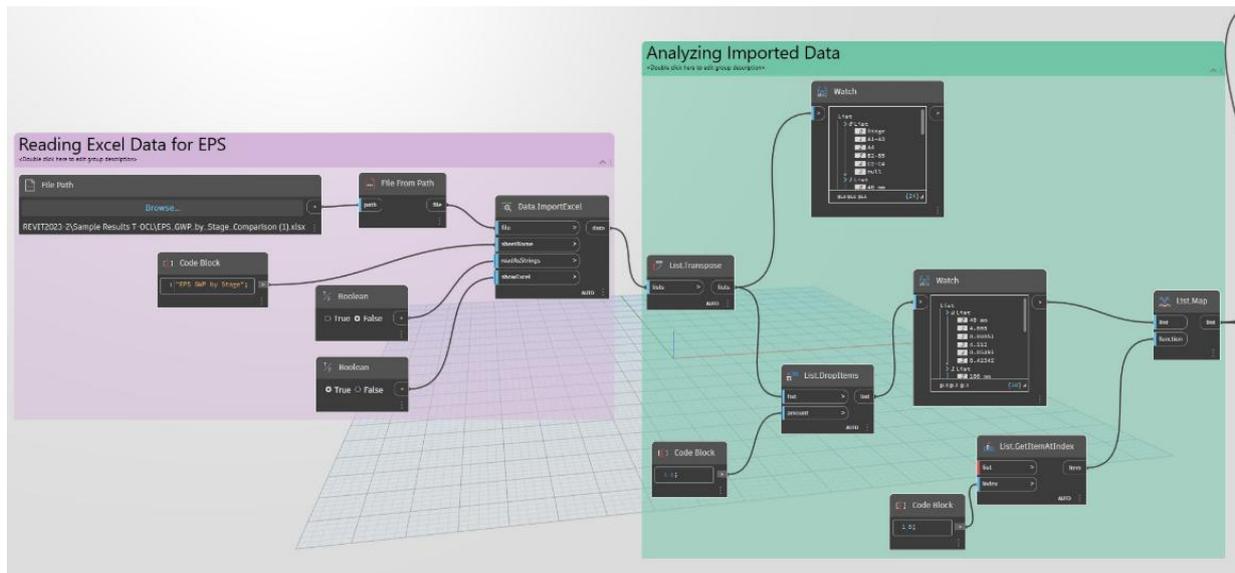


Figure 105. Dynamo in Revit

Before computing the new GWP value for each Insulation Wall instance, we need to extract the data from the Excel file, which contains the outcomes from OneClickLCA plugin.

To do so, first, I imported the data using 6 blocks (purple group):

1. File Path Block – Used to specify where the file is located in the PC memory.
2. File From Path Block - Used to open the file from the given path input thanks to the previous block.
3. Data.ImportExcel Block - Used to import the data from an opened Excel file. This block needs to be configured with 3 other parameters, defined using the 3 other blocks listed below. The result will be a List of Lists.
4. Code Block – Used to specify the sheet name to be selected from the Excel file (as a string).
5. Boolean Block 1 – Used to specify if the values must be considered as strings and not as integers, when possible (settled as *False*).
6. Boolean Block 2 – Used to specify if the Excel file must be visible to the user (settled as *True*).

Note – This parameter doesn't change anything in the workflow.

After importing the data, we need to analyze it to be able to extract just the information we need. To do so, we used 6 blocks (excluding *Watch Blocks*):

1. List.Transpose Block - Data.ImportExcel Block reads the data row by row. Since it's supposed to get rid of the text data (which is contained in the first column) and we'll need to select the GWP parameter column, we use the List.Transpose Block to rearrange the extracted data as we need.
2. List.DropItems Block – Used to remove a certain element from the list specified using an index. In this case we need to remove the first element which contains text only.
3. Code Block – Used to specify the index of the elements in the list to be removed.

The elaborated data is now a List which contains other Lists representing the numerical columns in the previously red Excel file. The column at index 5 is the one regarding the GWP data, so that's what we'll need to consider.

4. List.GetItemAtIndex – Used to select a specific element of an inputted List.
5. Code Block – Used to specify the index of the Element we need.

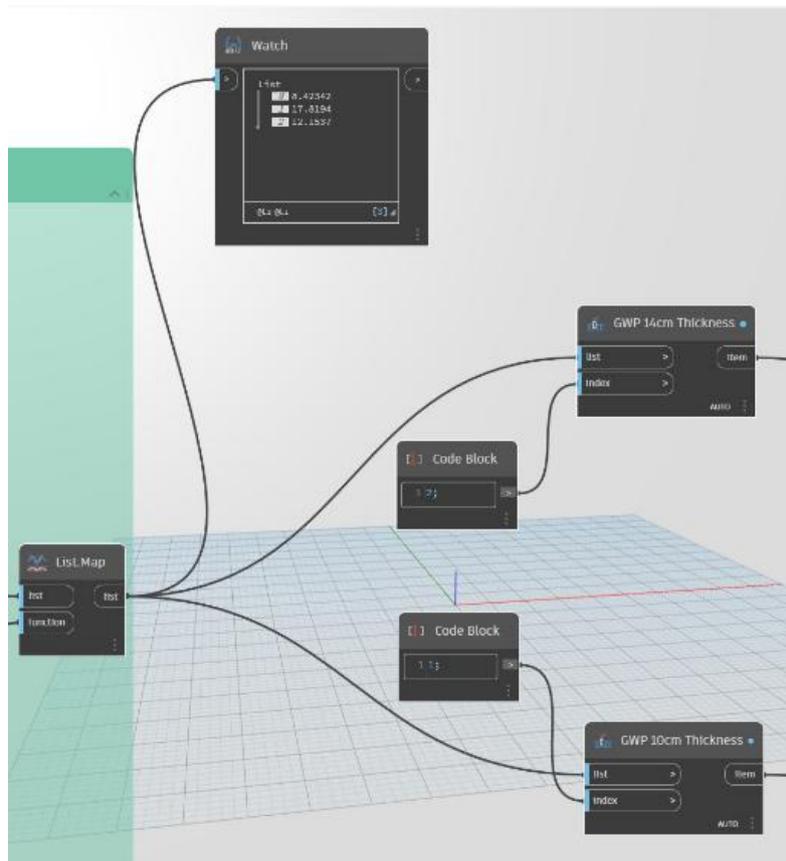


Figure 106. Dynamo in Revit

After selecting the 5th column containing the GWP data, we need to select the respective *Base GWP* value for the 10cm Insulation Wall with 14cm Insulation Wall. To do so, we used 4 other blocks:

1. List.GetItemAtIndex – Used to select a specific element of an inputted List, which is the list of GWP values in the Excel column.
2. Code Block – Used to specify the index of the Element we need.

This selection step has been performed 2 times to extract the two *Base GWP* values which we'll multiply later.

Step 5 – Computing the GWP Values and Editing Walls Instances

The last step requires multiplying the right *Base GWP* value by the area of each Insulation Wall and then editing its GWP parameter.

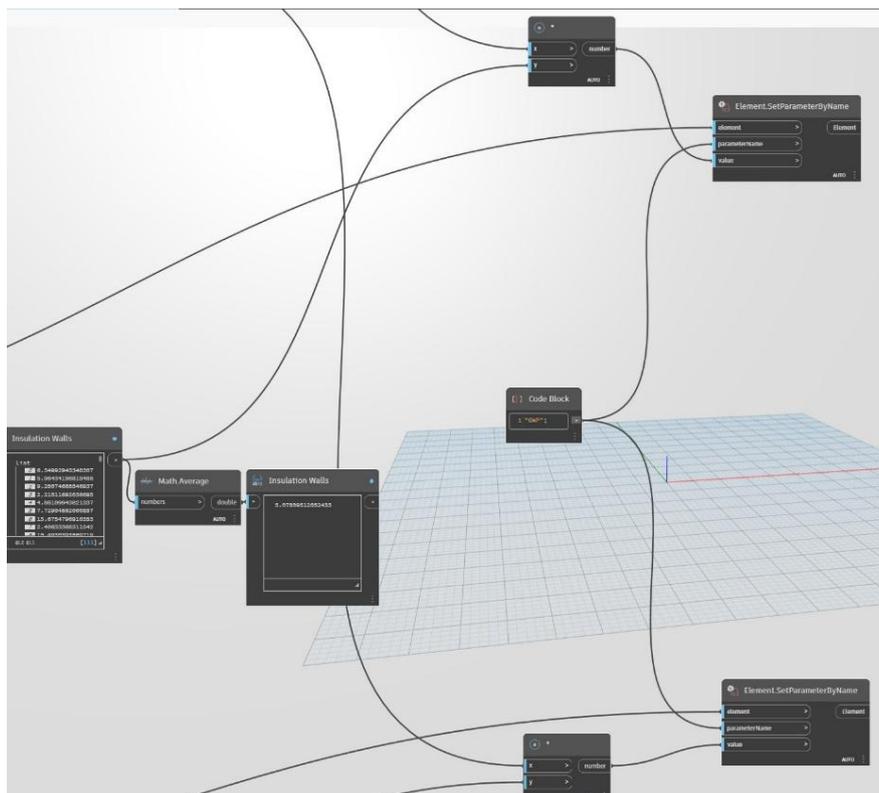


Figure 107. Dynamo in Revit

Now , there are two *Base GWP* values (one to be multiplied by the area of 10cm Insulation Walls and the other to be multiplied by the 14cm Insulation Walls) and two different lists containing the areas of 10cm Insulation Walls and 14cm Insulation Walls respectively, so what need to do now is taking every nth element of each “areas list” and multiply its value by the

right GWP parameter and finally take the n^{th} element (same index) from the Wall Instances list and set its GWP parameter with the computed result.

To do so, it has used five more blocks:

1. Multiplication Blocks – They have been used to multiply the *Base GWP* value with each area from the proper “areas list”, so the inputs are the Base GWP value (x parameter) and the list of areas (y parameter).

Note – This block, as others, in case a list is given as input, returns a list of values which is the outcome of each multiplication. At end, since every Wall Instance has an area defined, we’ll have a 1 to 1 correspondence between the output list and the Wall Instances list.

2. Element.SetParameterByValue Blocks – They have been used to set the GWP parameter for each Wall Element. These blocks require 3 parameters:
 - a. The Wall Instances list which contains the Wall Elements to be edited (10cm Insulation Walls and 14cm Insulation Walls in the two blocks respectively).
 - b. The parameter name, specified as String.
 - c. The new numerical value to be settled.
3. Code Block – Used to specify which parameter has to be edited (“GWP” in this case).

Cause of the 1 to 1 correspondence between the output list from multiplication blocks and the Wall Instances lists, each item from these last lists has been edited with a GWP defined with the formula given above.

Some optimizations could have been performed, such as skipping the deleting data step from the data analyzing group, since we selected a particular column discarding all the others later. However, this strategy seems to be a good compromise between performance and precision, as the execution time showed.

Revit Model Thematization through View Filters

Color Filters

Defining color filters require Revit preparation. In *View* → *Filters* section, an interval was defined for big, medium and small LCA impact: red, yellow and green respectively.

This way, every wall sample would've been colored with the proper color depending on the GWP value, computed with Dynamo.

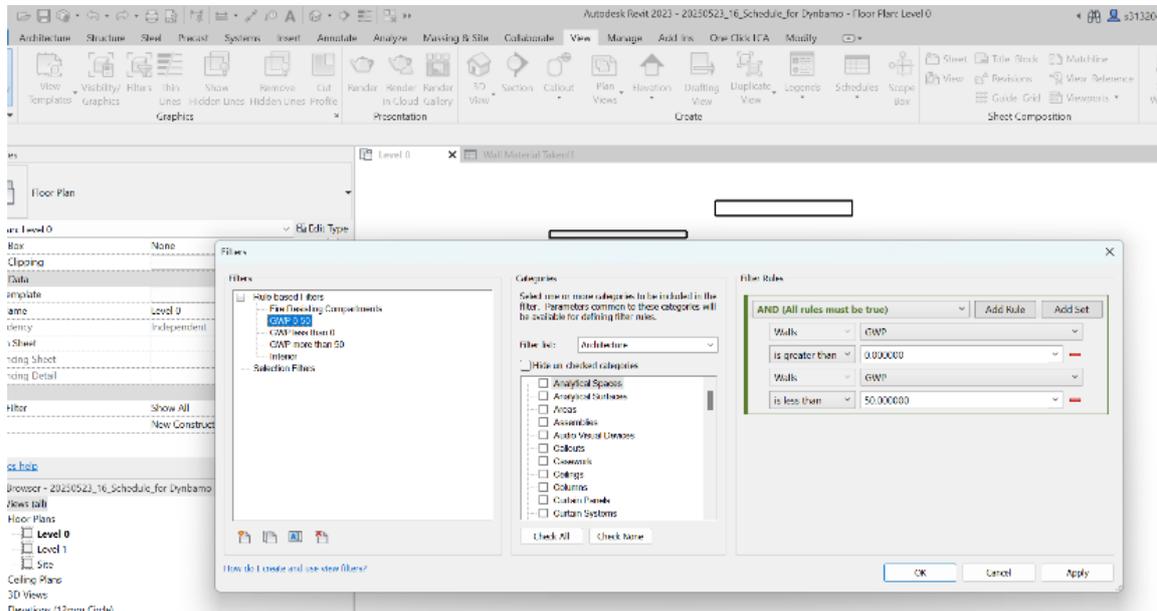


Figure 108. Color filters Revit

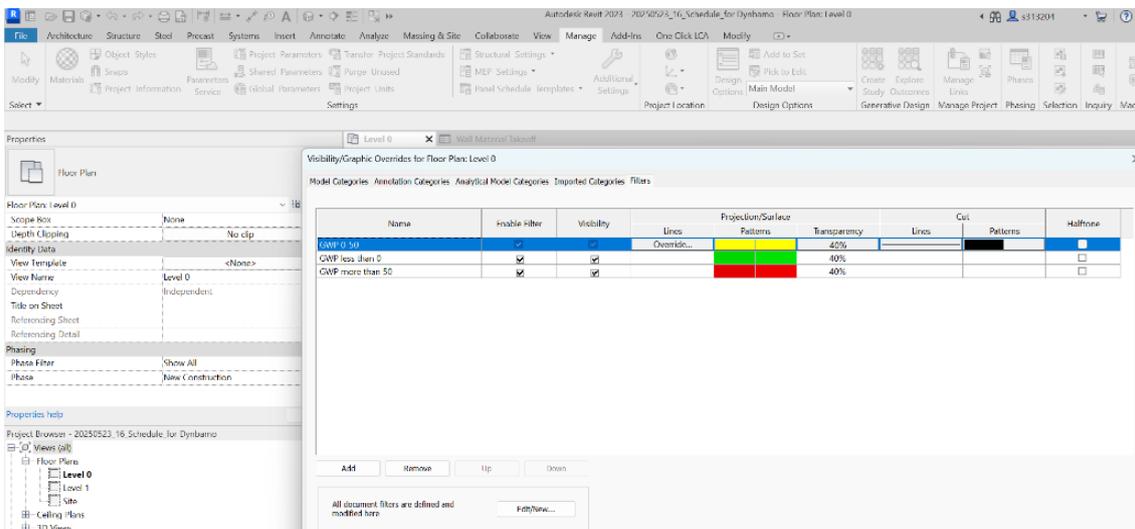


Figure 109. Color Filters in Revit

Apply to External Walls

Once the flow process was understood, it was applied to the official Revit project, starting with the Tally step. However, a bug with the Tally plugin was encountered: requesting support from Tally developers didn't help, so the plugin substituted: One Click LCA was used this time.

Continuing with One Click LCA Plugin

Setting up the Plugin for LCA in Cloud required selecting the project Elements we were interested in and other data as shown in these two pictures.

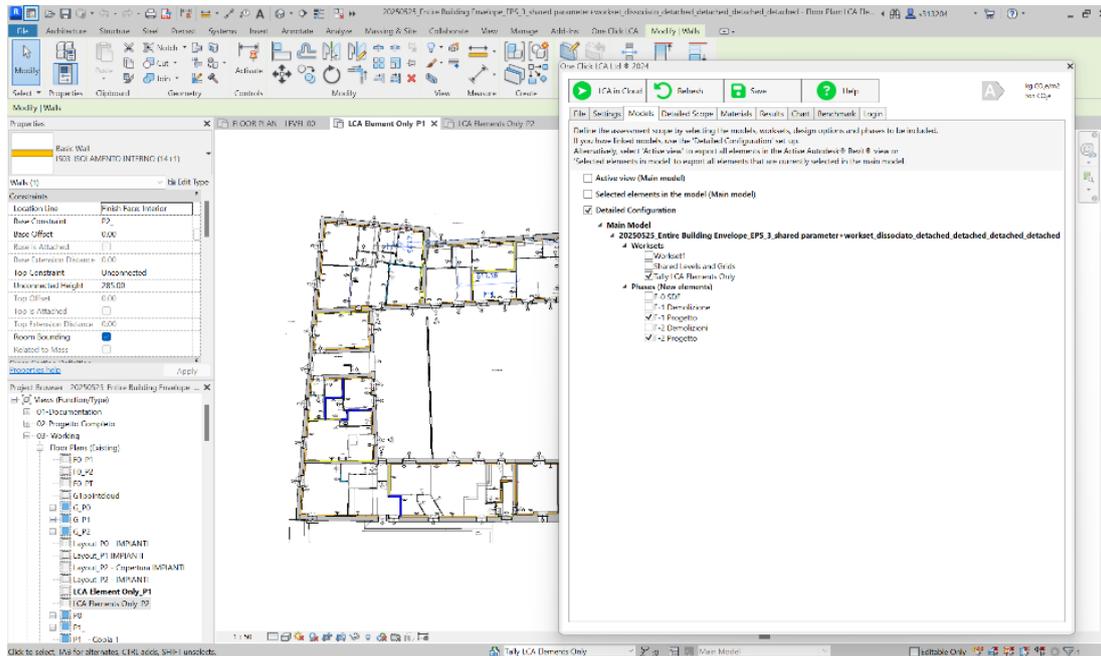


Figure 110. One Click LCA in Revit

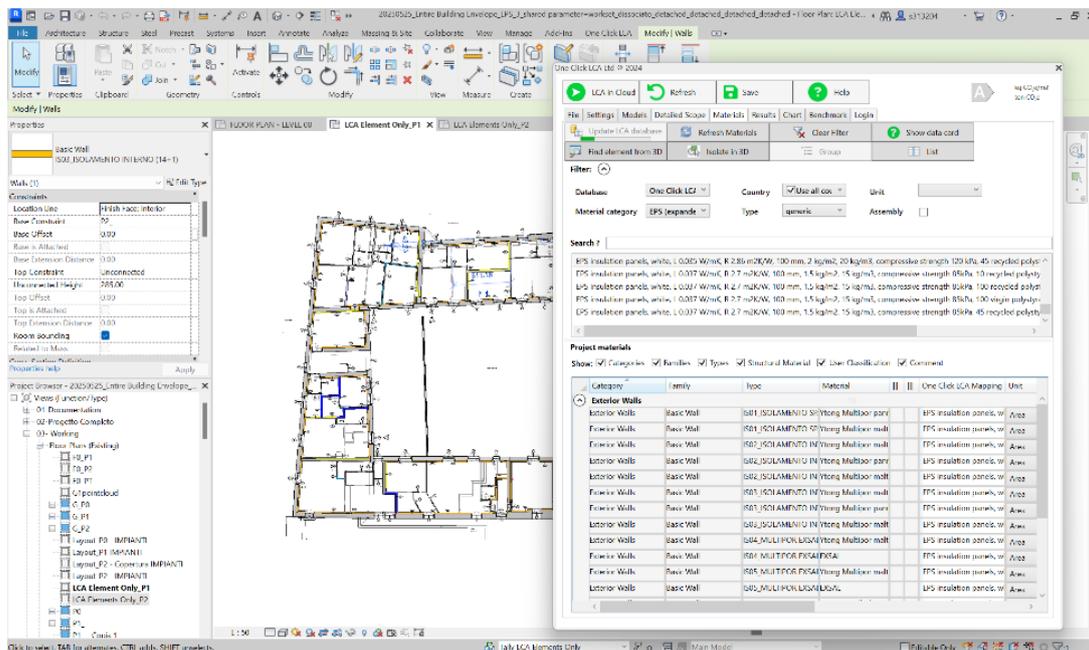


Figure 111. One Click LCA in Revit

Dynamo – Excel Data and Revit Data Together

According to the process explained before, Dynamo was used to select the Revit data which needed to be edited and then elaborate on the Excel files obtained in the previous step to split the GWP value for the three different thicknesses. The Dynamo project included these two parallel block flows, which were then put together in an operational net to compute the final

GWP value for every insulation wall instance and finally put that value as its GWP parameter in the Revit project.

Color-Coding in Visualization Stage

With the GWP value obtained for every wall, an average was computer thanks to Dynamo. This allowed us to produce the color code based on the GWP value:

- **From 0-50 Green**
- **50-100 Yellow**
- **More than 100 Red**

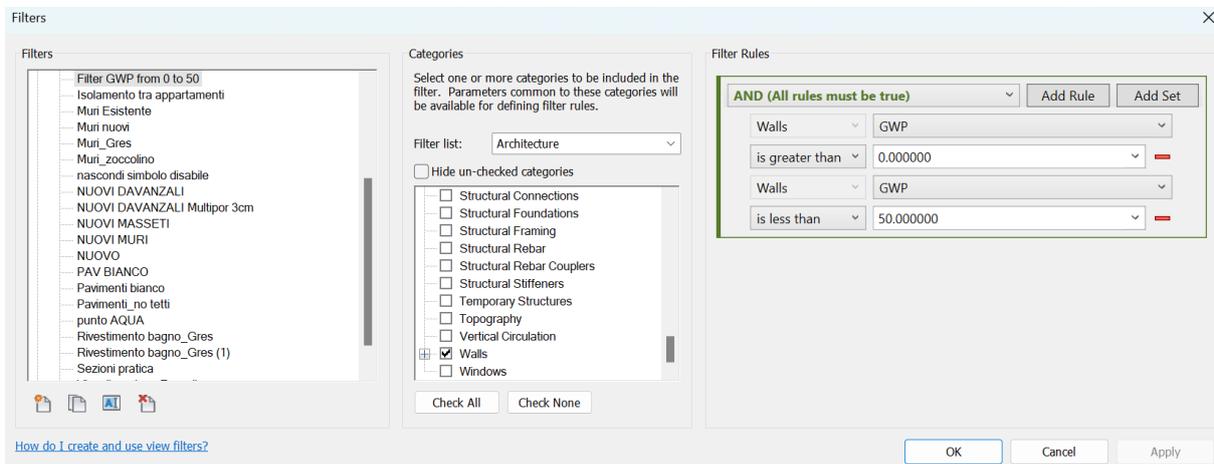


Figure 112. Color coding in Revit

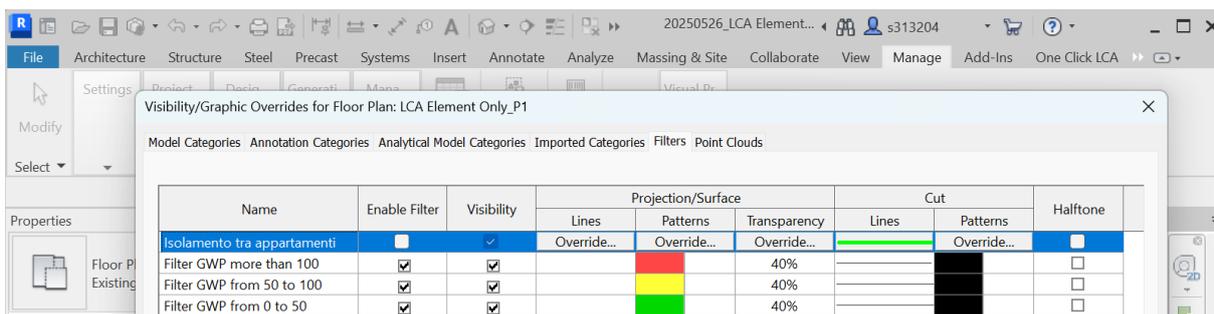


Figure 113. Color coding in Revit

Executing the Dynamo script, every insulation wall in the project was colored with the proper color based on its GWP value computed and settled with Dynamo.

What is visible in the Revit file is shown here.

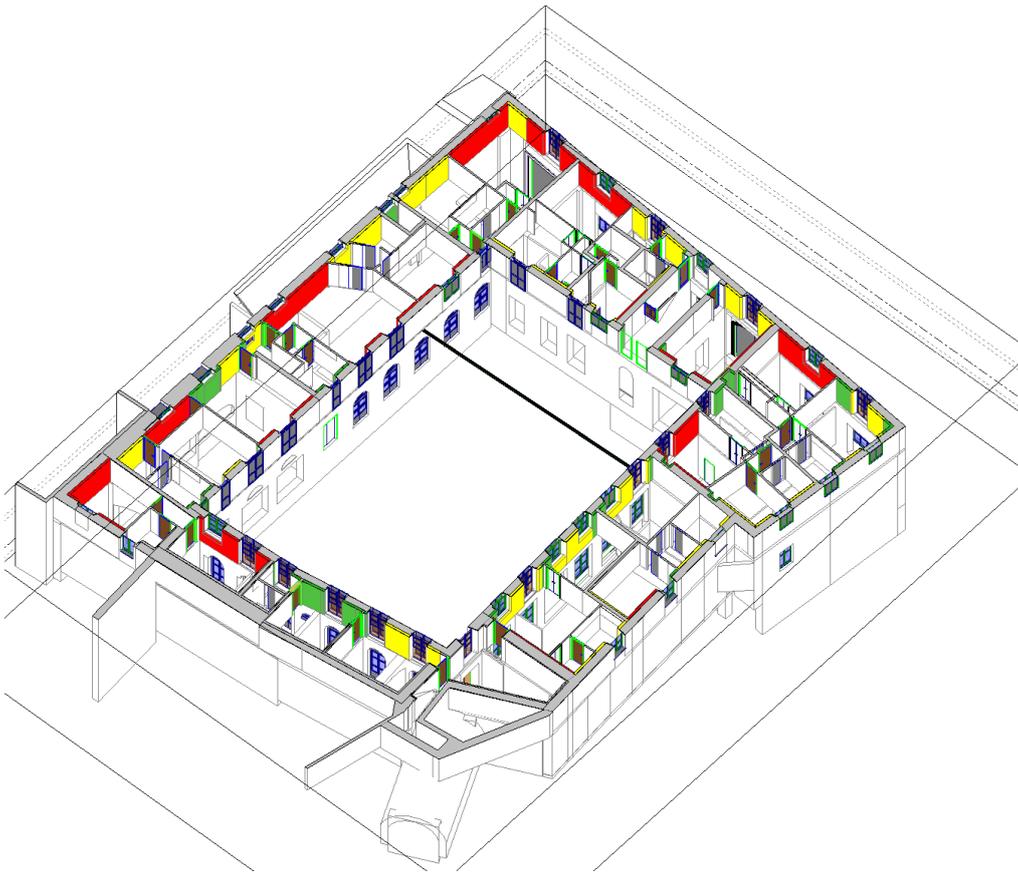


Figure 114. Screenshot of results of Dynamo atomization in Revit

Chapter 3: Results

Comparative Analysis of Tally and One Click LCA Plugins

Overview and Methodology

To assess the suitability of BIM–LCA integration workflows, a comparative analysis was performed using a simplified case study. The model consisted of three wall assemblies, each with insulation thicknesses of 40 mm, 100 mm, and 140 mm called sample 1, sample 2 and sample 3, and two insulation materials: A. Multipor M3 and B. Expanded polystyrene (EPS). All assemblies were modeled in Autodesk Revit, and Life Cycle Assessment (LCA) was conducted first with the Tally plugin and then with One Click LCA.

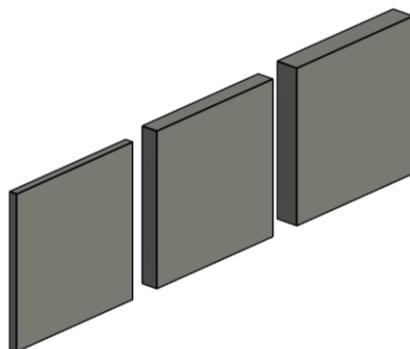


Figure 115. Revit model of wall assemblies with varying insulation thicknesses

Sample	Thickness	Material A –		Material B –	
		Tally	OneClick LCA	Tally	OneClick LCA
1	40 mm	✓	✓	✓	✓
2	100 mm	✓	✓	✓	✓
3	140 mm	✓	✓	✓	✓

Table 2. Combinations of Wall Assemblies, Insulation Thicknesses, Materials, and Life Cycle Assessment Tools

Plugin Workflow

Both Tally and One Click LCA offer effective interoperability with Revit, but their workflows and user experiences differ substantially. One Click LCA provides a broad, customizable database but requires more detailed input and a longer setup process. Tally, in contrast, offers a more streamlined interface and faster workflow, particularly for generating final reports. That

is why in this case study Mineral Wool is considered in Tally plugin which is the nearest version Multipor M3. In terms of output, Tally's Excel export is organized into multiple, clearly labeled sheets, making interpretation straightforward. One Click LCA consolidates all results into a single sheet, which can be more challenging to navigate. Additionally, Tally's free version is fully functional, while One Click LCA's free version is limited. However, Tally's Excel exports sometimes fail, leaving only the PDF report, which lacks element-level detail.

Tally Plugin Results

The following table summarizes the Tally results for mineral wool insulation at three thicknesses:

Thickness	GWP	ODP	AP	EP
40mm	5,25	1,67E-10	0,00967	0,0012
100mm	11,11	3,53E-10	0,0205	0,00254
140mm	15,15	4,81E-10	0,0279	0,00346

Table 3. Summary of Tally results for Mineral Wool insulation layers at three thicknesses

Environmental Impact of Multipor Xella by Thickness

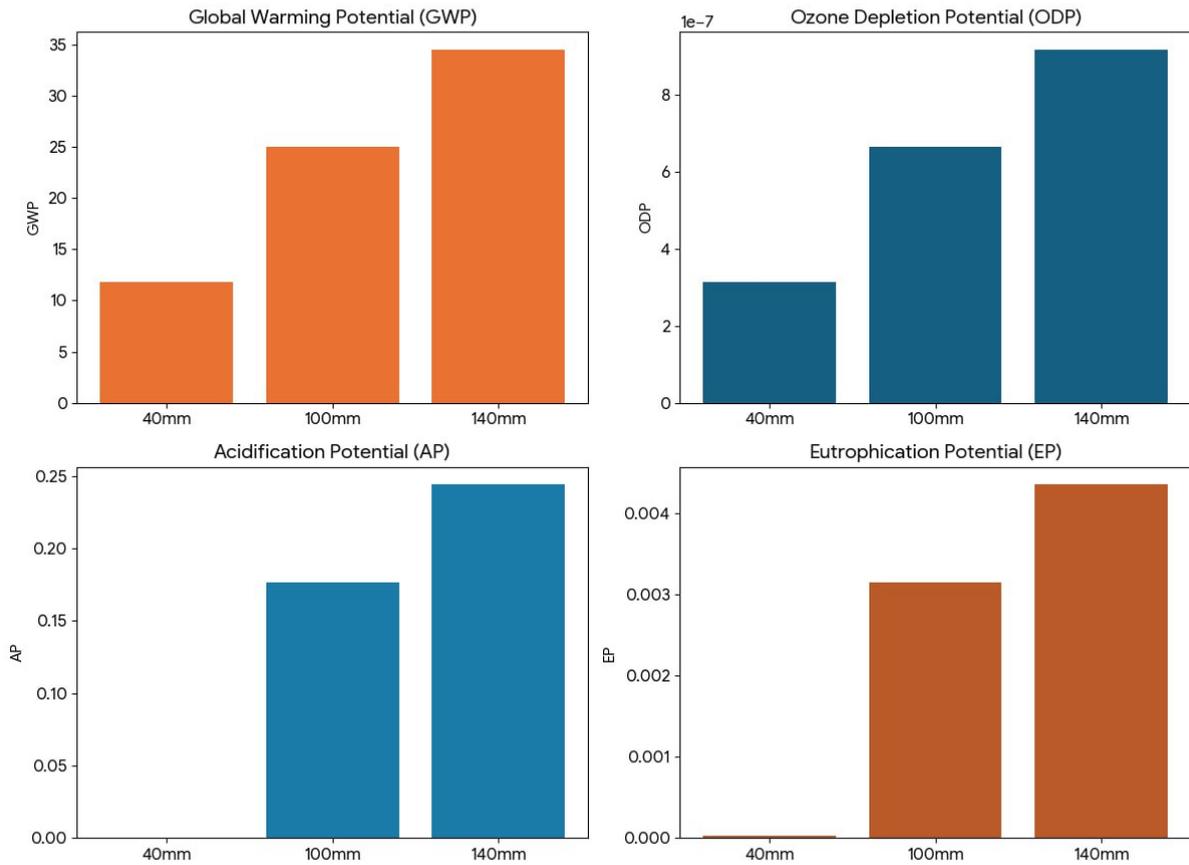


Figure 116. Environment of Mineral Wool by Tally

Interpretation- Comparative Analysis The data exhibits a clear overall trend: the environmental impact increases as the thickness of the Multipor Xella sample increases. However, taking a closer look at the values reveals two distinct behaviors in how the impact scales:

1. Global Warming Potential (GWP) & Ozone Depletion Potential (ODP):

- These metrics increase somewhat proportionately with the thickness.
- Moving from 40mm to 100mm (a 2.5x increase in thickness), GWP increases from 11.8 to 24.97 (roughly a 2.1x increase) and ODP scales similarly.
- Moving from 100mm to 140mm (a 1.4x increase in thickness), GWP increases from 24.97 to 34.5 (a 1.38x increase), which indicates that at larger thicknesses, the GWP and ODP scale almost perfectly linearly with the volume of the material.

3. Acidification Potential (AP) & Eutrophication Potential (EP):

- While these metrics also scale linearly between 100mm and 140mm (both increasing by roughly 1.38x, perfectly matching the 40% increase in material thickness), they behave very differently at the lowest thickness.
- The 40mm sample has exceptionally low baseline impacts for both AP (0.00029) and EP (0.000024). When jumping to 100mm, there is an exponential surge in Acidification and Eutrophication impacts, meaning thicker samples carry a significantly heavier burden on soil and water quality compared to thin panels.

Conclusion The environmental impact of Multipor Xella is directly tied to its thickness. Above a certain thickness threshold (between 40mm and 100mm), the environmental cost scales strictly linearly: adding 40% more thickness adds ~38% more environmental impact across all measured indexes

Expanded Polystyrene (EPS) Insulation comparison by Tally

The following table summarizes the Tally results for Expanded Polystyrene insulation at three thicknesses:

	A	B	C	D	E	F
1	Thickness	GWP	ODP	AP	EP	
2	40mm	4,212	1,672E-10	0,008528	0,0008047	
3	100mm	8,91	3,538E-10	0,01804	0,001702	
4	140mm	0	0	0	0	
5						

Figure 117. Summary of Tally results for EPS insulation layers at three thicknesses

Environmental Impact of EPS by Thickness

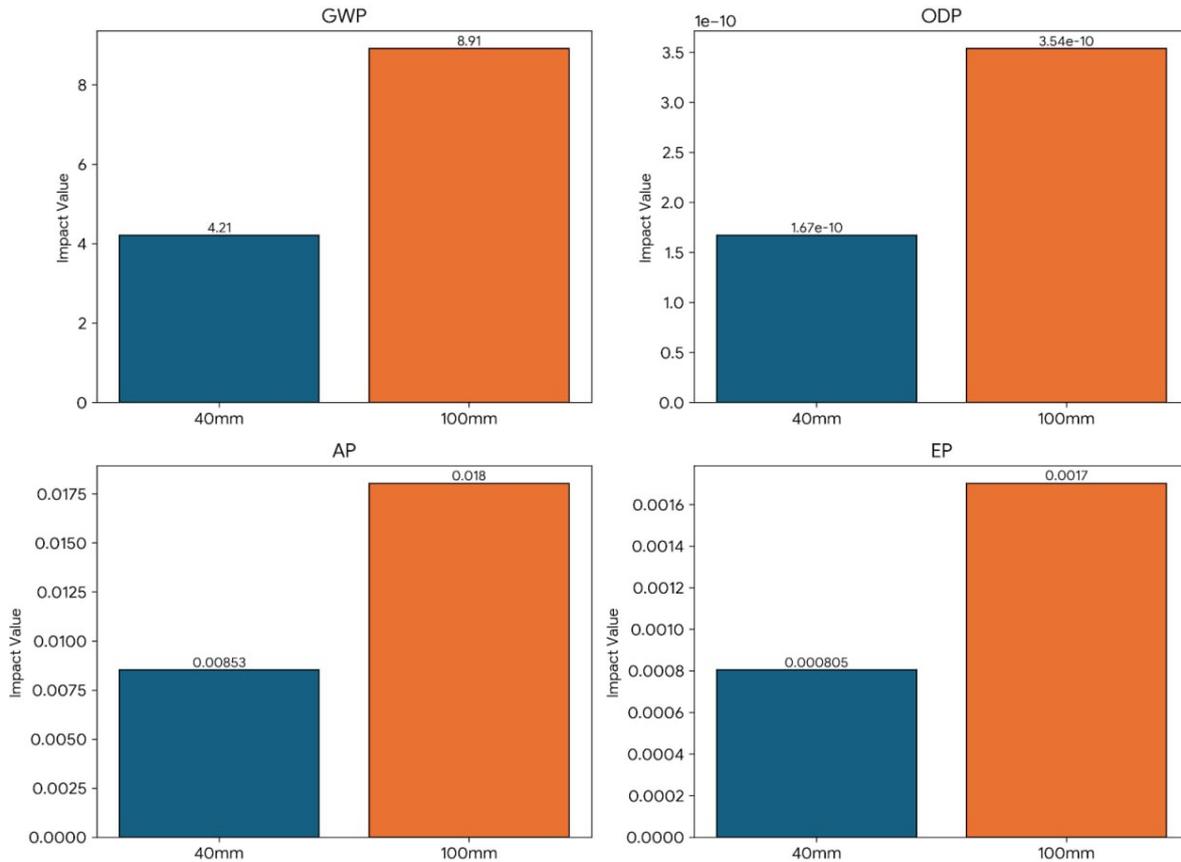


Figure 118. Global warming potential of EPS by Tally

Interpretation-

1. Direct Correlation Between Thickness and Impact As expected, there is a direct and significant increase in all environmental impact categories as the thickness of the EPS sample increases. From 40mm to 100mm:

- GWP (Global Warming Potential): Increased from 4.212 to 8.910.
- ODP (Ozone Depletion Potential): Increased from 1.672e-10 to 3.538e-10.
- AP (Acidification Potential): Increased from 0.0085 to 0.0180.
- EP (Eutrophication Potential): Increased from 0.0008 to 0.0017.

2. Uniform Scaling Across All Metrics When calculating the ratio of the 100mm impacts to the 40mm impacts, we see a remarkably consistent multiplier.

This consistency implies that the Tally plugin scales the underlying Life Cycle Assessment (LCA) profile of EPS uniformly across all environmental categories as the material quantity grows.

4. Sub-linear Scaling (Efficiency in Larger Thicknesses) Interestingly, while the physical thickness of the sample increases by a factor of 2.5x (from 40mm to 100mm), the environmental impact only increases by a factor of ~2.115x. This tells us that the environmental footprint does not strictly scale 1:1 with volume. This could be due to "fixed" environmental costs in the LCA calculation that occur regardless of thickness—such as the baseline energy to transport the panels, the manufacturing setup, or the facing/packaging materials that cover the EPS, which remain relatively constant regardless of how thick the core insulation is. **Conclusion** Using thicker Expanded Polystyrene (EPS) inevitably carries a heavier environmental footprint, roughly doubling the Global Warming Potential and other harmful metrics when going from a standard 40mm to 100mm board. However, the environmental "cost per millimeter" slightly decreases as the board gets thicker.

Environmental Impact Comparison of EPS vs Multipor Xella by Tally

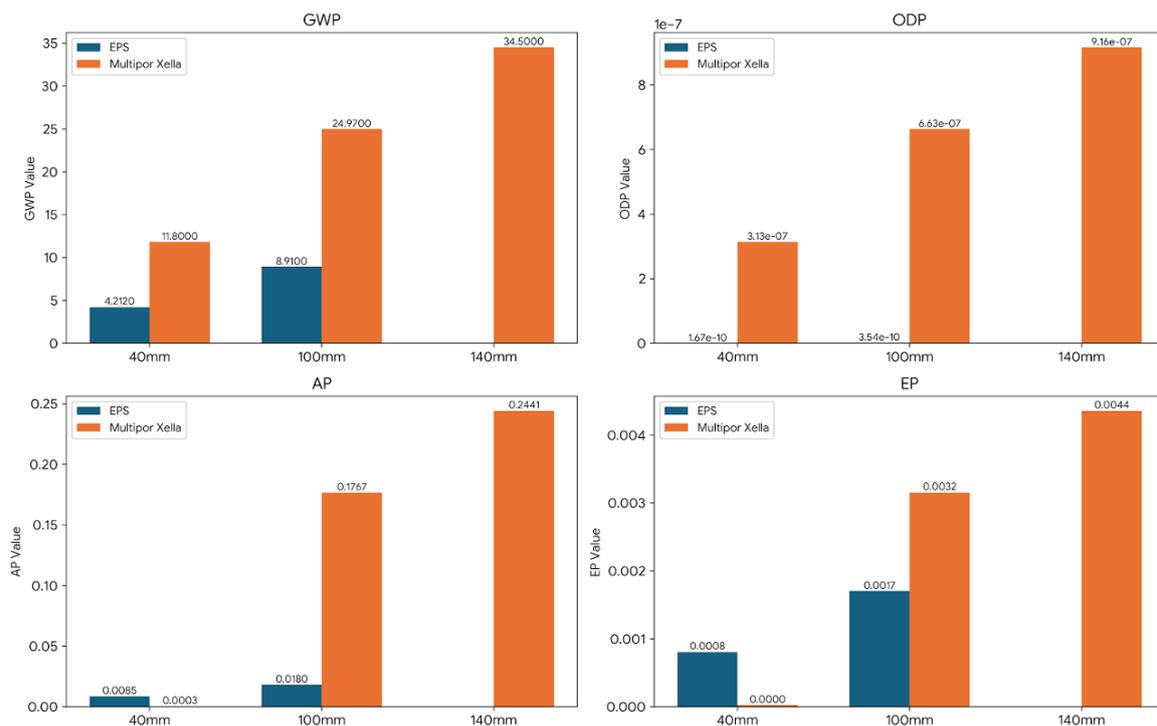


Figure 119. Environmental Impact Comparison of EPS vs Multipor Xella

Interpretation-

1. Global Warming Potential (GWP)
 - 40mm: EPS (4.212) is nearly 3 times more efficient than Multipor (11.80).
 - 100mm: EPS (8.910) maintains a massive advantage over Multipor (24.97).
 - Analysis: EPS is definitively superior in mitigating greenhouse gas emissions.

2. Ozone Depletion Potential (ODP)

- 40mm: EPS (1.67e-10) vs. Multipor (3.13e-07)
- 100mm: EPS (3.54e-10) vs. Multipor (6.63e-07)
- Analysis: EPS has an incredibly low impact on the ozone layer compared to Multipor. EPS values are literally orders of magnitude (thousands of times) lower than Multipor's values at all thicknesses.

3. Acidification Potential (AP)

- 40mm: Multipor (0.00029) performs better than EPS (0.0085).
- 100mm: EPS (0.018) is vastly superior to Multipor (0.1767).
- Analysis: While Multipor has a slight advantage at the thin 40mm measurement, its Acidification Potential scales extremely poorly. By the time you reach standard insulation thicknesses (100mm), Multipor creates nearly 10 times the acidification impact of EPS.

4. Eutrophication Potential (EP)

- 40mm: Multipor (0.000024) is slightly more efficient than EPS (0.0008).
- 100mm: EPS (0.0017) overtakes Multipor (0.00315).
- Analysis: Similar to Acidification Potential, Multipor is slightly cleaner at 40mm, but EPS demonstrates a much better environmental curve as thickness increases, making EPS the better option at 100mm.

One Click LCA Plugin Results

For Multipor Xella Insulation, as seen in the table, by increasing layers GWP increases.

Thickness	GWP (kg CO ₂ e)	ODP (kg CFC11e)	AP (kg SO ₂ e)	EP (kg PO ₄ e)	POCP (kg Ethene)
40 mm	5.25	1.67e-10	0.00967	0.0012	0.000832
100 mm	11.11	3.53e-10	0.0205	0.00254	0.00176

Thickness	GWP (kg CO ₂ e)	ODP (kg CFC11e)	AP (kg SO ₂ e)	EP (kg PO ₄ e)	POCP (kg Ethene)
140 mm	15.15	4.81e-10	0.0279	0.00346	0.0024

Table 4. Summary of OneClick LCA results for Multipor Xella at three thicknesses

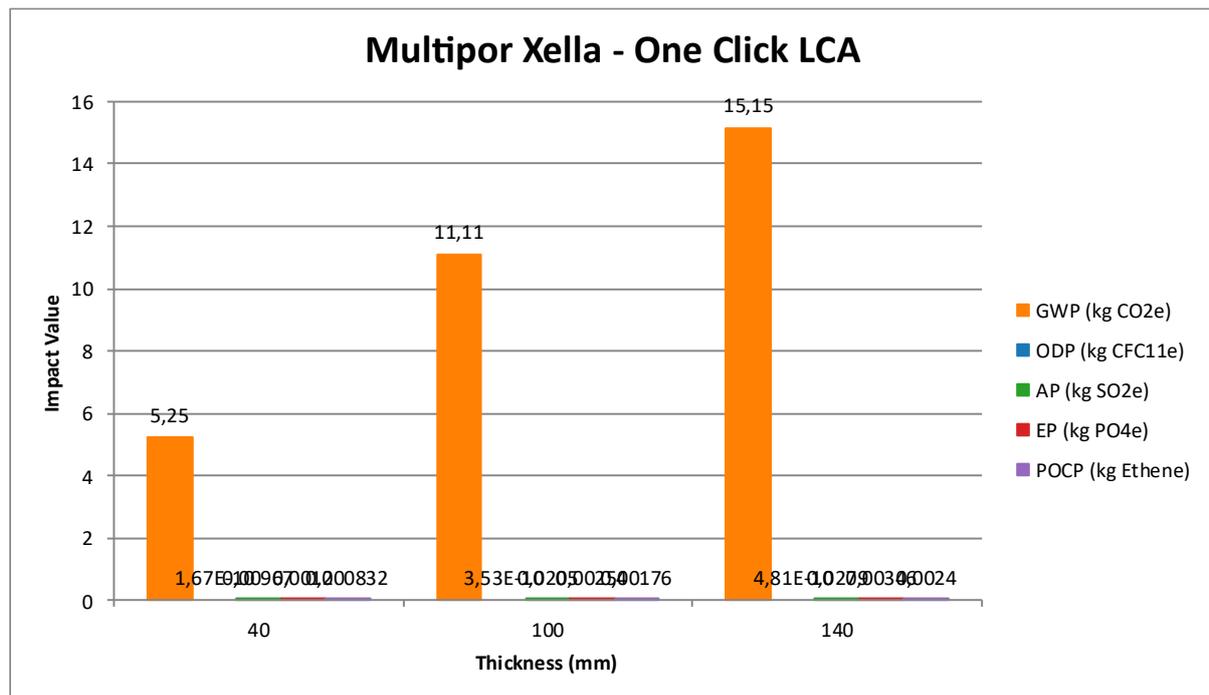


Figure 1190. Comparison of results for Multipor Xella at three thicknesses by OneClick LCA

Interpretation- The environmental impact of **Multipor XELLA insulation** increases consistently with material thickness across all five evaluated impact categories. This is expected, as thicker materials require more raw inputs, transport, and processing energy, directly contributing to higher emissions and environmental load.

Other impact categories (ODP, AP, EP, POCP) also increase consistently with thickness, though values remain relatively small in absolute terms.

The environmental impact of **Multipor XELLA insulation** increases consistently with material thickness across all five evaluated impact categories. This is expected, as thicker materials require more raw inputs, transport, and processing energy, directly contributing to higher emissions and environmental load.

Expanded Polystyrene (EPS) Insulation results by OneClickLCA

Thickness	GWP (kg CO ₂ e)	ODP (kg CFC11e)	AP (kg SO ₂ e)	EP (kg PO ₄ e)	POCP (kg Ethene)
40 mm	3.66	5.99e-08	0.00569	0.000745	0.000401
100 mm	7.74	1.27e-07	0.012	0.00158	0.000849
140 mm	10.56	1.73e-07	0.0164	0.00215	0.00116

Table 5. Summary of OneClick LCA results for EPS at three thicknesses

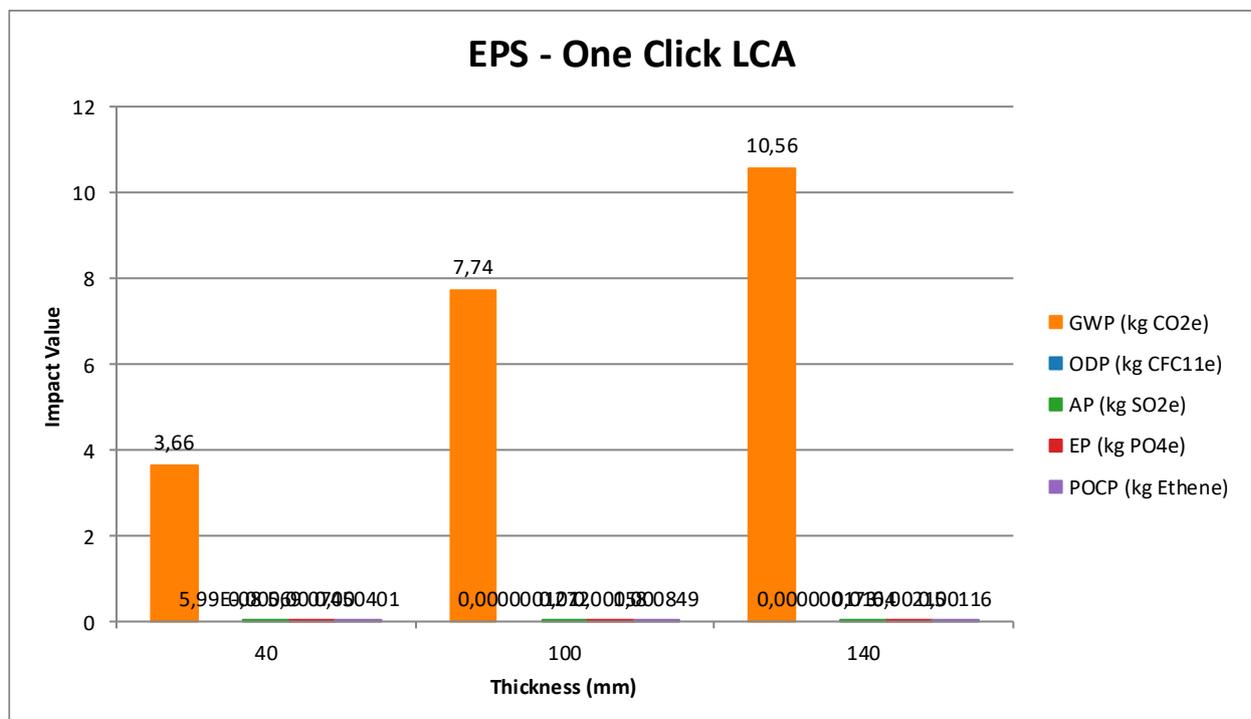


Figure 1201. Bar chart of EPS results at three thicknesses by OneClick LCA

Interpretation- Similar to Multipor, EPS results display a linear correlation between thickness and impacts.

- Global Warming Potential (GWP): increases from 3.66 kg CO₂e at 40 mm → 7.74 kg CO₂e at 100 mm → 10.56 kg CO₂e at 140 mm.
- Other categories (ODP, AP, EP, POCP): all show proportional growth with thickness, though ODP values are expressed in scientific notation due to very small magnitudes.

Environmental Impact Comparison of EPS vs Multipor Xella by OneClickLCA

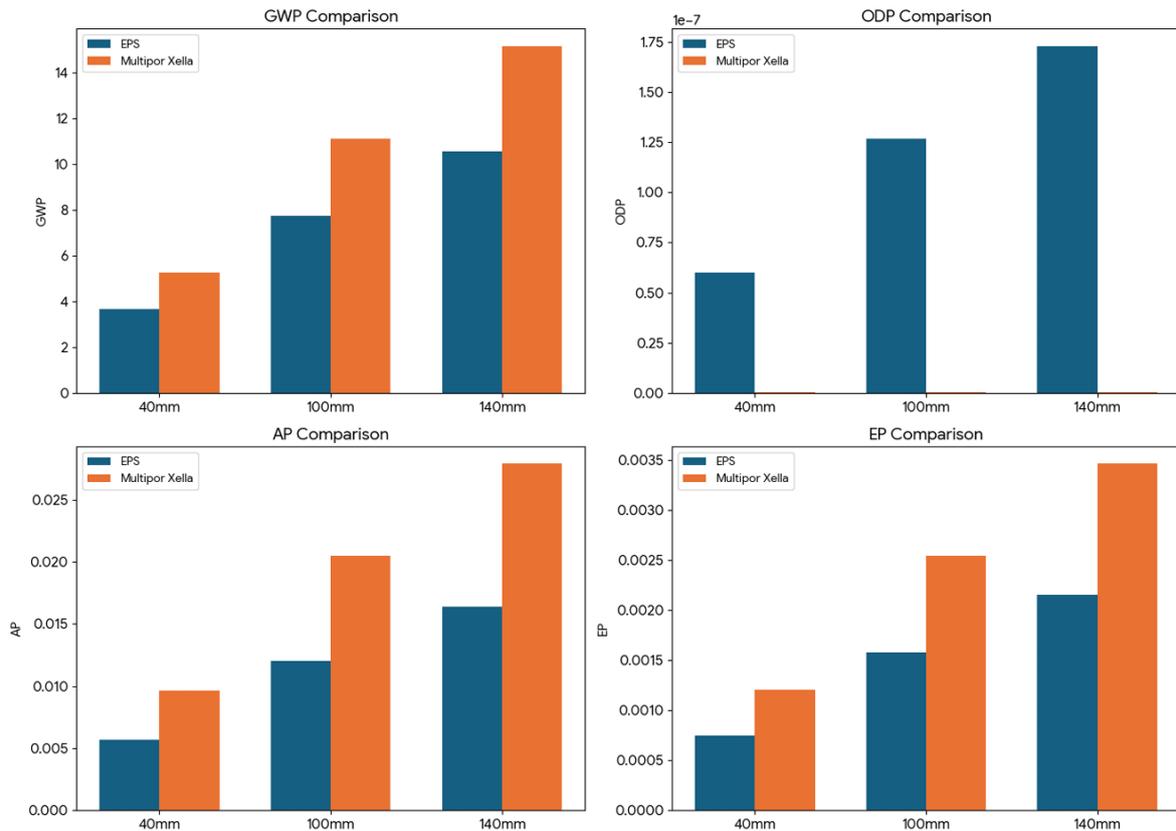


Figure 122. Environmental Impact Comparison of EPS vs Multipor Xella

1. Global Warming Potential (GWP)

- Result: EPS consistently scores lower than Multipor Xella across all thicknesses.
- Example (100mm): EPS has a GWP of 7.74, while Multipor Xella has a GWP of 11.11.
- Impact: EPS contributes significantly less to greenhouse gas emissions and global warming.

2. Ozone Depletion Potential (ODP)

- Result: Multipor Xella heavily outperforms EPS in this category.
- Example (100mm): EPS has an ODP of 1.25, whereas Multipor Xella has an ODP of 0.0001. Multipor's ODP is several orders of magnitude lower.
- Impact: Multipor Xella does far less damage to the Earth's ozone layer.

3. Acidification Potential (AP)

- Result: EPS has lower acidification potential than Multipor Xella.

- Example (100mm): EPS is at 0.012 compared to Multipor's 0.0205.
- Impact: EPS contributes less to the acidification of soil and water (which can lead to acid rain and damage to ecosystems).

4. Eutrophication Potential (EP)

- Result: EPS shows lower eutrophication potential.
- Example (100mm): EPS is at 0.00158 compared to Multipor's 0.00254.
- Impact: EPS contributes less to the over-enrichment of water bodies with minerals and nutrients, reducing the risk of harmful algal blooms.

Comparative Results

EPS Environmental Impact Analysis OneClickLCA vs Tally Comparison

A	B	C	D	E	F	G	H	I
Thickness	GWP OneClickLCA	GWP Tally	ODP OneClickLCA	ODP Tally	AP OneClickLCA	AP Tally	EP OneClickLCA	EP Tally
40mm	3.66	4.212	5.99e-08	1,672E-07	0.00569	0.008528	0.000745	0.0008047
100mm	7.74	8.91	1.27e-07	3,538E-07	0.012	0.01804	0.00158	0.001702
140mm	10.56	0	1.73e-07	0	0.0164	0	0.00215	0

Figure 123. Summary of EPS insulation layer results at three thicknesses from both plugins

Environmental Impact of EPS: OneClickLCA vs Tally

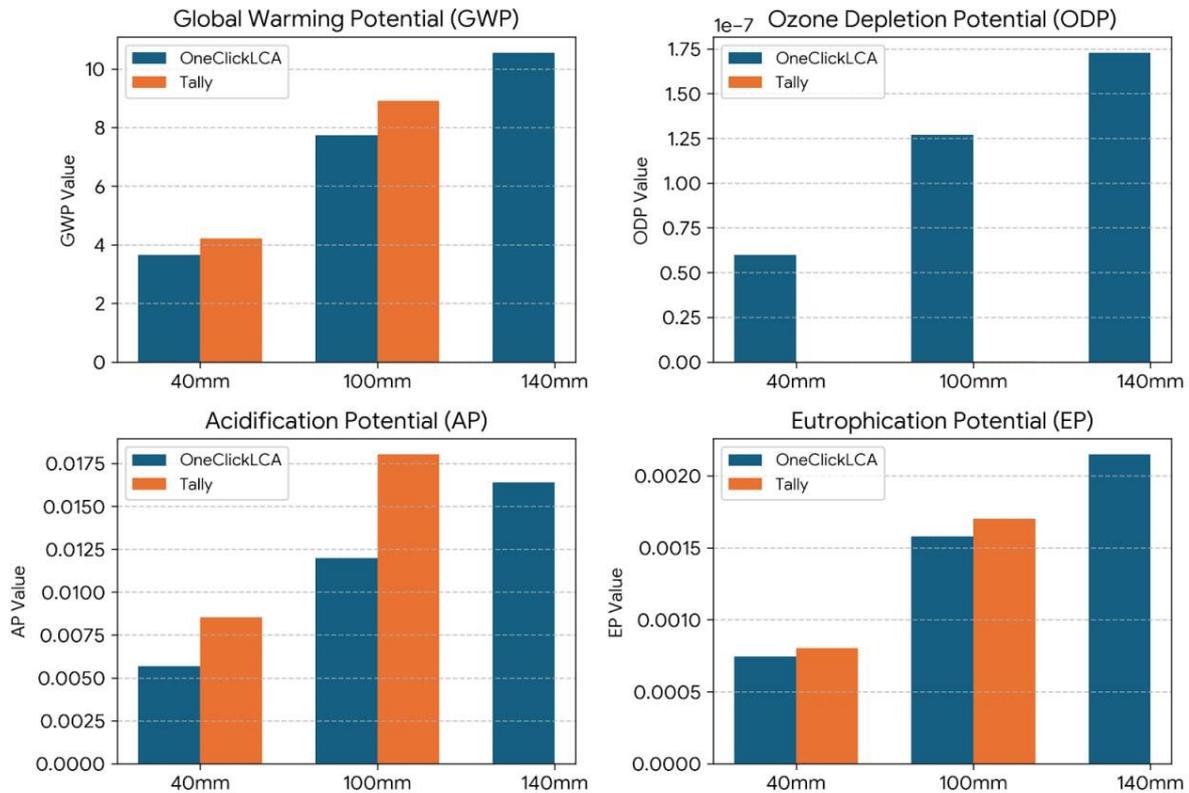


Figure 121. Bar chart comparison of EPS results at three thicknesses by OneClick LCA and Tally

1. Direct Correlation with Thickness Both plugins demonstrate that all environmental impact categories (GWP, ODP, AP, EP) scale almost perfectly linearly with the thickness of the EPS board. As the sample goes from 40mm to 100mm (a 2.5x increase in material), the environmental impact indices also increase by approximately 2.1x to 2.5x in both software tools.

2. Consistent Impact Overestimations in Tally (GWP, AP, EP) When comparing the shared data points (40mm and 100mm), Tally consistently calculates a higher environmental impact for 3 out of the 4 available metrics:

- Global Warming Potential (GWP): Tally's results are approximately 15% higher than OneClickLCA's.
- Acidification Potential (AP): Tally is roughly 50% higher than OneClickLCA.
- Eutrophication Potential (EP): Tally estimates are about 8% higher.

3. Massive Discrepancy in Ozone Depletion Potential (ODP) The most notable difference is found in the ODP values. OneClickLCA estimates the ODP in the magnitude of 10^{-8} , whereas Tally reports it in the magnitude of 10^{-10} . This means OneClickLCA's evaluated impact for Ozone Depletion is almost 360 times higher than Tally's.

Interpretation- Scaling Impact: Specifying thicker EPS insulation leads to a proportionally larger carbon footprint and overall environmental detriment. The difference between a 40mm board and a 140mm board is nearly a 300% increase in environmental cost.

- Tool & Database Reliability: The differences between the two plugins highlight that environmental assessment tools rely on different background databases (e.g., GaBi vs. Ecoinvent), dataset regionality, or varying LCA boundaries

Multipor Xella Environmental Impact Analysis OneClickLCA vs Tally Comparison

A	B	C	D	E	F	G	H	I
Thickness	GWP (OneClickLCA)	GWP (Tally)	ODP (OneClickLCA)	ODP (Tally)	AP (OneClickLCA)	AP (Tally)	EP (OneClickLCA)	EP (Tally)
40mm	5.25	11.80	1.67e-10	3.14E-04	0.00967	0.0002896	0.00120	2.36E-02
100mm	11.11	24.97	3.53e-10	6.63E-04	0.02050	0.1767000	0.00254	0.003152
140mm	15.15	34.50	4.81e-10	9.16E-04	0.02790	0.2441000	0.00346	0.004355

Figure 125. Summary of Multipor Xella insulation layer results at three thicknesses from both plugins

Environmental Impact Analysis Comparison: OneClickLCA vs Tally

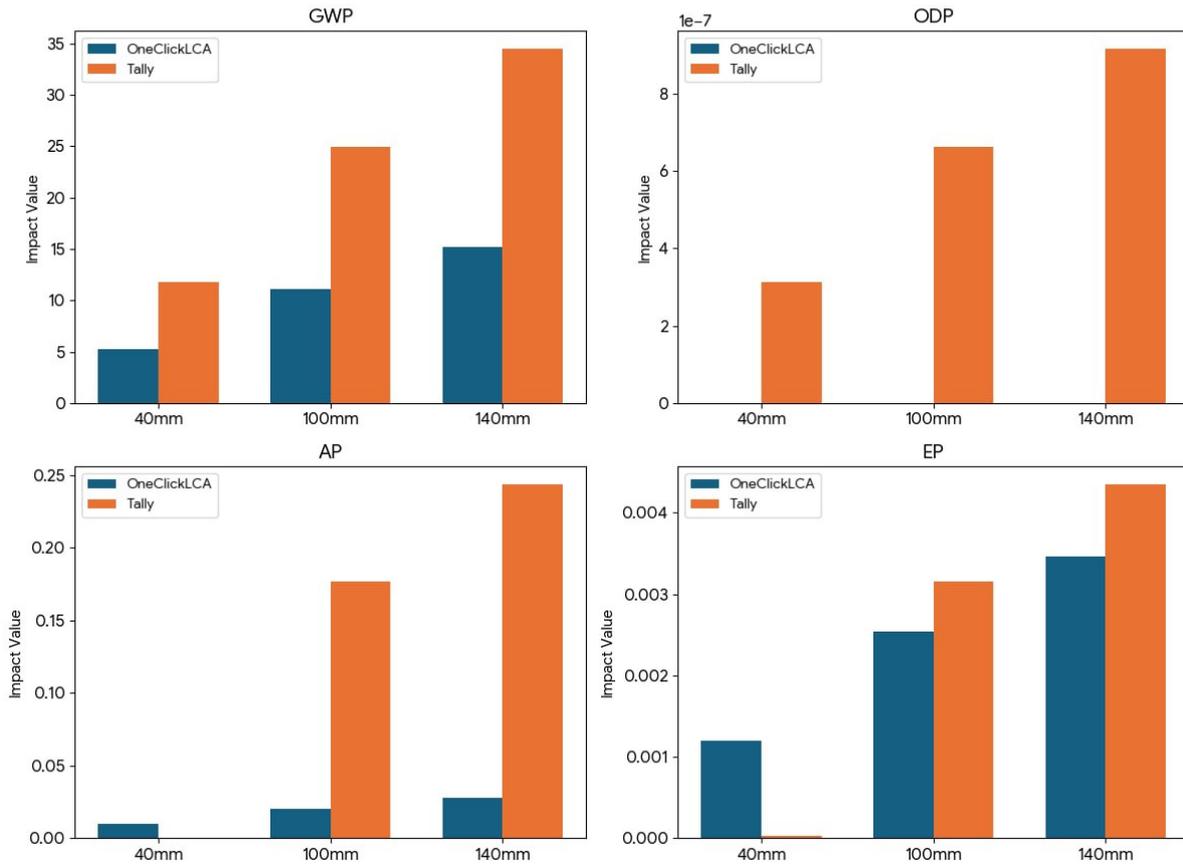


Figure 126. Bar chart comparison of Multipor Xella results at three thicknesses by OneClick LCA and Tally

Comparison of Environmental Indices Despite measuring the same material, the two plugins return notably different values. This is common in Life Cycle Assessment (LCA) tools because they often rely on different background databases (e.g., Ecoinvent vs. GaBi) and calculation methodologies.

- Global Warming Potential (GWP): Both tools show that GWP increases proportionally with thickness. However, Tally's estimates are consistently higher (more than double) than those of OneClickLCA. For instance, at 140mm, Tally calculates a GWP of 34.50, while OneClickLCA estimates it at 15.15.
- Ozone Depletion Potential (ODP): The difference here is the most striking, differing by orders of magnitude. Although both tools reflect an increase as the material thickness grows, Tally assesses the ozone impact to be drastically higher than OneClickLCA.
- Acidification Potential (AP): The behavior of AP between the tools is inconsistent. For the smallest thickness (40mm), OneClickLCA reports a higher AP (0.00967) compared to

Tally (0.00029). However, for larger thicknesses (100mm and 140mm), Tally's estimates jump significantly, becoming roughly 8 to 9 times higher than those of OneClickLCA.

- Eutrophication Potential (EP): A similar trend to AP is observed here. At 40mm, OneClickLCA's estimation is higher. Yet, for 100mm and 140mm, Tally predicts a slightly higher Eutrophication Potential.

Interpretation- of Multipor Xella Based on the analysis of both datasets, we can draw the following conclusions regarding the environmental impact of Multipor Xella:

1. Direct Proportionality with Thickness: There is a clear, direct, and almost linear correlation between the thickness of the Multipor Xella panels and their environmental impact. Across all four indices (GWP, ODP, AP, and EP) and in both software tools, increasing the thickness from 40mm to 140mm roughly triples the environmental burden.

2. Tool Discrepancies Require Context: The significant absolute differences between OneClickLCA and Tally suggest that when evaluating the sustainability of Multipor Xella for certification purposes (like LEED or BREEAM), the choice of the LCA tool and its underlying dataset will heavily influence the final score. Tally tends to be far more conservative (yielding higher impact numbers) for global warming and ozone depletion.

Implications for LCA Tool Selection

This comparative study demonstrates that the choice of LCA tool significantly influences both the results and their interpretation. It is therefore essential to contextualize findings within each tool's assumptions, scope, and intended application. For this case study, Tally proved more suitable for the desired level of detail and available data, but users should carefully consider the methodological differences when selecting a tool for their own projects.

Key Reasons for Choosing Tally for this Case Study

The main reason, in this case, Tally considers also Usage Stage, while OneClickLCA amount of this stage is mostly zero. o that the amount of GWP is higher compared to One Click LCA, which will be explained in detail in continue, precisely in Case study sector.

Selection between Tally and One Click LCA plugins based on the results of samples goes on like the Tally results are higher because it considers all the stages of 'usage stages'. As it is visible, the B rows are empty in the Excel of One Click LCA results. In other words, One Click LCA has not considered / calculated all stages of usage stage, so the sum of the results are lower.

In this step, what we do is using sample results for GWP amount of each one squared meter of each material of each thickness which have from results of Tally plugin and the area of each element which we have in Revit based on geometry information.

Reporting and Visualization Capabilities

Strong visual output (thematic BIM views or GWP heat maps) supports decision-making by clearly identifying high-impact elements. The tool should also meet regulatory reporting standards and produce results in formats that are easy to interpret and share.

Furthermore, Tally is a tool with a user-friendly interface and well-documented support can reduce setup time and training needs. OneClickLCA did not offer the same level of flexibility for this kind of customized, automated process.

Summary of Results

This chapter presented a comparative Life Cycle Assessment (LCA) of insulation materials using two leading BIM-integrated plugins: Tally and One Click LCA. The analysis focused on wall assemblies with varying insulation thicknesses (40 mm, 100 mm, and 140 mm) and two materials (Multipor M3 and expanded polystyrene, EPS), modeled in Autodesk Revit.

Key Findings:

- **Workflow and Usability**

Both plugins demonstrated strong interoperability with Revit. Tally offered a streamlined, user-friendly workflow and more accessible output formats, while One Click LCA provided a broader, customizable database but required more detailed input and a longer setup process.

- **Impact Trends**

Tally consistently showed a *decrease* in environmental impacts (e.g., Global Warming Potential, Ozone Depletion Potential) as insulation thickness increased. This counterintuitive trend suggests that Tally normalizes results per functional unit (such as thermal performance or surface area), making thicker insulation appear environmentally preferable within its modeling logic.

In contrast, One Click LCA results *increased* proportionally with insulation thickness, aligning with conventional LCA expectations where environmental impacts scaled with material quantity.

- **Magnitude of Results**

Tally reported significantly higher absolute impact values, especially for thinner insulation layers, compared to One Click LCA. These discrepancies are likely due to differences in underlying LCA databases (e.g., GaBi vs. Ecoinvent), system boundaries, and methodological frameworks.

- **Interpretation and Tool Selection**

The divergent results highlight that Tally may be more suitable for whole-building analyses where functional performance is prioritized, while One Click LCA is better for direct, quantity-based material comparisons. The choice of LCA tool substantially influences both the results and their interpretation.

Implications for Sustainable Design

- The findings underscore the importance of contextualizing LCA results within the framework and assumptions of each tool.
- For this case study, Tally was selected as the preferred plugin due to its compatibility with the available data and the level of detail required for the analysis.
- Ultimately, the selection of an LCA tool should be guided by the specific goals of the assessment, the nature of the building project, and the desired balance between functional performance and material efficiency.

These are the results of Tally for the whole building:

Report Summary

Created with Tally

Non-commercial Version 2023.09.13.01

Goal and Scope of Assessment

LCA_Mineral Wool_Entire Envelope Building

Author	s313204
Company	Studio 74
Date	25/05/2025
Project	Contrada Marconi
Location	Chieri Via Marconi 4
Gross Area	1500 m ²
Building Life	50 years
Boundaries	Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO ₂ eq)	29.286	159,9	0	749,2	0
Acidification (kg SO ₂ eq)	209,4	0,7409	0	3,456	0
Eutrophication (kg Neq)	3,576	0,06033	0	0,1754	0
Smog Formation (kg O ₃ eq)	945,0	24,48	0	68,62	0
Ozone Depletion (kg CFC-11eq)	8,020E-004	5,477E-012	0	1,377E-010	0
Primary Energy (MJ)	360.969	2.325	0	12.838	0
Non-renewable Energy (MJ)	345.645	2.270	0	12.004	0
Renewable Energy (MJ)	16.329	56,23	0	846,2	0
Environmental Impacts / Area					
Global Warming (kg CO ₂ eq/m ²)	19,52	0,1066	0	0,4995	0
Acidification (kg SO ₂ eq/m ²)	0,1396	4,940E-004	0	0,002304	0
Eutrophication (kg Neq/m ²)	0,002384	4,022E-005	0	1,169E-004	0
Smog Formation (kg O ₃ eq/m ²)	0,63	0,01632	0	0,04575	0
Ozone Depletion (kg CFC-11eq/m ²)	5,346E-007	3,651E-015	0	9,183E-014	0
Primary Energy (MJ/m ²)	240,6	1,550	0	8,559	0
Non-renewable Energy (MJ/m ²)	230,4	1,513	0	8,003	0
Renewable Energy (MJ/m ²)	10,89	0,03749	0	0,5642	0

Figure 124. Report summary of Multiport

Report Summary

Created with Tally

Non-commercial Version 2023.09.13.01

Goal and Scope of Assessment

LCA_Entire Building Envelope_ EPS

Author s313204
Company Studio 74
Date 25/05/2025

Project Contrada Marconi
Location Chieri Via Marconi 4
Gross Area 1500 m²
Building Life 50 years

Boundaries Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Environmental Impact Totals					
Global Warming (kg CO ₂ eq)	12,614	274,4	0	170,2	0
Acidification (kg SO ₂ eq)	22,48	1,272	0	2,689	0
Eutrophication (kg Neq)	1,366	0,1035	0	1,025	0
Smog Formation (kg O ₃ eq)	603,6	42,02	0	22,56	0
Ozone Depletion (kg CFC-11eq)	5,185E-007	9,399E-012	0	3,130E-011	0
Primary Energy (MJ)	364.874	3.991	0	2.917	0
Non-renewable Energy (MJ)	361.391	3.895	0	2.728	0
Renewable Energy (MJ)	3.428	96,50	0	192,3	0
Environmental Impacts / Area					
Global Warming (kg CO ₂ eq/m ²)	8,409	0,183	0	0,1135	0
Acidification (kg SO ₂ eq/m ²)	0,01499	8,478E-004	0	0,001793	0
Eutrophication (kg Neq/m ²)	9,106E-004	6,903E-005	0	6,836E-004	0
Smog Formation (kg O ₃ eq/m ²)	0,4024	0,02801	0	0,01504	0
Ozone Depletion (kg CFC-11eq/m ²)	3,457E-010	6,266E-015	0	2,087E-014	0
Primary Energy (MJ/m ²)	243,2	2,661	0	1,945	0
Non-renewable Energy (MJ/m ²)	240,9	2,597	0	1,819	0
Renewable Energy (MJ/m ²)	2,285	0,06434	0	0,1282	0

Figure 125. Report summary of EPS

Revit Model Thematization through View Filters

Color Filters

Defining color filters require Revit preparation. In *View* → *Filters* section, an interval was defined for big, medium and small LCA impact: red, yellow and green respectively.

This way, every wall sample would have been colored with the proper color depending on the GWP value, computed with Dynamo.

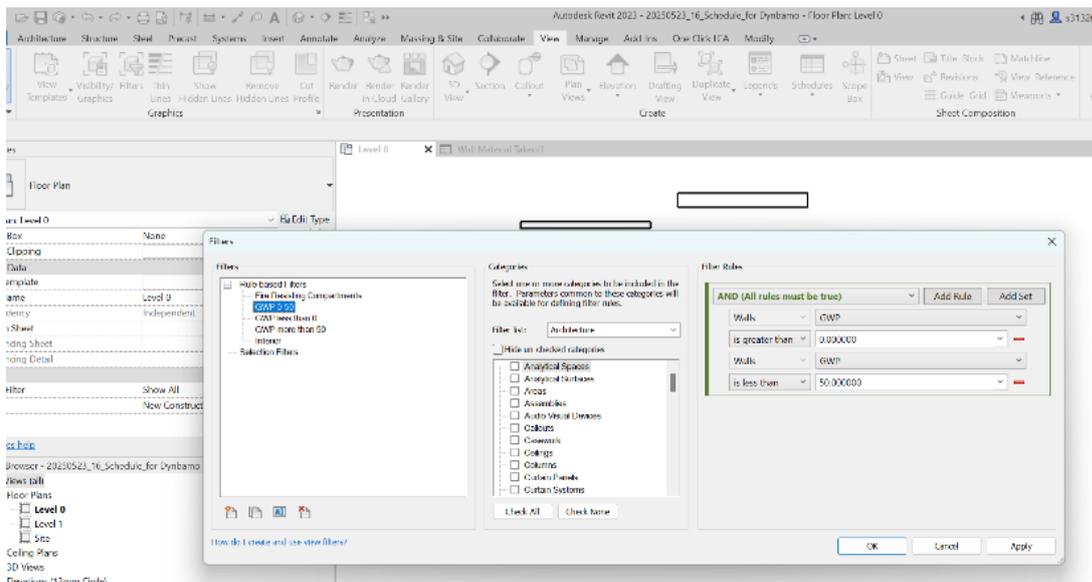


Figure 126. Color Filters Categories Revit

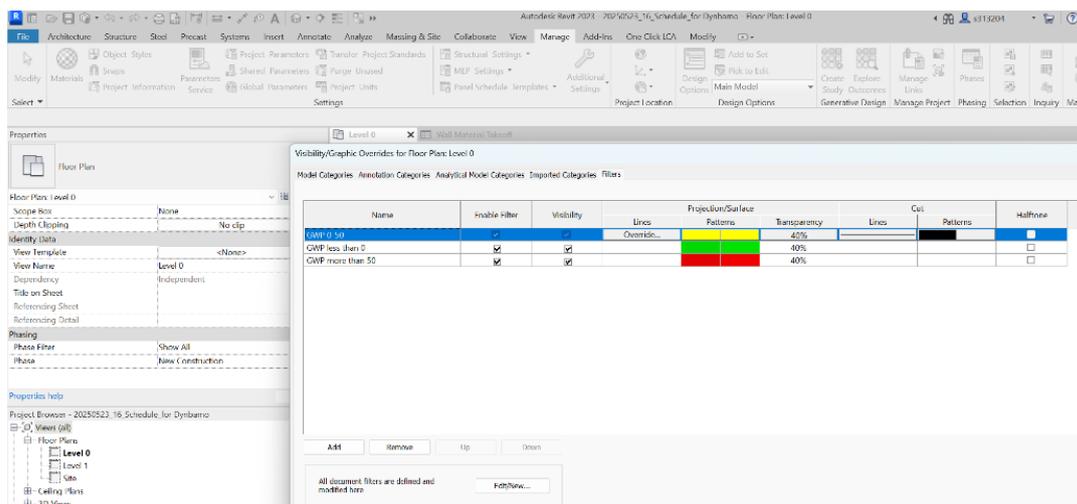


Figure 127. Color Filters Visibility in Revit

In addition, for the Whole Building was calculated.

Whole building LCA with One Click LCA Plugin

Setting up the Plugin for LCA in Cloud required selecting the project Elements we were interested in and other data as shown in these two pictures.

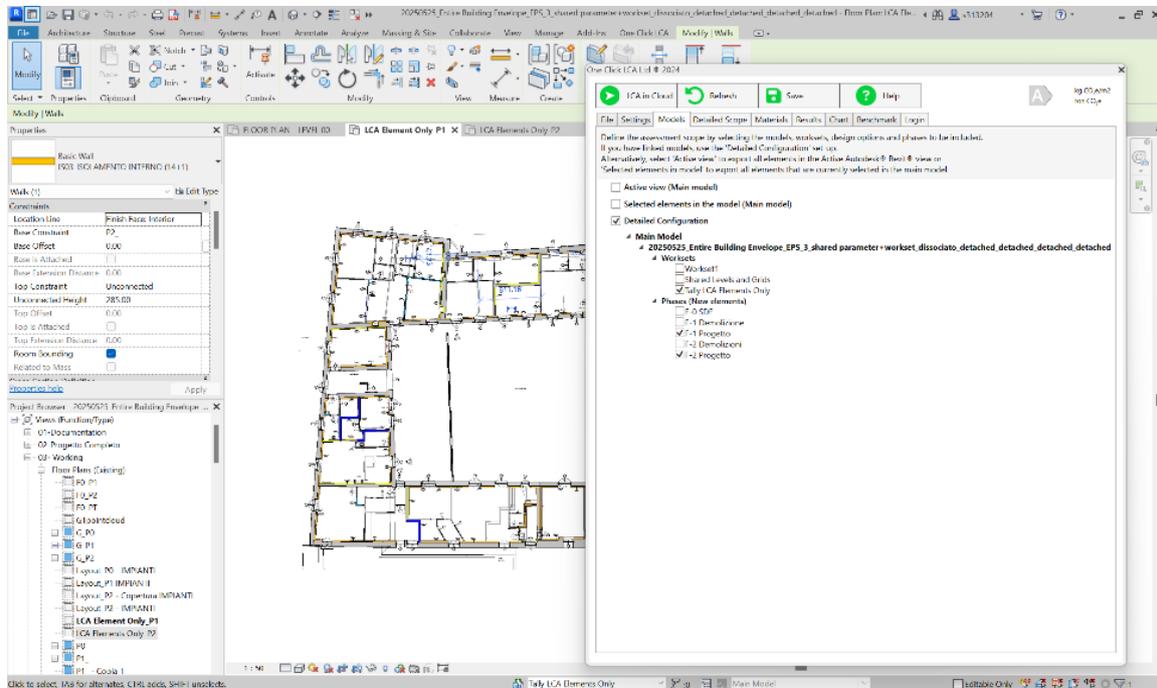


Figure 128. One Click LCA in Revit

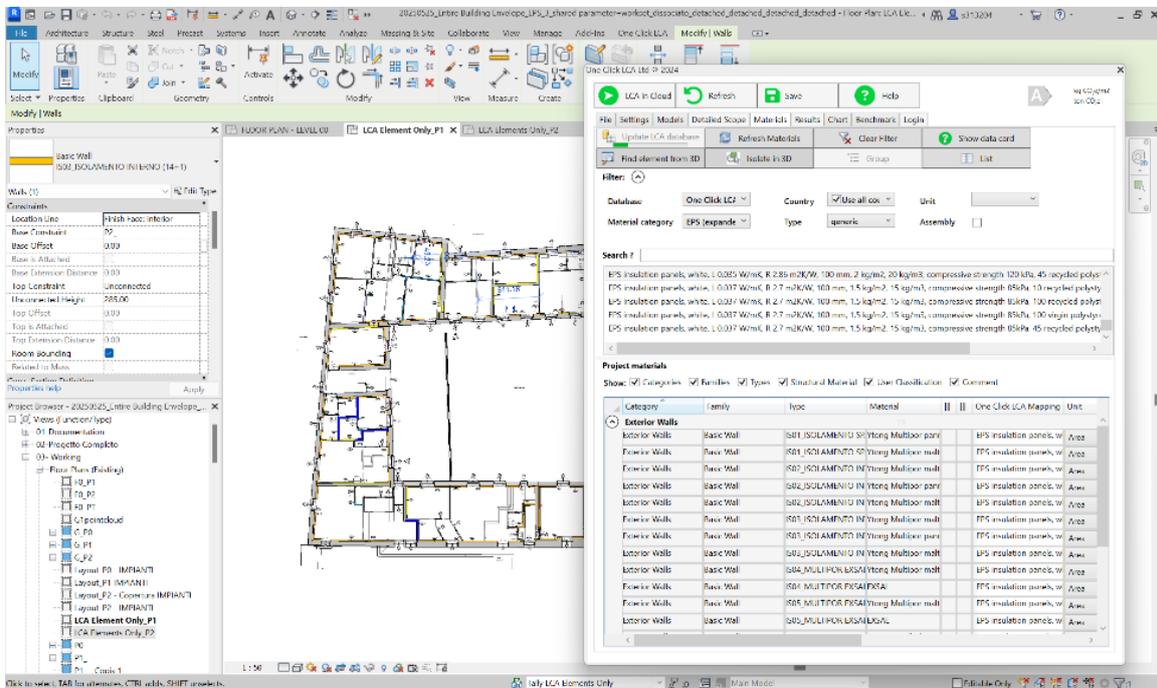


Figure 129. One Click LCA in Revit

Dynamo – Excel Data and Revit Data Together

According to the process explained before, Dynamo was used to select the Revit data which needed to be edited and then elaborate on the Excel files obtained in the previous step to split the GWP value for the three different thicknesses. The Dynamo project included these two parallel block flows, which were then put together in an operational net to compute the final GWP value for every insulation wall instance and finally put that value as its GWP parameter in the Revit project.

Color-Coding in Visualization Stage

With the GWP value obtained for every wall, an average was computer thanks to Dynamo. This allowed us to produce the color code based on the GWP value:

- **From 0-50 Green**
- **50-100 Yellow**
- **More than 100 Red**

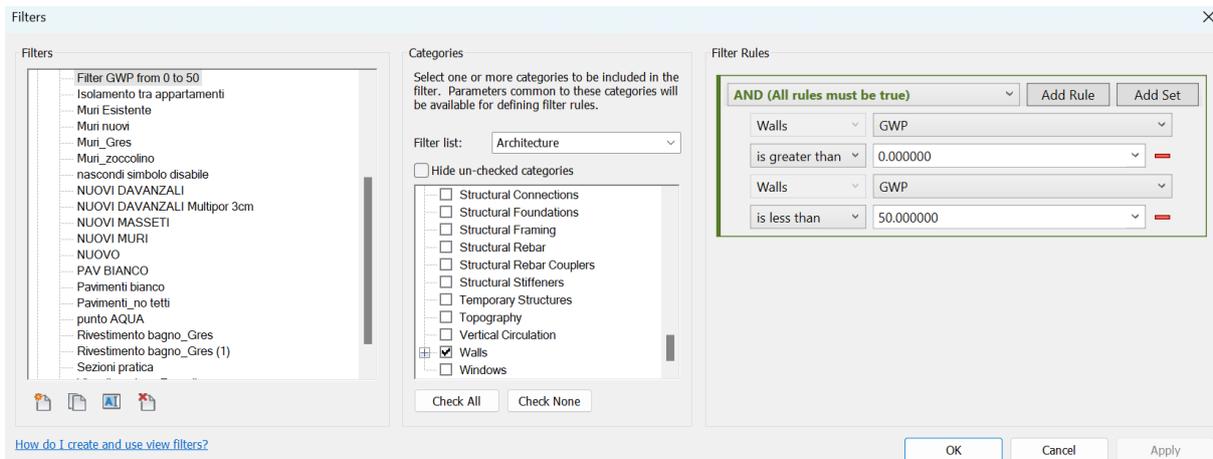


Figure 130. Filters Categories in Revit

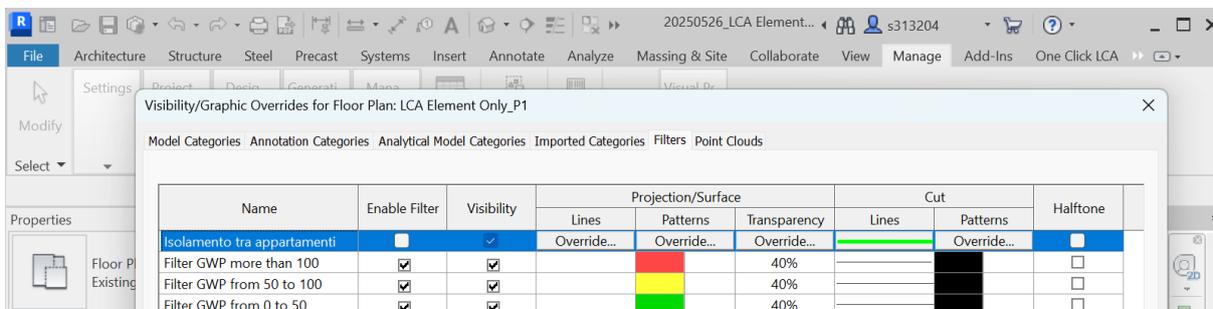


Figure 131. Color Coding Visibility in Revit

Executing the Dynamo script, every insulation wall in the project was colored with the proper color based on its GWP value computed and settled with Dynamo.

What is visible in the Revit file is shown here.

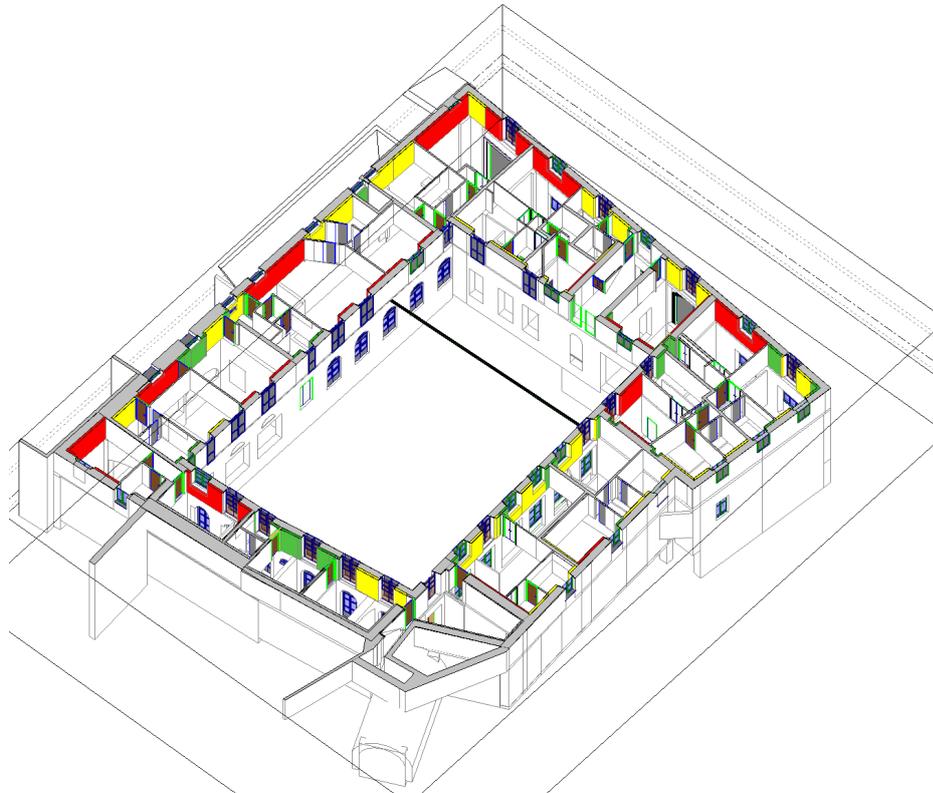


Figure 132. Screenshot of the Results of Dynamo atomization in Revit

Chapter 4: Conclusion

This thesis developed and tested a BIM-LCA approach for reducing the carbon footprint of building envelope insulation, using a residential case study in Chieri, Turin. The research combined advanced Revit modeling, comparative plugin analysis, and automated visualization to deliver actionable insights for sustainable renovation.

Revit Modeling: Foundation for Reliable LCA

The study began with the creation of a detailed Revit model of the case study building, focusing on three wall assemblies with insulation thicknesses of 40 mm, 100 mm, and 140 mm, using both Multipor M3 and expanded polystyrene (EPS) as insulation materials. Given the historic nature of the building, several irregular wall geometries were present. To ensure accurate area calculations and seamless LCA integration, all standard walls were modeled using Revit’s “Wall” category, which supports reliable material takeoff and parameter assignment. For highly irregular wall segments—where the “Model-In-Place” method would normally be considered—the “Pillar” component was utilized. This approach allowed these elements to merge with the last layer of adjacent walls using the same material, preserving both geometric fidelity and data interoperability. By avoiding “Model-In-Place” for walls, the workflow maintained full compatibility with Revit’s Material Takeoff (MTO) schedules and ensured that each envelope element could be linked to its corresponding LCA data for automated carbon footprint assessment. This modeling strategy proved essential for the success of the BIM-LCA workflow, especially in the context of irregular, existing buildings.

Plugin Comparison: Tally vs. One Click LCA

A comparative analysis of the Tally and One Click LCA plugins was conducted to assess their suitability for BIM-integrated LCA:

- **Tally** normalizes environmental impacts per functional unit (e.g., thermal performance), resulting in lower reported impacts as insulation thickness increases. It also considers usage stage (stages B- Refferbishment), producing higher overall GWP values. Tally’s element-level outputs facilitate automated data assignment in Revit, although occasional issues with Excel exports were noted.
- **One Click LCA** reports impacts in direct proportion to material quantity, with GWP increasing alongside insulation thickness. It does not fully account for usage stage impacts, so the last amount of GWP is lower than the amount of Tally plugin.

As a result, Tally was the tool with nearer to real amount of GWP for this case study due to its compatibility with the available data, inclusion of usage stage impacts, and support for automated, element-level LCA integration.

Material Results: EPS vs. Multipor

A central finding of this research is that **EPS insulation consistently demonstrated lower Global Warming Potential (GWP) emissions compared to Multipor**, across all thicknesses and both plugins. For example, using One Click LCA, the GWP for 140 mm EPS was 10.56 kg CO₂e, while for Multipor it was 15.15 kg CO₂e at the same thickness. This indicates that selecting EPS as the insulation material can significantly reduce the embodied carbon of the building envelope, making it a favorable choice for carbon footprint reduction in residential renovations.

Visualization: From Data to Design Intelligence

The final phase of the workflow involved integrating LCA results into the Revit model using Dynamo. GWP values were assigned to each wall element and visualized using color-coded filters—green for low impact, yellow for medium, and red for high impact (see Figures 135 and 136). This thematization enabled rapid identification of high-impact components and supported evidence-based decisions for sustainable design.

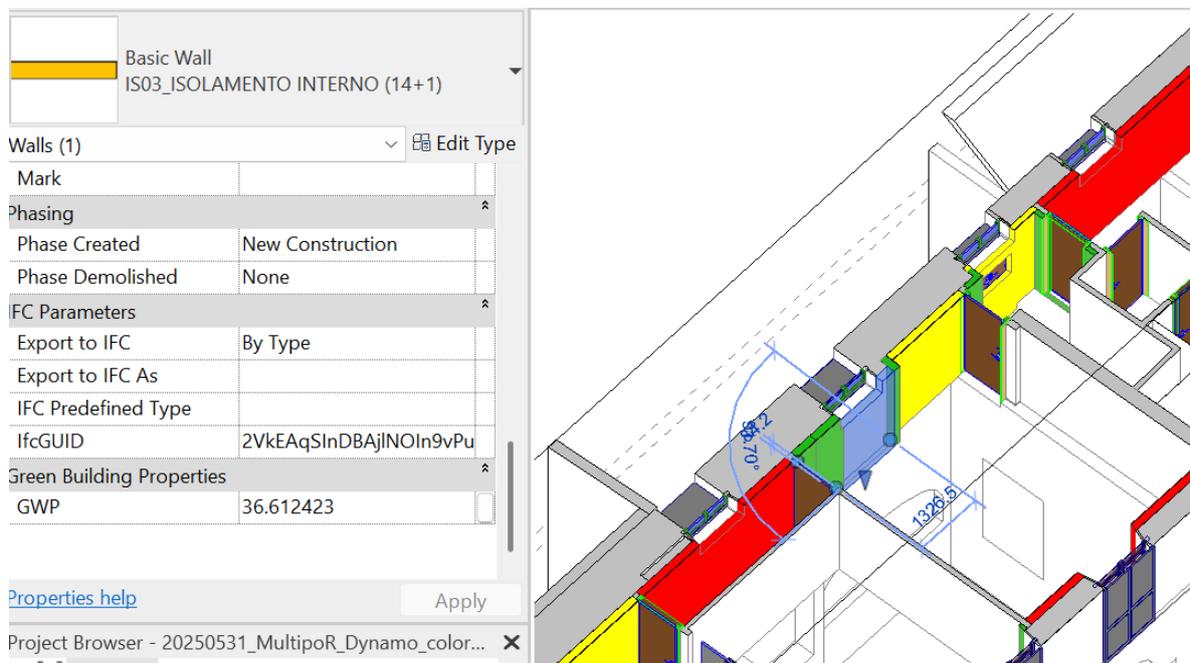


Figure 133. Example of color-coded wall elements in Revit based on GWP

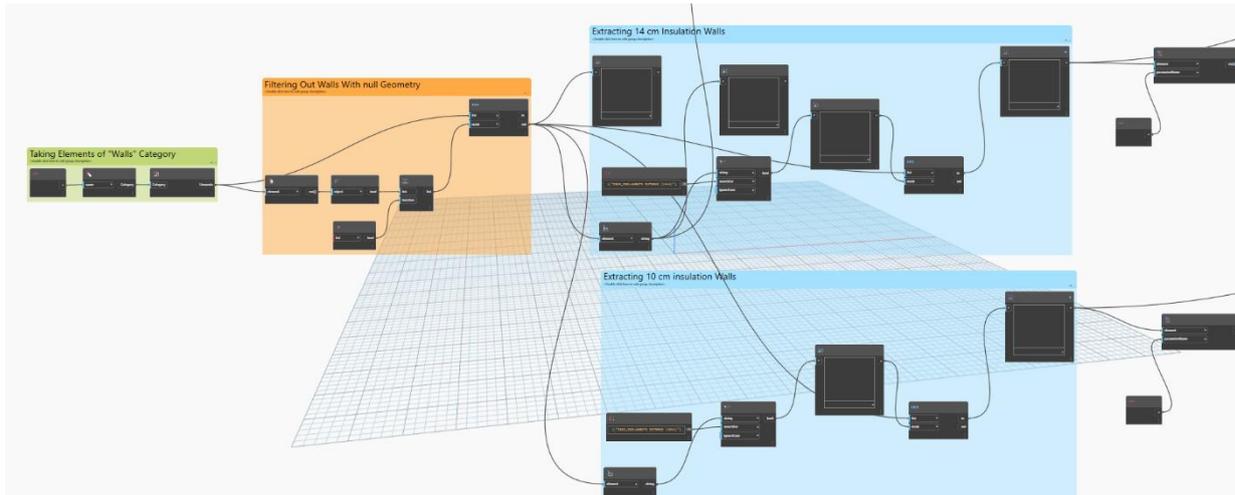


Figure 134. Dynamo workflow for automated GWP assignment

Practical Recommendations

- **Modeling Best Practices**

Always use the Wall category in Revit for envelope elements to ensure accurate area calculations and LCA integration. Avoid “Model-In-Place” for walls, even with irregular shapes; use components such as Pillar for complex geometries, which automatically takes the material of the last layer of element, and it is a suitable methodology for modeling long years old existing buildings.

- **Material Selection**

EPS is recommended as an insulation material for building envelopes when reducing embodied carbon is a priority, as it demonstrated lower GWP emissions than Multipor in this study.

- **Plugin Selection**

Choose LCA tools based on project objectives. Tally is suited for whole-building, performance-based analyses, while One Click LCA is preferable for direct material quantity comparisons as seen in this thesis study.

- **Workflow Automation and Visualization**

Employ Dynamo and Revit’s visualization tools to automate LCA data integration and to create clear, actionable outputs for design teams and stakeholders.

Future Research

Further research should apply this BIM-LCA workflow to a broader range of building types and insulation materials, test additional LCA databases, and enhance real-time feedback mechanisms. Addressing plugin export limitations and improving interoperability between BIM and LCA platforms will also be valuable for advancing this field. Additionally, future studies should explore the use of alternative, more environmentally friendly insulation materials, such as paper-based or bio-based products, which may offer further reductions in carbon footprint.

Final Remarks

This thesis demonstrates that a carefully structured BIM-LCA workflow—beginning with robust Revit modeling, followed by informed plugin selection and culminating in effective visualization—can significantly improve the transparency, accuracy, and impact of environmental assessments in building design. The findings, especially regarding the lower GWP of EPS insulation, provide actionable guidance for reducing the carbon footprint of building envelopes and advancing sustainable construction practices in the context of residential renovation.

In summary

This thesis investigated a BIM-LCA approach for assessing the carbon footprint of building envelope insulation in a residential case study in Chieri, Turin. The project involved modeling and evaluating two insulation materials—EPS and Multipor Xella—using both the Tally and One Click LCA tools and comparing their results in terms of Global Warming Potential (GWP) and other environmental indicators.

A central challenge encountered was the building's irregular walls, common in historical constructions. These geometries made it difficult to achieve accurate material quantification using standard modeling techniques. To address this, the BIM model was developed from point cloud data, and irregular sections were carefully reconstructed using “Model In-Place” tools to match the as-built conditions. This ensured that LCA calculations were based on realistic quantities rather than simplified approximations.

An important methodological decision concerned how to draw the insulation layers in the BIM model. Two approaches were tested: integrating insulation within the wall assembly and modeling it as a separate wall component. The second method—drawing insulation as its own

layer—proved more suitable for LCA purposes. This approach allowed for precise quantity take-off of the insulation alone, simplified the assignment of Environmental Product Declarations (EPDs), and made it easier to assess different insulation thicknesses or material types without altering the rest of the wall’s structure. It also provided clearer data for stage-by-stage environmental impact analysis.

For LCA tool selection, both Tally and One Click LCA were applied in the case study. Tally offered the advantage of working directly within Revit, making it easier to assign materials and quickly obtain environmental results for multiple scenarios. One Click LCA, operating through its cloud platform, provided detailed life-cycle stage outputs and compliance with EN 15804, making the results highly transparent and aligned with European standards. Using both tools on the same building elements allowed for a direct comparison of results, revealing variations in GWP values due to differences in underlying databases and calculation methods.

The Dynamo scripting workflow developed in this study proved to be an effective way to bring calculated GWP values back into the Revit model. By automating the import of results from Excel into Revit parameters and applying color filters, the approach transformed numerical data into a visual map of environmental impact. This made it possible to identify high-impact elements briefly, supporting clearer communication with project stakeholders and enabling more informed design adjustments.

The comparative LCA results confirmed that most environmental impact occurs in the use stage (B2-B5), with EPS showing significantly higher GWP than Multisorb. This reinforces the importance of insulation material selection in reducing embodied carbon, especially in renovation projects where other envelope elements remain fixed.

Overall, the research demonstrates that in a BIM–LCA approach, accurate geometric modeling of external walls, level of information inclusion, Environmental impact factor and increasing Level Of Development; careful insulation layer drawing methodology, and the combined use of different LCA tools can yield both precise and actionable results. The combination of detailed modeling, tool-based analysis, and Dynamo-based visualization creates a practical workflow that can be applied to similar projects seeking to minimize embodied carbon.

Future research could extend this work by exploring paper-based insulation materials within the same BIM–LCA approach. Such studies could provide valuable insights into the environmental potential of bio-based and recyclable materials, supporting the shift toward more circular and low-carbon construction practices.

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