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Master's Degree Thesis titled:

Understanding the relevance of Embodied Carbon in Green Building Rating Systems; through the application of Life Cycle Assessment in a Single-Family Residential case study.

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Glossary:

- **BIM:** Building Information Model
- **BREEAM:** Building Research Establishment Environmental Assessment Method
- **DGNB:** German Sustainable Building Council
- **EA:** Energy & Atmosphere
- **EC:** Embodied Carbon
- **EE:** Embodied Energy
- **CLT:** Cross Laminated Timber
- **GBRS:** Green Building Rating Systems
- **GHG:** Greenhouse Gas
- **LCA:** Life Cycle Assessment
- **LCC:** Life Cycle Costing
- **LCI:** Life Cycle Inventory
- **LCIA:** Life Cycle Impact Assessment
- **LEED:** Leadership in Energy and Environmental Design
- **MR:** Materials & Resources
- **OC:** Operational Carbon
- **OE:** Operational Energy
- **WBLCA:** Whole Building Life Cycle Assessment
- **WE:** Water Efficiency

Title:

Understanding the relevance of Embodied Carbon in Green Building Rating Systems; through the application of Life Cycle Assessment in a Single-Family Residential case study.

Abstract:

Green Building Rating System's (GBRS's) have been developed in the last 3 decades to assess and quantify a buildings environmental impact. Majority of GBRS's fail to address the multi-dimensional nature of sustainability and consider (almost solely) the environmental aspect, whilst largely neglecting the social and economic components of sustainability's triad definition (environmental, social, economic). Whilst GBRS's are predominantly focused on addressing the environmental component of sustainability's triad definition, it can be said that these rating systems are ineffectively quantifying environmental impacts. GBRS's lack of focus on Embodied Energy (EE), Embodied Carbon (EC) and Life Cycle Assessment (LCA) are resulting in misleading environmental assessment results.

In this thesis, an in-depth study of the 'state-of-the-art' with regards to sustainable assessment of the built environment will be undertaken. The development of International Standards as well as GBRS's will be studied. Specific attention will be placed on understanding the integration (or lack thereof) of LCA methodology in international GBRS's as well as inclusion of EE (in proportion to Operational Energy (OE)).

The importance of assessing EC emissions will be explored through a case study of a two-storey single-family residential building, designed by PAT architecture firm, located in Briaglia, Italy. A LCA will be conducted and compared to a 'Business-As-Usual' case in order to quantify the reduction in environmental impacts of low-embodied carbon materials selection. Based on the structure of the LEED rating system, a score for the 'Materials & Resources' category will be assigned for the case study and utilised to understand the relevance and weight of LCA in the LEED GBRS.

Keywords: Sustainable Building Assessment, Green Building Rating Systems, LEED Rating System, Sustainable Architecture, Single-family Residential Building, Built Environment, Life Cycle Assessment, Whole Life Assessment, Carbon Footprint

Introduction:

The topic of sustainable development is broad and complex, with many literature debates on the most accurate definition. The most generally accepted definition of the term "sustainability" derives from the 1987 Brundtland Commission Report, provided by the United Nation's World Commission on Environment and Development (WCED), stating that "sustainability" is: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Also according to the 1987 Brundtland Commission Report, sustainability is characterized in three main pillars, namely; Environment, Economy and Equity (the three "E's"). The relationships among these dimensions are generally assumed to be compatible and mutually supportive (Boström, 2012). The environmental dimension of sustainability dominated the debate in the 1980s, with the economic pillar growing in attention by end of the 1990s (Lami *et al.,* 2020). The social dimension, although gaining recognition in the 2000s, remains the least explored component of sustainability (Lami *et al.,* 2020).

With regards to sustainable development of the built environment, many GBRS's have emerged in the last two decades in order to promote energy efficient architecture worldwide. These GBRS's, although mostly effective in reducing energy consumption and addressing the "environmental" pillar of sustainability, fail to address the economic and social pillars, which remain largely unconsidered (the social aspect more so than the economic).

Whilst GBRS's are predominantly focused on addressing the environmental component of sustainability's triad definition, it can be said that these rating systems are ineffectively quantifying environmental impacts. GBRS's focus almost solely on operational energy assessment whilst embodied energy assessment remains largely neglected. Few GBRS's consider a LCA approach and LCA remains largely optional. Integrating LCA into GBRS's is crucial to better understanding a buildings environmental impact, and in turn, decarbonizing the built environmental. A transparent, integrated and extensive Whole Life carbon audit ought to be a requirement for developments of GBRS's.

The largest component of EE is related to a building's materiality. Material choices are crucial to a building's sustainability. Many GBRS certified buildings fall short on the evaluation of materials, scoring very low points in EE categories with regards to OE categories.

Thesis Formulation:

a. Questions

- *To what extent is the LCA methodology integrated into international Green Building Rating Systems?*
- *Do Green Building Rating Systems consider Embodied Energy (EE) and Embodied Carbon (EC)? If so, to what degree?*
- *Is a transparent and stringent whole life carbon emissions audit required to obtain a green rating certificate (considering the main international Green Building Rating Systems)?*
- *Why are most GBRS certified buildings falling short in categories that consider embodied energy?*
- *To what degree are low-embodied carbon material choices reflected in embodied energy categories of GBRS?*

b. Hypotheses

LCA is partially integrated into some international GBRS's, although with negligible weighting. LCA is not a requirement for most GBRS's and buildings can obtain green building certifications without conducting a LCA. Most GBRS's largely neglect EE and EC and a full carbon emissions audit is not necessary to achieve a green certificate or high green rating. As buildings approach net-zero operational emissions, the importance of considering embodied emissions becomes more apparent, although this is not always reflected in GBRS's. Many green building certified buildings score very lowly for categories relating to EE, either due to a relative lack of consideration of material selection in relation to operational energy or to stringent requirements for embodied energy related categories in GBRS's.

c. Thesis Structure

In Chapter One of this thesis; the International Standards Organization (ISO), informed by the United Nations Sustainable Development Goals, will be explored. The ISO's definition and methodology of the 'life style thinking' approach will also be highlighted. Green Building Rating Systems (GBRS's), developed in response to the current global crisis, and largely informed by the International

Standards will be explored, understanding the brief history, category distribution, limitations and characteristics of different rating systems.

In Chapter Two, the application and incorporation of LCA and EC in GBRS will be unpacked; understanding the degree to which different GBRS's emphasis LCA application. The degree to which GBRS's consider OC and EC respectively will also be explored. It is apparent that much larger emphasis is placed on OC in GBRS than EC, regardless of the increasing recognition of the importance of EC related emissions.

In Chapter Three a further exploration into the distribution of credits available for OC and EC in the LEED rating system will be investigated through the analysis of 5 LEED certified building's. These building's all fall in the LEED BC+C: New Construction category and differ in uses of commercial and hospitality. As hypothesized in Chapter Three, it is visible in the LEED building scorecard's that the 'Materials & Resources' (MR) category is (by a significant margin) the lowest scoring category. What is not clear is the reasoning behind the significant low MR category scores, which will be explored through the Bricolla House case study in Chapter Four.

In Chapter Four, a LCA of the Bricolla House Case Study, a detached single-family residential home, located in Northwest Italy, will be performed using the EURECA tool in order to quantitively understand the impact of low-carbon building material choices. The Bricolla House utilizes low-embodied materials such as Hemplime and Timber to minimize it's environmental impact. The LCA results of the Bricolla House will be compared to a 'Business-As-Usual' result in order to comparatively quantify the results. Once an LCA of the Bricolla House has been performed, a LEED score for the Materials & Resources (MR) category will be assigned to the project. This will inform an understanding of MR category and allude to a understanding of why this category is the lowest scoring in all of the analysed LEED certified building's in Chapter Three. Scenario 1; that the Bricolla house scores highly in the MR category, alludes to a lack of consideration of EC and material choices of other projects (still achieving high green building ratings). Scenario 2, that the Bricolla House scores poorly in the MR category alludes to the LEED credit allocation in this category being difficult to achieve as all considerations have been in place to ensure low-embodied material choices for the Bricolla house.

In Chapter Five, the results obtained from the LCA of the Bricolla House and the 'Business-As-Usual' case will be interpreted, analysed and compared to benchmark results of existing literature and standards. The role of software in LCA conduction as well it's impact on the comparability of LCA results will also be explored. Finally, a critical consideration of the LEED MR category (and GBRS's in general) will be undertaken in order to understand the inclusion of LCA in LEED. The importance of greater acknowledgement of EC in GBRS's and the role of LCA in achieving the 2030 Agenda goals will be discussed.

INTERNATIONAL STANDARDS AND GREEN BUILDING RATING SYSTEMS

1.1. International Standards

In 2015, the United Nations (UN) made their '2030 Agenda' publicly available, setting an ambitious 15-year plan to address some of the world's most pressing issues. In the 2019 UN Sustainable Development Goals (SDG's) Report the 17 SDG's, ranging from basic human rights such as 'zero hunger' and 'no poverty', through 'quality education' and 'decent work and economic growth' to 'sustainable cities and communities' and 'climate action' are highlighted (UN, 2018). In the report, the 2030 Agenda was described as a "blueprint for shared prosperity in a sustainable world – a world where all people can live productive, vibrant and peaceful lives on a healthy planet" (UN, 2020).

In direct response to the UN's 17 SDG's, the International Organization for Standardization (ISO) presents standards and general principles to address the social, environmental and economic dimensions of sustainability in multiple sector's. The UN's 2030 Agenda calls on all elements of society, and to be successful, requires consensus. As the construction sector represents a large part of our physical environment, as well as the large impact that the construction sector has on all area's of society, ISO has developed standards specifically relating to the sustainability of the construction sector. Over 1100 standards and related documents have been published by ISO relating to buildings and construction. These standards are developed by groups of experts in technical committees and cover; structures, building materials and products, energy performance and sustainability, fire safety and firefighting, concrete and cement, timber, masonry, information management in construction, heating, cooling and lighting, lists and escalators, design life, durability and service life planning.

Within the energy performance and sustainability category of ISO, ISO has developed standards aimed at improving the energy performance of buildings. These standards include: ISO/TC 163 (*Thermal performance and energy use in the built environment*), ISO/TC 205 (*Building environment design*) and ISO 21930 (*Sustainability in buildings and civil engineering works- Core rules for environmental product declarations of construction products and services*). Within the design life, durability and service life planning category, ISO 15686-5 (*Buildings and construction assets- Service life planning – Part 5: Life-cycle costing*) incorporates Life-Cycle thinking and methodology. ISO

14001 is an environmental management systems standard aimed to provide requirements with guidance for use that relate to environmental systems.

According to ISO 14001, it is crucial to understand that a product/building has a 'life cycle', defined as "'Consecutive and interlinked stages of a product (or service) system, from raw material acquisition or generation from natural resources to final disposal. Life cycle stages include acquisition of raw materials, design, production, transportation/delivery, use, end-of-life treatment and final disposal.' A systematic approach that incorporates life-cycle thinking, can prevent environmental impacts from being unintentionally shifted elsewhere within the life cycle.

ISO 15392:2008 identifies and establishes general principles for sustainability in building construction. It applies life-cycle thinking to buildings and other construction works, understanding that a building has a life cycle from inception to end-of-life. ISO 15392:2008 can also be applied to materials, products, services and processes relating to the building's life-cycle. It is not intended to provide the basis for assessment.

1.2. Green Building Rating Tools

1.2.1. Overview

With regards to sustainable building assessment, Green Building Rating Systems (GBRS's) have been developed in response to the global climate crisis. Combatting the drastic consumption of materials and energy by the construction sector (more 40% of total energy consumption (in developed area's), 36% of CO_2 emissions and 14% of the world's drinkable water), GBRS's are aimed at improving the environmental performance of buildings. An important stimulus in the development of sustainable assessment in the built environment was the creation of the Building Research Establishment Environmental Assessment Method (BREEAM), proposed in the UK in the 1990s. There are currently 56 certified tools (certified with the Green Building Council) worldwide and many other uncertified tools (Ascionea *et al.,* 2021), with over 1.04 billion m2 of floor space being certified (Mattinzioli *et al.,* 2021).

According to Mattinzioli *et al., (*2021), the 10 tools which are found to be the most prominent on the current sustainable building rating systems market are: BREEAM (UK), HQE (France), LEED (USA), Passivhaus (Germany), Beam Plus (Hong Kong), CASBEE (Japan), Green Globes (Canada), Green Star

(Australia), Estidama (Abu Dhabi) and DGNB (Germany) (Mattinzioli *et al.,* 2021). BREEAM and HQE have the highest number of certifications, with BREEAM being the first sustainable building rating system to be implemented and influencing the development of other systems (Mattinzioli *et al.,* 2021). LEED system is the most internationally utilized and due to its transparent rating system has the highest market recognition and use (Mattinzioli *et al.,* 2021). LEED spans the most countries, followed by BREEAM. Mattinzioli *et al.,* (2021) highlight that there is a large differences between local and international rating systems, and that the establishment of an "international consensus" is necessary (Mattinzioli *et al.,* 2021).

According to the review of Mattinzioli *et al.,* (2021), GBRS have either followed a BREEAM- and LEED-based category selection, or formed a new category layout. BREEAM- and LEED-based categories are the following; management (MAN), water (WAT), land and ecology (LAND), transport and accessibility (TRA), indoor environmental quality (IEQ), material and resources (MAT), emissions (EMI), regional considerations (REG) and innovation (INN) (Mattinzioli *et al.,* 2021). Sustainable building rating systems such as CASBEE, Passivhaus, DGNB and HQE have developed an alternative approach to category selection. Overall, energy can be found to be largest category of interest as seen in all sustainable building rating systems.

1.2.2. GBRS Limitations

While GBRS's provide better performing buildings than conventional ones, when comparing energy efficiency, water efficiency and carbon emission reduction, they are also praised for stimulating open dialogue and debate, assisting in re-shaping the design process to an approach which is more "thoughtful, innovative and integrated" (Mattinzioli *et al.,* 2021). However, despite the increasing numbers of GBRS's being released around the globe, there are still significant shortcomings, resulting in "misleading" and non-representative sustainability results" (Mattinzioli *et al.,* 2021). As highlighted by Awadh (2017), "Green Building Rating Systems are environmental-oriented tools and should not be confused with Sustainability Assessment Systems. Indeed, the achievement of a green building certification does not necessarily mean that the building succeeded in achieving sustainability targets." (Ascionea *et al.,* 2021).

Following the 1987 Brundtland Commission Report definition of sustainability based on three pillars (environmental, social and economic), it is important to note that many rating system's lack one or two of these essential considerations (Ascionea *et al.,* 2021). While many rating system's are insufficiently valuing economic and social considerations, some new tools are proposing their inclusion through additional evaluation criteria. Rating system's that have an integrated approach considering all three pillars of sustainability can be deemed both "green" and "sustainable" (Ascionea *et al.,* 2021).

The review titled *"Building rating systems: A novel review about capabilities, current limits and open issues (2021)"*, Ascionea *et al.,* (2021) attempts to answer the following the crucial question; "How much does the level of (green building) certification reflect the green, sustainable, healthiness, and indoor environmental quality feature of the buildings?". In this review, present knowledge of GBRS is summarized, while questioning in what ways rating systems can be improved for enlarging the sustainability assessment. Ascionea *et al.,* (2021) highlight that even the most utilized rating systems (eg. LEED) have lacked many requirements and were found to "still fail in sufficiently covering all dimensions of sustainability".

1.2.3. Category weighting's

In this review by Ascionea *et al*., (2021), the categories and weights of three GBRS (namely BREEAM, LEED and LiderA) are illustrated by way of an example. The category weighting of BREEAM is as follows; BREEAM gives the greatest priority to Health and Wellbeing (21%), second greatest to Energy (20%), next Materials (12%) and Transport (11%). Other categories are Management, Water, Land use and Ecology and Pollution. LEED v4.1 gives the greatest weight to Energy and Atmosphere (32%), then Indoor Environmental quality (15%), next Materials and Resources (17%), other categories are Water efficiency, Sustainable sites, Location and transportation, Innovation and regional priority. LiderA gives the greatest weight to Resources (32%) and second greatest weight to Socio-economic experience (19%), the other categories are Site and Integration, Environmental loadings and Sustainable use (Ascionea *et al.,* 2021).

A review concerning GBRS's comparison papers is performed in the paper by Ascionea *et al*., (2021), through considering 36 examined papers (of which 83% of papers refer to LEED). Many different GBRS's were considered, including but not limited to; LEED, BREEAM, LiderA, GBC Historic Building, GS, ASGB, Estidama, Minergie, SABA (Jordan), ect. The GBRS's spanned across a wide range of locations, including but not limited to; Italy, Portugal, India, Korea, Qatar, ect. The category application of GBRS's was general applications, office buildings, commercial buildings, residential buildings. The following conclusions were drawn; the "Environmental pillar" has the highest importance in most rating systems, LEED is considered the most flexible tool (with many case studies on the application of LEED in several countries), 'climatic data and the geographical position' is excluded from the assessment of renewable energy in some tools, a single rating system fails to evaluate all aspects of a building as the evaluation system gives priority to a single feature and the evaluation of Indoor Environmental Quality (IEQ) is often overlooked (Ascionea *et al.,* 2021).

The attention of sustainability in the built environment has often been perceived as a soley environmental issue, while largely neglecting its social (as well as economic) component (Atanda, 2018). According to Ascionea *et al.,* (2021), in order to create a more holistic approach to sustainable building assessment, it is necessary to add new criteria to existing GBRS's, considering criteria such as; microclimate around buildings, daylight quality in surrounding areas (also for safety reasons), stormwater management, and environmental management plan. Ascionea *et al.,* (2021) also agree that the human dimension should be more strongly considered; human quality of life and well-being, healthiness of spaces (presence of bio-contaminants and infectious disease transmission) could be new categories to be introduced and increased weight should be given for indoor comfort as well environmental indoor air quality. Social sustainability assessment is lacking in most GBRS's and should be considered with higher importance. The authors locate their review in a post COVID19 context, emphasizing the importance of health and safety of users with regards to environmental indoor air quality. Also considering the COVID-19 outbreak, spatial stiffness should be observed as an obstacle, and functional adaptability should be prioritized in rating systems. The GBRS BREEAM does consider functional adaptability, but only in the waste category and with a weighting as little as 10%. LiderA and LEED both consider flexible and adaptable spaces, but also of low-weight (Lider, 4% and LEED, 5%). According to Ascionea *et al.,* (2021), other important criteria to consider are environmental hazards and seismic risks, heat island effects, as well as noise and light pollution. The inclusion of economic evaluations, such as the Cost-Optimal Methodology and integration of LCA should be considered (Ascionea *et al.,* 2021). DGNB (German Sustainability Council) is working with ISO on Life Cycle Costing (LCC) in construction.

LIFE CYCLE ASSESSMENT AND EMBODIED ENERGY IN GREEN BUILDING RATING SYSTEMS

2.1. Life Cycle Assessment

Life Cycle Assessment (LCA) is a tool and scienced-based method aimed to quantify the environmental impacts of a product's entire life cycle. LCA follows four steps which were established by the International Organization for Standardization (ISO) in ISO 14040 and 14044. The four main steps of ISO are; 'Goal and Scope Definition, Inventory Analysis, Impact Assessment and Interpretation (as seen in Figure 1).

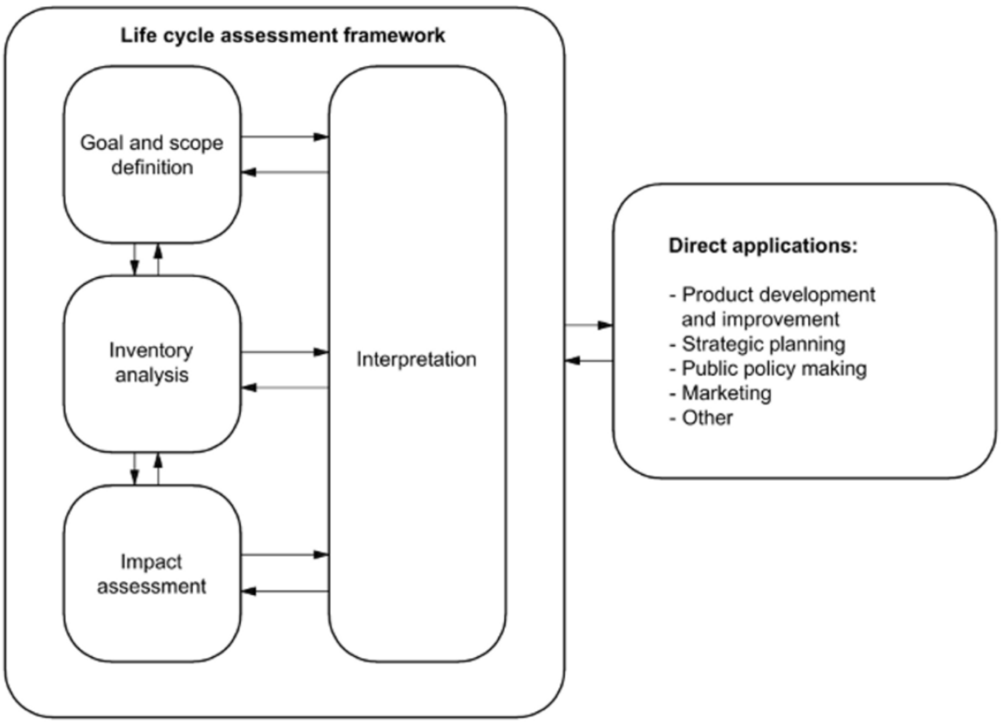


Figure 1: Life cycle assessment stages. Reference: ISO 14044

2.1.1. Goal and Scope Definition

Within the 'Goal and Scope Definition' step of performing an LCA, it is important to clearly state the aim and objectives for performing the LCA as well as the audience for which it is intended. Clear definitions should be provided for the product/system under analysis and the 'System Boundary' should be defined. The 'System Boundary' defines processes will be included in the product system. As seen in Figure 2, different 'System Boundaries' include;

- from cradle to cradle: all the processes of the production cycle are included in the analysis (from the extraction of raw materials to their disposal). The revaluation of the product at the end of it's life (through the recovery of materials and energy) is also considered.

- from cradle to grave: all the possesses of the production cycle are included in the analysis (from the extraction of raw materials to their disposal). The revaluation of the product at the end of it's life (through the recovery of materials and energy) is *not* considered.

- from cradle to gate: production processes from the extraction of raw materials to the end of it's production cycle are analysed (without considering the distribution, use and disposal)

- from gate to gate: only production of the product is analysed, excluding all phases relating to extraction, distribution, use and end of life.

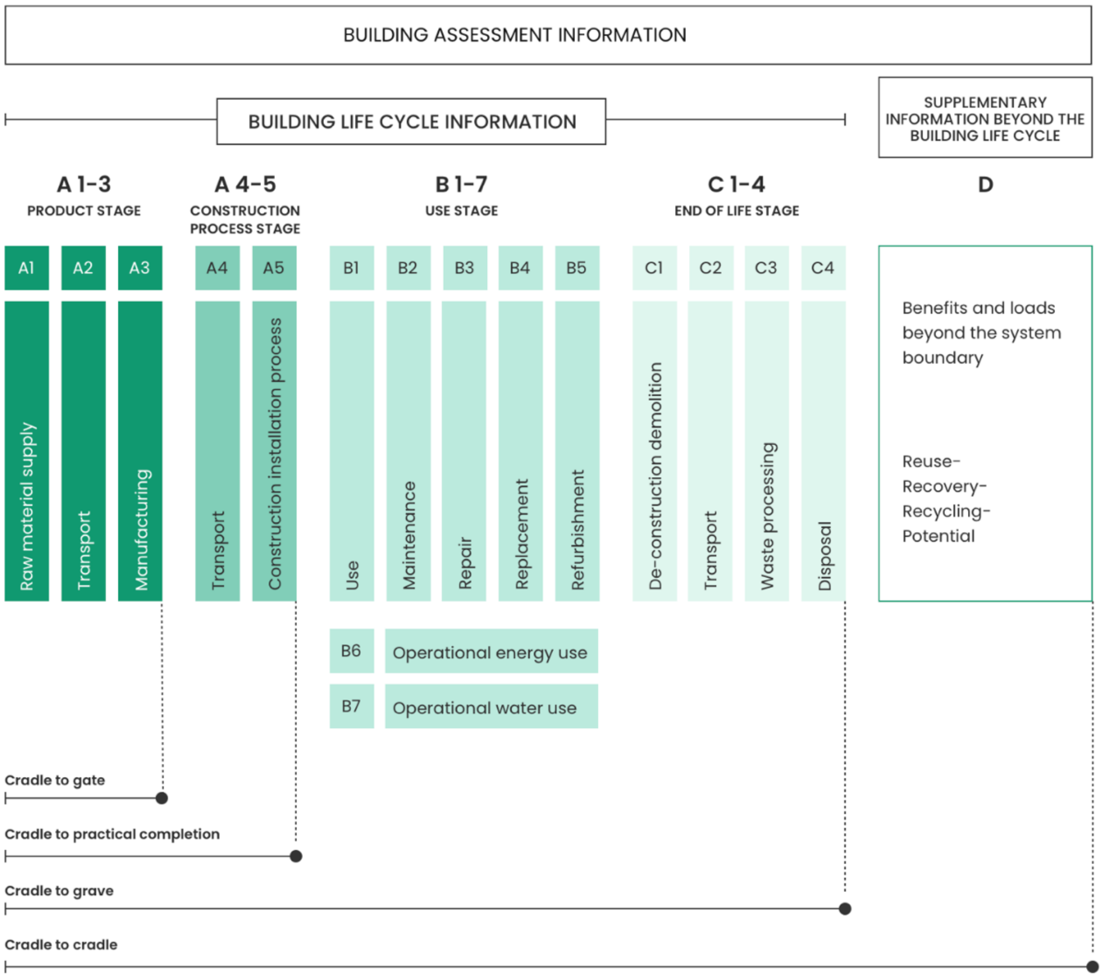


Figure 2: Building Life Cycle Information showing System Boundaries. Reference: One Click LCA (2023)

2.1.2. Life Cycle Inventory (LCI)

The LCI is a methodology step in the LCA which involves creating an inventory of input and output flows for a product system. Creating the LCI involves data collection for each process included in the system boundaries. Data can be divided into three categories; primary data (data collected directly in the plant/company where the product is produced), secondary data (obtained from LCA databases or literature) and tertiary data (estimated and average data values).

2.1.3. Life Cycle Impact Assessment (LCIA)

The LCIA refers to the phase of LCA that asses the type and extent of environmental impacts that arise based on the LCI data collected in the previous step. Consumption and emissions relating to the specific project/product and it's system boundaries are attributed to specific impact categories, relating to environmental impacts.

2.1.4. Interpretation and Improvement Analysis

Crucial to the conduction of the LCA and as defined by ISO EN 14040:2006 [48] is the phase of interpretation of the results. In this phase, it is important to identify critical points (i.e. materials and processes which contribute most to the overall impacts), to check that the inventory is complete and to evaluate the reliability of the results. It is also important to perform a "consistency check", evaluating whether the data, methods and assumptions of the study are applied consistency in the analysis.

2.2. LCA and Embodied Energy in Green Building Rating Systems

2.2.1. Green Building Rating System's Limitations

Regardless of the wide implementation of Green Building Rating Systsm's, Abdelaal, F. *et al.*, (2022) emphasize that buildings carbon emissions have continued to rise by nearly 1% per year since 2010. GBRS, designed to evaluate the environmental impact of buildings, are underperforming on many fronts. While large and well-encouraged efforts have been placed on developing and implanting GBRS, there is much improvement still to come if the built environment is to decarbonize at a rate rapid enough to reach the Paris agreement goals of at least 40% reduction in greenhouse gases by 2030. LCA has been utilized as an assessment tool in the building sector since 1990 and has grown in popularity in the last decade. Many authors in recently published papers are encouraging a LCA approach to green building assessment, including rigorous Embodied Carbon (EC) and Operational Carbon (OC) auditing, stating that "the application of LCA (in the built environment context) could be vital to sustainability and the improvement of buildings and construction processes" (W.O. CollingeaC.L et al.,).

In Calder, B.'s book titled 'Architecture: from prehistory to climate emergency', he highlights an eye-opening example of the inefficiency of BREEAM's rating system, using a case study of a building that, in 2017, was awarded the highest environmental rating ever received. The Bloomberg Headquarters, designed by architects Foster & Partners received a 98.5% rating by BREEAM, which, as argued by Calder, does not adequately represent its environmental impact. Foster & Partners are a competent team aiming at an ineffective target. If BREEAM's targets for EC and OC were more stringent, it's possible that Foster & Partners would have made more progress reaching them (Calder, 2021).

The Bloomberg Headquarters claimed a "73% reduction in water use" and a "35% reduction in the amount of energy used to run the building (EC)" which were widely discussed and publicized (Calder, 2021). What was lesser discussed was the abundant energy costs (EE) of constructing the new building, which consisted of concrete, steel, bronze and stone (Calder, 2021). The building was also not on a virgin site, and a large concrete framed office building of the 1950's was demolished in order to proceed with the new construction. The energy costs of the demolition, the waste it produced as well as the energy costs of new materials production, although uncalculated, must have been, as Calder argues, “substantial”. In view of the advocates of reuse and building adaption “the greenest building is the one that already exists”, and the Bloomberg HQ is “not a truly sustainable building itself nor is it a model to others for the future” (Sturgis in Calder (2022), pg. 436).

According to Calder (2022), a true climate audit should measure the total carbon cost of replacing what currently exists to weigh against the possible future savings of energy that would result from upgrading what is already there. It is apparent that the built environment is not decarbonizing at a rapid enough rate to reach the Paris agreement goals of GHG reduction of at least 40% by 2030. There needs to be a shift from reliance on voluntary assessment systems to transparent and compulsory regulation of EC and OC (Calder, 2022).

2.2.2. EC and OC in GBRS

In 2022, Abdelaal, F. *et al*. conducted a study titled ‘Comparison of Green Building Rating Systems from a LCA Perspective’ in which the efficiency, validity and reliability of five international GBRS (namely LEED, BREEAM, BEAM Plus, Green Star and Homestar) were evaluated in terms of auditing the building’s total carbon emissions (EC and OC). Results from their study indicated that whole life LCA is an optional assessment in GBRS, with negligible weighting. A building can achieve a high sustainability rating without conducting an LCA assessment. The assessment of EC is overlooked, while OC is considered a priority. Recent studies argue that EC emissions of buildings share a considerable proportion of a buildings total emissions and should no longer be neglected. According to Abdelaal, F. *et al.,* (2022), focus needs to be shifted from OC towards a full life cycle perspective in order to achieve the emissions reduction targets needed to decarbonise the built environment.

According to Architecture 2030, “building operations are responsible for 27% (of total emissions) annually, while building and infrastructure materials and construction are responsible for 13% annually”. EC refers to the total Greenhouse Gas (GHG) emissions resulting from producing a building materials OC relates to the energy consumed during a building’s service life, including energy for heating, cooling, ventilation, etc. (UK Green Building Council, 2017).

In recent years, more attention has been focused on improving the OE of buildings than the EE. As buildings approach net zero OE emissions, the importance of considering EE becomes more apparent. While reduction in OE takes place over the long lifetime of the building, reduction in EE emissions has an immediate benefit, making them a good “near-term target for climate change mitigation" (Pai, V. *et al.,* 2021). Reducing EC is crucial in the early design stages as thoughtful initial design is of utmost importance. Ways to reduce EC emissions include specifying less materials through optimization as well choosing low-embodied materials. LCA can be used to estimate the embodied impacts of a building.

2.2.3. LCA in GBRS

In the study of Abdelaal, F. *et al.,* (2022), it is highlighted that in recent years LCA has been incorporated into few GBRS's. The depth and recognition of LCA application in BREEAM, LEED, CABSEE, BEAM Plus, Green Star is explored, reviewing in detail the weighting of LCA in each GBRS as well as their carbon emission auditing requirements (Abdelaal, F. *et al.,* 2022).

BREEAM (Building Research Establishment Environmental Assessment Method) was released in the UK in 1990 as the first GBRS in the world (Abdelaal, F. *et al.,* 2022). In BREEAM, a total of 5 points are available for performing a LCA of the main building elements. However, Whole Life LCA is an optional assessment criteria and building can achieve a BREEAM certificate without performing a WLCA (Abdelaal, F. *et al.,* 2022). EC Emissions in BREEAM are recognized in the "Materials" category (for 6 points) and "Waste" category (for 4 points) (Abdelaal, F. *et al.,* 2022). OE emissions are assessed in the categories "water" and "Energy" and account for a total of 29 points (Abdelaal, F. *et al.,* 2022). "Reporting and auditing building EC emissions is partially required in the form of submitting the Environmental Product Declarations (EPDs) for at least five construction materials." (Abdelaal, F. *et al.,* 2022).

LEED (Leadership in Energy and Environmental Design) is the most popular and widely utilized rating system in the world, released in 1998 by the US Green Building Council (Abdelaal, F. *et al.,* 2022). Similarly to BREEAM, LEED awards points for conducting a Whole Building LCA (WBLCA). Up to 3 points are available, although WBLCA is not a mandatory requirement in order to achieve a LEED certification (Abdelaal, F. *et al.,* 2022). In the LEED assessment system, 32 points are allocated to assessing OE while 11 points are allocated to EE assessment (Abdelaal, F. *et al.,* 2022). EE assessment is represented in the "Materials and Resources" category, including EPD's (Environmental Product Declaration) (Abdelaal, F. *et al.,* 2022).

Based on the BREEAM rating system, BEAM Plus was issued in Hong Kong in 1996 (Abdelaal, F. *et al.,* 2022). BEAM Plus awards only 1 point for conducting a building LCA report. This LCA report needs only to include three LCA impact categories, including elements and materials used in building foundations, walls, façade and primary and secondary structure but and does not necessarily need to include GWP (Abdelaal, F. *et al.,* 2022). Similarly to BREEAM and LEED, BEAM Plus awards points for submitting material EPD's but auditing the buildings embodied emissions is not mandatory. 34 points are allocated to assessing the building's OE under the category "Energy and Water" (Abdelaal, F. *et al.,* 2022).

Green Star is the most used rating system in Australia and New Zealand, it was first introduced in Australia in 2003 and adopted in New Zealand in 2007 (Abdelaal, F. *et al.,* 2022). Green Star Design and As-Built also consider LCA as an optional assessment. 8 points are allocated to embodied emissions until the "Materials" category, yet EC emissions auditing is not required to achieve these points. Compared to a reference building, a building must have at least 10% reduction in GHG emissions during it's operational phase (Abdelaal, F. *et al.,* 2022).

In the current version of Homestar, a New Zealand based GBRS, LCA is not recognised and carbon emission auditing is not required. Although, in the "Sustainable Materials" category, using at least 50% recycled/used construction materials awards environmental certifications. 6 points out of 120 total points are awarded for the reduction of EC during the construction stages (Abdelaal, F. *et al.,* 2022).

To conclude the study titled 'Comparison of Green Building Rating Systems from LCA Perspective' by Abdelaal, F. *et al.,* (2022), whole building LCA criteria weighting in the studied international GBRS's is less than 6% in each system. The average weighting of EC emissions assessment is around one-third of the weighting of OC emissions assessment. Most importantly, projects can achieve green building certificates without assessing or auditing embodied carbon emissions.

The following table (Figure 3) breaks down the allocation of credits within each category of BREEAM v2.0, LEED v4.0, BREAM Plus v2.0, Greenstar v1.0 and Homestar v4.1 as well as the 'optional' or 'compulsory' inclusion of LCA.

GBRS	Topic	Category	Credits	Points
BREEAM v2.0	Life Cycle Assessment (LCA)	Materials	MAT 01 Life Cycle Impacts	5 (Optional)
	Embodied Energy (EE)	Materials	- MAT 01 Life Cycle Impacts (EPD's) - MAT 03 Responsible Sourcing of Construction Products - MAT 06 Material Efficiency	6
		Waste	- WST 01 Construction Waste Management - WST 02 Recycled Aggregates	4
	Operational Energy (OE)	Energy	- ENE 01 Energy Use & Carbon Emissions - ENE 04 Low Carbon Design - ENE 05 Energy-Efficient Refrigeration Systems - ENE 08 Energy Efficient Equipment	23
		Water	- WAT 01 Water Consumption - WAT 04 Water Efficient Equipment	6
GBRS	**Topic**	**Category**	**Credits**	**Points**
LEED v4.0	Life Cycle Assessment (LCA)	Material and Resources	- MR Building Life Cycle Impact Reduction	5 (Optional)
	Embodied Energy (EE)	Material and Resources	- MR Building Life Cycle Impact Reduction - MR Environmental Product Declarations - MR Sourcing of Raw Materials - MR Construction and Demolition Waste	11

	Operational Energy (OE)	Energy and Atmosphere	- EA Optimize Energy Performance - EA Renewable Energy Production - EA Enhanced Refrigerant Management - EA Green Power and Carbon Offsets	24
		Water Efficiency	- WE Outdoor Water Use Reduction - WE Indoor Water Use Reduction	8
GBRS	**Topic**	**Category**	**Credits**	**Points**
BEAM Plus v2.0	Life Cycle Assessment (LCA)	Materials and Waste	- MW10 Life Cycle Assessment	1 (Optional)
	Embodied Energy (EE)	Materials and Waste	- MW1 Building Re-use - MW3 Prefabrication - MW5 Sustainable Forest Products - MW6 Recycled Materials - MW7 Ozone Depleting Substances - MW8 Regional Materials - MW9 Use of Certified Green Products	10
	Operational Energy (OE)	Energy Use	- EU1 Low Carbon Passive Design - EU2 Reduction of CO2 Emissions - EU3 Peak Electricity Demand Reduction - EU5 Renewable and Alternative Energy Systems - EU8 Energy Efficient Appliances	27

		Water Use	- WU1 Annual Water Use - WU2 Water Efficient Irrigation - WU3 Water Efficient Appliances	6
GBRS	**Topic**	**Category**	**Credits**	**Points**
Green Star v1.0	Life Cycle Assessment (LCA)	Materials	- 19A.1 LCA	6 (Optional)
	Embodied Energy (EE)	Materials	- 20 Responsible Building Materials - 21 Sustainable Products - 22 Construction and Demolition Waste	8
	Operational Energy (OE)	Energy	- 15 Greenhouse Gas Emissions - 16 Peak Electricity Demand Reduction	22
		Water	- 18 Potable Water	12
Home star v4.1	Life Cycle Assessment (LCA)	N.A	N.A	N.A
	Embodied Energy (EE)	Materials	- MAT-1 Sustainable Materials	15
		Waste	- WST-1 Construction Waste Minimization	
	Operational Energy (OE)	Energy, Health and Comfort	- EHC-1 Thermal Comfort - EHC-2 Efficient Space Heating - EHC-5 Hot Water Heating - EHC-8 Renewable Energy	39
		Water	- WAT-1 Water Use - WAT-2 Sustainable Water Supply	14

Figure 3: Breakdown of Life Cycle Assessment, Embodied Energy and Operational Energy within each GBRS

In 2022, Wai Lam Ng et. al., conducted a study on the integration and application of life cycle energy assessment methodology in the most widely used GBRS (namely BREAAM, LEED, CASBEE, GBI, Green Mark, GreenRE, Green Ship and Green Star). It is highlighted in their study that EE is often overlooked in GBRS's (Wai Lam Ng et. Al, 2022). Results show that EE holds 16-19% of total energy in non-green and green-rated non-residential buildings and therefore EE should not be neglected in GBRS (Wai Lam Ng et. Al, 2022).

There has been significant effort to reduce the OE of buildings, as GBRS are largely focused on a buildings 'operational stage' (Wai Lam Ng et. Al, 2022). Considering a large variety of GBRS (namely BREAAM, LEED, CASBEE, GBI, Green Mark, GreenRE, Green Ship and Green Star), energy efficiency criteria has the largest weighting, ranging from 19-61%, while EE only accounts for 9-12.5% of the total weight (Wai Lam Ng et. Al, 2022). According to Abdelaal, F. *et al.,* (2022), whole building LCA criteria weighting in the studied international GBRS's is less than 6% in each system. Wai Lam Ng et. al. (2022) state that: "The low emphasis of EE assessment in the existing GBCSs resulted in the ineffectiveness to minimize the overall energy use for green-rated buildings." Regardless of the wide implementation of GBRS's, Abdelaal, F. *et al*., (2022) emphasize that buildings carbon emissions have continued to rise by nearly 1% per year since 2010.

2.2.4. Construction Materials in GBRS

According to Wai Lam Ng et. al. (2022), to effectively reduce the EE of a buildings life cycle, efforts could be focused on construction materials. Construction materials contribute to 68-74% of total EE which can be greatly reduced using low-embodied or recycled construction materials (Wai Lam Ng et. Al, 2022). Recycled steel should be encouraged in GBRS's (Wai Lam Ng et. Al, 2022).

In Pai, V, *et al.,* (2021) study titled *"Whole building life cycle assessment for buildings: A case study ON HOW to achieve the LEED credit",* the author emphasises the importance of understanding the LCA system boundaries. A WBLCA was conducted in the study (with cradle-to-grave system boundaries) which revealed that a wood-framed building had less environmental impact when compared to a lightweight steel frame building. This conclusion was coherent with various other studies which indicate that wood requires less fossil fuel energy to manufacture into usable products than steel and concrete (Pai, V, *et al.,* 2021). Important to note in this study is that when conducting a cradle-to-cradle analysis, steel frame buildings may show lower environmental impacts than a wood frame building (Pai, V, *et al.,* 2021). This is due to the fact that steel is easier to reuse and recycle at the end of a buildings life span when compared to wood (Pai, V, *et al.,* 2021). As wood contains a large amount of adhesive agents, paints and other additives, it requires much more energy to make it reusable than steel. In the LEED rating system, specifications require a cradle-to-grave analysis. Pai, V, *et al.,* (2021) argue that it is important to analysis the comparison between cradle-to-grave and cradle-to-cradle assessment impacts.

2.2.5. Conclusion

It is apparent in all of the above literature that the focus of GBRS's needs to shift to account, to a larger extent, EC emissions. LCA should be a crucial consideration in GBRS's in order to adequately assess a building's environmental impact. As LCA and EC are not compulsory considerations in GBRS's, buildings are receiving high green building certifications without in-depth consideration of EC. As buildings become increasing efficient in OC, EC (largely including building material choices) becomes increasingly important. In the next chapter of this thesis, the allocation of points within the 'Materials & Resources' (MR) category of the LEED rating system will be understood through the analysis of LEED certified building's.

UNDERSTANDING EMBODIED ENERGY AND OPERATIONAL ENERGY IN GREEN BUILDING RATING SYSTEMS THROUGH LEED CERTIFIED BUILDING EXAMPLES

3.1. Introduction to Chapter 3

The LEED (Leadership in Energy and Environmental Design) Rating System is the most widely used Green Building Rating System (GBRS) (US Green Building Council, 2019). It was developed by US Green Building Council and is now utilized in over 160 countries worldwide. There are four levels of LEED Certification; the lowest level is 'Certified' (building's obtaining 40-49 points), followed by 'Silver' (buildings obtaining 50-59 points) and 'Gold' (building's obtaining 60-79 points). 'Platinum' is the highest rating a building can receive (building's obtaining 80+ points). On the following page (Figure 4) is the LEED v4 Checklist, highlighting the category and credit distribution within each category for LEED v4. Within each category, there are 'prerequisite's', meaning compulsory credits that the building must achieve. All other 'credit's' are voluntary.

In this Chapter, 5 LEED Certified Building's, retrieved from the LEED website will be analysed in respect to their credit allocation and credit achievement of Operational Energy (OE) and Embodied Energy (EE) credits. As discussed in the previous chapter, many building's are receiving high green building certification's whilst largely neglecting EE considerations. Many Green Building Rating System's (GBRS's) do not require Life Cycle Assessment (LCA) conduction and almost solely focus on OE, resulting in misleading assessment outcomes.

The chosen case studies span across uses of Residential, Commercial and Hospitality building uses and fall under the category of "LEED BC+C: New Construction". These case studies were selected due to their high degree of data availability on the LEED Database.

LEED v4 for BD+C: New Construction and Major Renovation
Project Checklist

Y	?	N			
			Credit	Integrative Process	1
0	**0**	**0**		**Location and Transportation**	**16**
			Credit	LEED for Neighborhood Development Location	16
			Credit	Sensitive Land Protection	1
			Credit	High Priority Site	2
			Credit	Surrounding Density and Diverse Uses	5
			Credit	Access to Quality Transit	5
			Credit	Bicycle Facilities	1
			Credit	Reduced Parking Footprint	1
			Credit	Green Vehicles	1
0	**0**	**0**		**Sustainable Sites**	**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
			Credit	Site Development - Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
0	**0**	**0**		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
			Credit	Water Metering	1
0	**0**	**0**		**Energy and Atmosphere**	**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
			Credit	Renewable Energy Production	3
			Credit	Enhanced Refrigerant Management	1
			Credit	Green Power and Carbon Offsets	2

Y	?	N			Points
0	0	0	**Materials and Resources**		**13**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
			Credit	Construction and Demolition Waste Management	2
0	0	0	**Indoor Environmental Quality**		**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1
0	0	0	**Innovation**		**6**
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	0	0	**Regional Priority**		**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	0	0	**TOTALS**	Possible Points:	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

Figure 4: LEED v4 Checklist. Reference: US Green Building Council

3.2. LEED Certified Building 1: International Olympic Committee Headquarters

Address: Route de Vidy 9, Lausanne, Switzerland, 1007

Rating System: LEED BC+C: New Construction | LEED v4

Last certified on: 07 June 2019

Certification level: Platinum (94 points)

Size: 22 600 sqm

Architects: 3XN Architects

Figure 5: Olympic House glass and steel façade. Reference: https://www.archdaily.com/919974/olympic-house-3xn

3.1.1. Building Information and Sustainable Principles:

The International Olympic Committee Headquarters is a 25,000 square meter building opened in 2019 in Lausanne, Switzerland and designed by architects 3XN (U.S. Green Building Council, 2019). It is an open-plan commercial building, mainly serving as office space and occupied by 500 members of the Olympic Committee. In 2019, the new International Olympic Committee Headquarters had received the most points (94) of any LEED v4 Building Design and Construction project to date and was hailed by the public as 'the most sustainable modern building in Switzerland' and 'one of the most sustainable structures in the world' (McGrath, K, 2019).

Key features of the design included considering a Circular Economy, User Wellness, Resource Efficiency and Adherence and Excellence in LEED. Figure 7 shows a perspective view of the building, Figure 6 shows the Glass façade with Steel framing and Figure 5 shows the building interior and internal staircase (U.S. Green Building Council, 2019).

3.1.2. Materiality:

According to U.S. Green Building Council (2019), 95% of materials from an existing building on the site were deconstructed and reused in the Olympic House and over 75% of the construction waste on site while building the Olympic House was recycled. Building material preference was given to materials and furniture that have a lower than average environmental footprint over their life cycle (U.S. Green Building Council, 2019). The project team did conduct a Life Cycle Assessment (LCA), achieving 3 out of 5 available points.

The building consists of a concrete structure, with a full glass façade on all four sides of the building. The glass facades contains additional steel frames and there is an accessible green roof above the first storey. The abundant use of glass can be seen in the 'Representational Materiality Elevation' (Figure 9).

What is interesting to note is that although this building scored extremely highly in the LEED certification system, and is considered to be 'one of the most sustainable structures in the world', it's LCA score is less than excellent. The building only achieved 3 out of 5 points for the "building life cycle impact reduction", translating to a 60% achievement, not in line with the extremely high scores received for other categories. Arguably, it is not fit to crown such a building as the 'one of the most sustainable structures in the world' when the LCA result is less than high achieving. This alludes to the skewed interpretation of the LEED Rating System (as well as many other GBRS), which prioritize OE to a misleadingly high amount.

Figure 8: Figure x: Olympic House glass and steel façade and green roof. Reference: https://www.archdaily.com/919974/olympic-house-3xn

Figure 8: : Interior showing floors and internal timber staircase. Reference: https://www.archdaily.com/919974/olympic-house-3xn

Figure 8: Glass façade showing Steel Framing. Reference: https://www.archdaily.com/919974/olympic-house-3xn

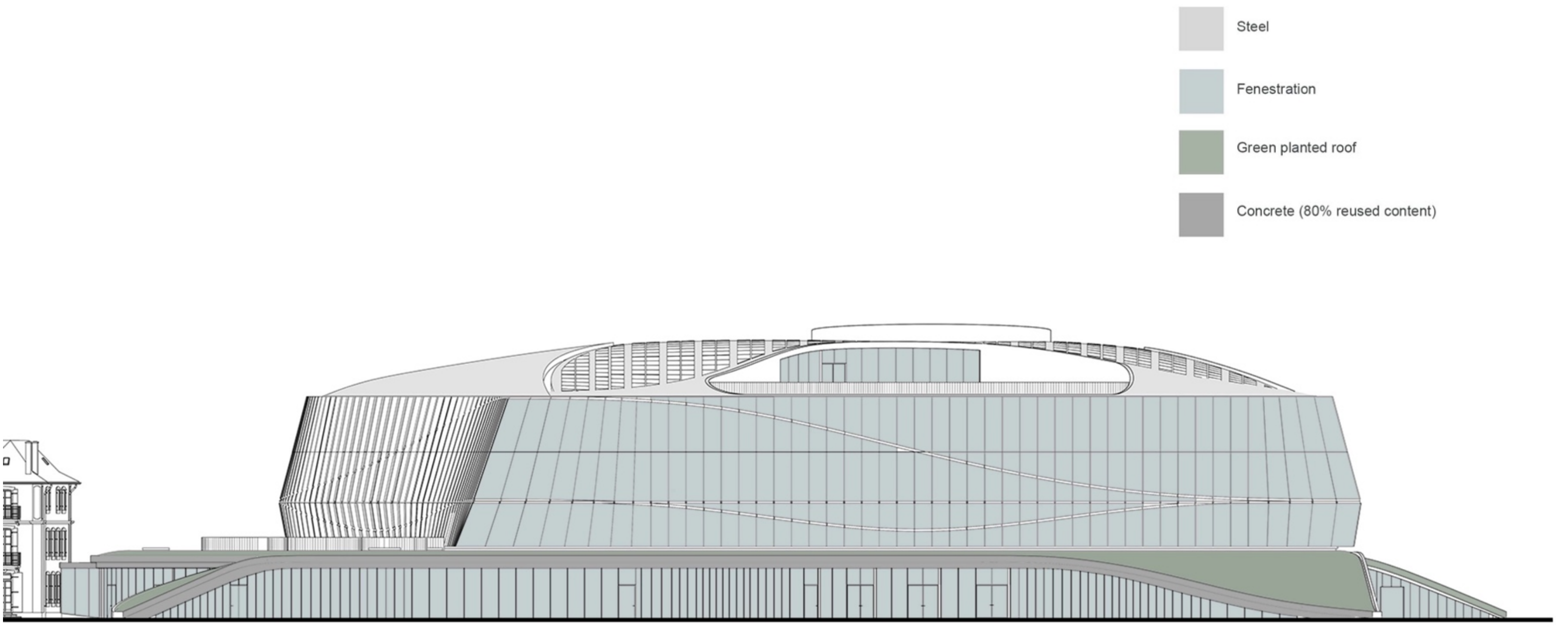


Figure 9: Representational Materiality Elevation

3.1.3. LEED point allocation:

The International Olympic Committee Headquarters scored very highly in LEED v.4, achieving 94 out of 100 points (the highest score out of the 5 analysed case studies). The histogram below (Figure 10) shows the 'Percentage (%) of credits achieved per category', based on the LEED scorecard for the Olympic House (Figure13). Many of the categories achieved 100% of available credits (Sustainable Sites, Water Efficiency, Innovation, Regional Priority, Integrative Process Credits). The 'Materials and Resources' category, relating directly to EE, is the lowest scoring category, achieving 62% of credits available (8/13 points). The 'Materials and Resources' (MR) category score is significantly lower than the categories relating to OE. 'Water Efficiency' (WE) scored 100% of total category credit points available and 'Energy and Atmosphere' (EA) stored 94% of available points. Figure 11 is a pie chart showing the distribution of LEED v4 Category Points. It is clear that 'Energy and Atmosphere' is the greatest contributor to the overall points, accounting for 33 points, followed by 'Location & Transportation', accounting for 20 points. The 'Material & Resources' category accounts for 10 points.

When considering the distribution of OE and EE in LEED v4, it is clear that OE occupies more points. Summing the 'Energy & Atmosphere' and 'Water Efficiency' categories, OE occupies 44 of 110 total points (40%). EE ('Materials & Resources' category) has 10 points of 110 total points (9%). This ratio, 40% and 9% to OE and EE accordingly, does not accurately depict the distribution of OE and EE in a life-cycle approach (as alluded to in the previous Chapter).

3.1.4. Point Allocation Graphs:

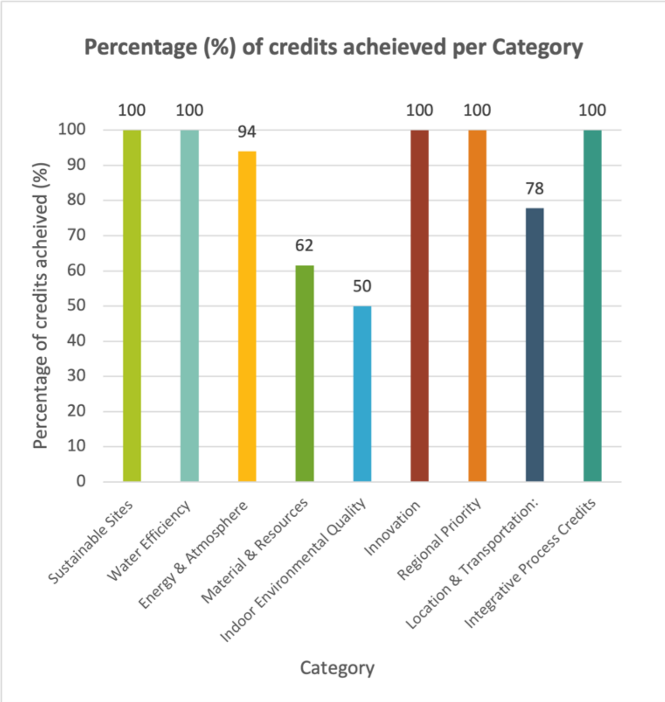


Figure 10: Graph showing the percentage of credits achieved per category for Case Study Two. Reference: Author.

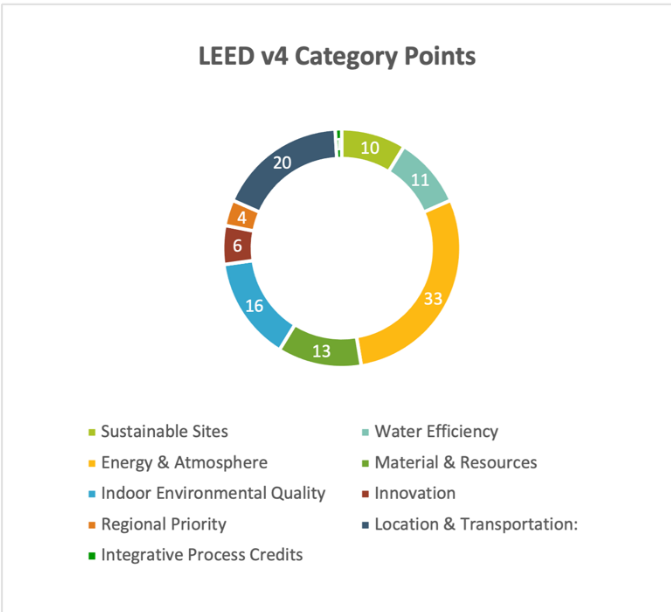


Figure 11: Graph showing the distribution of category points in LEED version 4. Reference: Author.

3.1.5. LEED scorecard for The International Olympic Committee Headquarters:

1000059080, Lausanne

Olympic House

LEED BD+C: New Construction (v4)

PLATINUM, AWARDED SEP 2020

SUSTAINABLE SITES		AWARDED: 10 / 10
Prereq	Construction activity pollution prevention	0 / 0
Credit	Site assessment	1 / 1
Credit	Site development - protect or restore habitat	2 / 2
Credit	Open space	1 / 1
Credit	Rainwater Mgmt	3 / 3
Credit	Heat island reduction	2 / 2
Credit	Light pollution reduction	1 / 1

WATER EFFICIENCY		AWARDED: 11 / 11
Prereq	Outdoor water use reduction	0 / 0
Prereq	Indoor water use reduction	0 / 0
Prereq	Building-level water metering	0 / 0
Credit	Cooling tower water use	2 / 2
Credit	Water metering	1 / 1
Credit	Outdoor water use reduction	2 / 2
Credit	Indoor water use reduction	6 / 6

ENERGY & ATMOSPHERE		AWARDED: 31 / 33
Prereq	Fundamental commissioning and verification	0 / 0
Prereq	Minimum energy performance	0 / 0
Prereq	Building-level energy metering	0 / 0
Prereq	Fundamental refrigerant Mgmt	0 / 0
Credit	Enhanced commissioning	6 / 6
Credit	Advanced energy metering	1 / 1
Credit	Demand response	0 / 2
Credit	Renewable energy production	3 / 3
Credit	Enhanced refrigerant Mgmt	1 / 1
Credit	Green power and carbon offsets	2 / 2
Credit	Optimize energy performance	18 / 18

MATERIAL & RESOURCES		AWARDED: 8 / 13
Prereq	Storage and collection of recyclables	0 / 0
Prereq	Construction and demolition waste Mgmt planning	0 / 0
Credit	Building life-cycle impact reduction	3 / 5
Credit	Building product disclosure and optimization - environmental product d...	1 / 2
Credit	Building product disclosure and optimization - sourcing of raw materia...	1 / 2
Credit	Building product disclosure and optimization - material ingredients	1 / 2
Credit	Construction and demolition waste Mgmt	2 / 2

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 9 / 16
Prereq	Minimum IAQ performance	0 / 0
Prereq	Environmental tobacco smoke control	0 / 0
Credit	Enhanced IAQ strategies	1 / 2
Credit	Low-emitting materials	3 / 3
Credit	Construction IAQ Mgmt plan	1 / 1
Credit	IAQ assessment	1 / 2
Credit	Thermal comfort	0 / 1
Credit	Interior lighting	2 / 2
Credit	Daylight	0 / 3
Credit	Quality views	1 / 1
Credit	Acoustic performance	0 / 1

INNOVATION		AWARDED: 6 / 6
Credit	Innovation	5 / 5
Credit	LEED Accredited Professional	1 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 4 / 4
Credit	Optimize energy performance	1 / 1
Credit	Thermal comfort	0 / 1
Credit	Sensitive land protection	1 / 1
Credit	Site development - protect or restore habitat	1 / 1
Credit	Rainwater Mgmt	1 / 1
Credit	Light pollution reduction	0 / 1

LOCATION & TRANSPORTATION		AWARDED: 14 / 20
Credit	LEED for Neighborhood Development location	0 / 16
Credit	Sensitive land protection	1 / 1
Credit	High priority site	2 / 2
Credit	Surrounding density and diverse uses	4 / 5
Credit	Access to quality transit	4 / 5
Credit	Bicycle facilities	1 / 1
Credit	Reduced parking footprint	1 / 1
Credit	Green vehicles	1 / 1

INTEGRATIVE PROCESS CREDITS		AWARDED: 1 / 1
Credit	Integrative process	1 / 1

TOTAL	94 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Figure 13: LEED Scorecard for the Olympic House (US Green Building Council, 2020)

3.2. LEED Certified Building 2: HITT Contracting CoLab

Address: 2757 Hartland Road, Falls Church, Virginia, United States, 22043

Rating System: LEED BC+C: New Construction | LEED v4

Last certified on: 01 August 2019

Certification level: Platinum (80 points)

Size: 800 sqm

Architects: William McDonough + Partners

Figure 16: HIIT Contracting CoLab, Glulam and CLT Structure. Reference: https://www.hitt.com/research-and-

Figure 16: HIIT interior with exposed timber structure. Reference: https://www.hitt.com/research-and-

Figure 16: HIIT Contracting CoLab interior. Reference: https://www.hitt.com/research-and-development/colab/

3.2.1. Building Information and Sustainable Principles:

The HIIT Contracting CoLab is a 8,600 square feet building located in Falls Church, VA. It is a designated space for research and testing that will "rapidly transform the construction and real estate industries" (U.S. Green Building Council, 2019).

The building optimizes natural daylight, has an array of photovoltaic solar panels and optimizes a water-based, hydronic method of heating using a closed loop recirculating system. More than 30% of the site is open space, planted with indigenous vegetation and the South side of the building features a green wall including 8 different plant species. The exterior rainscreen system was designed with disassembly in mind with each panel being easy to remove. Educational information about the building's sustainability is readily available and displayed within the building (U.S. Green Building Council, 2019).

3.2.2. Materiality:

The HIIT Contracting CoLab is a Cross Laminated Timber (CLT) and Glulam structure, as can be seen in Figure 13. The CLT is used for coloumns, beams as well as floor slabs and was sourced from FSC certified Black Spruce. As seen in Figure's 11 and 12, the building's structure, as well as external and internal walls (also comprised of CLT and timber infill) are exposed, minimizing material use (a key consideration in 'sustainable design'). The building contains 'healthy materials' which are free from potentially harmful chemicals. Materials with transparent documentation, including Cradle-to-Cradle certification were prioritized. Cherry and Maple trees were harvested from site and reclaimed as custom doors and other timber elements (U.S. Green Building Council, 2019).

The 'Material Representational Elevations' below (Figures 17-20) depict the proportion of CLT structure and glass openings. The glass used for fenestration is low-e compliant. The project team decided on the largely timber material selection due to its favourable LCA results.

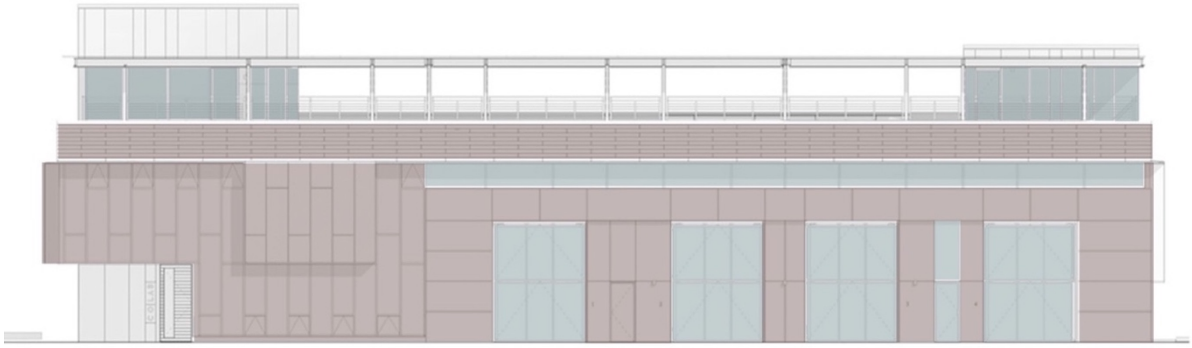


Figure 18: South Elevation. Reference: ArchDaily, edited by Author.

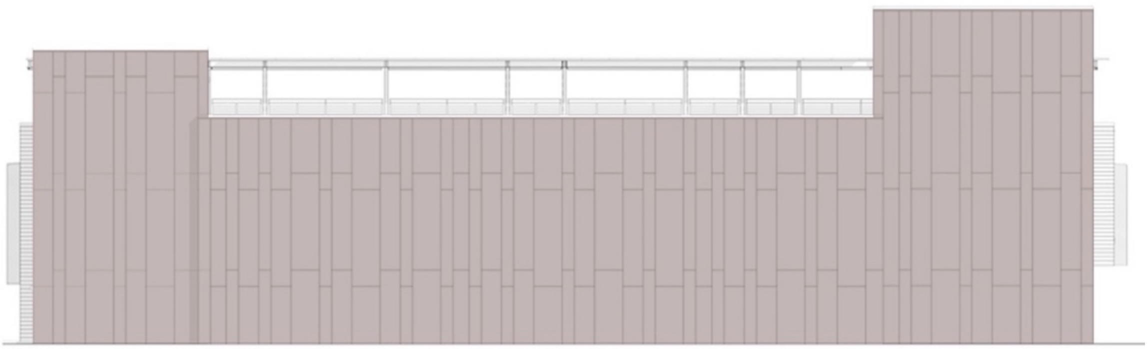


Figure 17: North Elevation. Reference: ArchDaily, edited by Author.

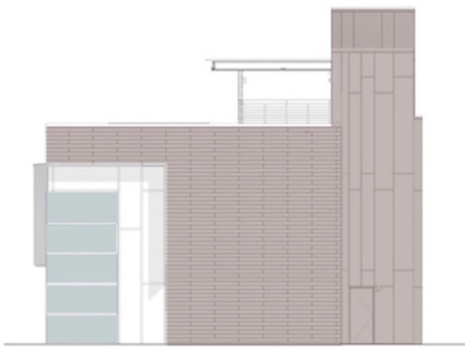
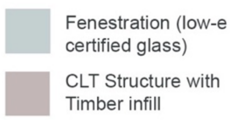


Figure 20: East Elevation. Reference: ArchDaily, edited by Author.

Figure 19: West Elevation. Reference: ArchDaily, edited by Author.



3.2.3. LEED Point Allocation:

In line with the point allocation analysed in LEED Certified Building 1 (Olympic House), the HIIT Contracting CoLab received a higher percentage of achievable credits for the categories associated with OE than those associated with EE. As can be seen in Figure 20 (below), the highest percentage of achievable credits was achieved in the 'Innovation' and 'Integrative Process Credits' categories. 82% of achievable credits are received for the EA category and 73% of credits were achieved for the WE category. The MR category scored 69% of available credits. Although the percentage of credits acquired for the MR (relating to EE) category is lower than that of WE and EA (relating to OE), the project team did conduct a building Whole Building LCA and received 3 out of 5 points for building "life-cycle impact reduction".

The HIIT Contacting CoLab achieved the highest score for the MR category out of all the studied LEED certified building's. This is largely due to material selection, the use bio-based materials such as Glulam timber structure and CLT walls with preferable LCA results.

Figure 22 (below) shows the distribution of points within categories for LEED v4. It is clear that the EA category occupies the most points, followed by 'Location and Transportation'. 10 points are available for the 'Materials and Resources' category.

3.2.4. Point allocation graphs:

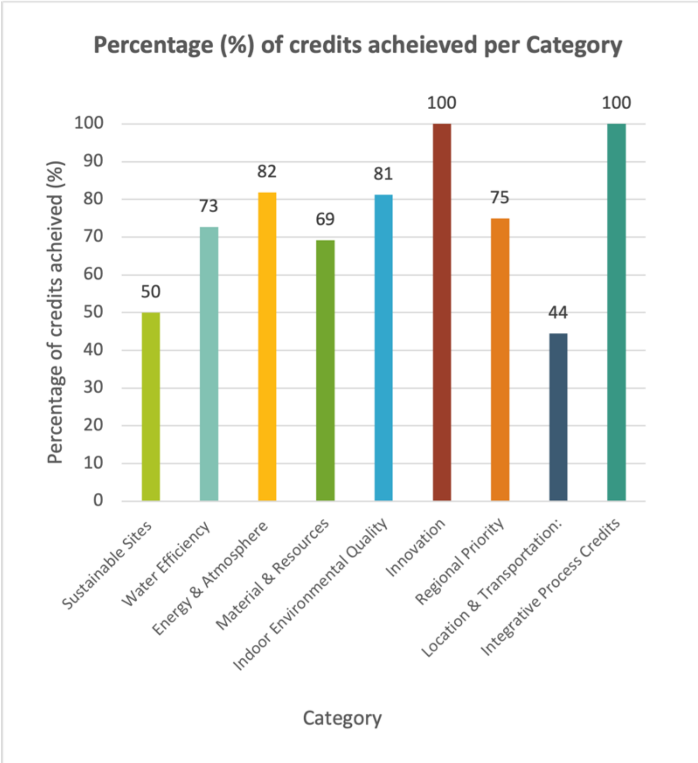


Figure 21: Graph showing the percentage of credits achieved per category for Case Study Three. Reference: Author.

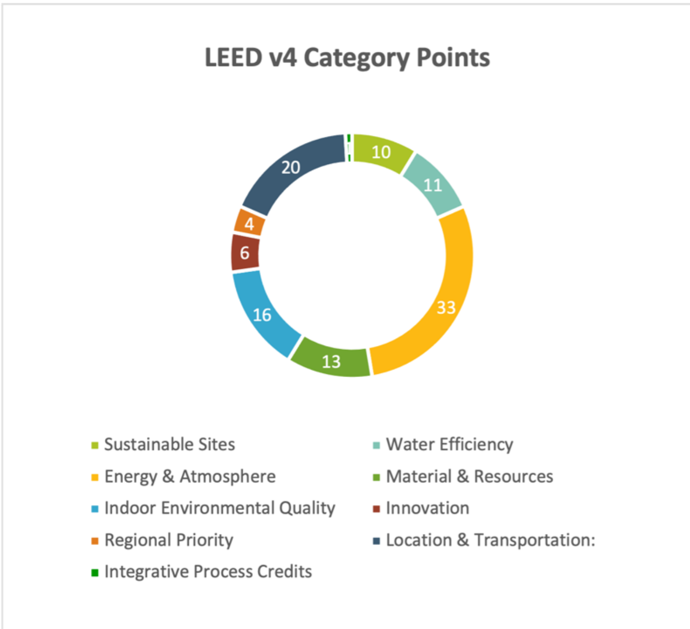


Figure 22: Graph showing the distribution of category points in LEED version 4. Reference: Author.

3.2.5. LEED scorecard for HIIT CoLAB:

1000105962, Falls Church, Virginia

CoLAB

LEED BD+C: New Construction (v4)

PLATINUM, AWARDED AUG 2019

SUSTAINABLE SITES		AWARDED: 5 / 10
Prereq	Construction activity pollution prevention	0 / 0
Credit	Site assessment	1 / 1
Credit	Site development - protect or restore habitat	0 / 2
Credit	Open space	1 / 1
Credit	Rainwater Mgmt	0 / 3
Credit	Heat island reduction	2 / 2
Credit	Light pollution reduction	1 / 1

WATER EFFICIENCY		AWARDED: 8 / 11
Prereq	Outdoor water use reduction	0 / 0
Prereq	Indoor water use reduction	0 / 0
Prereq	Building-level water metering	0 / 0
Credit	Cooling tower water use	0 / 2
Credit	Water metering	1 / 1
Credit	Outdoor water use reduction	2 / 2
Credit	Indoor water use reduction	5 / 6

ENERGY & ATMOSPHERE		AWARDED: 27 / 33
Prereq	Fundamental commissioning and verification	0 / 0
Prereq	Minimum energy performance	0 / 0
Prereq	Building-level energy metering	0 / 0
Prereq	Fundamental refrigerant Mgmt	0 / 0
Credit	Enhanced commissioning	3 / 6
Credit	Advanced energy metering	1 / 1
Credit	Demand response	0 / 2
Credit	Renewable energy production	3 / 3
Credit	Enhanced refrigerant Mgmt	0 / 1
Credit	Green power and carbon offsets	2 / 2
Credit	Optimize energy performance	18 / 18

MATERIAL & RESOURCES		AWARDED: 9 / 13
Prereq	Storage and collection of recyclables	0 / 0
Prereq	Construction and demolition waste Mgmt planning	0 / 0
Credit	Building life-cycle impact reduction	3 / 5
Credit	Building product disclosure and optimization - environmental product d...	1 / 2
Credit	Building product disclosure and optimization - sourcing of raw materia...	2 / 2
Credit	Building product disclosure and optimization - material ingredients	1 / 2
Credit	Construction and demolition waste Mgmt	2 / 2

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 13 / 16
Prereq	Minimum IAQ performance	0 / 0
Prereq	Environmental tobacco smoke control	0 / 0
Credit	Enhanced IAQ strategies	2 / 2
Credit	Low-emitting materials	3 / 3
Credit	Construction IAQ Mgmt plan	1 / 1
Credit	IAQ assessment	1 / 2
Credit	Thermal comfort	1 / 1
Credit	Interior lighting	2 / 2
Credit	Daylight	2 / 3
Credit	Quality views	1 / 1
Credit	Acoustic performance	0 / 1

INNOVATION		AWARDED: 6 / 6
Credit	Innovation	5 / 5
Credit	LEED Accredited Professional	1 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 3 / 4
Credit	Optimize energy performance	1 / 1
Credit	Access to quality transit	0 / 1
Credit	Site development - protect or restore habitat	0 / 1
Credit	Rainwater Mgmt	0 / 1
Credit	Outdoor water use reduction	1 / 1
Credit	Indoor water use reduction	1 / 1

LOCATION & TRANSPORTATION		AWARDED: 8 / 20
Credit	LEED for Neighborhood Development location	0 / 16
Credit	Sensitive land protection	1 / 1
Credit	High priority site	1 / 2
Credit	Surrounding density and diverse uses	2 / 5
Credit	Access to quality transit	3 / 5
Credit	Bicycle facilities	0 / 1
Credit	Reduced parking footprint	0 / 1
Credit	Green vehicles	1 / 1

INTEGRATIVE PROCESS CREDITS		AWARDED: 1 / 1
Credit	Integrative process	1 / 1

TOTAL	80 / 110

40-49 Points 50-59 Points 60-79 Points 80+ Points

Figure 23: LEED Scorecard for CoLAB (US Green Building Council, 2019)

3.3. LEED Certified Building 3: Lucile Packard Children's Hospital Stanford

Address: 725 Welch Road, Palo Alto, California, United States, 94304

Rating System: LEED BC+C: New Construction |v3 - LEED 2009

Last certified on: 12 April 2018

Certification level: Platinum (82 points)

Size: 48 402 sqm

Architects: Perkins+Will

Figure 24: The Lucile Packard Children's Hospital Stanford. Reference: Gregorski, T. (2017)

3.3.1. Building Information and Sustainable Principles:

The Lucile Packard Children's Hospital Stanford is a health care system exclusively dedicated to children and expectant mothers. It is a 521,000 square foot building located in Palo Alto, CA. The hospital is an innovatively designed, colour-coded and child friendly space designed with eyecatching murals and art (U.S. Green Building Council, 2020). The building is designed to reduce energy consumption by 38% and energy costs by 45%. It utilizes horizontal louvers, vertical fins as well as displacement ventilation. The building enhances a connection to nature and the outdoors, utilizing biophilic design strategies (U.S. Green Building Council, 2020).

3.3.2. Materiality:

More than 28% of the buildings materials contain recycled content and more than 26% of materials were extracted or manufactured locally (within 500 miles of Palo Alto) (U.S. Green Building Council, 2020)..The outdoor canopy, the main public elevator tower, the panelling and trim in the cafeteria as well as a series of corner "nooks" were made from reclaimed redwood from a deconstructed naval hanger in a nearby area (U.S. Green Building Council, 2020). The building contains 'healthy materials', screening out products and materials that contain potentially toxic substances (U.S. Green Building Council, 2020).

3.3.3. LEED point allocation:

As can be seen in Figure 26, the Lucile Packard Children's Hospital scored 50% of possible credits for the 'Materials and Resources' category, being the lowest scoring category. No points have been allocated for the conduction of a LCA and it is assumed that the LEED v2009 used for this building assessment did not include LCA as an achievable credit. The highest scoring categories are 'Innovation' and 'Regional Priority' (100% of credits achieved), followed by 'Sustainable Sites' (92% of credits achieved).

The pie chart below, Figure 25, depicts the distribution of credits within the LEED v2009 certification. It is clear that the most points are awarded for the 'Energy and Atmosphere' credit, followed by 'Sustainable Sites'.

3.3.4. Point allocation graphs

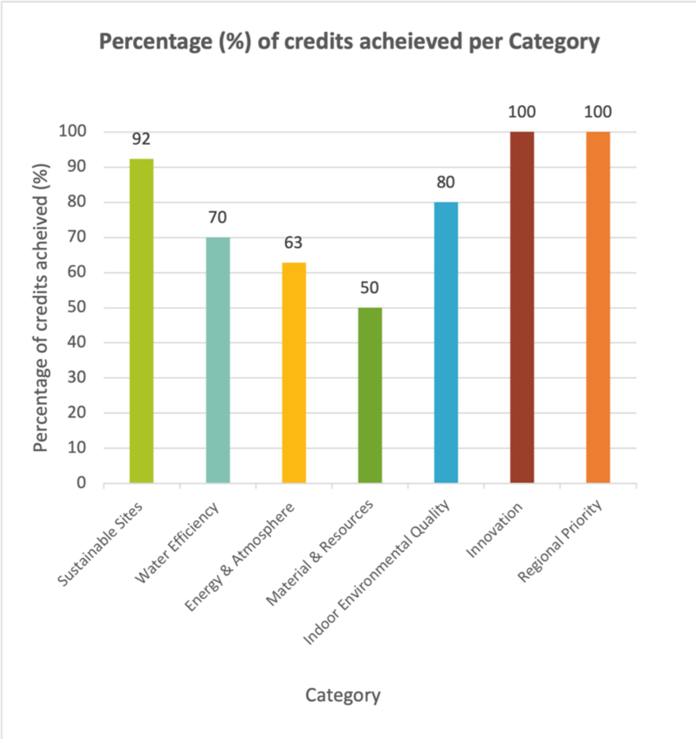


Figure 26: Graph showing the percentage of credits achieved per category for Example Four. Reference: Author.

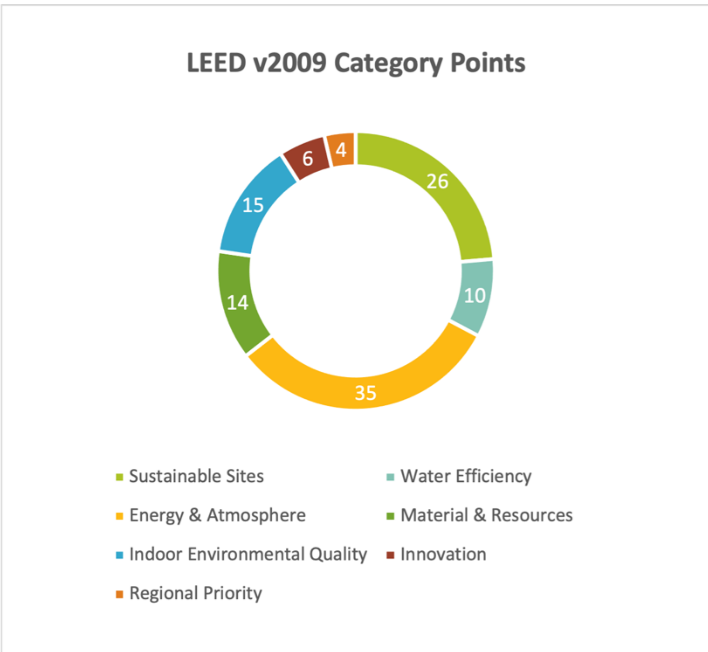


Figure 25: Graph showing the distribution of category points in LEED version 2009. Reference: Author.

3.3.5. LEED scorecard for The Lucile Packard Children's Hospital Stanford:

1000013696, Palo Alto, California

Lucile Packard Children's Hospital

LEED BD+C: New Construction (v2009)

PLATINUM, AWARDED APR 2018

SUSTAINABLE SITES		AWARDED: 24 / 26
SSp1	Construction activity pollution prevention	REQUIRED
SSc1	Site selection	1 / 1
SSc2	Development density and community connectivity	5 / 5
SSc3	Brownfield redevelopment	1 / 1
SSc4.1	Alternative transportation - public transportation access	6 / 6
SSc4.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc4.3	Alternative transportation - low-emitting and fuel-efficient vehicles	3 / 3
SSc4.4	Alternative transportation - parking capacity	2 / 2
SSc5.1	Site development - protect or restore habitat	0 / 1
SSc5.2	Site development - maximize open space	1 / 1
SSc6.1	Stormwater design - quantity control	1 / 1
SSc6.2	Stormwater design - quality control	1 / 1
SSc7.1	Heat island effect - nonroof	1 / 1
SSc7.2	Heat island effect - roof	1 / 1
SSc8	Light pollution reduction	0 / 1

WATER EFFICIENCY		AWARDED: 7 / 10
WEp1	Water use reduction	REQUIRED
WEc1	Water efficient landscaping	4 / 4
WEc2	Innovative wastewater technologies	0 / 2
WEc3	Water use reduction	3 / 4

ENERGY & ATMOSPHERE		AWARDED: 22 / 35
EAp1	Fundamental commissioning of building energy systems	REQUIRED
EAp2	Minimum energy performance	REQUIRED
EAp3	Fundamental refrigerant Mgmt	REQUIRED
EAc1	Optimize energy performance	15 / 19
EAc2	On-site renewable energy	0 / 7
EAc3	Enhanced commissioning	2 / 2
EAc4	Enhanced refrigerant Mgmt	0 / 2
EAc5	Measurement and verification	3 / 3
EAc6	Green power	2 / 2

MATERIAL & RESOURCES		AWARDED: 7 / 14
MRp1	Storage and collection of recyclables	REQUIRED
MRc1.1	Building reuse - maintain existing walls, floors and roof	0 / 3
MRc1.2	Building reuse - maintain interior nonstructural elements	0 / 1
MRc2	Construction waste Mgmt	2 / 2
MRc3	Materials reuse	0 / 2
MRc4	Recycled content	2 / 2

MATERIAL & RESOURCES		CONTINUED
MRc5	Regional materials	2 / 2
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	1 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 12 / 15
EQp1	Minimum IAQ performance	REQUIRED
EQp2	Environmental Tobacco Smoke (ETS) control	REQUIRED
EQc1	Outdoor air delivery monitoring	1 / 1
EQc2	Increased ventilation	1 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	1 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - flooring systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and agrifiber products	1 / 1
EQc5	Indoor chemical and pollutant source control	1 / 1
EQc6.1	Controllability of systems - lighting	0 / 1
EQc6.2	Controllability of systems - thermal comfort	1 / 1
EQc7.1	Thermal comfort - design	1 / 1
EQc7.2	Thermal comfort - verification	1 / 1
EQc8.1	Daylight and views - daylight	0 / 1
EQc8.2	Daylight and views - views	0 / 1

INNOVATION		AWARDED: 6 / 6
IDc1	Innovation in design	0 / 1
IDc2	LEED Accredited Professional	0 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 4 / 4
EAc2	On-site renewable energy	0 / 1
SSc1	Site selection	1 / 1
SSc2	Development density and community connectivity	1 / 1
SSc4.1	Alternative transportation - public transportation access	1 / 1
WEc1	Water efficient landscaping	1 / 1
WEc3	Water use reduction	0 / 1

TOTAL 82 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Figure 27: Lucile Hospital LEED Scorecard (US Green Building Council, 2018)

3.4. LEED Certified Building 4: National Museum of African American Hist

Address: 1500 Constitution Avenue, Washington, District of Columbia, United States, 20013-7012

Rating System: LEED BC+C: New Construction | v3 - LEED 2009

Last certified on: 27 February 2018

Certification level: Gold (66 points)

Size: 35 628 sqm

Architects: Adjaye Associates, Freelon Adjaye Bond, SmithGroup

Figure 28: National Musuem of African American Hist. Reference: Ekin Yalgin, National Musuem of African American History and Culture

3.4.1. Building Information and Sustainable Principles:

The National Museum of African American History and Culture opened it's doors on 24 September 2016 and welcomed more than 3,5 million visitors in it's first 2 years to celebrate and explore the African American story (U.S. Green Building Council, 2016). The museum houses a collection of nearly 40 000 historical and cultural artefacts with 3 000 on public display (U.S. Green Building Council, 2016). Sustainability principles of the building include 'passive design strategies'; including a "compact and climate responsive" building form, locating 60% of the space below ground (requiring less energy for heating and cooling), window overhangs and building programmes within a "nested" layout (protects exhibits from sun damage) (U.S. Green Building Council, 2016).

3.4.2. Materiality:

79% of the construction waste was recycled through stringent waste management control (U.S. Green Building Council, 2016). 23% of the materials used included recycled and recyclable content. Structural steel, metal ceilings, acoustic ceilings and gypsum board contented sources of recycled content and 25% of the materials used are regional (extracted or manufactured within 500 miles of the project site) (U.S. Green Building Council, 2016). Regional materials include structural steel, stainless steel, gypsum board, partitions and metal lockers. 66% of wood products used are certified by the Forest Stewardship Council (FSC) and contain 'Chain of Custody' certifications (U.S. Green Building Council, 2016).

The building's exterior design incorporates African American architectural traditions, drawing on traditional patterning. The architects (David Adjaye and team) extensively studied decorative ironwork found throughout southern architecture before making their design choice. The façade consists of approximately 1 200 ornate, bronze-coated cast aluminium panels, with the opacity between the panels varying for an interesting lighting effect (as seen below in Figure 29). In the interior, the terrazzo floors are "trimmed in bronze and speckled with African marble" (Cornachio, 2016).

3.4.3. LEED point allocation:

Figure 31 shows the percentage of points achieved (%) per category for the National Museum of African American Hist. As can be seen, the highest achieving categories are 'Innovation' (achieving 100% of available points), followed by 'Water Efficiency (achieving 80% of available points). The lowest scoring categories are 'Energy & Atmosphere' (achieving only 40% of available points) and 'Materials & Resources' (achieving only 43% of available points). This is the first LEED certified building example which scored a lower result for 'Energy & Atmosphere' than 'Materials & Resources' (with a difference of only 3%).

Figure 30 depicts the distribution of credits available in LEED version 2009. As also seen in the previous first LEED certified building example (above), the category 'Energy & Atmosphere' occupies the most points (35 points), followed by 'Sustainable Sites' (26 points). 14 points are allocated the 'Materials & Resources' category.

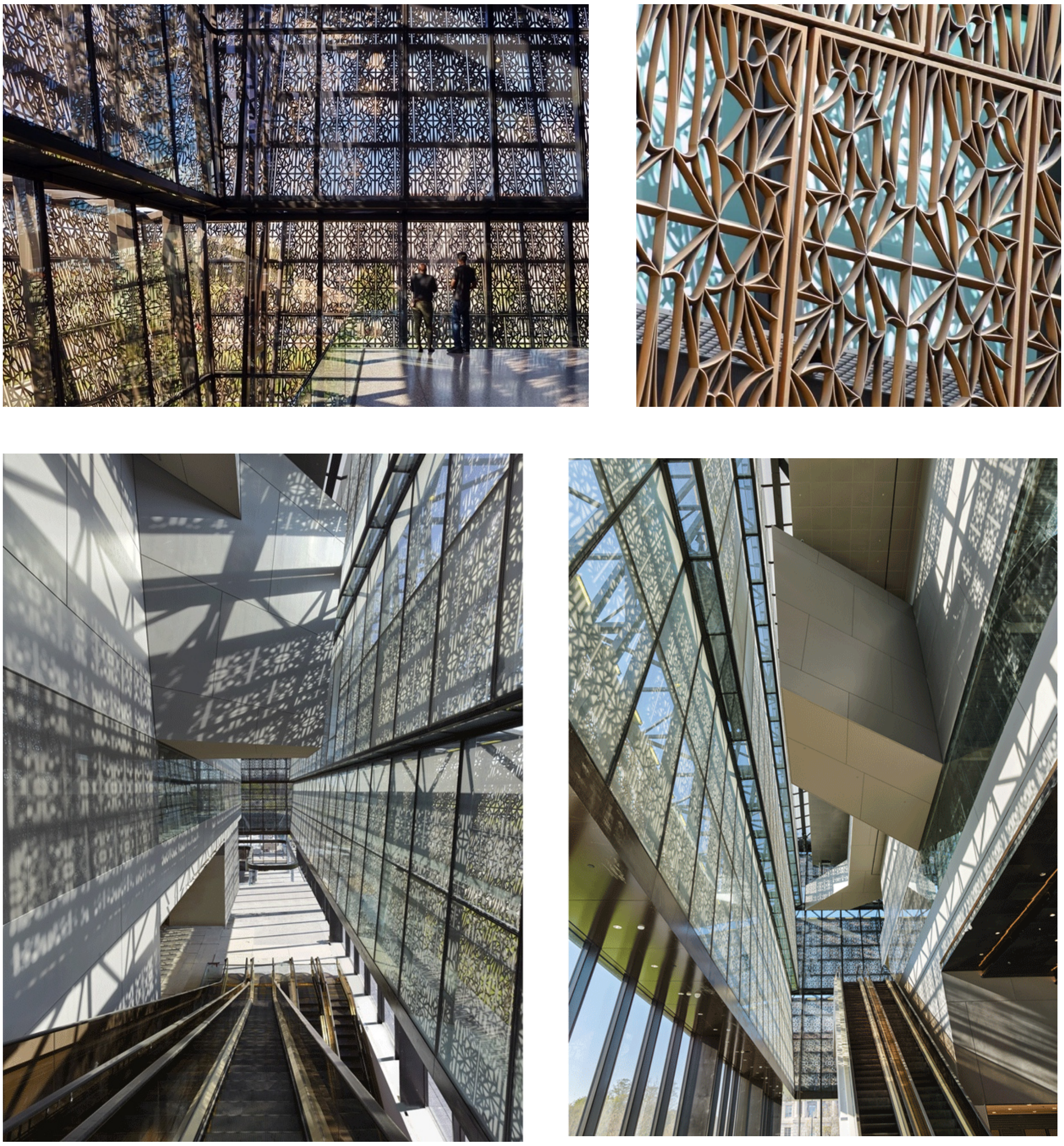


Figure 29: National Museum of African American History Facade Photographs. Reference: https://architizer.com/blog/practice/details/architectural-details-david-adjaye-smithsonian/

3.4.4. Point allocation graphs:

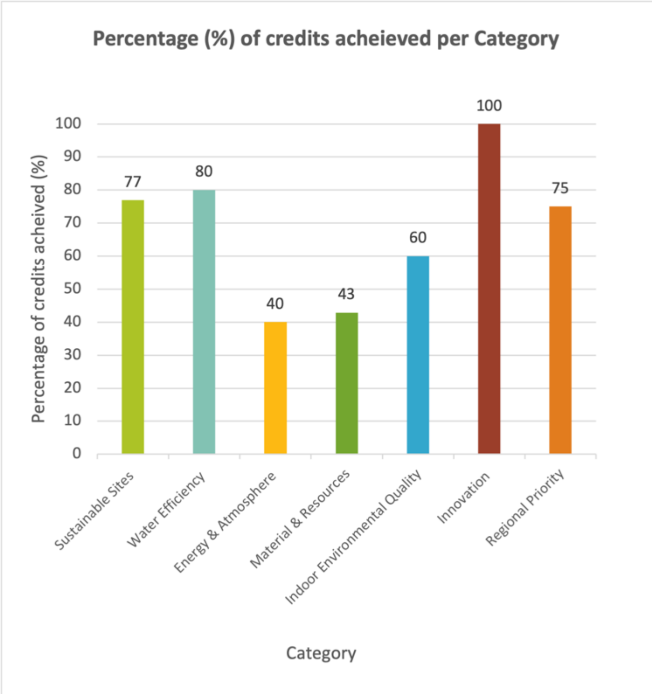


Figure 31:Graph showing the percentage of credits achieved per category for Example Five. Reference: Author.

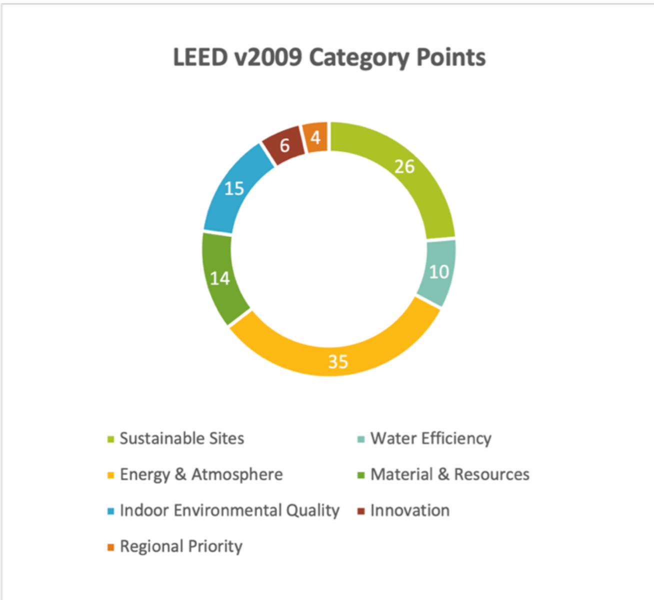


Figure 30: Graph showing the distribution of category points in LEED version 2009. Reference: Author.

3.4.5. LEED Scorecard for the National Museum of African American Hist:

1000017297, Washington, District of Columbia

National Museum of African American Hist

LEED BD+C: New Construction (v2009)

GOLD, AWARDED FEB 2018

SUSTAINABLE SITES		AWARDED: 20 / 26
SSp1	Construction activity pollution prevention	REQUIRED
SSc1	Site selection	1 / 1
SSc2	Development density and community connectivity	5 / 5
SSc3	Brownfield redevelopment	1 / 1
SSc4.1	Alternative transportation - public transportation access	6 / 6
SSc4.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc4.3	Alternative transportation - low-emitting and fuel-efficient vehicles	3 / 3
SSc4.4	Alternative transportation - parking capacity	0 / 2
SSc5.1	Site development - protect or restore habitat	0 / 1
SSc5.2	Site development - maximize open space	1 / 1
SSc6.1	Stormwater design - quantity control	0 / 1
SSc6.2	Stormwater design - quality control	0 / 1
SSc7.1	Heat island effect - nonroof	1 / 1
SSc7.2	Heat island effect - roof	1 / 1
SSc8	Light pollution reduction	0 / 1

WATER EFFICIENCY		AWARDED: 8 / 10
WEp1	Water use reduction	REQUIRED
WEc1	Water efficient landscaping	2 / 4
WEc2	Innovative wastewater technologies	2 / 2
WEc3	Water use reduction	4 / 4

ENERGY & ATMOSPHERE		AWARDED: 14 / 35
EAp1	Fundamental commissioning of building energy systems	REQUIRED
EAp2	Minimum energy performance	REQUIRED
EAp3	Fundamental refrigerant Mgmt	REQUIRED
EAc1	Optimize energy performance	6 / 19
EAc2	On-site renewable energy	1 / 7
EAc3	Enhanced commissioning	2 / 2
EAc4	Enhanced refrigerant Mgmt	0 / 2
EAc5	Measurement and verification	3 / 3
EAc6	Green power	2 / 2

MATERIAL & RESOURCES		AWARDED: 6 / 14
MRp1	Storage and collection of recyclables	REQUIRED
MRc1.1	Building reuse - maintain existing walls, floors and roof	0 / 3
MRc1.2	Building reuse - maintain interior nonstructural elements	0 / 1
MRc2	Construction waste Mgmt	2 / 2
MRc3	Materials reuse	0 / 2
MRc4	Recycled content	2 / 2

MATERIAL & RESOURCES		CONTINUED
MRc5	Regional materials	2 / 2
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 9 / 15
EQp1	Minimum IAQ performance	REQUIRED
EQp2	Environmental Tobacco Smoke (ETS) control	REQUIRED
EQc1	Outdoor air delivery monitoring	0 / 1
EQc2	Increased ventilation	0 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	1 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - flooring systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and agrifiber products	1 / 1
EQc5	Indoor chemical and pollutant source control	0 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - thermal comfort	0 / 1
EQc7.1	Thermal comfort - design	1 / 1
EQc7.2	Thermal comfort - verification	1 / 1
EQc8.1	Daylight and views - daylight	0 / 1
EQc8.2	Daylight and views - views	0 / 1

INNOVATION		AWARDED: 6 / 6
IDc1	Innovation in design	0 / 1
IDc2	LEED Accredited Professional	0 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 3 / 4
EAc1	Optimize energy performance	1 / 1
EAc2	On-site renewable energy	1 / 1
MRc1.1	Building reuse - maintain existing walls, floors and roof	0 / 1
SSc5.1	Site development - protect or restore habitat	0 / 1
SSc6.1	Stormwater design - quantity control	0 / 1
WEc2	Innovative wastewater technologies	1 / 1

TOTAL 66 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Figure 32: National Museum of African American History & Culture Scorecard (US Green Building Council, 2018)

3.5. LEED Certified Building 5: Milestone Lombos Student Housing

Address: Rua de Feitoria, Lisboa, Portugal, 1050-217

Rating System: LEED BC+C: New Construction | LEED v4.1

Last certified on: 19 July 2021

Certification level: Gold (60 points)

Size: 8 860 sqm

Architects: Ernst Hoffmann Ziviltechniker, Josef Weichenberger Architects

Figure 33: Milestone Lombos Student Housing. Reference: https://www.fragmentos.pt/en/projects/lombos-10

3.5.1. Building Information and Sustainable Principles:

The Milestone Lombos Student Housing building is located in Lisbon, Portugal and is 9,043 square meters in size. Key sustainability features of this project include open space on the ground as well as terrace, water efficient appliances, renewable energy systems, submitting 27 EPD's, adaptable sun projection elements.

3.5.2. Materiality:

As can be seen in the 'Representative Materiality Elevation' (Figure 37) below, the structure of the Milestone Lombos building is concrete, with 'brick and plaster' external and internal walls. The staircases are comprised of steel, with concrete elements surrounding the staircases. The ground floor is clad in steel/aluminium with sections of glass and fenestration. A repetitive window style is applied throughout the building, alluding to the brick and plaster construction. Although the recycled/reuse content of building materials is not clear, there appears to be a lack of consideration of low embodied building materials.

The design and building team conducted a whole building LCA, creating an understanding of relative environmental impacts of material choices (LCA data not accessible to the public). Although an LCA was conducted, the project only received 1 point (out of 5 available points) for the LCA outcome, alluding to a lack of consideration of low embodied building materials. Although the material choice does not seem carefully considered in terms of EC, the project did excelled at total construction waste reduction, with 24,23kg/square meter wastage (exceeding the initial goal of 36,6 kg/square meter).

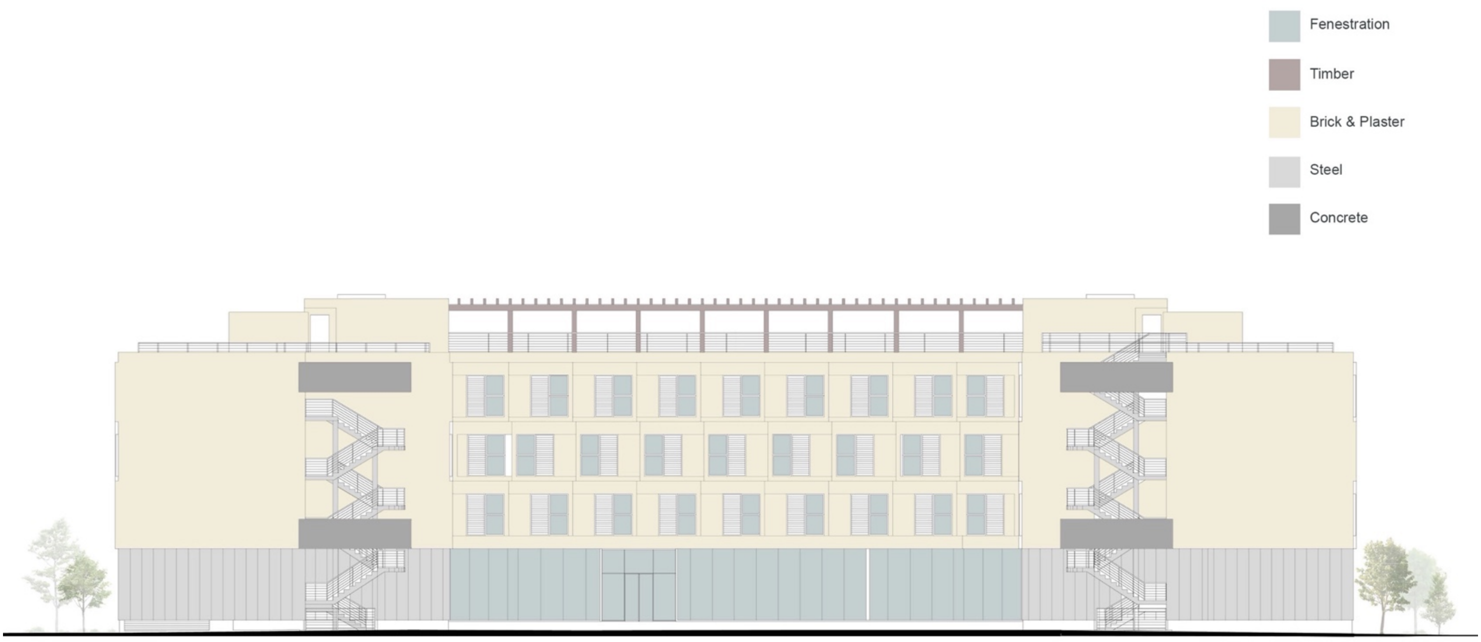


Figure 34: Milestone Lombos Student Housing Representative Materiality Elevation

Figure 37: Milestone Lombos Side-Façade. Reference: https://www.fragmentos.pt/en/projects/lombos-10

Figure 37: Facade detail. Reference: https://www.fragmentos.pt/en/projects/lombos-10

Figure 37: Front Façade. Reference: Reference: https://www.fragmentos.pt/en/projects/lombos-10

3.5.3. LEED point allocation:

As can be seen in Figure 38, the MR category scored only 31% of possible achievable credits, with only achieving 1 out of 5 points for the “Building Life-Cycle Impact Reduction” credit associated with the LCA result. This is the lowest score for the MR category out of all of the LEED certified building’s studied. The highest scoring categories for the Milestone Lombos project were ‘Integrative Process’ (scoring 100% of achievable credits) and ‘Innovation’ (83% of achievable credits). What is interesting to note in this case study is that the building achieved a LEED certification while only achieving 1 out of 5 points for the LCA conduction. This is arguably due to a lack of consideration of low-embodied building materials and flags awareness as buildings are receiving LEED certifications without significant efforts in lowering their upfront carbon emissions.

3.5.4. Point allocation graphs:

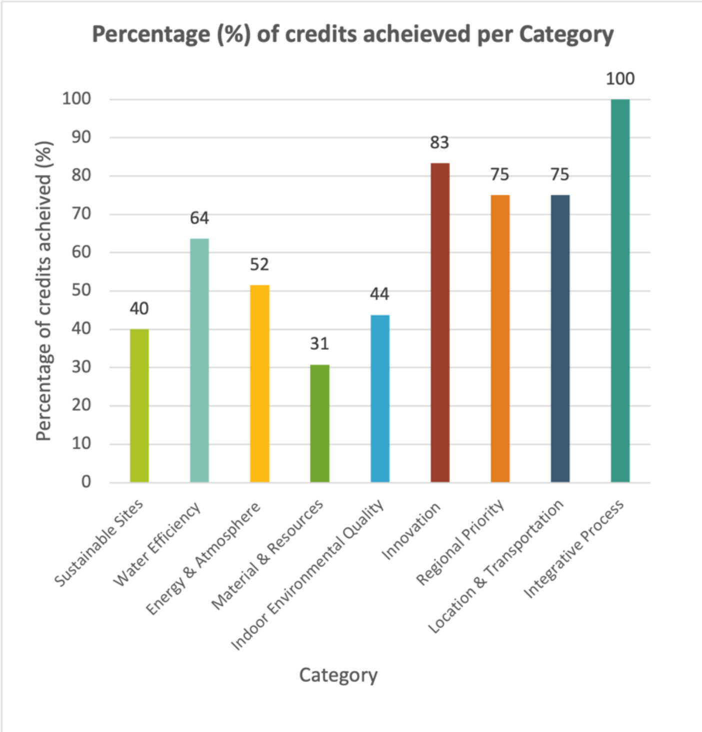


Figure 38: Graph showing the percentage of credits achieved per category for Case Study Six. Reference: Author.

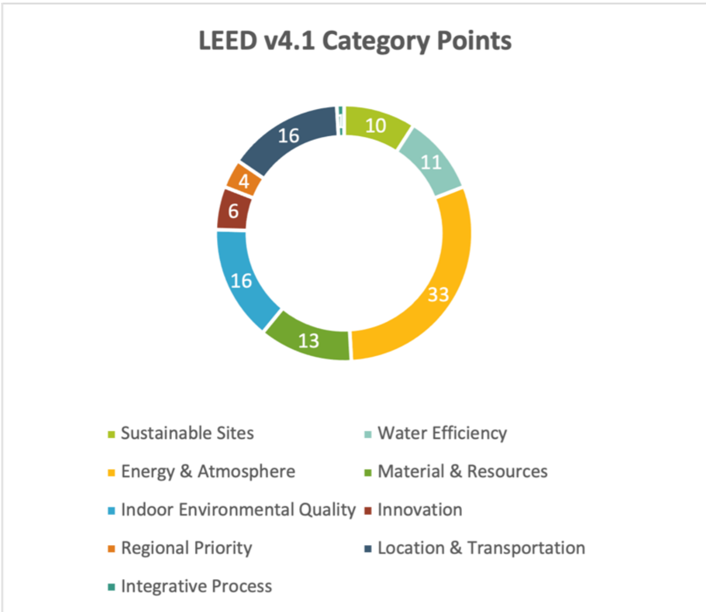


Figure 39: Graph showing the distribution of category points in LEED version 4.1. Reference: Author.

3.5.5. LEED scorecard for the Milestone Lombos Student Housing buildingN

1000123936, Lisboa

Milestone Lombos

LEED BD+C: Hospitality (v4.1)

GOLD, AWARDED JUL 2021

SUSTAINABLE SITES		AWARDED: 4 / 12
Prereq	Construction Activity Pollution Prevention	0 / 0
Credit	Site Assessment	1 / 1
Credit	Protect or Restore Habitat	0 / 2
Credit	Open Space	1 / 1
Credit	Rainwater Mgmt	0 / 3
Credit	Heat Island Reduction	1 / 2
Credit	Light Pollution Reduction	1 / 1
Prereq	Solar Access to Green Space	REQUIRED
Prereq	Offsite Financial Support for Habitat Protection	REQUIRED

WATER EFFICIENCY		AWARDED: 7 / 12
Prereq	Outdoor Water Use Reduction	0 / 0
Prereq	Indoor Water Use Reduction	0 / 0
Prereq	Building-Level Water Metering	0 / 0
Credit	Optimize Process Water Use	0 / 2
Credit	Water Metering	1 / 1
Credit	Outdoor Water Use Reduction	2 / 2
Credit	Indoor Water Use Reduction	4 / 7

ENERGY & ATMOSPHERE		AWARDED: 17 / 33
Prereq	Fundamental Commissioning and Verification	0 / 0
Prereq	Minimum Energy Performance	0 / 0
Prereq	Building-Level Energy Metering	0 / 0
Prereq	Fundamental Refrigerant Mgmt	0 / 0
Credit	Optimize Energy Performance	10 / 18
Credit	Enhanced Commissioning	3 / 6
Credit	Advanced Energy Metering	0 / 1
Credit	Renewable Energy	4 / 5
Credit	Enhanced Refrigerant Mgmt	0 / 1
Credit	Grid Harmonization	0 / 2

MATERIAL & RESOURCES		AWARDED: 4 / 13
Prereq	Storage and Collection of Recyclables	0 / 0
Prereq	Construction and Demolition Waste Mgmt Planning	0 / 0
Credit	Building Life-Cycle Impact Reduction	1 / 5
Credit	Environmental Product Declarations	1 / 2
Credit	Sourcing of Raw Materials	0 / 2
Credit	Material Ingredients	0 / 2
Credit	Construction and Demolition Waste Mgmt	2 / 2

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 10 / 19
Prereq	Minimum IAQ Performance	0 / 0
Prereq	Environmental Tobacco Smoke Control	0 / 0
Credit	Enhanced IAQ Strategies	2 / 2
Credit	Low-Emitting Materials	0 / 3
Credit	Construction IAQ Mgmt Plan	0 / 1
Credit	IAQ Assessment	1 / 2
Credit	Thermal Comfort	1 / 1
Credit	(inactive) Interior Lighting	2 / 2
Credit	Daylight	0 / 3
Credit	Quality Views	1 / 1
Credit	Acoustic Performance	1 / 1
Prereq	Learning controls for thermal comfort	REQUIRED
Prereq	ETS Control for Projects in Japan and Airport Projects with Security R...	REQUIRED

INNOVATION		AWARDED: 5 / 6
Credit	Innovation	5 / 5
Credit	LEED Accredited Professional	0 / 1

REGIONAL PRIORITY CREDITS		AWARDED: 3 / 4
Credit	Optimize Energy Performance	1 / 1
Credit	Thermal Comfort	1 / 1
Credit	Sensitive Land Protection	1 / 1
Credit	Protect or Restore Habitat	0 / 1
Credit	Rainwater Mgmt	0 / 1

LOCATION & TRANSPORTATION		AWARDED: 12 / 20
Credit	LEED for Neighborhood Development Location	0 / 16
Credit	Sensitive Land Protection	1 / 1
Credit	High Priority Site and Equitable Development	0 / 2
Credit	Surrounding Density and Diverse Uses	5 / 5
Credit	Access to Quality Transit	3 / 5
Credit	Bicycle Facilities	1 / 1
Credit	Reduced Parking Footprint	1 / 1
Credit	Electric Vehicles	1 / 1

INTEGRATIVE PROCESS CREDITS		AWARDED: 1 / 1
Credit	Integrative Process	1 / 1

TOTAL 63 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Figure 40: Milestone Lombos LEED Scorecard (US Green Building Council, 2021)

3.6. LEED Case Studies Conclusion:

It is important to note that the above 6 case studies, chosen from the official LEED website, are evaluated using differing versions of the LEED rating system. The Lucile Packard Children's Hospital and the National Museum of African American Hist were evaluated using LEED version 2009. The Olympic House and the HITT Contracting CoLab were evaluated using LEED version 4 while the Milestone Lombos Student Housing project got a LEED certification based on the LEED version 4.1, the latest version of the LEED certification system.

The MR category is in every building case the lowest scoring category, with only an average of 49% of the total category credits achieved. The MR category is directly related to the EE while categories such as EA are directly related to OE. In the selected case studies, WE is the highest scoring category, with an average of 81% of category credits achieved. EA is the second highest scoring category with an average of 76% of category credits achieved. It can be noted that OE remains of top priority in the achievement of credits in these LEED Certified Buildings. It is interesting to note that LEED Certified Buildings are still receiving LEED Certifications, while there is little consideration of EC emissions (low scoring results in the MR category with many projects not preforming a LCA). The possible reasons for not conducting a Whole Building LCA (including extensive amounts of work for little impact in the LEED result) will be discussed further on in this thesis. There appears to be an urgency for a more rigid and compulsory EC emissions audit in order to achieve a LEED certification.

Figure 41 (below) shows the relationship between the LEED Category and the % of total credits achieved in that category. It is clear that the MR category. Only an 49% of MR credits are achieved while an average of 76% of EA credits are achieved. These results are an average of the 5 LEED Certified Buildings as discussed above.

Category:	% credits achieved:
Energy & Atmosphere (Operational Energy):	76%
Materials & Resources (Embodied Energy):	49%

Figure 41: Table showing the % credits achieved for the Energy & Atmosphere and Materials & Resources category

When considering a broader range of LEED Certified Building's (a larger quantity of additional 24 LEED certified building's to the above 5 LEED certified building's) the percentage of credits achieved for the EA category is 68% (Figure 43) and the percentage of credits achieved for the MR category is 44% (Figure 46). 40% of LCA credits are achieved across all 29 LEED Certified Building's (Figure 45).

Figure 42: Percentage of LCA Credits achieved. Reference: Author.

Figure 44: Percentage of EA Credits achieved. Reference: Author.

Figure 43: Percentage of MR Credits achieved. Reference: Author.

Case Study Name:	#	Area (sqm):	Certification Type (LEED version: Building Type):	Level:
Milestone Lombos	1	8 850	LEED v4.1 BD + C: HP	Gold
African Museum	2	35 628	LEED v2009: BC + C: NC	Gold
HIT Colab	3	800	LEED v4: BC + C: NC	Platinum
Olympic House	4	22 600	LEED v4: BC + C: NC	Platinum
Lucile Packard Children's Hospital	5	48 402	LEED v2009: BC + C: NC	Platinum
Ghella Meeting Center	6	153	LEED v4: BC + C: NC	Platinum
Esa Esrin B12	7	439	LEED v4: BC + C: NC	Gold
Struttura per la formazione CEAS-ESFE	8	1 700	LEED v4: BC + C: NC	Gold
Mapei Football Centre	9	4 316	LEED v4: BC + C: NC	Certified
FANUC Italia Nuova sede	10	130 889	LEED v4: BC + C: NC	Gold
Galdi Village	11	2 120	LEED v4: BC + C: NC	Gold
Prometeia HQ	12	9 455	LEED v4: BC + C: NC	Gold
Superstudio MAXI	13	7 114	LEED v4: BC + C: NC	Gold
Rozzanno Offices	14	1 066	LEED v4: BC + C: NC	Gold
Residenza Camponogara	15	8 726	LEED v4: BC + C: NC	Gold
Progetto Manifattura AmbitoB-Lotto 1	16	25 600	LEED v4: BC + C: NC	Gold
Studentato Via Giovenale	17	21 300	LEED v4: BC + C: NC	Gold
Marcigliana 901	18	900	LEED v4: BC + C: NC	Platinum
SEDE A.P.P.M. TRENTO	19	2 036	LEED v4: BC + C: NC	Silver
Museo d'arte Fondazione Luigi Rovati	20	4 454	LEED v4: BC + C: NC	Gold
Studentato Via Giovenale	21	21 300	LEED v4: BC + C: NC	Gold
IMC	22	830	LEED v4: BC + C: NC	Gold
Berlin Packaging EMEA Headquarters	23	3 131	LEED v4: BC + C: NC	Gold
Sviluppo Genova - Ex area Dufour	24	550	LEED v4: BC + C: NC	Gold
RSA Grosseto	25	6 250	LEED v4: BC + C: NC	Silver
IT10 Chiesi Farmaceutici Pilotis San Leo	26	2 877	LEED v4: BC + C: NC	Gold
Gianni Giorgi - Alberti	27	1 350	LEED v4: BC + C: NC	Platinum
Residenza San Celso	28	9 370	LEED v4: BC + C: NC	Gold
Rondo' dei Talenti	29	3 500	LEED v4: BC + C: NC	Certified

Figure 45: LEED Certified Building's Information. Reference: Author.

Case Study #:	EA points achieved (out of 44):	EA (%) achieved:	MR points achived (out of 13):	MR (%) achieved:	Conduction of LCA:	Points achieved for LCA (out of 5):
1	24	53	4	31	Yes	1
2	22	49	6	43	No	0
3	35	80	9	69	Yes	3
4	42	95	8	62	Yes	3
5	29	64	7	50	No	0
6	36	82	4	31	No	0
7	33	75	3	23	Yes	3
8	37	84	5	38	Yes	3
9	26	59	4	31	No	0
10	36	82	6	46	Yes	3
11	33	75	6	46	Yes	3
12	33	75	7	54	Yes	3
13	35	80	5	38	Yes	3
14	26	59	9	69	Yes	4
15	30	68	6	46	Yes	3
16	30	68	4	31	No	0
17	26	59	4	31	No	0
18	39	89	8	62	Yes	5
19	23	52	2	15	No	0
20	27	61	5	38	No	0
21	26	59	4	31	No	0
22	31	70	5	38	No	0
23	27	61	9	69	Yes	4
24	33	75	5	38	No	0
25	25	57	3	23	No	0
26	30	68	8	62	Yes	3
27	35	80	8	62	Yes	3
28	28	64	7	54	Yes	3
29	13	30	5	38	Yes	3
		68		44		

Figure 46: Operational Energy and Embodied Energy in LEED Case Studies. Reference: Author.

Figure 45 show the LEED certified building's name, number, area (m^2), certification type and level. Figure 46 shows the LEED certified building's points achieved for the EA Category (Energy & Atmosphere) and the MR Category (Materials & Resources). It also shows whether the project team conducted a LCA and the points achieved (out of 5 available points) for the LCA result. As an average of only 40% of possible credits have been achieved for LCA application across certified building's, it is clear that there is an urgency for more compliance with LCA application within the LEED rating system.

LIFE CYCLE ASSESSMENT OF THE BRICOLLA HOUSE AND BUSINESS-AS-USUAL CASE STUDY

4.1. Analysis of Bricolla Case Study

4.1.1. Bricolla Case Study Aim:

The aim of this case study is to evaluate the Embodied Carbon (EC) emissions of the selected Case Study: Bricolla House by PAT architectural studio and to understand the impact of low-embodied energy material selection. In order to understand the EC emissions of the Bricolla House, a Whole Building Life Cycle Assessment (WBLCA) of the Bricolla House will be conducted, through the use of the EURECA Tool with data input from the ICE Database. In order to contextualize the results of the LCA performed on the Bricolla House, a LCA will also be conducted on a figurative 'Business-As-Usual case', defined by standard practices of Italy, for means of comparison.

4.1.2. Bricolla House Description:

The Bricolla House is a single-family detached residential home, designed by PAT architectural firm and located in the hills of North-western Italy (Briaglia, Cuneo). The building is two-storey's with extensive outside living spaces. The building's structure on the ground floor draws on a stereotomic structural system, consists of concrete foundations, a concrete retaining wall as well as concrete coloumns and beams. On the first floor the design takes on a tectonic nature, with a structural steel frame and timber drywall infill. The 'total floor area' of the house is 492,1 m^2 with a 'heated floor area' of 254,8 m^2. The house design favours low-embodied construction materials, prioritizing hemp products such as hempcrete and hemp-lime insulation. The Bricolla House floor plans, sections, building structure and envelope stratigraphy's will be elaborated upon and presented in pages 81-93.

4.1.3. Bricolla Case Study Methodology:

1. Understanding the Bricolla House design and material choices through architectural drawings/material quantity documents, material EPD's, research papers, ect.
2. Define the material choices and construction stratigraphy for the Bricolla House.
3. Define the material choices and construction stratigraphy for the 'Business-As-Usual' case.
4. Perform a LCA through the use of the EURECA tool for both the Bricolla House and the 'Business-As-Usual' case.

5. Drawing on the results from the EURECA analysis, develop graphic representations to clearly understanding the differences in the total life cycle EC emissions of the Bricolla house as well as the 'Business-As-Usual' case.
6. Assign a LEED score for the 'Materials & Resources' category for the Bricolla House.
7. Analyse the assigned LEED scores to better understand the difficulty/ease of achieving credits in the 'Materials & Resources' category of the LEED certification.

4.1.4. Bricolla Case Study Limitations:

Limitations of this case study include difficulties in data collection for specific building materials. The Bricolla house uses many materials which are not included in the ICE database and some materials do not have Environmental Product Declarations (EPD's). Compared to a 'Baseline' Building, EC data for Bricolla House was difficult to access. Other limitations of this case study include a skewed LEED score outcome as a result of only considering the 'Materials & Resources' category. ***

4.2. Bricolla Case Study Software and Tools:

4.2.1. EURECA:

EURECA is a calculation model developed in 2014 by a research team from the Department of Architecture and Design of the Politecnico di Torino. The main goal of EURECA is to determine two impact categories, EE and EC, for assessing the environmental sustainability of architectural projects through a LCA methodology. The current phase of the EURECA tool, most recently developed by Enrico Demaria, Angela Duzel, Federica Gallina, Benedetta Quaglio and Professor Roberto Giordano and is capable of quantifying equivalent carbon dioxide emissions for almost every phase of the building's life cycle.

The model assess impacts starting from the individual materials used, then processing to the individual technical elements (comprised of different materials) and ending with the entire building (made up of individual technical elements).

Each section of the tool comprises of data filled area's to be filled by hand (by the user) and other area's which are filled automatically (by means of the algorithm or on the basis of the data values already entered in previous sections). For the complete calculation, it is necessary for the user to know (as accurately as possible) the following data; the building use, the building's estimated lifecycle, the dimensional data of the project, the stratigraphy of the technical elements (including the EE and EC content of each material).

The model outputs the following results in the form of a final summary report; Total EE of the building [MJ] (initial, periodic, end of life, transport), Total EC of the building [$kgCO_2eq$] (initial, periodic, end of life, transport), Annual EE [$kWh/m_2/year$], Renewability Index [%], ratio between EE from renewable sources and total EE.

Figure 47 shows the EURECA software methodology. The first process is 'Raw Data Collection', followed by 'Project Data Entry' in EURECA. Project Data referring to 'Production', 'Transport' and 'End-of-Life' is entered and results in 'Results per System' and 'Results per Material'. The final EURECA output is 'Results Report'. It is important to note that this process is not always linear, with data inputs/corrections/attentions happening across processes.

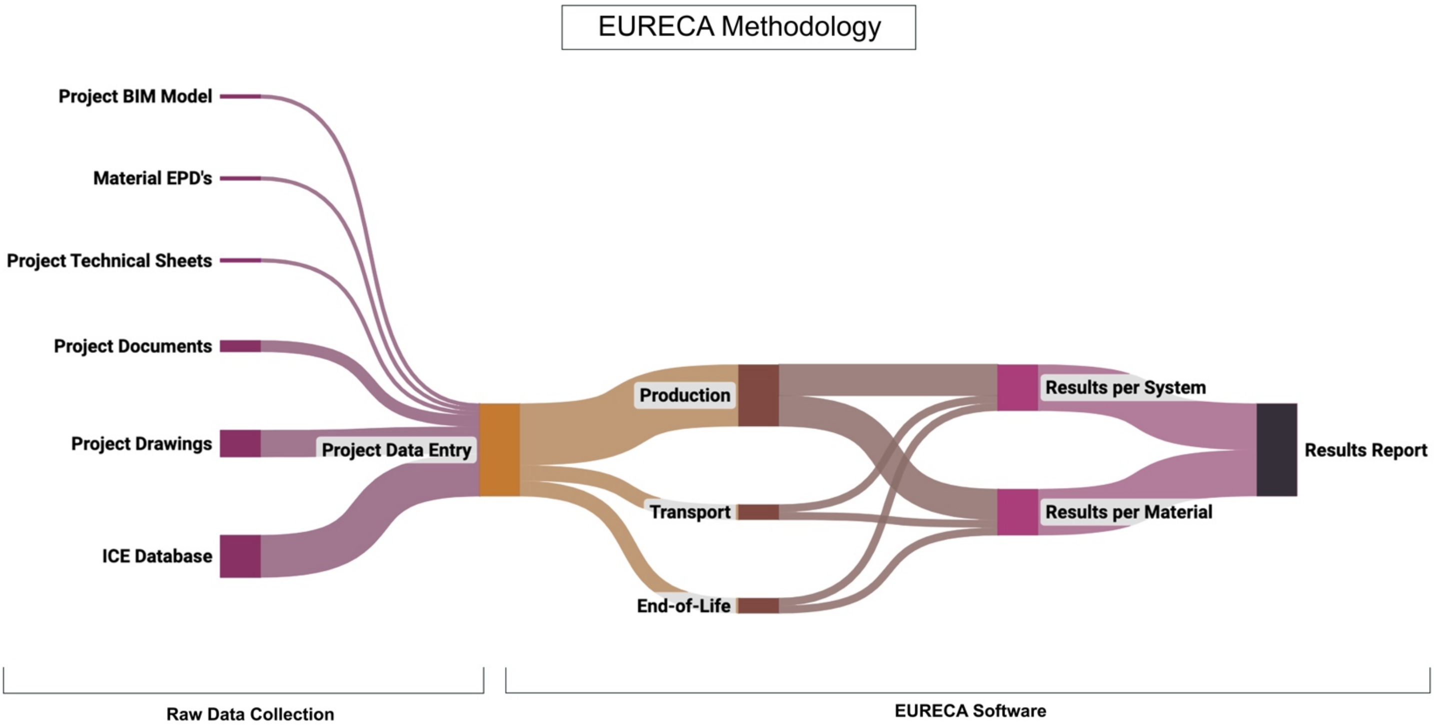


Figure 47: Sankey Flow diagram showing EURECA Methodology. Reference: Author.

4.2.2. ICE Database:

The ICE Database is a meta-database based upon a large literature review, where data is collected and complied on the EC of construction materials. The database retains a cradle to gate scope (Modules A1-A3 in the EN standards 15978 and 15804). The data available in the 2019 ICE version has been greatly improved over previous versions as carbon footprint standards and data has become increasingly available. EC data, in the form of CO_2e/kg, is collected from the ICE database and input in the EURECA tool.

4.3. LEED Certification outline for the 'Materials & Resources' category

Figure 48 shows the credit allocation with the LEED Materials & Resources (MR) category. The amount of points available per credit as well as each credit's 'Intent' and 'Requirements' are highlighted below. In the of the 'Building Life-Cycle Impact Reduction' credit, "Path 3" is described in the 'Requirements' as it is the applicable path for credit achievement with respect to the Bricolla House Case Study. "Paths 1 & 2" include only a 5% reduction in impact categories with regards to a baseline building and "Path 4" incorporates existing building material reuse (not applicable to Bricolla House). All information is retrieved from the LEED v4.1 Building Design and Construction guide (2023).

Credit's within LEED's Materials & Resources category

Prerequisite/ Credit	Name	Points:	Intent:	Requirement:
Prerequisite	**STORAGE & COLLECTION OF RECYCLABLES**	0	"To reduce the disproportionate burden of landfills and incinerators and to conserve natural resources for future generations." (LEED, 2023)	Provide dedicated areas accessible to waste haulers and building occupants for the collection and storage of recyclable materials for the entire building.
Credit	**BUILDING LIFE-CYCLE IMPACT REDUCTION**	1 to 5	"To encourage adaptive reuse and optimize the environmental performance of products and materials." (LEED, 2023)	Path 3: Conduct a LCA of the project's structure and enclosure that demonstrates a minimum of 10% reduction, compared with a baseline building, in at least three of the six impact categories listed below, one of which must be global warming potential (3 points).
Credit	**ENVIRONMENTAL PRODUCT DECLARATIONS**	1 to 2	"To encourage the use of products and materials for which life-cycle information is available and that have environmentally, economically, and socially preferable life-cycle impacts." (LEED, 2023)	Use at least 20 different permanently installed products sourced from at least five different manufacturers that meet one of the disclosure criteria below.
Credit	**SOURCING OF RAW MATERIALS**	1 to 2	"To reward project teams for selecting products verified to have been extracted or sourced in a responsible manner." (LEED, 2023)	Use products sourced from at least *five* different manufacturers that meet at least one of the responsible sourcing and extraction criteria below for at least *30%* , by cost, of the total value of building products (2 points).
Credit	**CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT**	1 to 2	"To reduce construction and demolition waste disposed of in landfills and incineration facilities through waste prevention and by reusing, recovering, and recycling materials, and conserving resources for future generations." (LEED, 2023)	Waste Prevention (2 points): divert at least 50% of all renovation and demolition waste (if any). Generate less than 10lbs./ft (50kg/m2) of waste materials from all new construction activities.

Figure 48: LEED MR Category Credits. Reference: Author.

4.4. Bricolla House Drawings

4.4.1. Ground Floor and First Floor Plans showing Wall Typologies

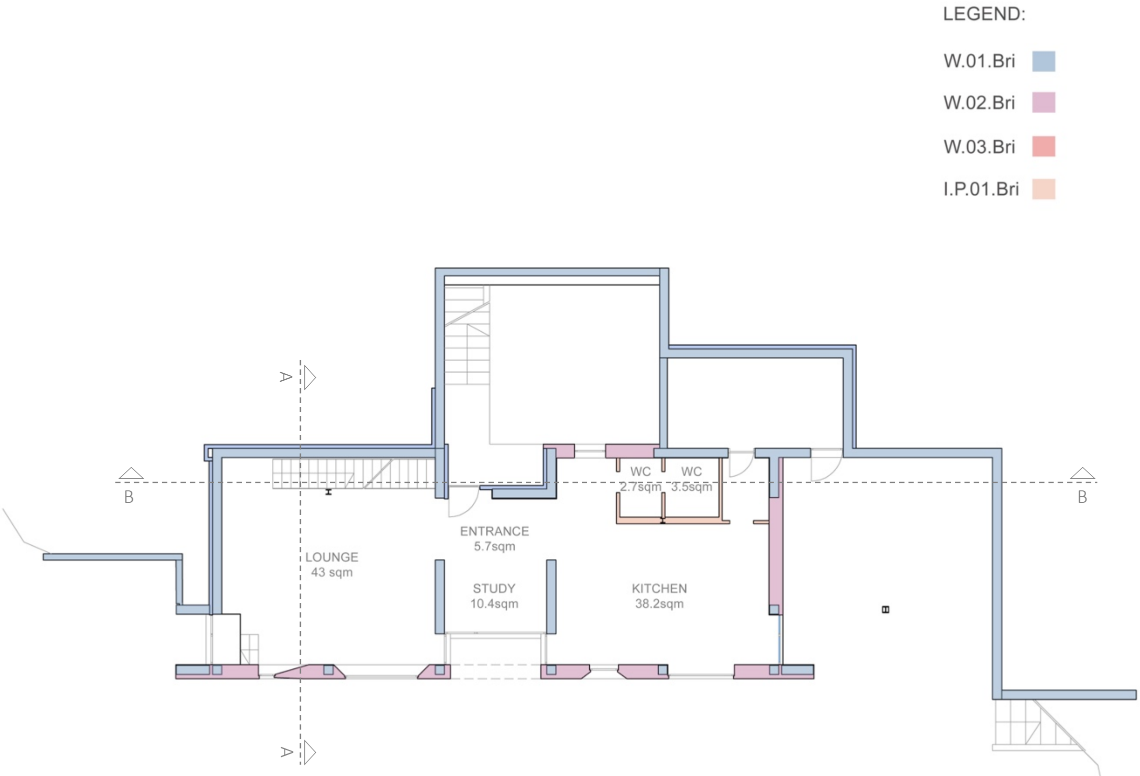


Figure 50: Bricolla Ground Floor Plan. Reference: Author.

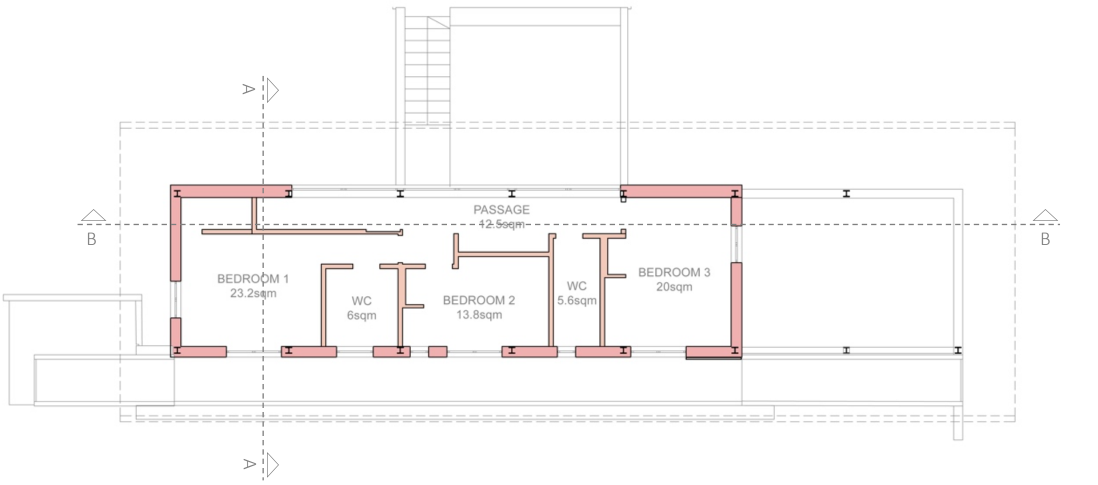
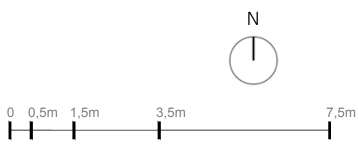


Figure 49: Bricolla First Floor Plan. Reference: Author.



4.4.2. Structural Drawings of Foundation and Steel Frame

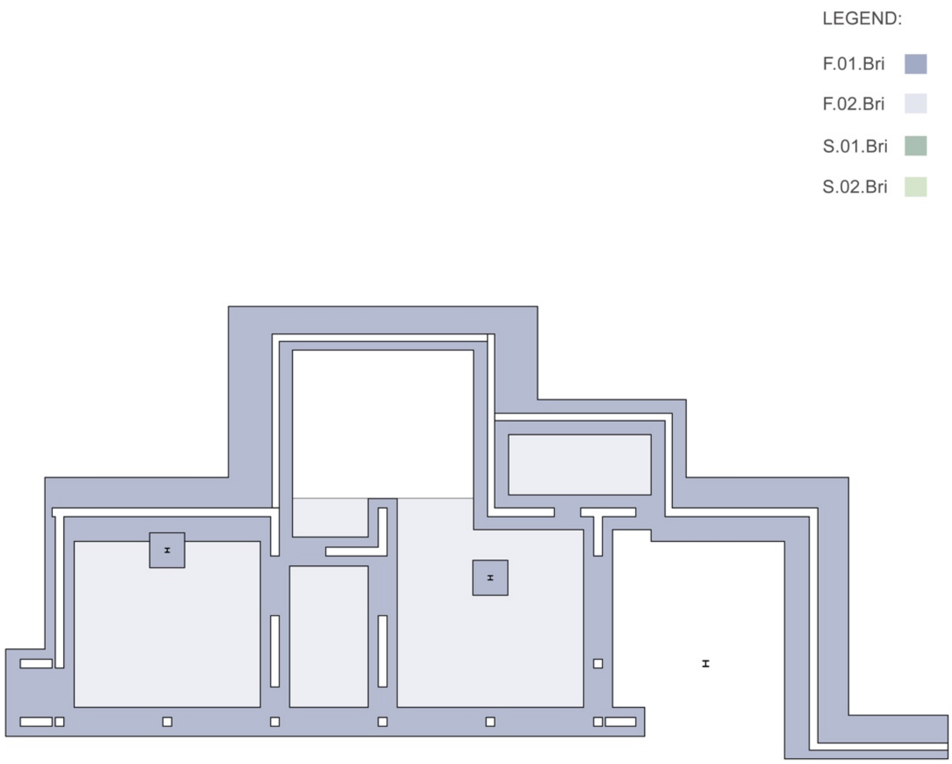


Figure 52: Bricolla Foundations in plan. Reference: Author.

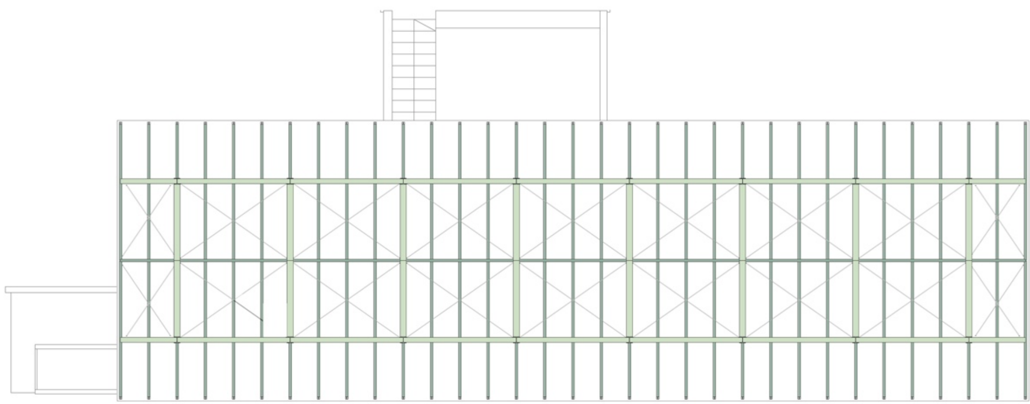
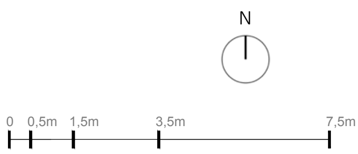


Figure 51: Bricolla Steel Frame. Reference: Author.



4.4.3. Ground Floor and First Floor Plans showing 'Heated Floor Area'

Figure 54: Ground Floor Plan showing 'heated floor area'

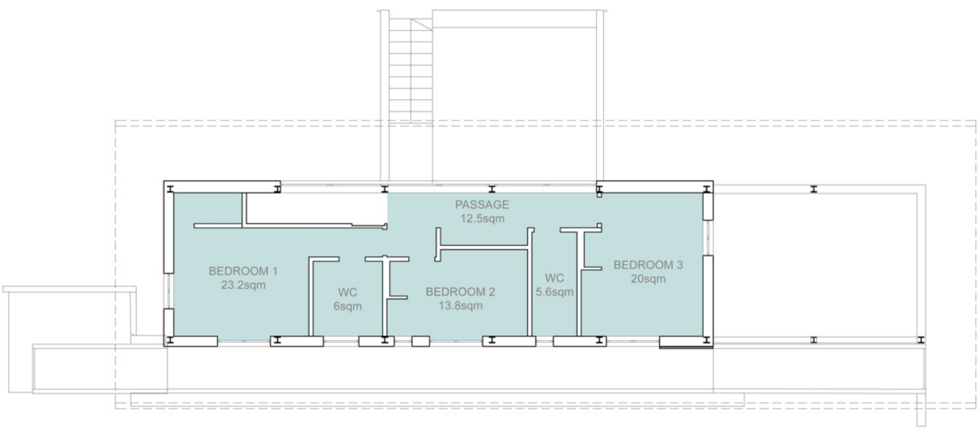
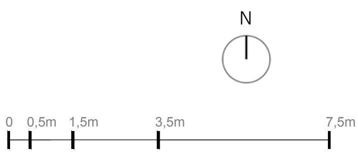


Figure 53: First Floor Plan showing 'heated floor area'



4.4.4. Roof Plan showing 'Heated Floor Area'

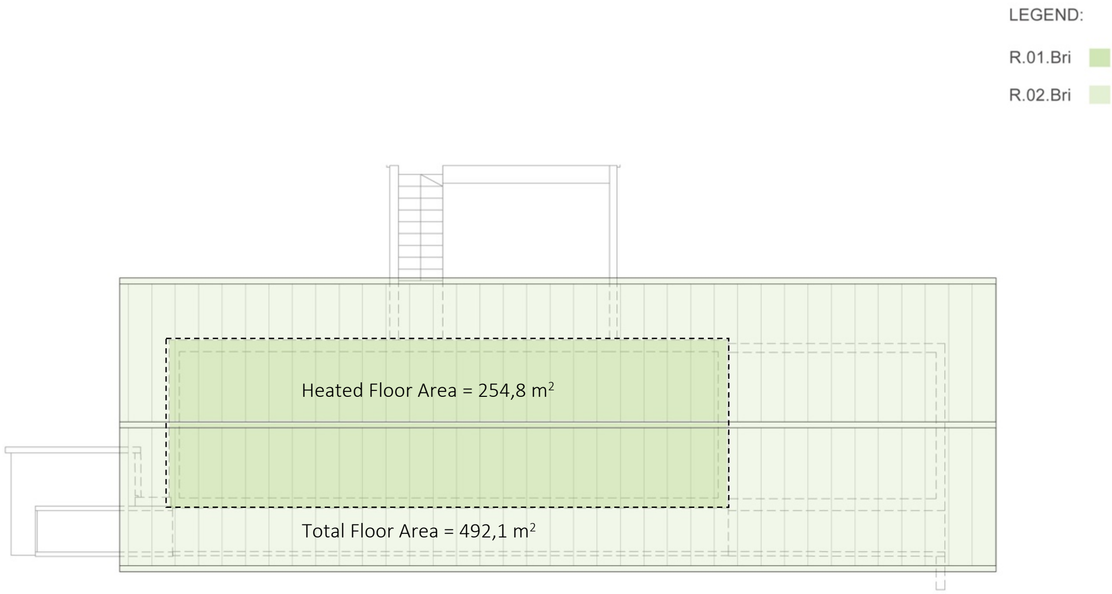
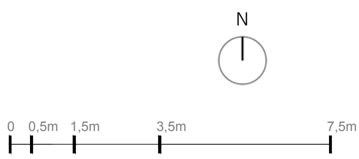


Figure 55: Roof Plan



4.4.5. Bricolla House Section showing Building Elements

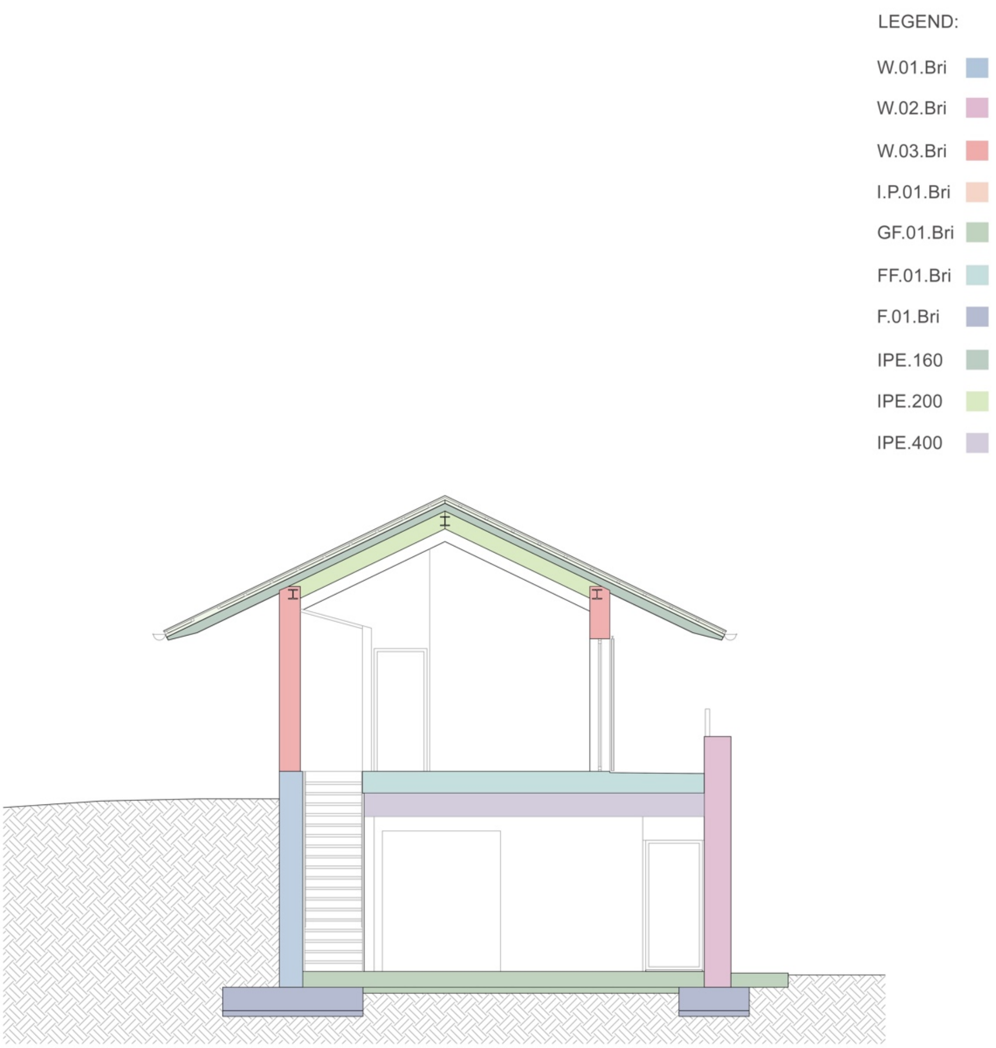


Figure 56: Bricolla House Section A-A

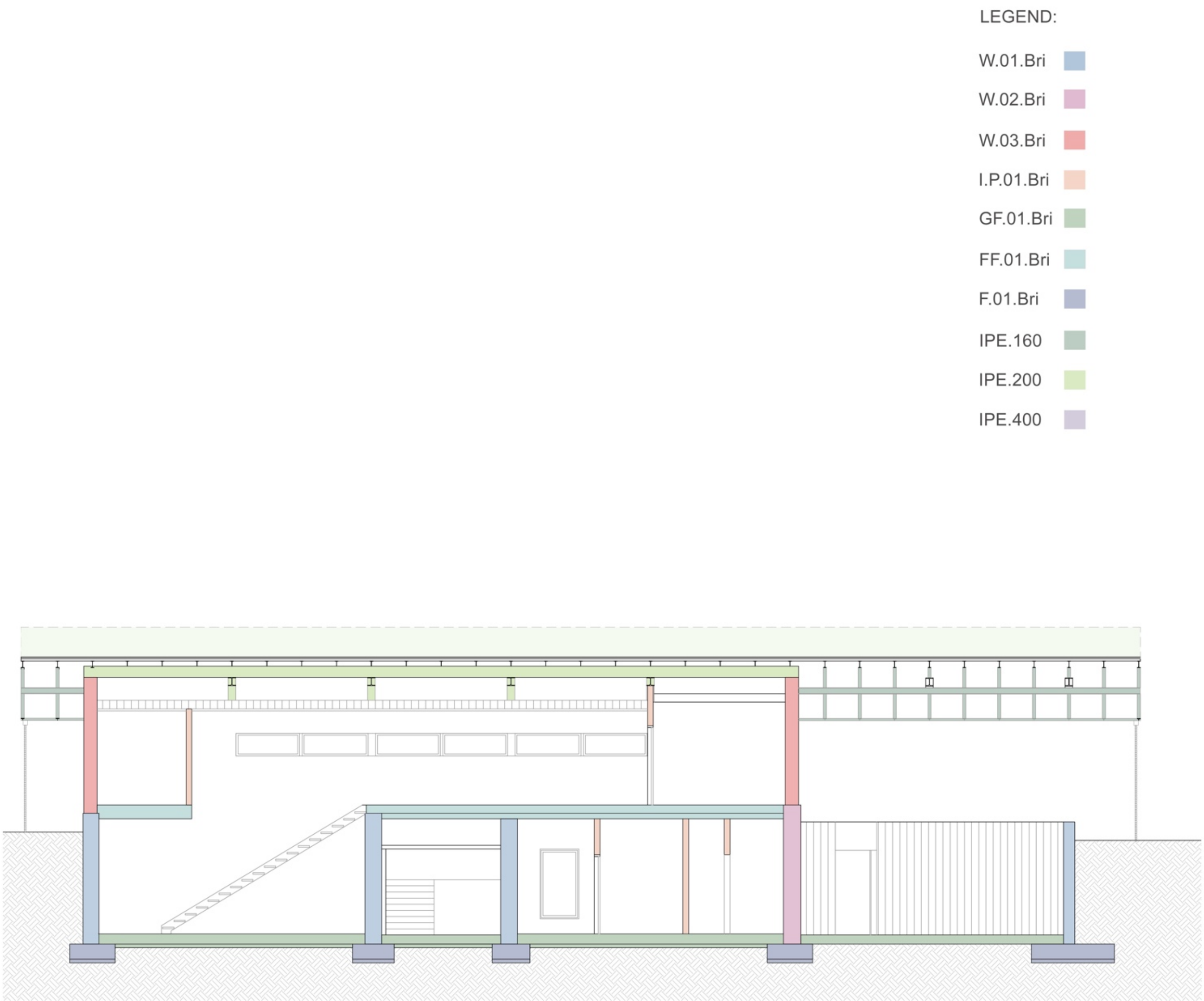


Figure 57: Bricolla House Section B-B

W.01.Bri: Concrete Retaining Wall

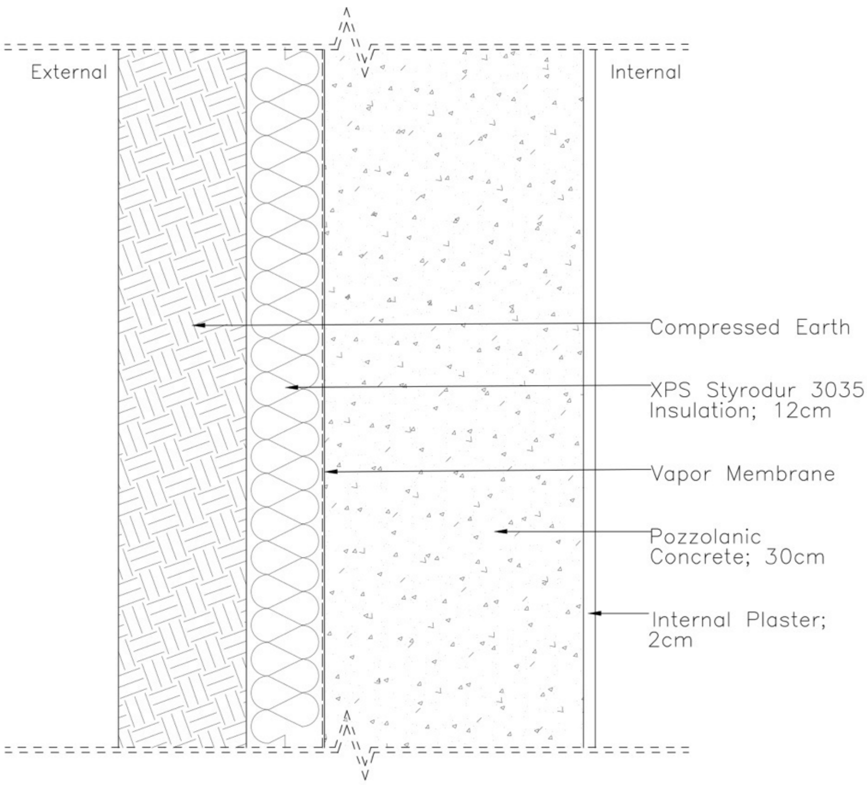


Figure 58: Concrete Retaining Wall Stratigraphy.
Reference: Author.

Figure 58 shows the Perimeter Retaining Wall stratigraphy. The Perimeter Retaining Wall is composed of pozzolanic concrete with a thickness of 30cm, internal plaster and external XPS Styrodur 3035 insulation.

W.02.Bri: Hempcrete Wall

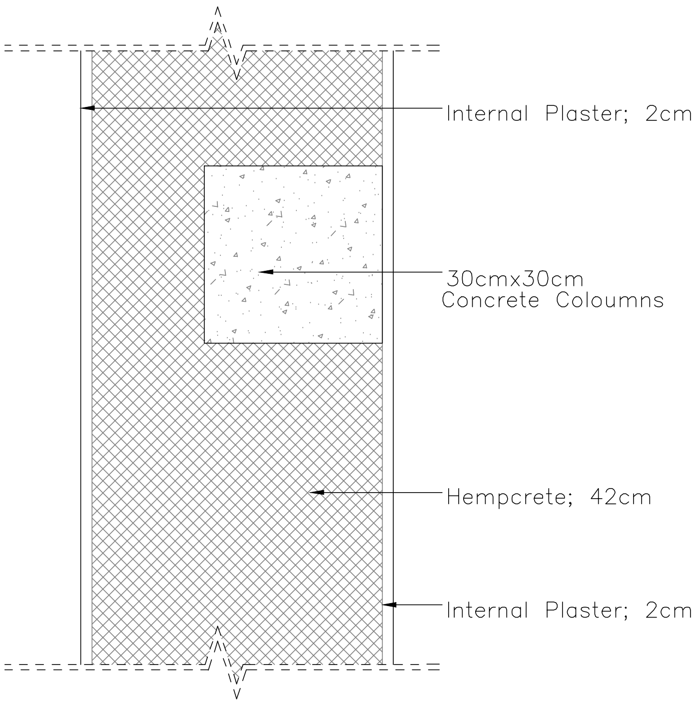


Figure 59: Hempcrete Wall Stratigraphy.
Reference: Author.

Figure 59 shows the Hempcrete Perimeter Wall stratigraphy. The Hempcrete Perimeter Wall is composed of internal and external plaster and 40cm of hempcrete supported by 30cm x 30xm concrete coloumns.

W.03.Bri: Timber Dry-Wall

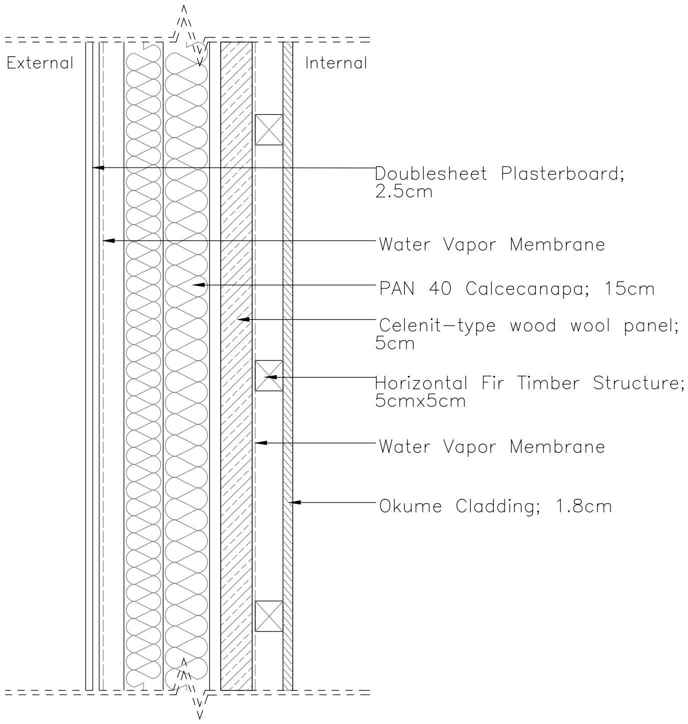


Figure 60: Timber Dry-Wall.
Reference: Author.

Figure 60 shows the First-Floor Perimeter Drywall Stratigraphy. This wall is composed of cladding in Okume plywood panels, a timber frame, a wood wool panel, PAN 40 Calcecanapa insulation and a double layer of plasterboard.

IP.01.Bri: Internal Partition

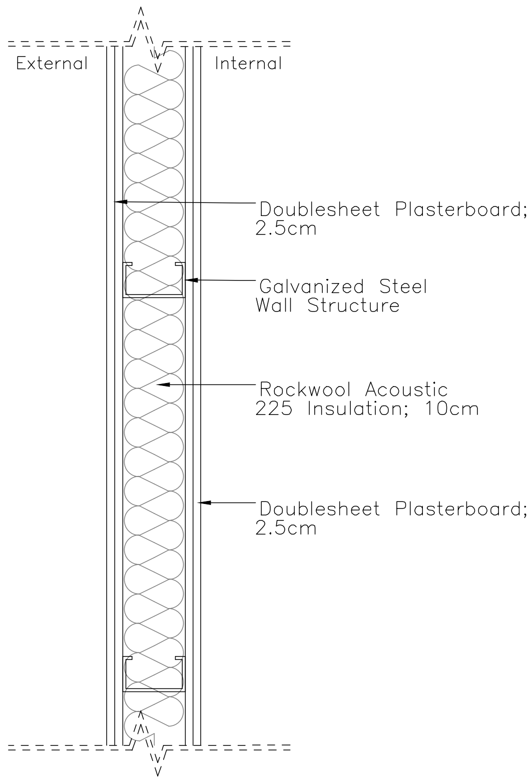


Figure 61: Internal Partition Wall.
Reference: Author.

Figure 61 shows the stratigraphy of the Internal partition walls. They are composed of a wall structure in galvanized steel with double sheet plasterboard on either side.

GF.01.Bri: Structural Slab on Ground

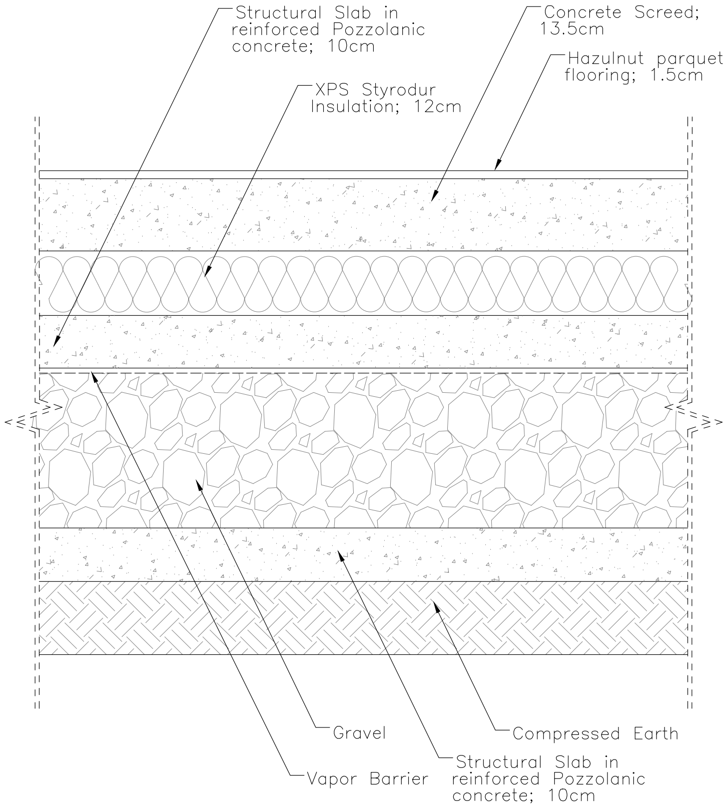


Figure 62: Ground Floor Stratigraphy. Reference: Author.

Figure 62 shows the Ground Floor stratigraphy, composed of gravel, followed by a structural slab in reinforced Pozzolanic concrete, XPS Styrodur 3035 insulation, a concrete screed with a hazelnut parquet floor finish.

FF.01.Bri: Structural Slab of First Floor

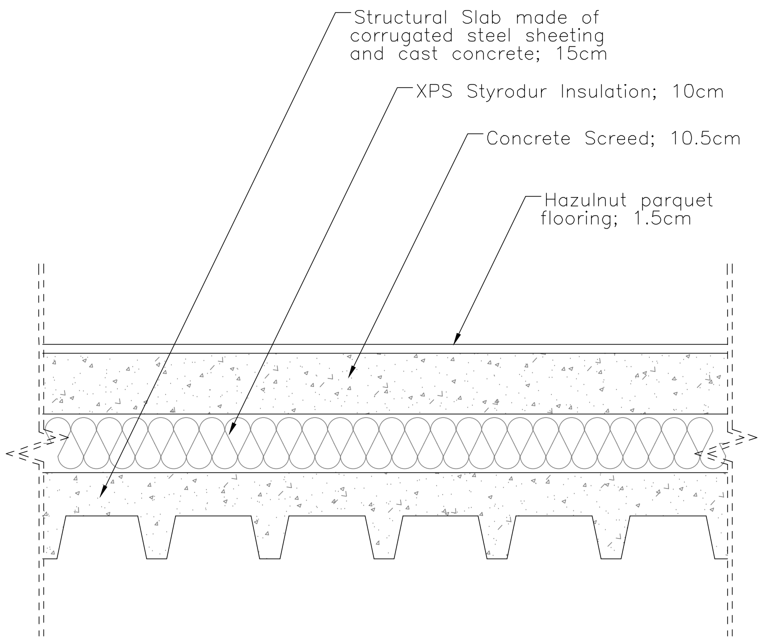


Figure 63: Intermediate Floor Stratigraphy. Reference: Author.

The first floor stratigraphy, as seen in Figure 63, is comprised of a structural slab made of a corrugated sheet followed by cast, reinforced concrete. Above the structural slab is XPS Styrodur 3035 insulation, a concrete screed and a parquet flooring finish.

R.01.Bri

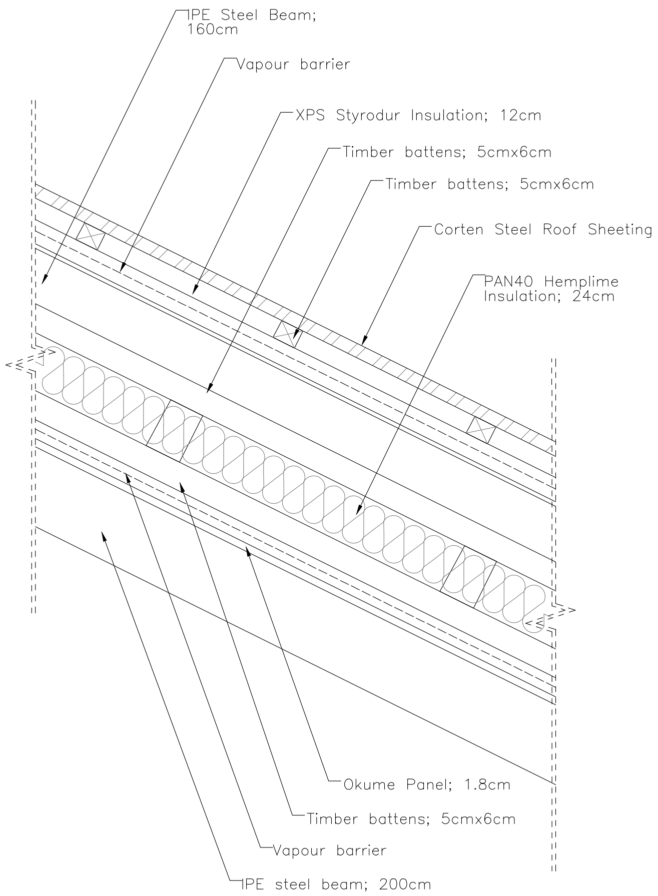


Figure 64: Roof Stratigraphy. Reference: Author.

The Roof Envelope is supported by Steel IPE 200 and IPE 160 frames. The roof finish is a Corten Steel Sheet supported by . There is a PAN40 Hemplime Insulation layer which is 24cm thick, supported by timber battens and finished with a 1,8cm thick Okume panel (as seen in Figure 64).

4.5. Bricolla House LCA: Introduction

This section of the thesis contains the 4 stages of the Bricolla House LCA (Goal & Scope Definition, Life Cycle Inventory, Life Cycle Impact Assessment and Interpretation of Results).

4.6. Bricolla LCA: Goal & Scope Definition

The Bricolla House LCA is aimed at understanding the Embodied Carbon (EC) emissions of the Bricolla House during it's entire life cycle (modules A1-A3 (Production), A4, C2 (Transport) and C2-C4 (End-Of Life) as defined by EN 15978). The performed LCA will consider the Whole Building, including all building elements (structural system as well as envelope). The performed LCA will not consider modules B1-B7 (Recurring) as it is beyond the scope of this study. The LCA will consider the related environmental impacts of both 'single elements' (single building materials) and 'components' (multiple building materials grouped into a system, eg. 'roof envelope' consisting of multiple materials). The focus of the LCA is on EC emissions and Embodied Energy (EE) will not be considered in the assessment.

The building life span considered in the LCA is 50 years (with post-assessment results also analysing the impact of a 100 year building life span). The functional unit of 'heated floor area' is m^2.

The environmental impacts relating to the 'Steel Rebar' supporting the concrete structure are not calculated in the LCA software (EURECA), due to the limitation of the software in including such elements. The impact assessment of 'Steel Rebar' is performed and calculated manually, adding to the results at the end of the study. Another limitation of the EURECA software, is it's inability to include infinite 'linear elements' in the LCA. 'Linear elements' include posts, coloumns, beams and frames. As a limited number of linear elements can be included in the assessment, some elements are excluded. In the case of this LCA, the timber battens supporting the cladding of the timber dry-wall were excluded as well as the timber battens supporting the insulation of the roof envelope.

In the EURECA software, it is advised to select 'Without Carbon Storage' EC data for timber elements. This largely affects the EC results of timber elements and should be noted when analysing the LCA outcomes.

4.7. Bricolla LCA: Life Cycle Inventory (LCI)

The following pages contain information concerning the building element stratigraphy of the Bricolla House as well as the data input values concerning the specific materials. This data was gathered from technical building sheets, building project drawings, EPD's as well as the ICE Database and was input into the EURECA Tool to obtain the final LCA results. Including the LCI data sheets in this thesis is important as the specific data entries and information pertaining to the LCA are transparent. In many cases, the LCI is excluded from research papers, making it difficult to get an accurate understand of the LCA study.

The fist technical sheet on page's 98 & 99 contains the Building Elements stratigraphy drawings for the Bricolla House. The LCI sheets on page 74 and 75 contain numerical information on the data input values for Modules A1-A4 (Production) relating to the Building Elements. The rows highlighted in pink signify the 'Hotspot Materials', those that contribute greatly to the EC result of that building element. Page 76 contains the data sheet for Modules A4, C2 (Transport) per each Building Material. Materials highlighted in blue have the highest EC value for this Module. Pages 77 & 78 contain the data sheets for Modules C1-C4 (End-Of-Life) for both 'Building Element' and 'Building Material'.

4.8.3.2. LCI: EC results per Technical Element for Modules A1-A3 (Production)

ROOF SYSTEM (R.01.Bri)

Component	Density (kg/m³)	Thickness (m)	Weight per sqm (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Corten Steel Sheeting	7850,00	0,0008	6,28	2,73	17,14
Okume Panel	700,00	0,02	12,60	0,31	3,91
Lime Hemp Insulation	40,00	0,24	9,60	0,09	0,86
OSB Panel	640,00	0,02	11,52	0,46	5,30
Okume Panel	700,00	0,02	12,60	0,31	3,91

Total Embodied Carbon (CO_2/m²)	31,12
Roof Area m²	282,15
Total (kgCO_2eq)	31,12 x 282,15 = **8 780,51**

FLOOR ON THE GROUND (GF.01.Bri)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Hazulnut Parquet Flooring	660,00	0,02	9,90	0,81	8,02
Concrete Screed	1200,00	0,14	162,00	0,10	16,20
XPS Insulation	35,00	0,12	4,20	0,71	2,98
Pozzolanic Concrete	2380,00	0,10	238,00	0,12	28,32

Total Embodied Carbon (CO_2/m²)	55,52
Ground Floor Area m²	265,56
Total (kgCO_2eq)	55,52 x 265,56 = **13 811,19**

HORIZONAL PARTITION (FF.01.Bri)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Hazulnut Parquet Flooring	660,00	0,02	9,90	0,81	8,02
Concrete Screed	1200,00	0,11	126,00	0,10	12,60
XPS Insulation	35,00	0,10	3,50	0,71	2,49
Pozzolanic Concrete	2380,00	0,09	214,20	0,12	25,70

Total Embodied Carbon (CO_2/m²)	48,81
Horizontal Partition Area m²	179,95
Total (kgCO_2eq)	42,51 x 179,95 = **8 462,63**

EXTERNAL WALL (W.02.Bri: Perimeter Wall Cast Hemp Lime)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Plaster - lime	1300,00	0,02	26,00	0,39	10,14
Cast Hemp Lime	240,00	0,40	96,00	0,09	8,64
Plaster - lime	1300,00	0,02	26,00	0,39	10,14

Total Embodied Carbon (CO_2/m²)	28,92
Wall Area m²	81,71
Total (kgCO_2eq)	28, 92 x 81,71 = **2 363,31**

EXTERNAL WALL (W.01.Bri: Perimeter Concrete Retaining Wall)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Plaster - lime	1300,00	0,02	26,00	0,39	10,14
Pozzolanic Concrete	2380,00	0,30	714,00	0,12	84,97
XPS Insulation	35,00	0,12	4,20	0,71	2,98

Total Embodied Carbon (CO_2/m²)	98,09
Wall Area	191,37
Total (kgCO_2eq)	126,41 x 191,37 = **24 191,87**

EXTERNAL WALL (W.03.Bri: Perimeter Timber Dry Wall)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Doublesheet Plasterboard	665,00	0,03	16,63	0,39	6,48
Lime Hemp Insulation	40,00	0,15	6,00	0,09	0,54
OSB Panel	640,00	0,02	12,80	0,46	5,89
Wood Wool Panel	700,00	0,018	12,60	0,40	5,04
Okume Panel	700,00	0,018	12,60	0,31	3,91

Total Embodied Carbon (CO_2/m²)	21,86
Wall Area	128,59
Total (kgCO_2eq)	21,86 x 128,59 = **2 810,98**

INTERNAL PARTITIONING (IP.01.Bri)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Doublesheet Plasterboard	665,00	0,03	16,63	0,39	6,48
Lime Hemp Insulation	40,00	0,15	6,00	0,09	0,54
Doublesheet Plasterboard	665,00	0,03	16,63	0,39	6,48

Total Embodied Carbon (CO_2/m²)	13,51
Partitioning Area	96,62
Total (kgCO_2eq)	13,51 x 96,62 = **1 305,10**

STEEL FRAME (IPE 160, HEB 200, IPE 300, IPE 400)

Component	Density (kg/m³)	Area Section (m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)	Embodied Carbon (kgCO_2eq)
IPE 160 Steel	7850,00	0,008	1,04	40,82	17781,19
HEB 200 Steel	7850,00	0,010	1,04	67,25	6395,35
IPE 300 Steel	7850,00	0,017	1,04	64,75	1249,09
IPE 400 Steel	7850,00	0,024	1,04	199,93	2037,73

Total EC (kgCO_2eq)	**27 463,36**

CONCRETE FOUNDATIONS (F.01.Bri)

Component	Density (kg/m³)	Thickness (m)	Weight (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Pozzolanic Concrete	2380,00	0,40	952,00	0,12	113,29

Total Embodied Carbon (CO_2/m²)	113,29
Foundation Area	118,28
Total (kgCO_2eq)	**13 366,08**

CONCRETE COLOUMNS & BEAMS

Component	Density (kg/m³)	Area Section (m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)	Total EC (kgCO_2eq)
Pozzolanic Concrete	2380,00	0,09	0,119	25,70	1827,55

Total (kgCO_2eq)	**1 827,55**

Figure 65: LCI tables of Building Elements Modules A1-A4. Reference: Author.

4.8.3.3. LCI: EC results per Material for Modules A4, C2 (Transport)

Material	Payload (t)	Transport							
		Type	Vehicle	# vehicles	Distance	Fuel	EE (MJ)	EC ($kgCO_2eq$)
Corten Steel Sheet	0,71	Road	Lorry < 7.5 t	1	60	Diesel	339,79	25,78
Okume Panel	21,11	Sea	Transatlantic	1	7976	HFO	3757	287,67
		Road	Articulated lorry 24 - 40 t	1	147	Diesel		
Lime Hemp Insulation	2,38	Road	Lorry < 7.5 t	1	290	Diesel	1719,38	130,46
OSB Panel	2,88	Road	Lorry < 7.5 t	1	50	Diesel	300,42	22,8
Hazulnut Parquet Flooring	3,60	Road	Lorry 7.5 - 12 t	1	184	Diesel	1447,84	109,86
Concrete Screed	47,96	Road	Articulated lorry 24 - 40 t	1	40	Diesel	1110,96	84,3
XPS Insulation	1,97	Road	Lorry < 7.5 t	1	365	Diesel	2140,29	162,4
Plaster - Lime	9,22	Road	Lorry 12 - 24 t	1	50	Diesel	463,9	35,2
Cast Hemp Lime	7,73	Road	Lorry 12 - 24 t	1	50	Diesel	454,49	34,49
Pozzolanic Concrete	427,60	Road	Articulated lorry 24 - 40 t	10,00	40,00	Diesel	6948,82	527,26
Doublesheet Plasterboard	5,35	Road	Lorry 7.5 - 12 t	1	317	Diesel	2605,24	197,68
Wood Wool Panel	16,20	Road	Articulated lorry 24 - 40 t	1	242	Diesel	3011,34	228,49
IPE 160 Steel	26,27	Rail	Train 500 t	1	1035	Diesel	574,53	43,59
HEB 200 Steel	7,46	Rail	Lorry 12 - 24 t	1	265	Diesel	2399,54	182,07
IPE 300 Steel	3,53	Road	Lorry 7.5 - 12 t	1,00	1035,00	Diesel	8131,13	616,98
IPE 400 Steel	6,47	Rail	Train 500 t	1	900	Diesel	410,03	37,91

Figure 66: LCI table of Materials for Module A4, C2 (transport). Reference: Author.

4.8.3.4. LCI: EC results per Technical Element for Modules C2-C4 (End-of-Life)

ROOF SYSTEM (R.01.Bri)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Corten Steel Sheeting	0,02	Reuse	80%	1,24
Okume Panel	1,35	Reuse	80%	2,50
Lime Hemp Insulation	1,03	Reuse	80%	1,90
OSB Panel	1,24	Recycle	100%	2,28
Okume Panel	1,35	Reuse	80%	2,50
				10,42

FLOOR ON THE GROUND (GF.01.Bri)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Hazulnut Parquet Flooring	1,43	Reuse	80%	2,64
Concrete Screed	11,70	Recycle	100%	43,14
XPS Insulation	0,67	Recycle	100%	1,12
Pozzolanic Concrete	34,37	Recycle	100%	63,38
				110,28

HORIZONTAL PARTITION (FF.01.Bri)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Hazulnut Parquet Flooring	1,06	Reuse	80%	1,77
Concrete Screed	6,77	Recycle	100%	22,59
XPS Insulation	0,38	Recycle	100%	0,63
Pozzolanic Concrete	38,36	Recycle	100%	38,40
				63,39

EXTERNAL WALL (W.02.Bri: Perimeter Wall Cast Hemp Lime)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Plaster - lime	2,09	Recycle	100%	3,86
Cast Hemp Lime	7,73	Recycle	100%	14,26
Plaster - lime	2,09	Recycle	100%	3,86
				21,98

EXTERNAL WALL (W.01.Bri: Perimeter Concrete Retaining Wall)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Plaster - lime	1,40	Recycle	100%	2,58
Pozzolanic Concrete	51,29	Recycle	100%	299,60
XPS Insulation	0,23	Recycle	100%	0,42
				302,6

EXTERNAL WALL (W.03.Bri: Perimeter Timber Dry Wall)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Doublesheet Plasterboard	2,14	Recycle	100%	3,94
Lime Hemp Insulation	0,77	Recycle	100%	1,42
OSB Panel	1,65	Recycle	100%	3,04
Wood Wool Panel	16,2	Recycle	100%	2,99
Okume Panel	16,20	Reuse	80%	2,99
				14,38

INTERNAL PARTITIONING (IP.01.Bri)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Doublesheet Plasterboard	1,61	Recycle	100%	2,96
Lime Hemp Insulation	0,58	Recycle	100%	1,07
Doublesheet Plasterboard	1,61	Recycle	100%	2,96
				6,99

STEEL FRAME (IPE 160, HEB 200, IPE 300, IPE 400)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
IPE 160 Steel	17,78	Recycle	100%	30,53
HEB 200 Steel	5,98	Recycle	100%	11,34
IPE 300 Steel	1,2	Recycle	100%	2,22
IPE 400 Steel	1,96	Recycle	100%	3,61
				47,7

CONCRETE FOUNDATIONS (F.01.Bri)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Pozzolanic Concrete	111,38	Recycle	100%	211,12

CONCRETE COLOUMNS & BEAMS

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Pozzolanic Concrete	13,25	Landfill	100%	28,08

Figure 67: LCI per Technical Element for Modules C2-C4 (End-of-Life)

4.8. Bricolla LCA: Life Cycle Impact Assessment (LCIA)

Figure 69 below shows the Total Building EC (kgCO_2eq) per Life-Cycle Stage (Initial, Recurring, End of Life, Transport as defined by EN 15978). The Total EC of Bricolla House is 152 964,15 kgCO_2eq. The Total EC per m^2 (of 'heated floor area') is 600,33 kgCO_2eq/m^2. When considering 'total floor area', the Total EC per m^2 is 310,84 kgCO_2eq/m^2. When considering a 'Building Life-Span' of 50 years, the Total Building EC is 12,01 kgCO_2eq/year. If considering a 'Building Life-Span' of 100 years then the the Total Building EC is 6,00 kgCO_2eq/year.

Figure 70 represents the Total Building EC per 'Life-Cycle Stage'. 97% of Total Building EC (kgCO_2eq) comes from the Initial Phases (A1, A2, A3). Transport (A4, C2) contributes 2% and End of Life (C2, C3, C4) contributes less than 1%. Recurring (B1, B2, B3, B4, B5) is not considered in this study.

Total EC Results: Bricolla House

Life-Cycle Stage	Whole Buidling Embodied Carbon ($kgCO_2eq$)
Initial (A1, A2, A3)	149 323,58
Recurring (B1, B2, B3, B4, B5)	N.A.
End of Life (C2, C3, C4)	1 024,56
Transport (A4, C2)	2 616,01
	152 964,15

Heated area (m^2)	254,8
Unheated area (m^2)	237,3
Whole Building Embodied Carbon ($kgCO_2/m^2$)	152 964,15 / 254,8 = **600,33**
	Whole Building Embodied Carbon / 'Heated Floor Area'
Whole Building Embodied Carbon ($kgCO_2/m^2$)	152 964,15 / 492,1 = **310,84**
	Whole Building Embodied Carbon / 'Total Floor Area'
Building Life-Span (years)	50
Whole Building Embodied Carbon ($kgCO_2/m^2/yr$)	152 964,15 / 254,8 / 50 = **12,01**
	Whole Building Embodied Carbon / 'Heated Floor Area' / Building Life Span
Building Life-Span (years)	100
Whole Building Embodied Carbon ($kgCO_2/m^2/yr$)	152 964,15 / 254,8 / 100 = **6,00**
	Whole Building Embodied Carbon / 'Heated Floor Area' / Building Life Span

Figure 69: Table showing Total Building Embodied Carbon per stage. Reference: Author.

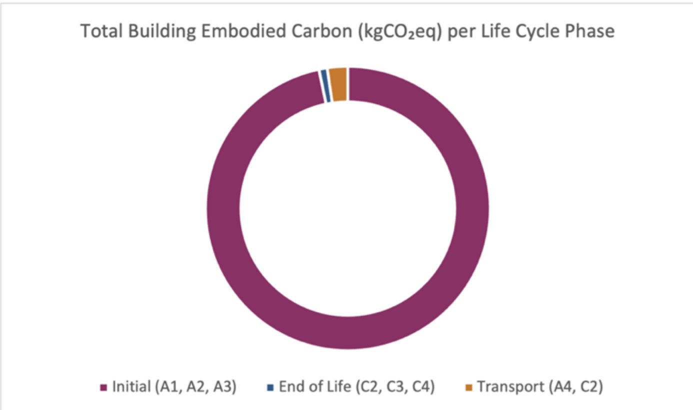


Figure 68: Total Building EC per Life-Cycle Stage. Reference: Author.

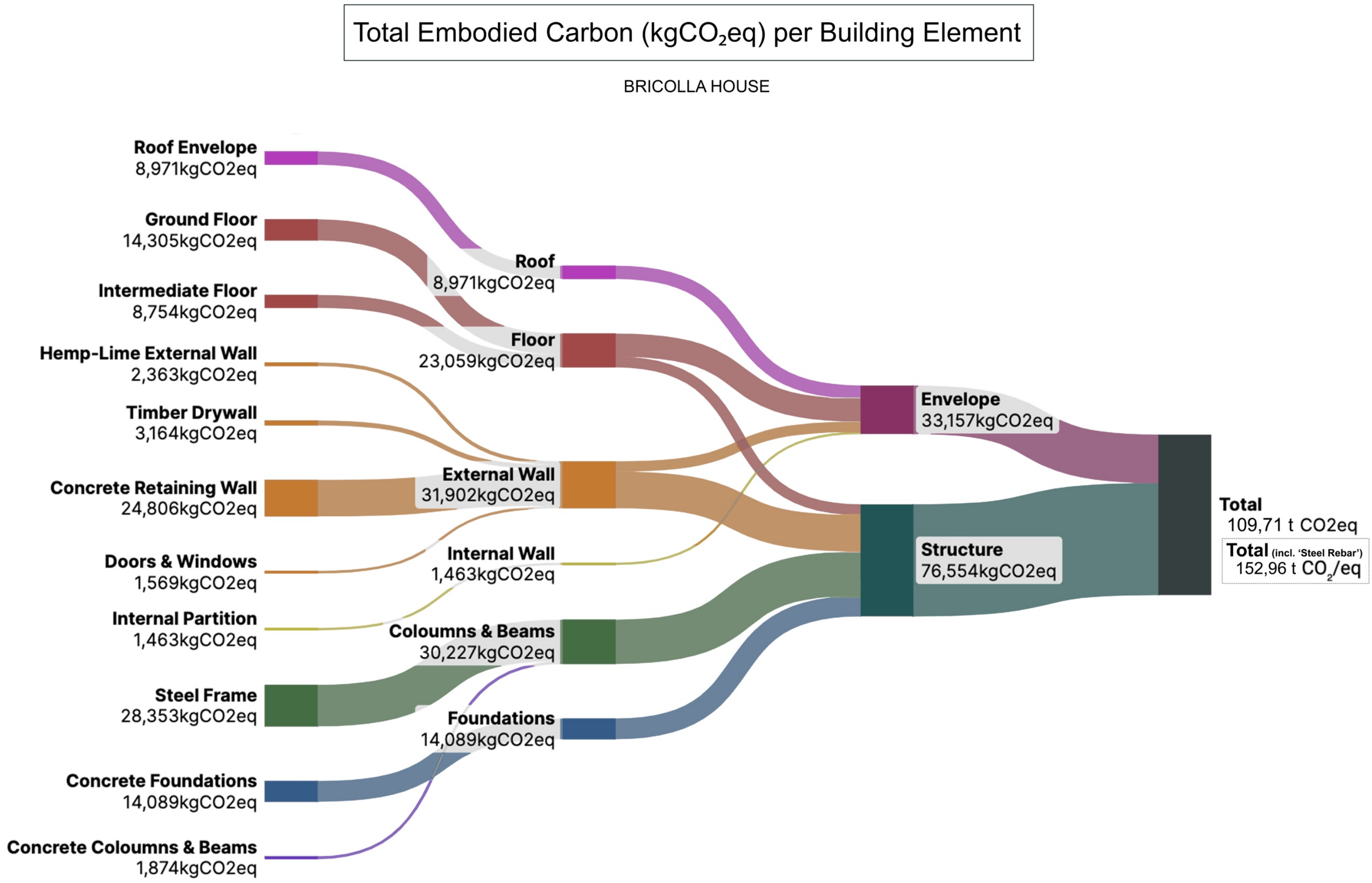


Figure 70: Sankey Diagram showing Total Embodied Carbon (kgCO2eq) per Building Element. Reference: Author.

The Sankey Diagram above (Figure 71) shows the Total EC (kgCO_2eq) per Building Element of the Bricolla House. As can be seen, the 'Steel Frame' contributes the most to the Total EC, followed by the 'Concrete Retaining Wall'. Structure accounts for 81% of total EC, while the 'Envelope' only accounts for 19%. This diagram is useful to represent graphically the 'share' of EC emissions allocated to each Building Element.

This Sankey Diagram does not consider the 'Steel Rebar', if considering 'Steel Rebar' the Total EC (kgCO_2eq) of the Bricolla House changes from 115,87 t CO_2eq to 147,75 t CO_2eq.

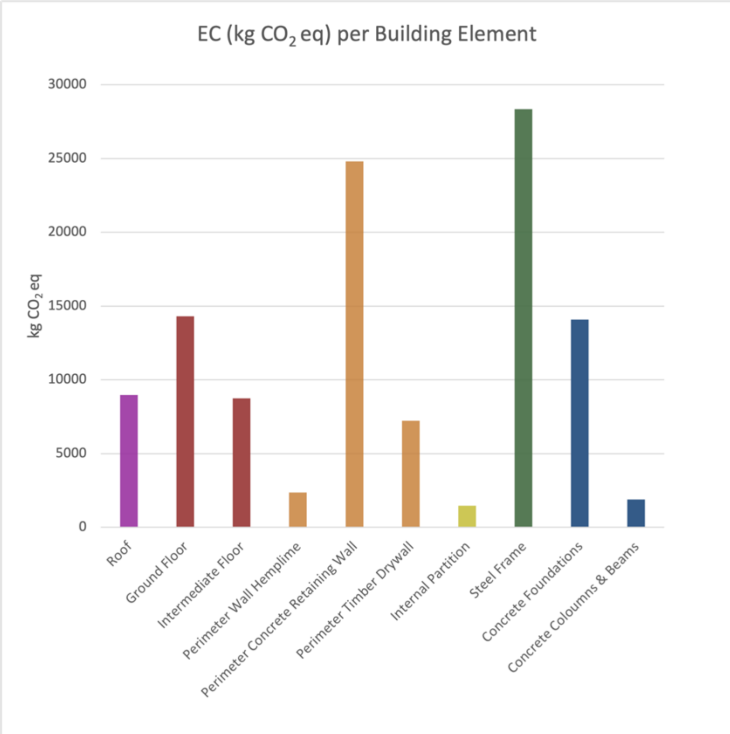


Figure 71: Histogram displaying Total Embodied Carbon (kgCO2eq) per Building Element. Reference: Author.

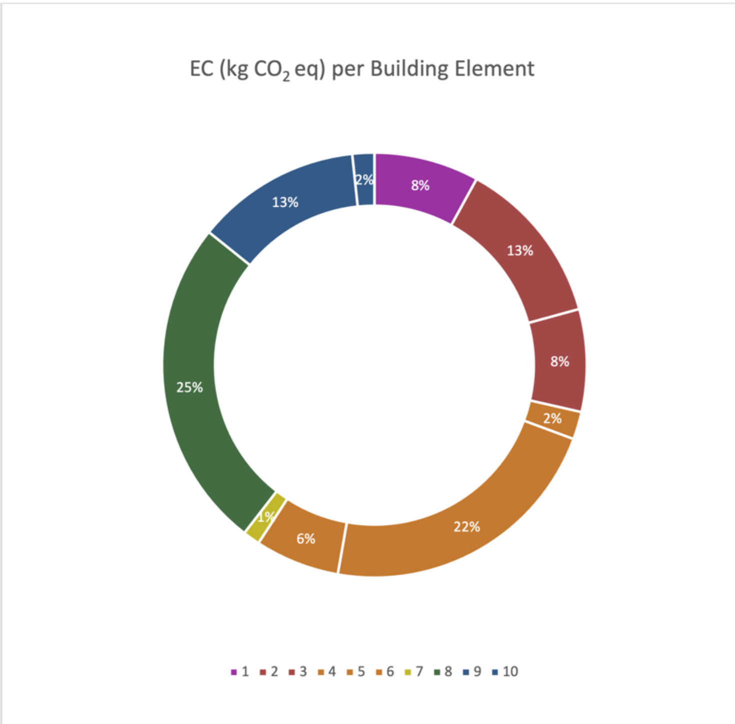


Figure 72: Pie Chart displaying Total Embodied Carbon (kgCO2eq) per Building Element. Reference: Author.

The graph's above (Figure's 72 & 73) show the same data as the above Sankey Diagram (Figure 71) but represented differently. Again, it is clear that the 'Steel Frame' contributes the most to the Total EC (36 759kgCO_2eq) followed by the 'Concrete Retaining Wall' (24 806 kgCO_2eq). The smallest contributors are the Hemp-Lime wall (due to it's low EC value), the Internal Partition (due to small quantity of material) and the Concrete Coloumns & Beams (due to small quantity of material).

The Sankey Diagram below (Figure 74) shows the Total Weight (t) per Building Material of the Bricolla House. Figure 75 shows Total EC (kgCO_2eq) per Building Material of the Bricolla House. The largest contributor of Total Weight (t) is 'Pozzolanic Concrete' followed by the 'Concrete Screed' and then 'Steel' and 'Steel Rebar'. The largest contributor to total EC (kgCO_2eq) is 'Pozzolanic Concrete', followed by 'Steel Structure' and then 'Steel Rebar'. What is interesting to note is that although 'Steel Rebar' and 'Steel Structure have small weights (21,70t and 26,92t accordingly), they have a large Total EC value's (43 253 kgCO_2eq for 'Steel Rebar' and 28 353 kgCO_2eq for 'Steel Structure'). This is due to the high EC value for steel per kg (1,04kgCO_2/kg) (for steel with 95% recycled content) and 'Steel Rebar' (1,99 kgCO_2/kg). Concrete has a lower EC value per unit of weight, of 0,1204kgCO_2/kg with 35% fly ash substitution. As can be seen from Figure's 74 and 75, both the weight of the building 'Structure' and the Total EC of the buildings 'Structure' are much greater than the weight and Total EC of the 'Envelope' (as to be expected). This is an important consideration has it points to the importance for designers/architects to first and foremost focus on reducing EC emissions of a building's structure.

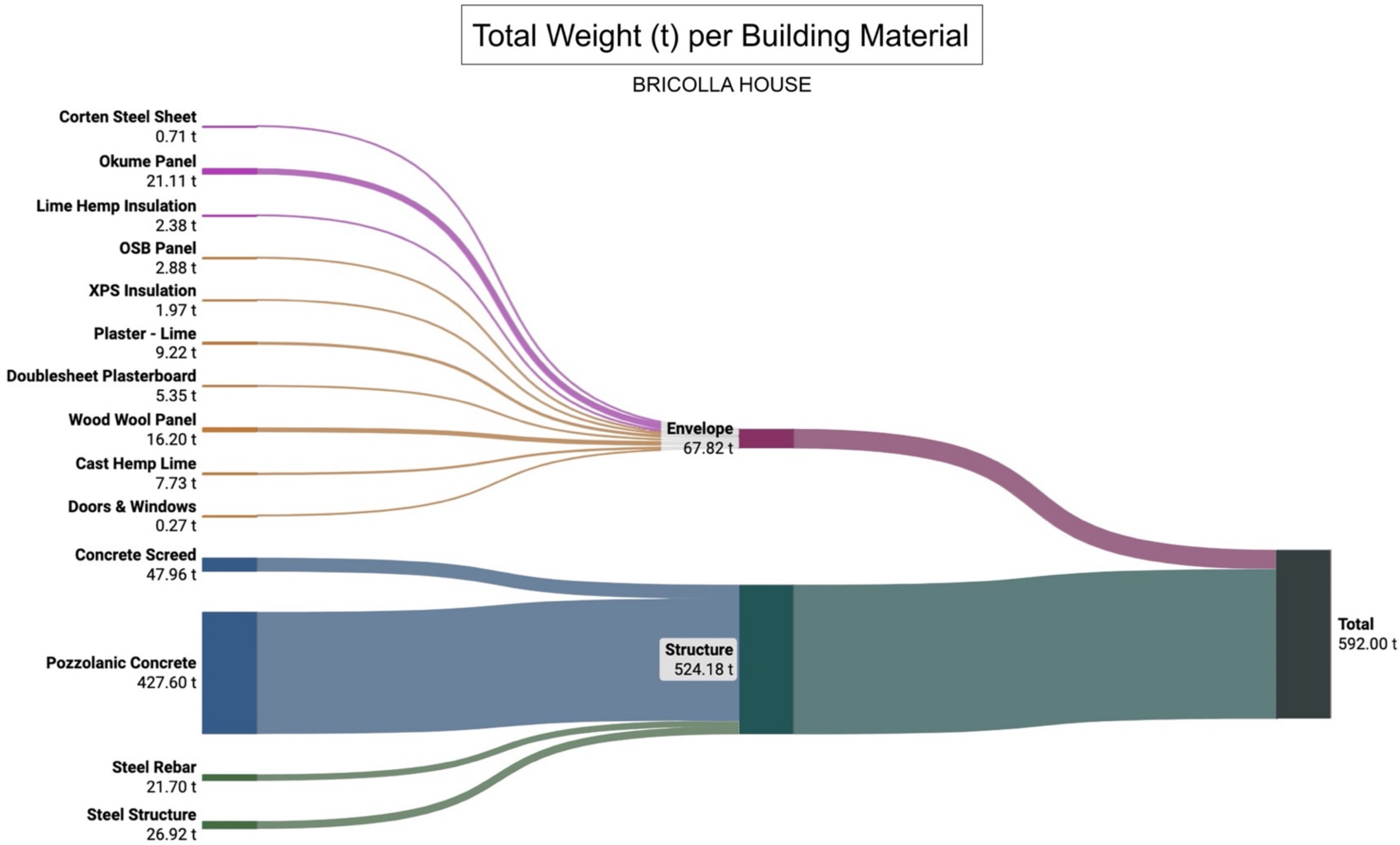


Figure 73: Sankey Diagram displaying the Total Weight (t) per Building Material. Reference: Author.

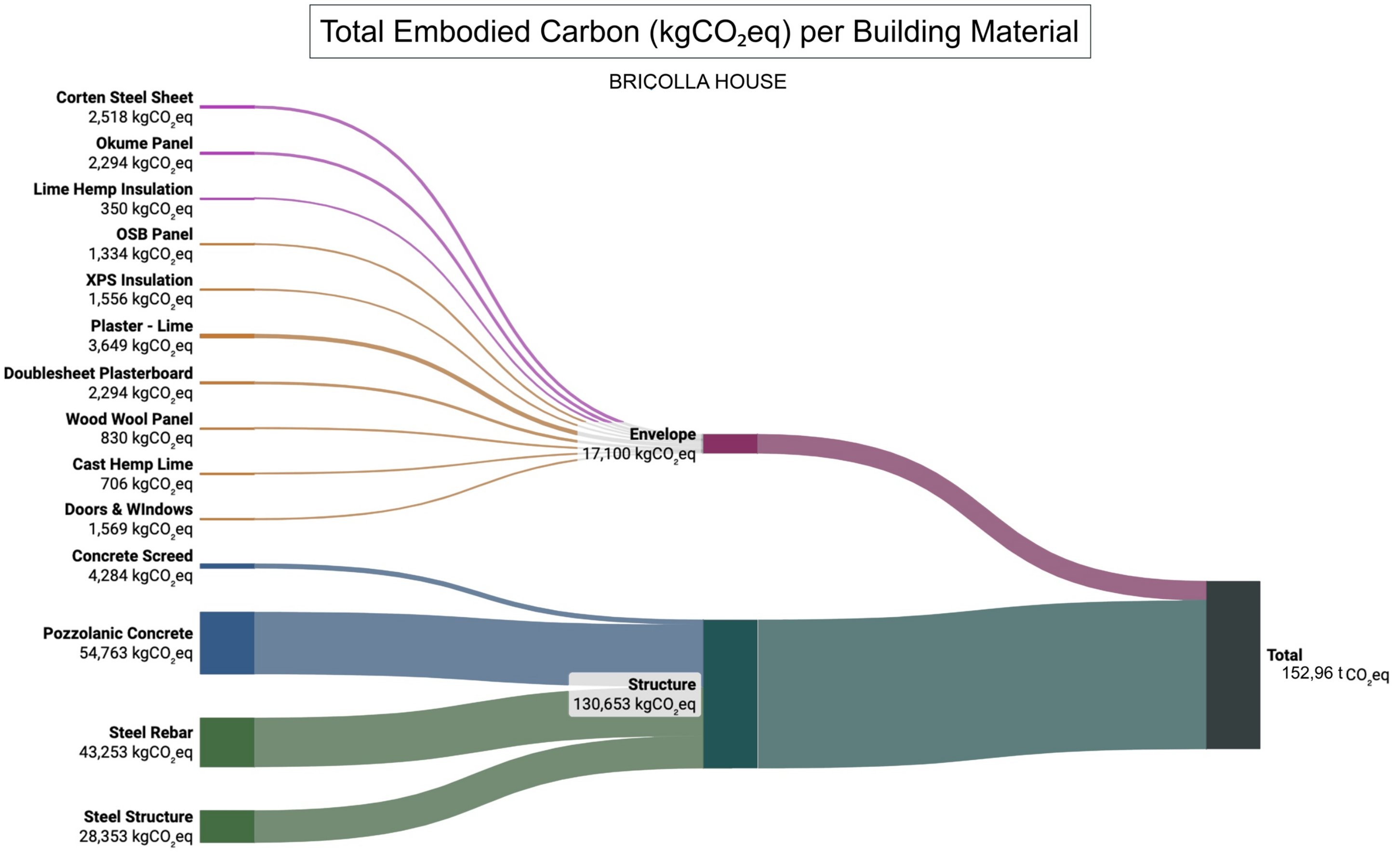


Figure 74: Sankey Diagram showing Total Embodied Carbon (kgCO2eq) per Building Material. Reference: Author.

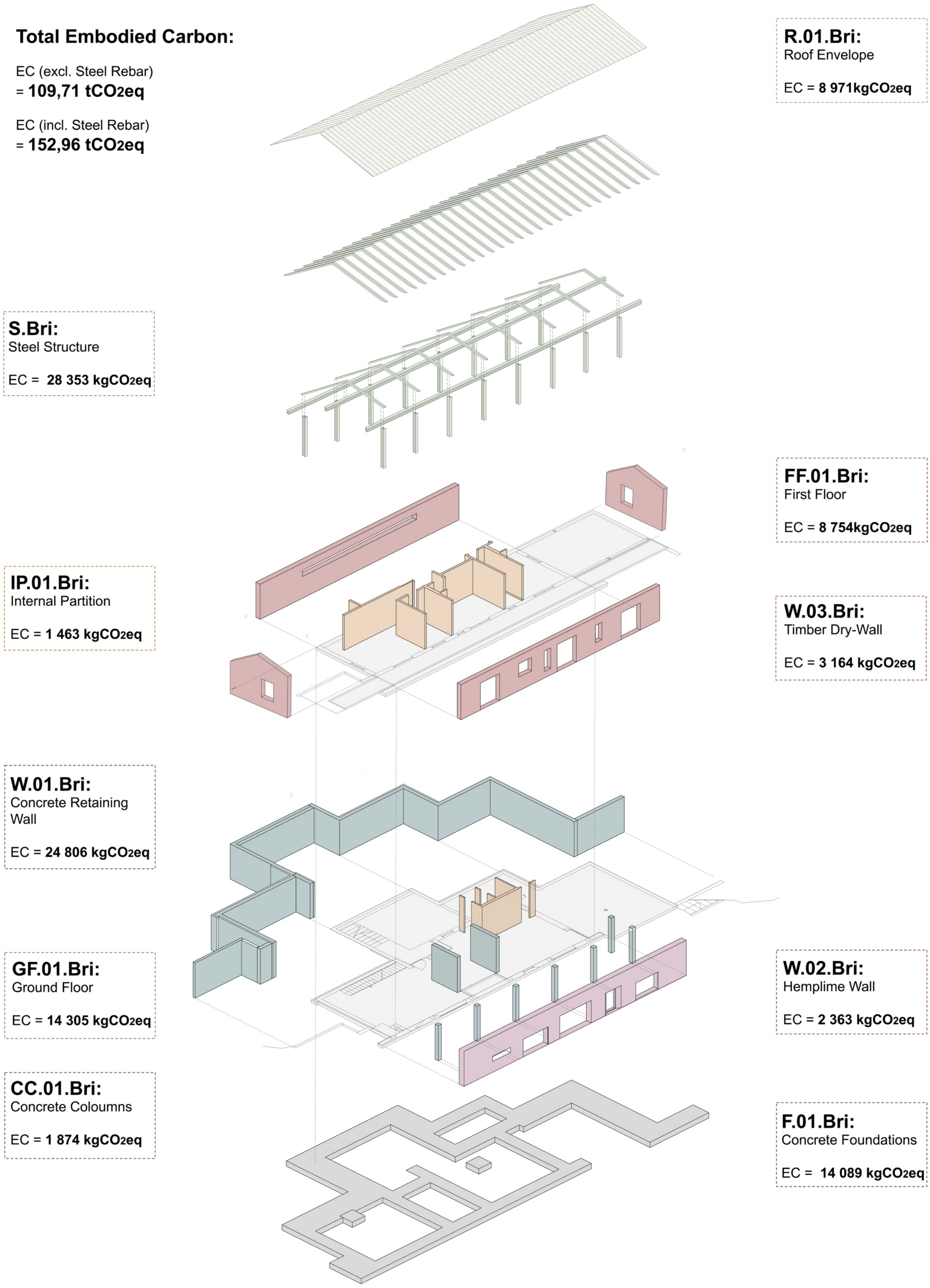


Figure 75: Total EC per Building Element (excl. Steel Bar)

4.9. Bricolla LCA: Interpretation and Improvement Analysis

The interpretation and improvement analysis of the LCA results obtained for the Bricolla House will be discussed and elaborated upon in Chapter 5 (Interpretation of Results).

What is to be noted is that there could be improvement on the LCA conduction of environmental impacts relating to 'Doors & Windows' of the Bricolla House. Although this building element was included in the LCA, the depth and accuracy of data relating to this component could be improved in future works.

4.10. A Comparison Case; comparing the Bricolla House with a 'Business-As-Usual' Case

In this section, a 'Business-As-Usual' case will be defined in order to engage in a comparison in LCA results with the Bricolla House. The 'Business-As-Usual' case is designed to the general industry practice in Italy. The house maintains the same structure as the Bricolla House with concrete foundations, a large concrete retaining wall and concrete coloumns and beams on the ground floor. The first floor is 'lightweight' with a structural steel frame. The perimeter walls are hollow-brick and plaster (double skin) and the internal partitions are single-skin hollow-brick and plaster. Diagrams of the floor plans as well as building element stratigraphy drawings will follow below.

4.11. Business-As-Usual case Drawings:

4.11.1. Ground Floor Plan and Floor Stratigraphy

LEGEND:

W.01.Bau

W.03.Bau

I.P.01.Bau

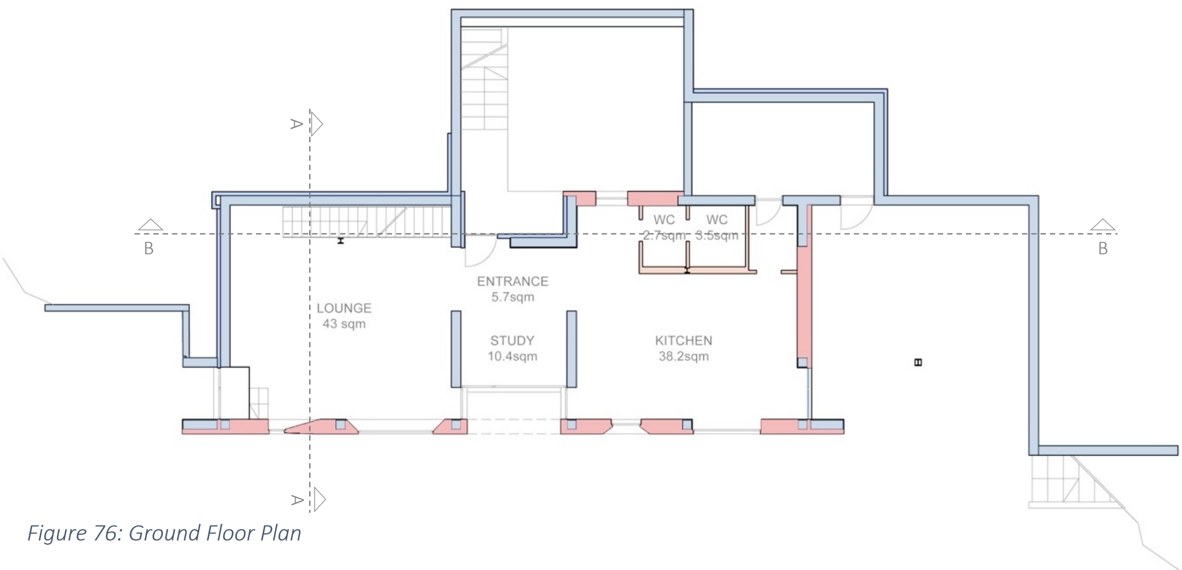


Figure 76: Ground Floor Plan

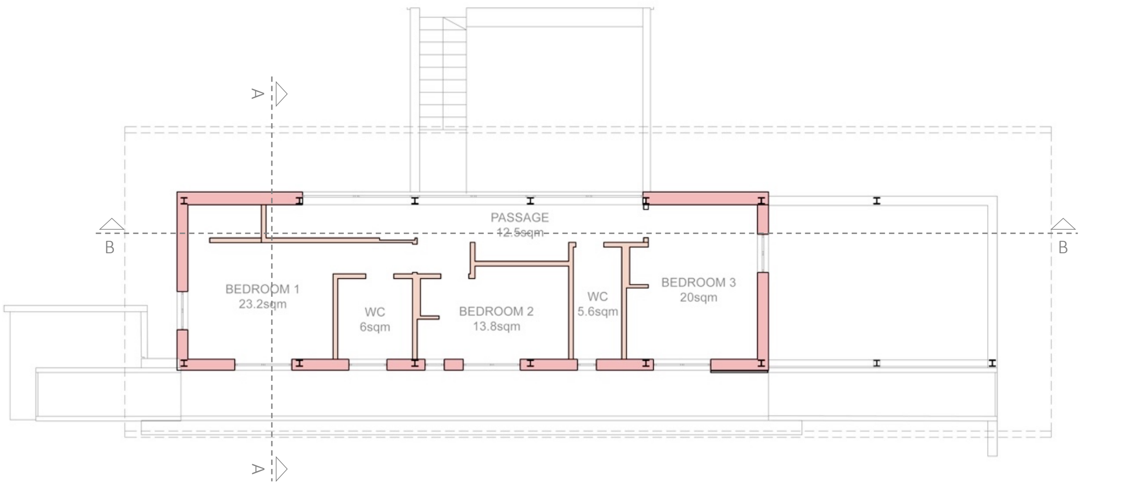
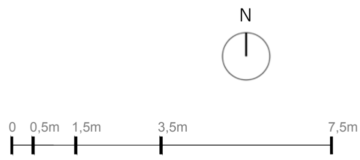


Figure 77: First Floor Plan



4.11.2. Ground Floor and First Floor Plans showing 'Heated Floor Area'

LEGEND:

GF.01.Bau

FF.01.Bau

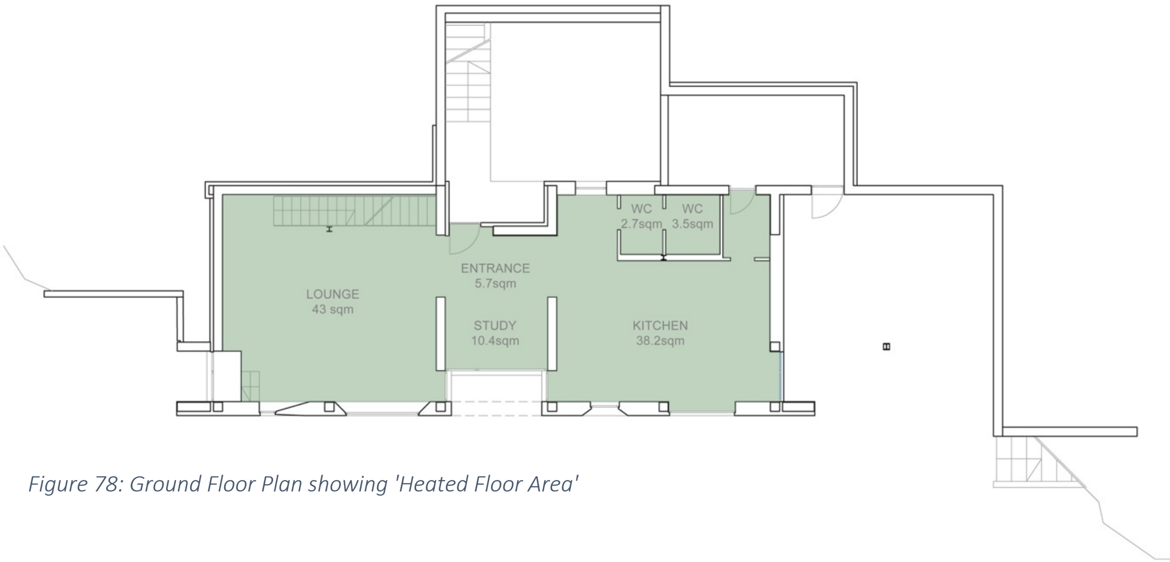


Figure 78: Ground Floor Plan showing 'Heated Floor Area'

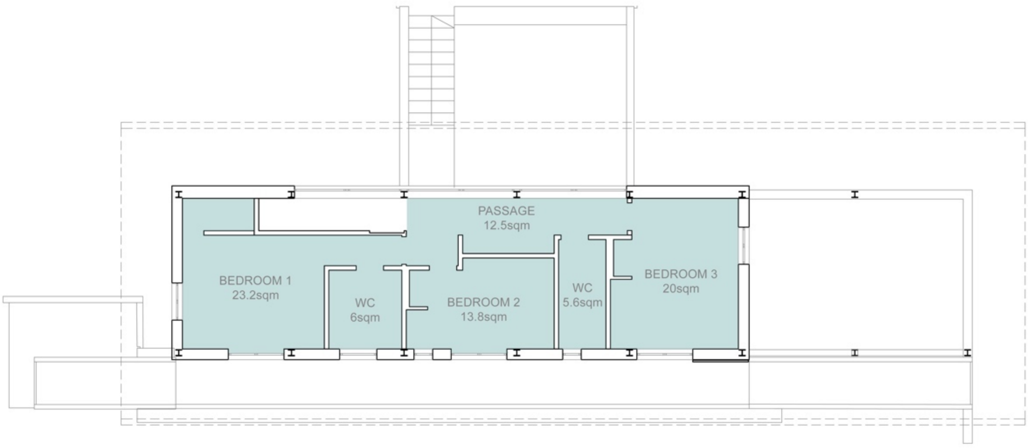
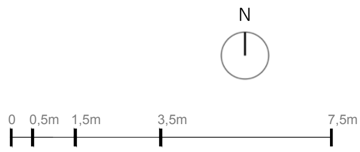


Figure 79: First Floor Plan showing 'Heated Floor Area'



4.11.3. Structural Drawings of Foundation and Steel Frame

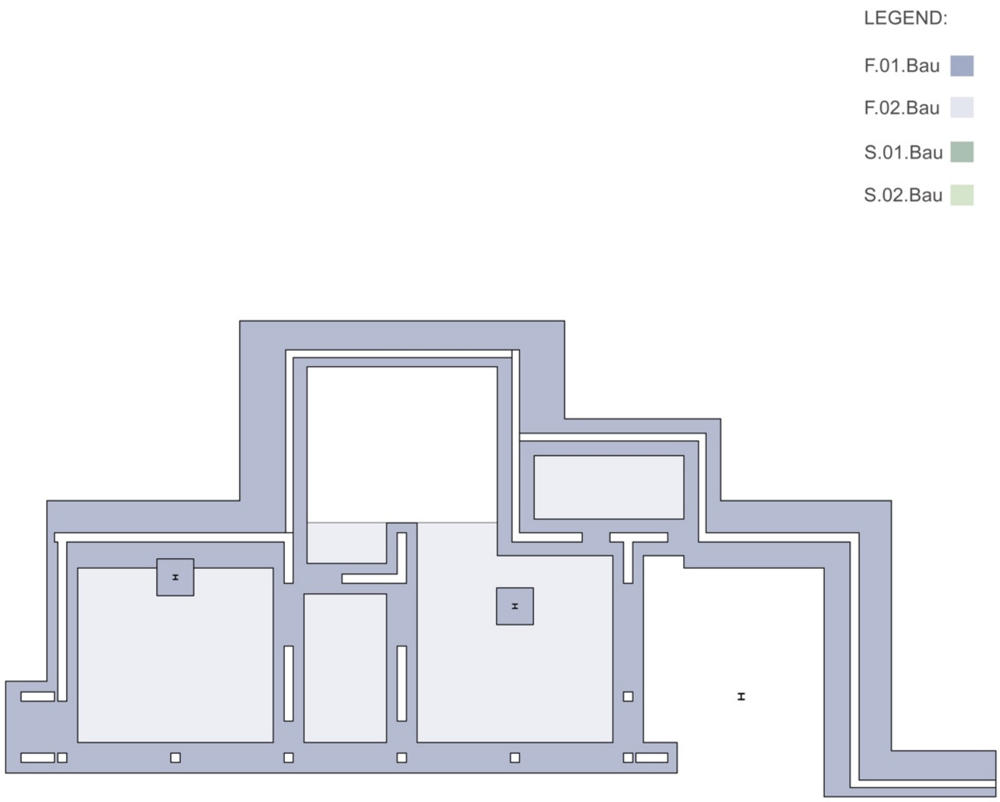


Figure 81: Foundations

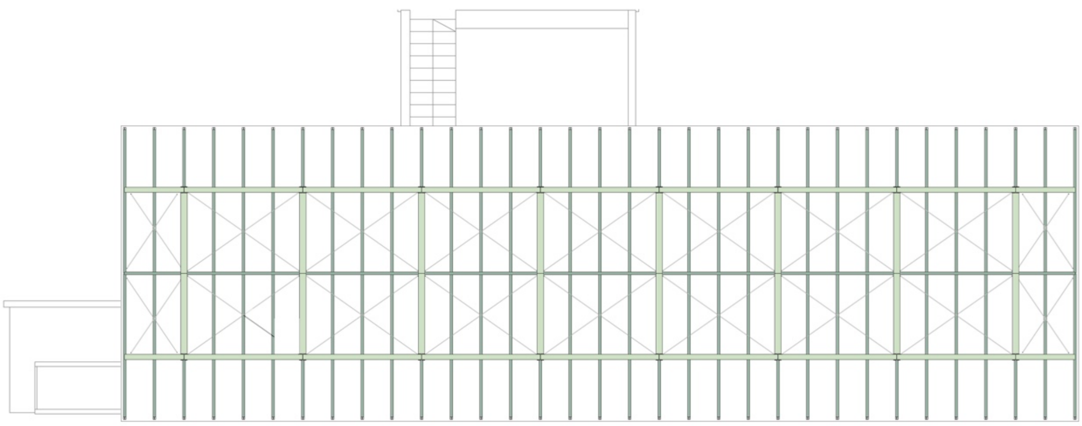
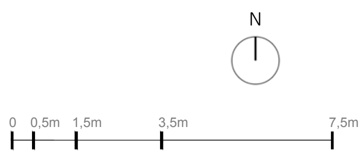


Figure 80: Steel Structure



4.11.4. Roof Plan showing 'Heated Floor Area'

LEGEND:

R.01.Bau

R.02.Bau

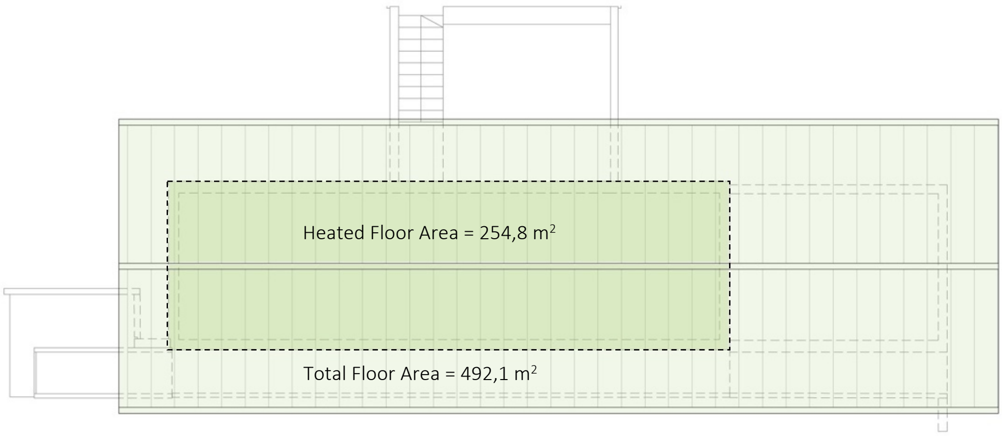
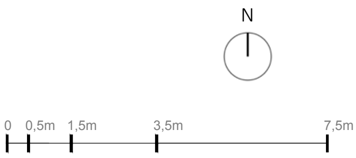


Figure 82: Roof Plan showing 'Heated' and 'Unheated' area



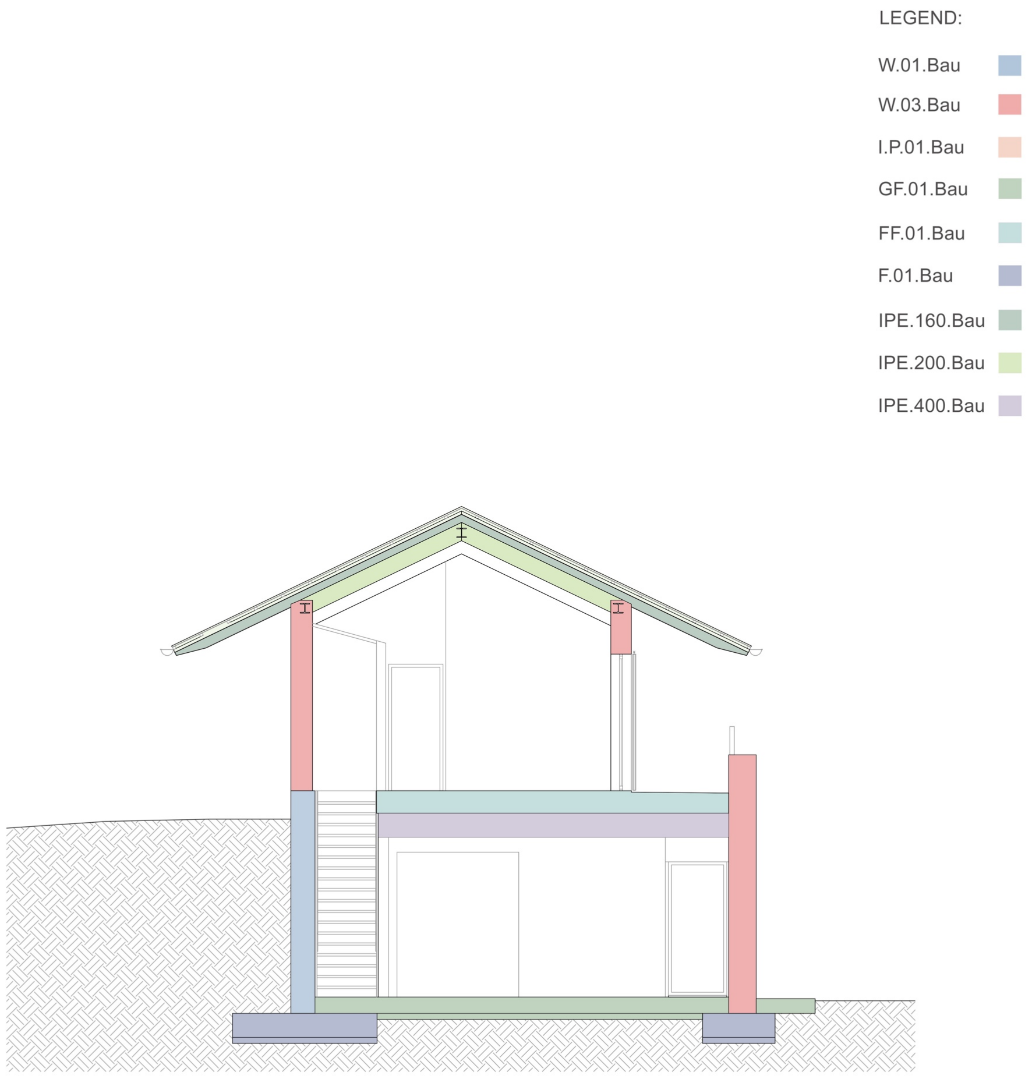


Figure 83: Business-As-Usual case Section A-A

LEGEND:

W.01.Bau
W.03.Bau
I.P.01.Bau
GF.01.Bau
FF.01.Bau
F.01.Bau
IPE.160.Bau
IPE.200.Bau
IPE.400.Bau

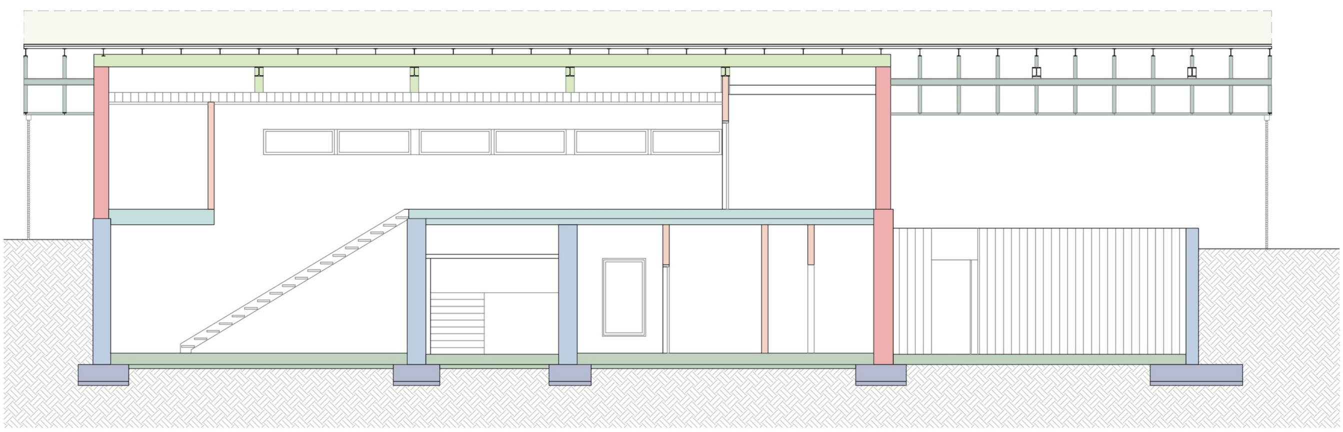


Figure 84: Business-As-Usual case Section B-B

W.01.Bau: Concrete Retaining Wall

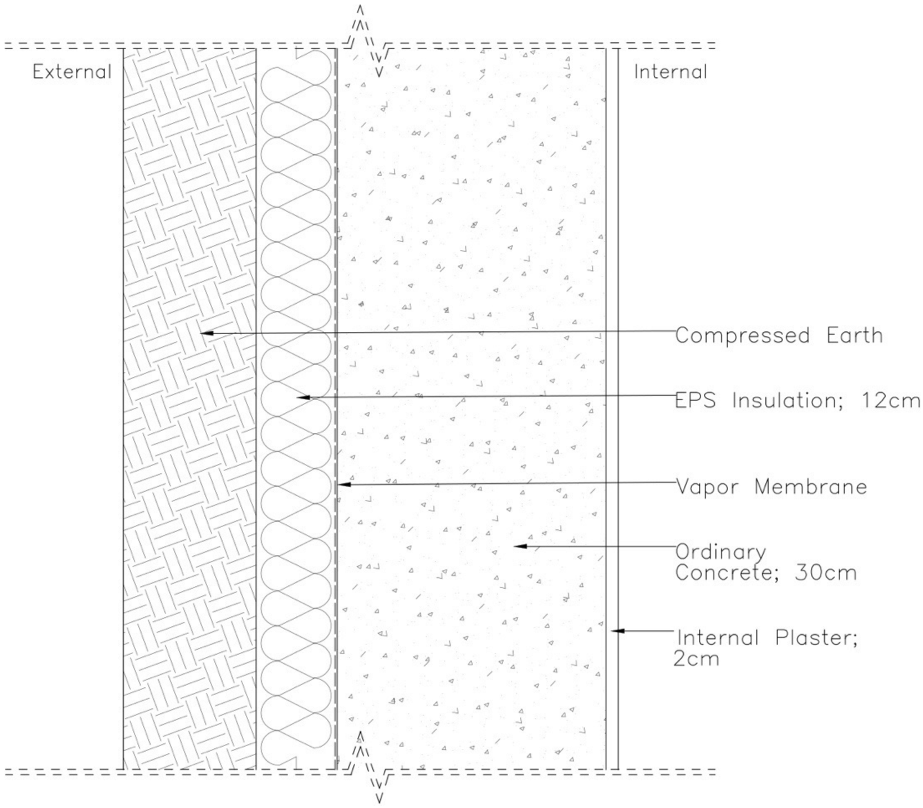


Figure 85: Concrete Retaining Wall Stratigraphy. Reference: Author.

Figure 86 shows the Concrete Retaining Wall Stratigraphy for the Business-As-Usual Case. The Concrete Retaining Wall is composed of 30cm of Ordinary Concrete (with Portland cement), EPS Insulation (12cm) and Internal Plaster (2cm).

W.01.Bau: Hollow Brick and Plaster Wall

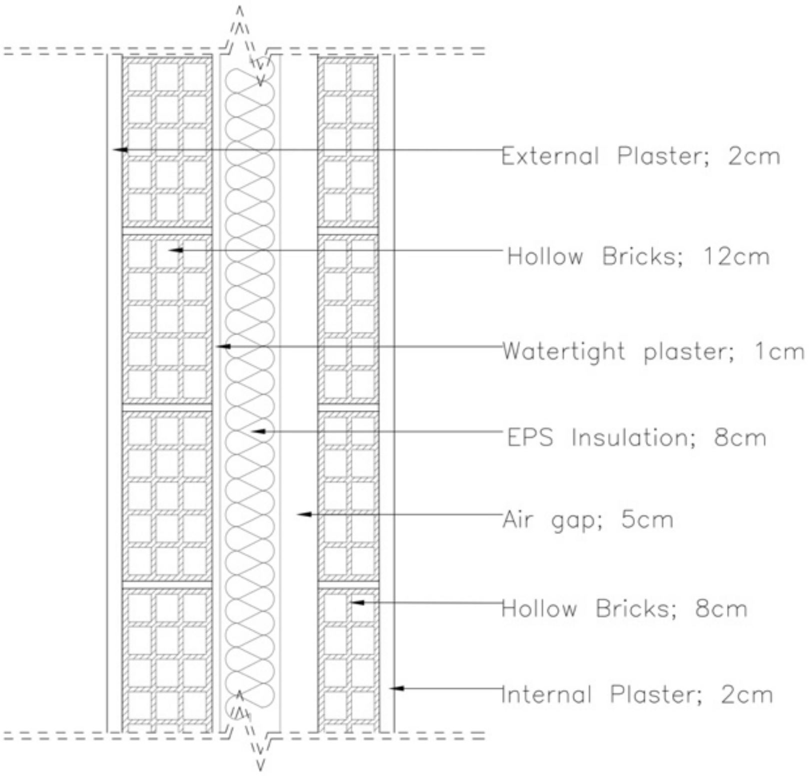


Figure 86:Hollow Brick & Plaster Wall Stratigraphy.
Reference: Author.

Figure 87 shows the External Wall Stratigraphy for the Business-As-Usual Case. The Hollow Brick & Plaster Wall is composed of Hollow Bricks (12cm), EPS Insulation (8cm), an air gap, another layer of Hollow Bricks (8cm) and Internal & External Plaster (2cm).

IP.01.Bau: Single-skin Hollow Brick

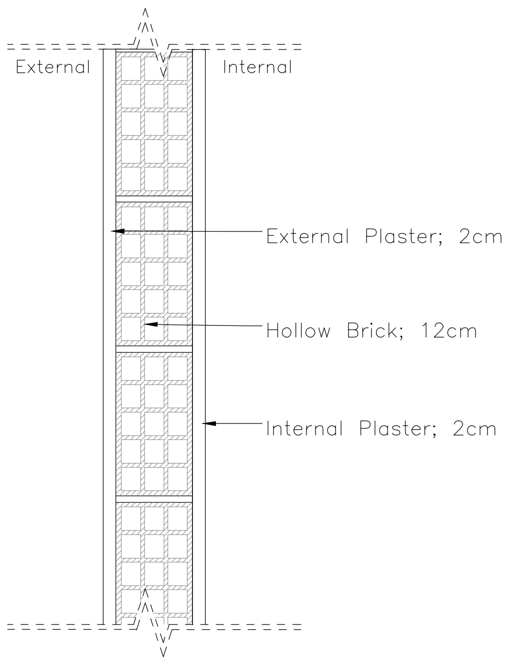


Figure 87: Hollow Brick Internal Partition Wall.
Reference: Author.

Figure 88 shows the stratigraphy of the Internal Partition walls. They are composed of a single skin of Hollow Brick (12cm)and Internal and External Plaster (2cm).

GF.01.Bau: Structural Slab on Ground

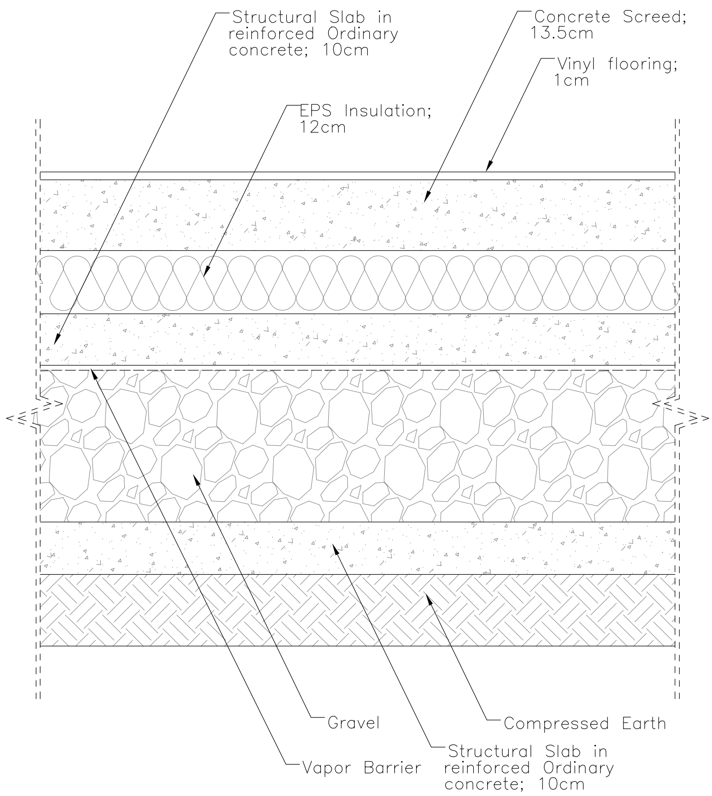


Figure 88: Ground Floor Stratigraphy. Reference: Author.

Figure 89 shows the Ground Floor Stratigraphy, composed of gravel, followed by a structural slab in reinforced Ordinary concrete (with Portland cement), XPS Styrodur 3035 insulation, a concrete screed with a Vinyl flooring finish.

FF.01.Bau: Structural Slab of First Floor

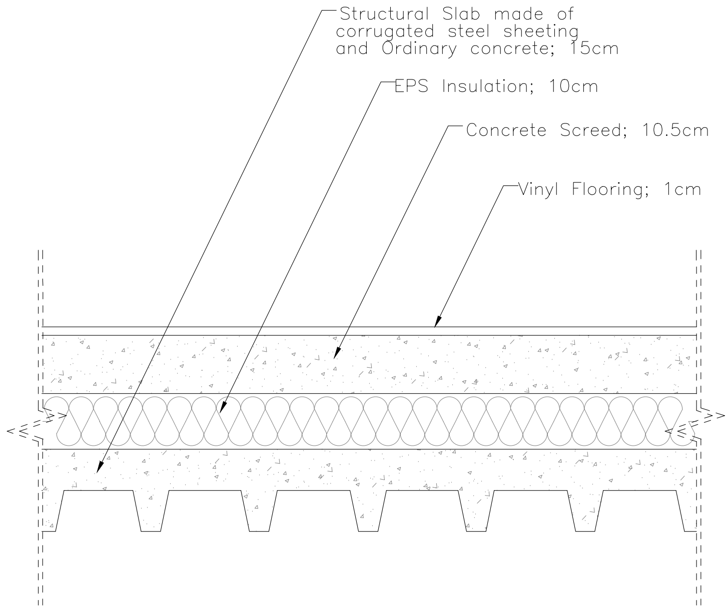


Figure 89: Intermediate Floor Stratigraphy

The first floor stratigraphy, as seen in Figure 90, is comprised of a structural slab made of a corrugated sheet followed by cast, reinforced Ordinary concrete (with Portland cement). Above the structural slab is XPS Styrodur 3035 insulation, a concrete screed and a Vinyl flooring finish.

R.01.Bau: Roof Envelope with Clay Roof Tiles

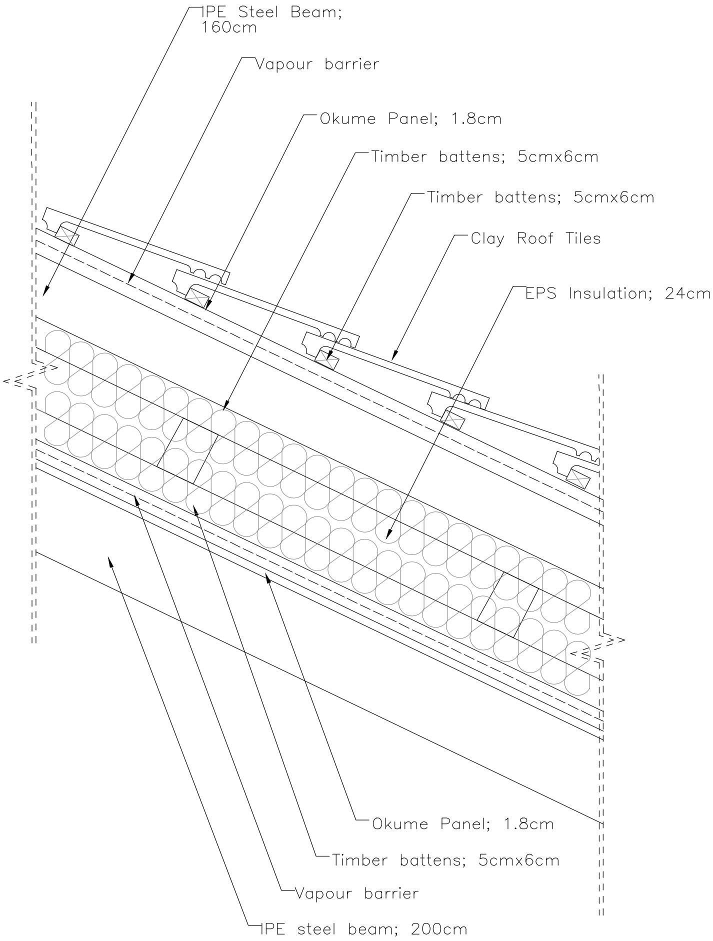


Figure 90: Roof Stratigraphy

The Roof Envelope is supported by Steel IPE 200 and IPE 160 frames. The roof finish is Clay Roof Tiles supported by timber battens. There is an EPS Insulation layer which is 24cm thick, supported by timber battens and finished with a 1,8cm thick Okume panel (as seen in Figure 91).

4.12. The Business-As-Usual Case Life Cycle Assessment Introduction

This section of the thesis contains the 4 stages of the Business-As-Usual case LCA (Goal & Scope Definition, Life Cycle Inventory, Life Cycle Impact Assessment and Interpretation of Results).

4.13. Goal & Scope Definition:

The Business-As-Usual Case LCA is aimed to understand the EC emissions of the Business-As-Usual Case during it's entire life cycle (Modules A1-A3 (Production), A4 & C2 (Transport) and C2-C4 (End-of-Life) as defined by EN 15978). Modules B1-B7 (Use Stage) is not considered in this LCA. The performed LCA will consider the Whole Building, including all building elements (structural system as well as envelope). The aim of conducting a LCA of the Business-As-Usual Case is to have a comparable case to contextualize the LCA results of the Bricolla House.

As defined in the Bricolla House LCA, the building life span considered in the Business-As-Usual case LCA is also 50 years (with post-assessment results also analysing the impact of a 100 year building life span). The functional unit of 'heated floor area' is m^2.

Also as defined in the Bricolla House LCA and similarly in the Business-As-Usual case LCA, the environmental impacts relating to the 'Steel Rebar' supporting the concrete structure are not calculated in the LCA software (EURECA), due to the limitation of the software in including such elements. The impact assessment of 'Steel Rebar' is performed and calculated manually, adding to the results at the end of the study. In the case of the Business-As-Usual case LCA (and the Bricolla House LCA), the timber battens supporting the cladding of the timber dry-wall were excluded as well as the timber battens supporting the insulation of the roof envelope. This is due to a limitation of the EURECA software in adding limited 'linear elements' (as discussed previously on page 91).

'Without Carbon Storage' EC data is selected for timber elements (this is a requirement for the EURECA software). This largely affects the EC results of timber elements and should be noted when analysing the LCA outcomes.

4.14. Life Cycle Inventory (LCI):

The following few pages contain information concerning the building element stratigraphy of the Business-As-Usual Case as well as the data input values concerning the specific materials. This building element dimensions are the same as the Bricolla House case, with specific data on materials selected for the Business-As-Usual Case extracted from the ICE Database and input into the EURECA Tool to obtain the final LCA results. As previously mentioned, including the LCI data sheets is important as the specific data entries and information pertaining to the LCA are transparent (unlike many LCA studies where specific information pertaining to the assessment are unclear).

4.14.1. LCI: EC results per Technical Element for Modules A1-A3 (PRODUCTION)

ROOF SYSTEM (R.01.Bau)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Clay Roof Tiles	1650,00	0,012	19,80	0,26	5,15
EPS Insulation	28,00	0,150	4,20	3,29	13,82
Plasterboard	665,00	0,013	8,65	0,39	3,37
Okume Panel	700,00	0,018	12,60	0,31	3,91

Total Embodied Carbon (CO_2/m²)	26,24
Roof Area m²	282,15
Total (kgCO_2eq)	26,24 x 282,15 = **9 635,53**

FLOOR ON THE GROUND (GF.01.Bau)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Vinyl Flooring	1330,00	0,005	6,65	3,19	21,21
Concrete Screed	2000,00	0,10	200,00	0,10	20,00
EPS Insulation	28,00	0,10	2,80	3,29	9,21
Ordinary Concrete	2400,00	0,10	240,00	0,14	33,60

Total Embodied Carbon (CO_2/m²)	84,03
Ground Floor Area m²	265,56
Total (kgCO_2eq)	84,03 x 265,56 = **20 060,45**

HORIZONAL PARTITION (FF.01.Bau)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Vinyl Flooring	1330,00	0,01	6,65	3,19	21,21
Concrete Screed	2000,00	0,10	200,00	0,10	20,00
EPS Insulation	28,00	0,09	2,52	3,29	8,29
Ordinary Concrete	2400,00	0,10	240,00	0,15	36,00

Total Embodied Carbon (CO_2/m²)	85,50
Horizontal Partition Area m²	179,95
Total (kgCO_2eq)	85,50 x 179,95 = **13 635,39**

EXTERNAL WALL (W.02.Bau: Hollow Bricks and Plaster)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Plaster - lime	1300,00	0,02	26,00	0,39	10,14
Hollow Brick	240,00	0,12	28,80	0,26	7,49
EPS Insulation	28,00	0,08	2,24	3,29	7,37
Hollow Brick	240,00	0,08	19,20	0,26	4,99
Plaster - lime	1300,00	0,01	13,00	0,39	5,07

Total Embodied Carbon (CO_2/m²)	35,06
Wall Area m²	209,14
Total (kgCO_2eq)	35,06 x 209,14 = **7 332,36**

EXTERNAL WALL (W.01.Bau: Ordinary Concrete Retaining Wall)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Plaster - lime	1300,00	0,02	26,00	0,39	10,14
Ordinary Concrete	2380,00	0,30	714,00	0,15	107,10
EPS Insulation	28,00	0,09	2,52	3,29	8,29

Total Embodied Carbon (CO_2/m²)	125,53
Wall Area m²	191,37
Total (kgCO_2eq)	161,23 x 191,37 = **28 950,80**

INTERNAL PARTITIONING (IP.01.Bau: Hollow Brick and Plaster)

Component	Density (kg/m³)	Thickness (m)	Weight per square meter (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Plaster - lime	665,00	0,02	13,30	0,39	5,19
Hollow Brick	240,00	0,12	28,80	0,26	7,49
Plaster - lime	665,00	0,02	13,30	0,39	5,19

Total Embodied Carbon (CO_2/m²)	17,86
Partitioning Area m²	96,62
Total (kgCO_2eq)	17,86 x 96,62 = **1 725,83**

STEEL FRAME (IPE 160, HEB 200, IPE 300, IPE 400)

Component	Density (kg/m³)	Area Section (m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)	Embodied Carbon (kgCO_2eq)
IPE 160 Steel	7850,00	0,008	1,21	49,57	21515,24
HEB 200 Steel	7850,00	0,010	1,21	75,70	7222,97
IPE 300 Steel	7850,00	0,017	1,21	161,47	1453,27
IPE 400 Steel	7850,00	0,024	1,21	227,96	2370,83

Total EC (kgCO_2eq)	**32 562,31**

CONCRETE FOUNDATIONS (F.01.Bau)

Component	Density (kg/m³)	Thickness (m)	Weight (kg/m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)
Ordinary Concrete	2400,00	0,40	960,00	0,15	144,00

Total Embodied Carbon (CO_2/m²)	144,00
Foundation Area	153,23
Total (kgCO_2eq)	**17 314,56**

CONCRETE COLOUMNS & BEAMS

Component	Density (kg/m³)	Area Section (m²)	Embodied Carbon (CO_2/kg)	Embodied Carbon (CO_2/m²)	Total EC (kgCO_2eq)
Ordinary Concrete	2400,00	0,09	0,150	33,21	2300,40

Total (kgCO_2eq)	**2 300,40**

Figure 91: Table showing LCI per Building Element for Modules A1-A3 (Production). Reference: Author.

4.14.3. LCI: EC results per Material for Modules A4, C2 (TRANSPORT)

Material	Payload (t)	Transport					
		Type	Vehicle	# vehicles	Distance	Fuel	EC ($kgCO_2eq$)
Clay Roof Tiles	5,59	Road	Lorry 7.5 -12 t	1	100	Diesel	62,72
EPS Insulation	2,25	Road	Lorry < 7.5 t	1	100	Diesel	44,84
Plasterboard	2,44	Road	Lorry < 7.5 t	1	60	Diesel	24,03
Okume Panel	3,56	Sea	Transatlantic	1	2000	HFO	94,43
		Road	Lorry 7.5 -12 t	1	150	Diesel	
Vinyl Flooring	1,61	Road	Articulated lorry 24 - 40 t	1	100	Diesel	73,87
Concrete Screed	89,18	Road	Articulated lorry 24 - 40 t	1	60	Diesel	290,16
Ordinary Concrete	397,15	Road	Articulated lorry 24 - 40 t	10	60	Diesel	765,17
Plaster - Lime	12,13	Road	Lorry 12 - 24 t	1	100	Diesel	134,74
Hollow Brick	12,82	Road	Lorry 12 - 24 t	1	100	Diesel	135,41
IPE 160 Steel	27,36	Rail	Train 500 t	1	1035	Diesel	43,59
HEB 200 Steel	7,56	Road	Lorry 12 - 24 t	1	265	Diesel	182,34
IPE 300 Steel	1,2	Road	Lorry 7.5 -12 t	1	1000	Diesel	560,86
IPE 400 Steel	1,96	Rail	Train 500 t	1	900	Diesel	37,91

Figure 92: Table showing LCI per Material for Modules A4, C2 (Transport). Reference: Author.

4.14.4. LCI: EC results per Building Element for Modules C2-C4 (END-OF-LIFE)

ROOF SYSTEM (R.01.Bau)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Clay Roof Tiles	5,59	Recycle	100%	10,30
EPS Insulation	0,45	Landfill	100%	0,83
Plasterboard	2,44	Recycle	100%	4,50
Okume Panel	3,55	Recycle	100%	6,56
				22,19

FLOOR ON THE GROUND (GF.01.Bau)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Vinyl Flooring	0,96	Recycle	100%	1,77
Concrete Screed	53,19	Landfill	100%	97,70
EPS Insulation	0,40	Landfill	100%	0,75
Ordinary Concrete	63,83	Landfill	100%	117,73
				217,95

HORIZONTAL PARTITION (FF.01.Bau)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Vinyl Flooring	0,65	Recycle	100%	1,20
Concrete Screed	35,99	Landfill	100%	66,38
EPS Insulation	0,25	Landfill	100%	0,45
Ordinary Concrete	43,19	Landfill	100%	79,65
				147,68

EXTERNAL WALL (W.02.Bau: Hollow Brick and Plaster)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Plaster - lime	5,44	Landfill	100%	10,03
Hollow Brick	6,02	Landfill	100%	11,11
EPS Insulation	0,47	Recycle	100%	0,86
Hollow Brick	4,02	Landfill	100%	7,41
Plaster - lime	2,72	Landfill	100%	5,01
				34,42

EXTERNAL WALL (W.01.Bau: Perimeter Concrete Retaining Wall)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Plaster - lime	1,40	Landfill	100%	2,58
Ordinary Concrete	51,29	Landfill	100%	334,60
EPS Insulation	0,14	Recycle	100%	0,25
				337,43

INTERNAL PARTITIONING (IP.01.Bau)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Plaster - lime	1,29	Landfill	100%	2,37
Hollow Brick	2,78	Landfill	100%	5,13
Plaster - lime	1,29	Landfill	100%	2,37
				9,87

STEEL FRAME (IPE 160, HEB 200, IPE 300, IPE 400)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
IPE 160 Steel	17,78	Recycle	100%	40,13
HEB 200 Steel	5,98	Recycle	100%	6,44
IPE 300 Steel	1,2	Recycle	100%	2,22
IPE 400 Steel	1,96	Recycle	100%	3,61
				52,4

CONCRETE FOUNDATIONS (F.01.Bau)

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Ordinary Concrete	84,24	Landfill	100%	155,36

CONCRETE FOUNDATIONS

Component	Weight (t)	Disposal type	Disposal Amount (%)	Embodied Carbon ($kgCO_2eq$)
Ordinary Concrete	15,34	Landfill	100%	28,28

4.15. Life Cycle Impact Assessment (LCIA):

The table below (Figure 95) highlights the 'Whole Building EC ($kgCO_2eq$) per Life-Cycle Stage (as defined by EN 15978) for the 'Business-As-Usual' case. The Initial stage (Production, Modules A1-A3) is by far the greatest contributor to the 'Whole Building EC, contributing 97,7% of the total amount. 'Transport' (Modules A4, C2) contributes 1,6% and 'End of Life' (Modules C2-C4) contributes 0,68%. The 'Recurring' stage (Modules B1-B5) is not included in this study. As seen in Figure 95 (below) the 'Whole Building EC per 'heated floor area' is 719,54 $kgCO_2eq/m^2$. If considering 'total floor area', then the 'Whole Building EC' is 372,64 $kgCO_2eq/m^2$. If considering a 'Building Life-Span' of 50 years, then the 'Whole Building EC per 'heated floor area' per year is 14,39 $kgCO_2eq/m^2/yr$. If considering a 'Building Life-Span' of 100 years, then the 'Whole Building EC' per 'heated floor area' per year is 7,20 $kgCO_2eq/m^2/yr$.

Total EC Results: Business-As-Usual Case

Life-Cycle Stage	Whole Buidling Embodied Carbon ($kgCO_2eq$)
Initial (A1, A2, A3)	179 846,72
Recurring (B1, B2, B3, B4, B5)	N.A.
End of Life (C2, C3, C4)	1067,77
Transport (A4, C2)	2349,68
	183 338,96
Heated area (m^2)	254,8
Unheated area (m^2)	237,3
Whole Building Embodied Carbon ($kgCO_2/m^2$)	183 338,96 / 254,8 = **719,54**
	Whole Building Embodied Carbon / 'Heated Floor Area'
Whole Building Embodied Carbon ($kgCO_2/m^2$)	183 338,96 / 492,1 = **372,64**
	Whole Building Embodied Carbon / 'Total Floor Area'
Building Life-Span (years)	50
Whole Building Embodied Carbon ($kgCO_2/m^2/yr$)	183 338,96 / 254,8 / 50 = **14,39**
	Whole Building Embodied Carbon / 'Heated Floor Area' / Building Life Span
Building Life-Span (years)	100
Whole Building Embodied Carbon ($kgCO_2/m^2/yr$)	183 338,96 / 254,8 / 100 = **7,20**
	Whole Building Embodied Carbon / 'Heated Floor Area' / Building Life Span

Figure 93: Table showing Total Building Embodied Carbon per stage. Reference: Author.

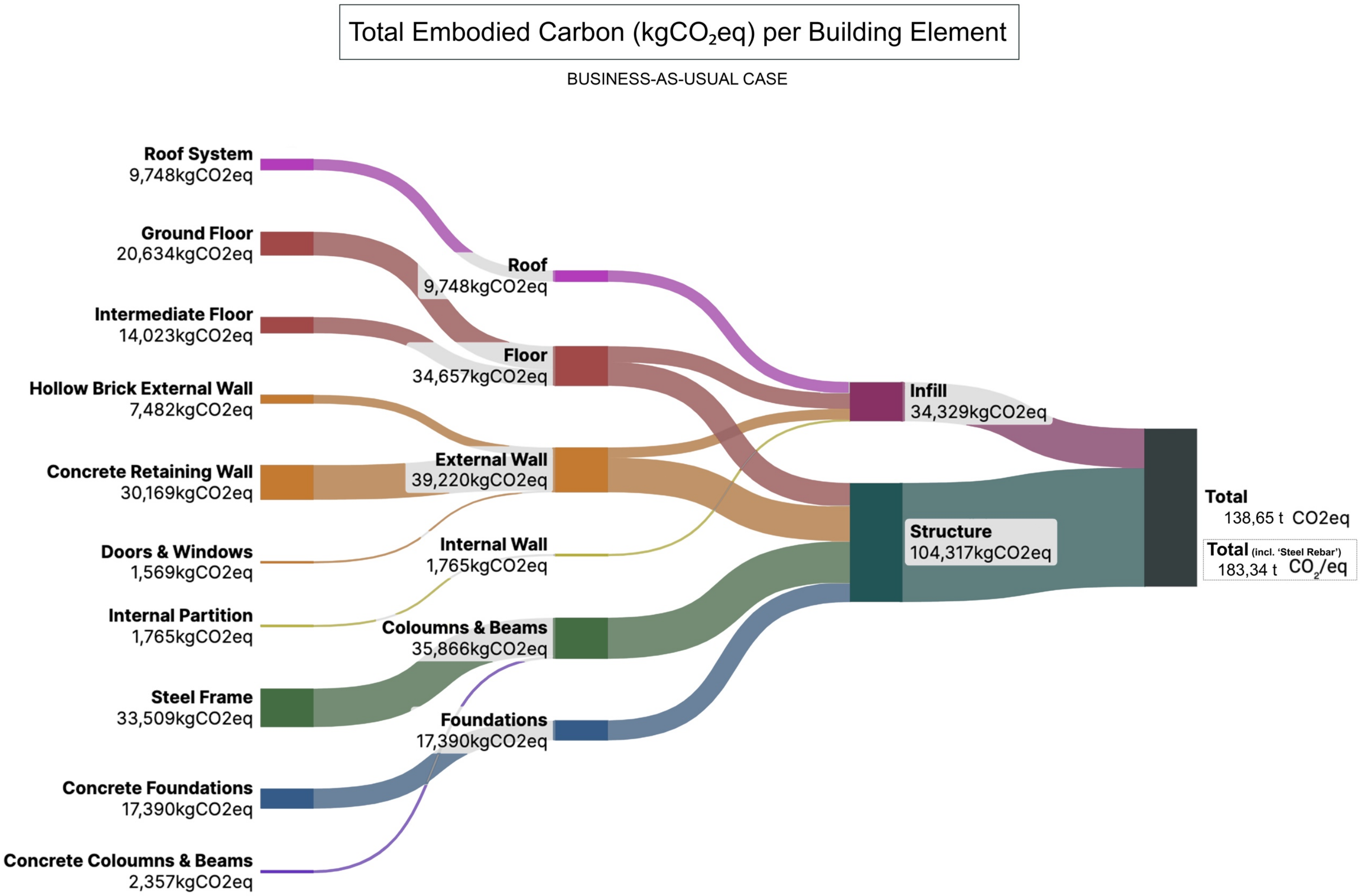


Figure 94: Sankey Diagram displaying Total Embodied Carbon (kgCO2eq) per Building Element, excluding 'Steel Rebar'. Reference: Author.

The Sankey Diagram above (Figure 96) shows the Total EC (kgCO_2eq) per Building Material of the Business-As-Usual Case. As can be seen, the 'Steel Frame' is the greatest contributor to the whole building total EC, with emissions accounting to 46 605 kgCO_2eq. The second greatest contributor is the 'Concrete Retaining Wall' with an emissions value of 29 663 kgCO_2eq. The 'Structure' contributes 78% to the Total EC value and the 'Envelope' contributes 22%.

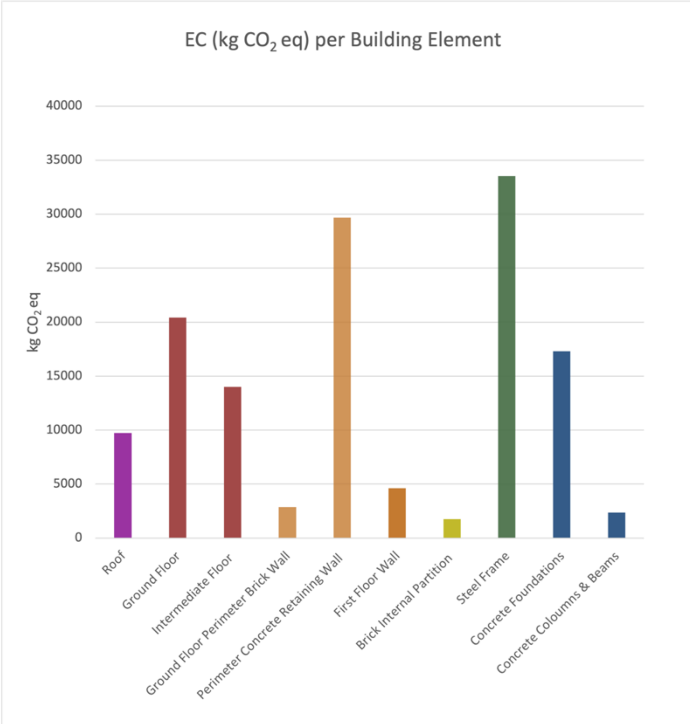


Figure 95: Histogram displaying Total Embodied Carbon (kgCO2eq) per Building Element. Reference: Author.

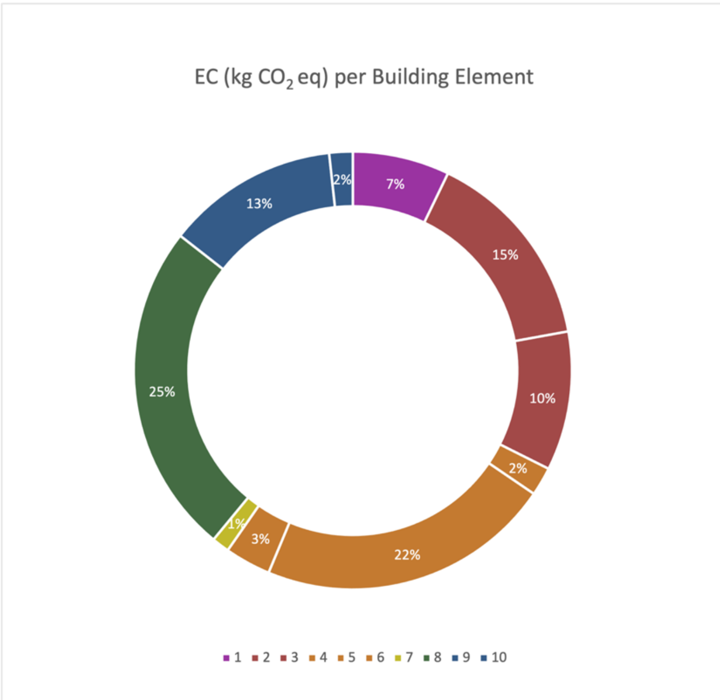


Figure 96: Pie Chart displaying Total Embodied Carbon (kgCO2eq) per Building Element. Reference: Author.

The graph's aside (Figure's 97 & 98) represent the same data as in the Sankey Diagram (Figure 96), showing the Total EC (kgCO_2eq) per Building Material of the Business-As-Usual Case). Again, it is clear that the 'Steel Frame' has the highest total EC followed by the 'Concrete Retaining Wall'. The elements with the lowest EC emissions are the 'Brick Internal Partition' and 'Concrete Coloumns & Beams'. This is due to the small 'amount' of these elements (material quantities of these elements are low).

The Sankey Diagram's (Figure's 100 and 101) show the Total Weight (t) per Building Material and Total EC (kgCO_2eq) per Building Material, accordingly, of the Business-As-Usual Case. As can be seen, 'Ordinary Concrete' has by far the highest weight of all the building materials. It is interesting to compare these two Sankey Diagram's and see that although 'Steel Structure' and 'Steel Rebar' both have a small weight (26,92t and 21,70t accordingly) they have large EC value's (33 509 kgCO_2eq and 43 523 kgCO_2eq). This is due to steel's high EC value per unit of weight, in comparison to 'Concrete'. The EC value for the 'Steel' Structure per kg is 1,21kgCO_2/kg (for steel with 65% recycled content) and 1,99 gCO_2/kg for 'Steel Rebar' (with no recycled content). For concrete the EC value per unit of weight is 0,15 kgCO_2/kg (using 'ordinary' Portland cement).

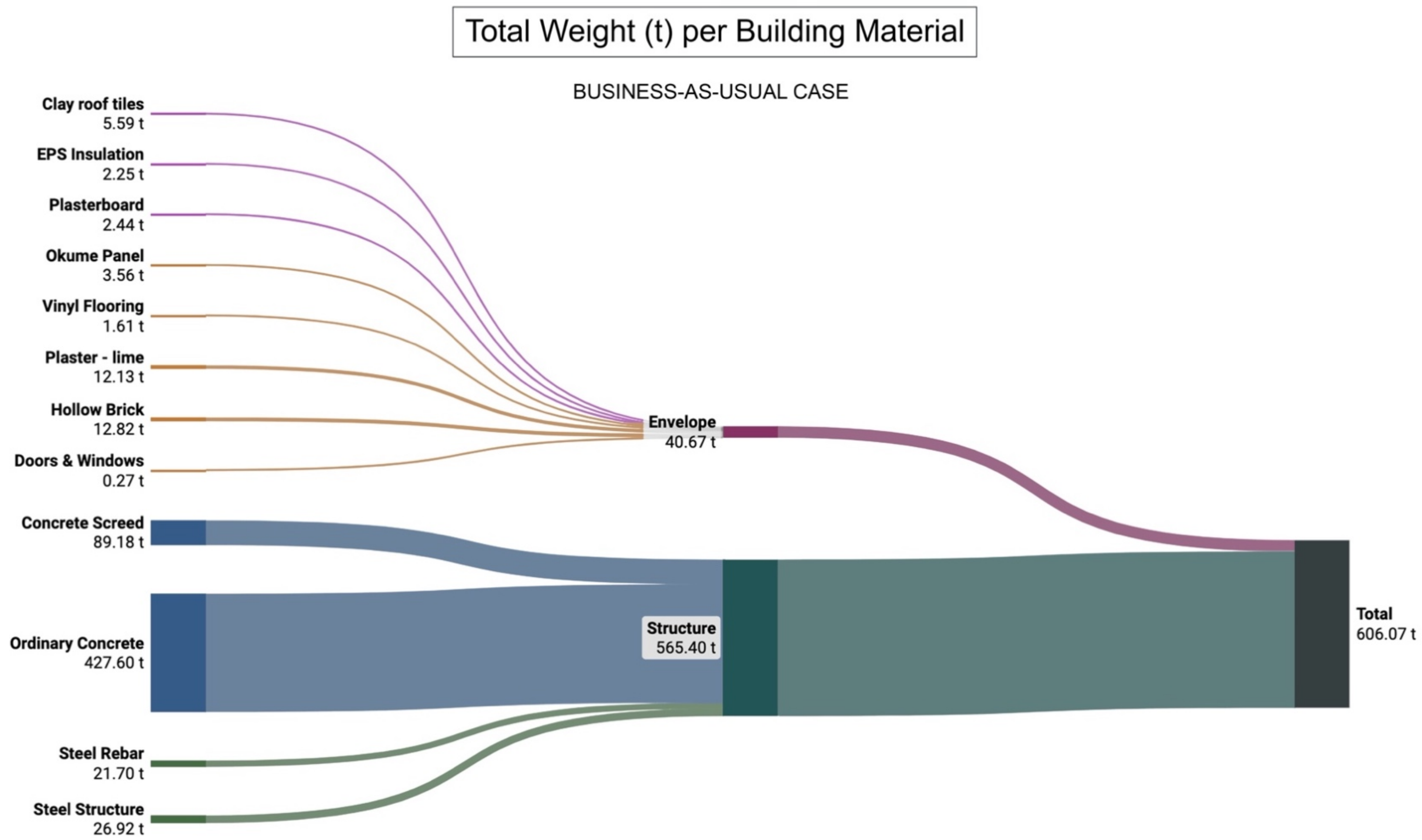


Figure 98: Sankey Diagram displaying Total Weight (t) per Building Element, including 'Steel Rebar'. Reference: Author.

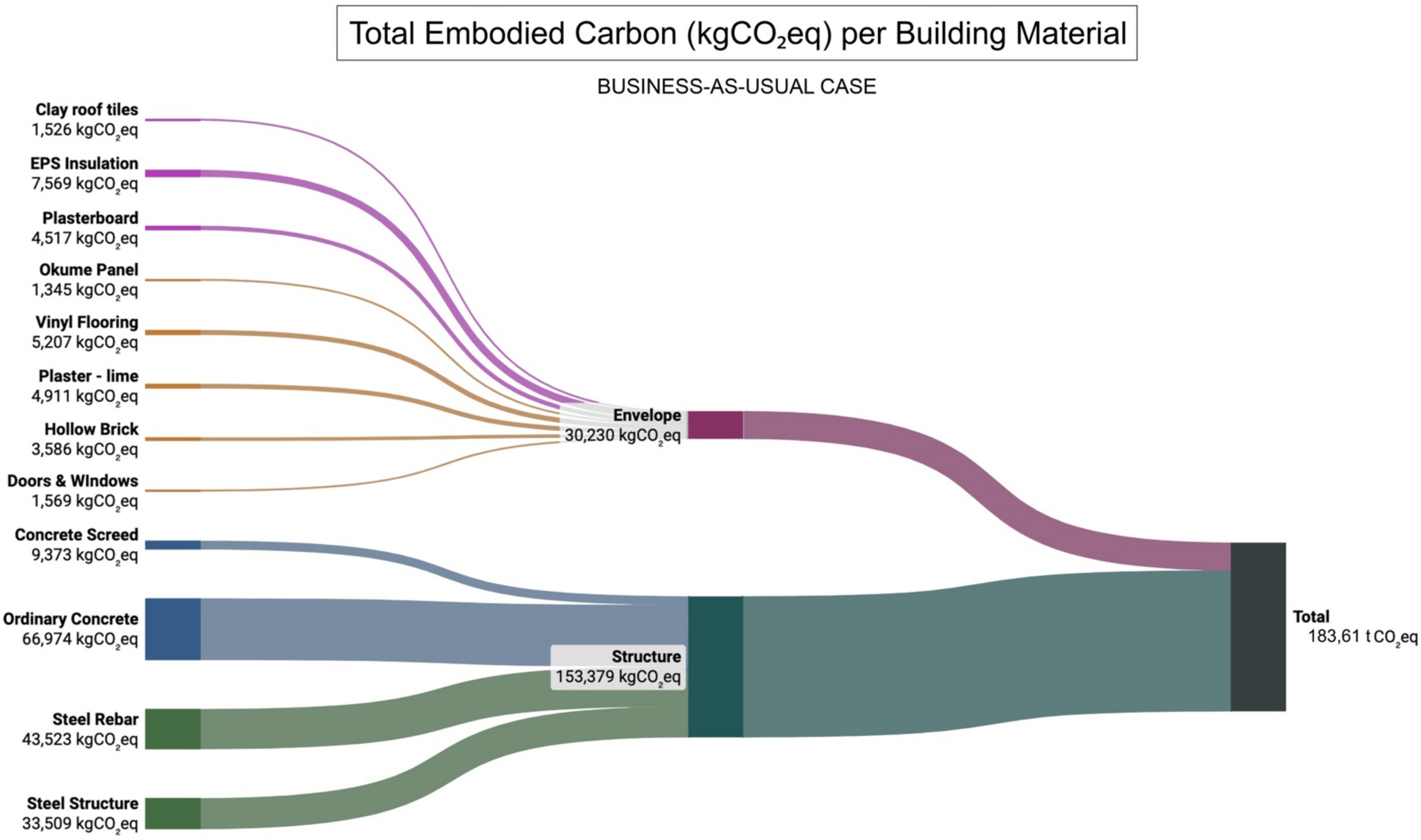


Figure 99: Sankey Diagram displaying Total Embodied Carbon per Building Material, including 'Steel Rebar'. Reference: Author.

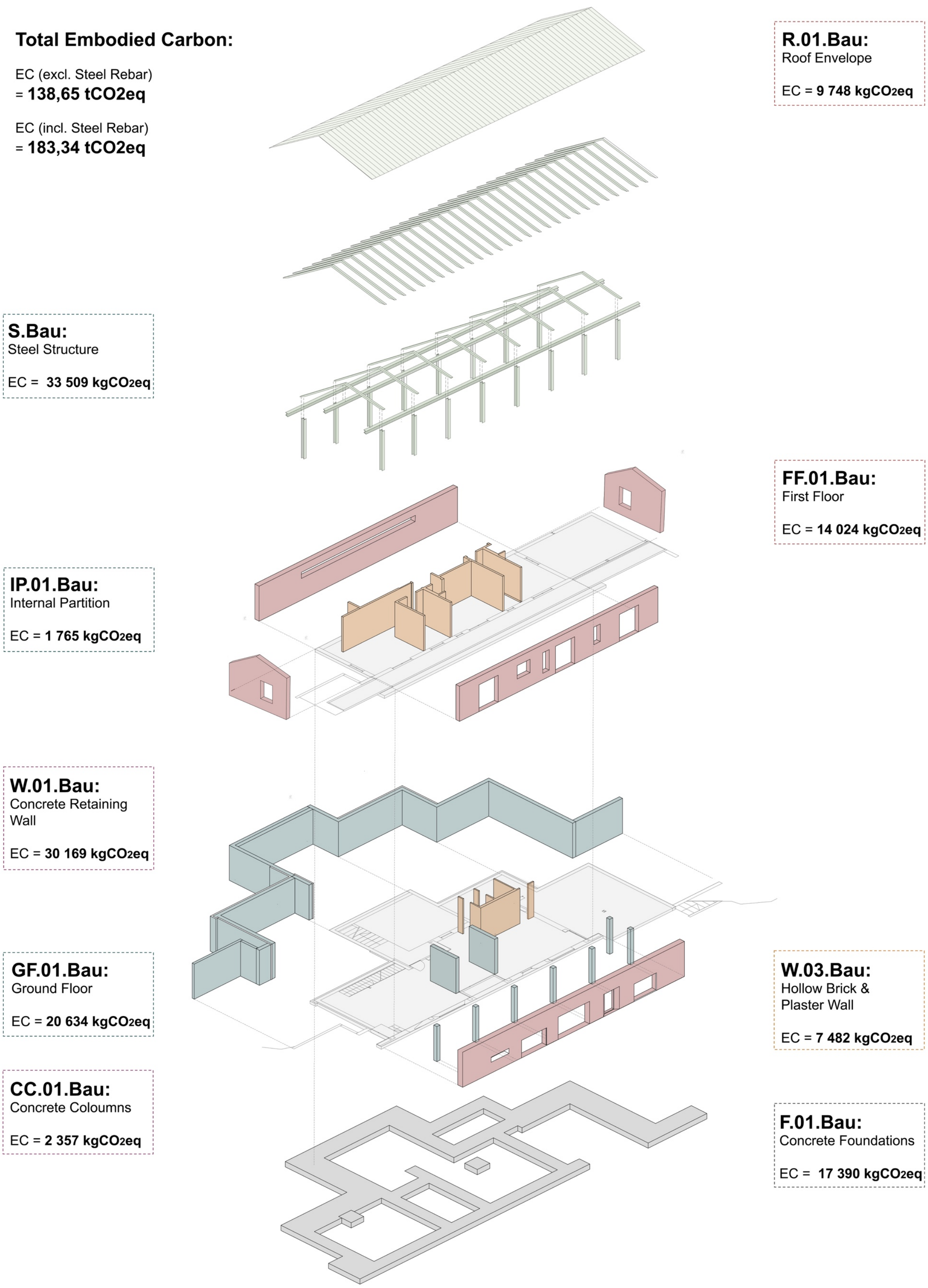


Figure 100: Total EC per Building Element (excl. Steel Bar)

4.16. Interpretation and Improvement Analysis:

The 'Interpretation and Improvement Analysis' of the results obtained from the Business-As-Usual Case LCA will be discussed, analysed and contextualized in Chapter Five (interpretation of Bricolla House LCA results and critical considerations on LCA results & software comparability).

As mentioned in the section on the Bricolla House LCA, there could be improvement on the LCA conduction of environmental impacts relating to 'Doors & Windows' of the Business-As-Usual case. Although this building element was included in the LCA, the depth and accuracy of data relating to this component could be improved in future works.

4.17. Comparative Results between Bricolla House and Business-As-Usual Case:

In this section, the LCA results of the Bricolla House and Business-As-Usual case will be compared. In this case, a comparison between the results of the Bricolla House and Business-As-Usual case is possible as the same methodology was applied for both case studies. The LCA system boundaries are the same (modules A1-A3, A4, C2-C4 as defied by EN 15978) and the Whole Building was considered in the LCA.

Figure 101 shows the LCA results of the Bricolla House and Business-As-Usual case as well as the current EU Benchmark (OneClickLCA,2021) and the UK 2030 Target (LETI, 2020).

	Bricolla House	Business-As-Usual Case	EU Benchmark	UK 2030 Target
EC TOTAL (tCO_2eq)	147,75	183,61		
EC ($kgCO_2/m^2$) *(heated floor area)*	600,33	719,54	510 - 600	300
EC ($kgCO_2/m^2$) *(total floor area)*	310,84	372,64		
EC ($kgCO_2/m^2/yr$) *(50 year lifespan)*	12,01	14,39		
EC ($kgCO_2/m^2/yr$) *(100 year lifespan)*	6,00	7,20		

Figure 101: Table showing EC results for Bricolla House and Business-As-Usual Case. Reference: Author.

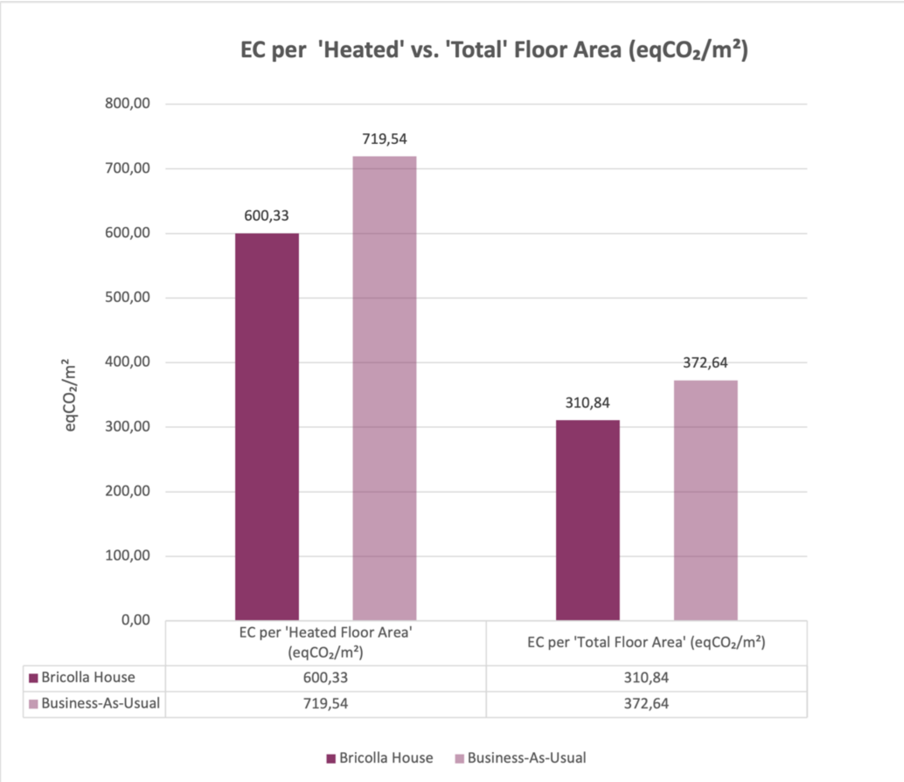


Figure 103: Histogram graph showing EC per floor area's. Reference: Author.

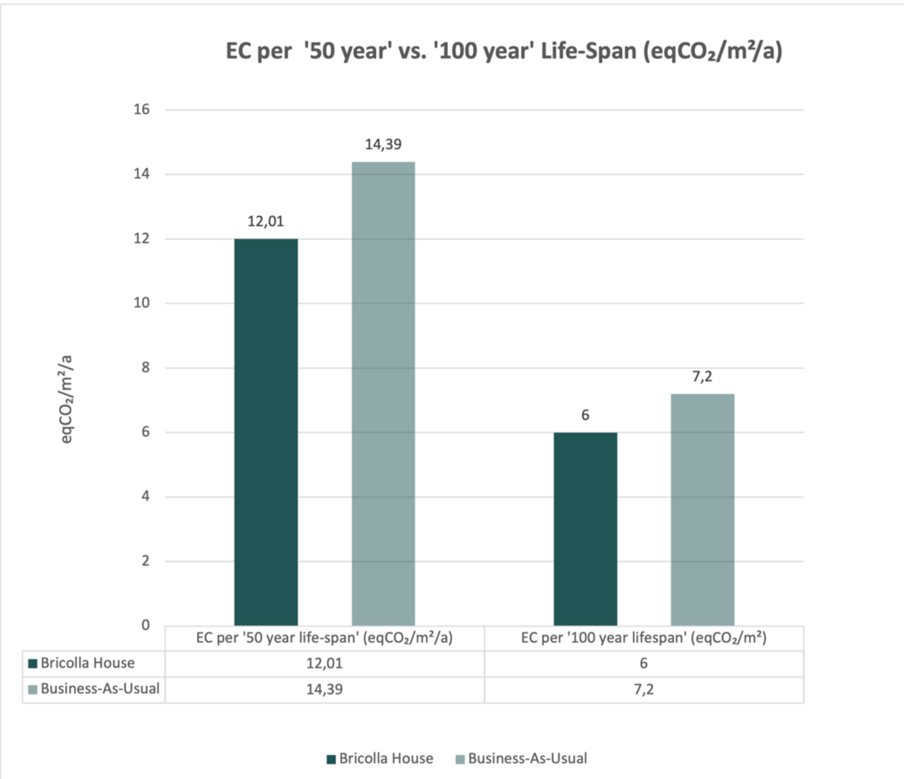


Figure 102: Histogram graph showing EC per building life-span's. Reference: Author.

As can be seen in the table above (Figure 103) as well as in the histograms above (Figures 104 & 105), the Total EC per 'heated floor area' for the Bricolla House is 600,33 $eqCO_2/m^2$, for the Business-As-Usual case it is 719,54 $eqCO_2/m^2$. The result for the Bricolla House is in line with the EU 2030 Target as defined by One Click LCA (2021). The Business-As-Usual case EU result is slightly higher than the benchmark. This will be discussed in more detail in Chapter 5.

If considering the 'total floor area' (heated and unheated spaces) the results are 310,84 $eqCO_2/m^2$ for the Bricolla House and 372,64 $kgCO_2/m^2$ for the Business-As-Usual Case. When considering a lifespan of 50 years, the Total EC per 'heated floor area' per year for Bricolla House is 12,01 $eqCO_2/m^2/yr$ and is 6,00 $eqCO_2/m^2/yr$ when considering a lifespan of 100 years. For the Business-As-Usual case it is 14,39 $eqCO_2/m^2/yr$ when considering a lifespan of 50 years and 7,20 $eqCO_2/m^2/yr$ when considering a lifespan of 100 years.

The table below (Figure 106) shows a comparison between the Total EC ($kgCO_2eq$) per Building Element of the Bricolla House and the Business-As-Usual Case. The reduction percentage (%) in emissions between the Bricolla House and the Business-As-Usual Case is highlighted and is useful in understanding the different reduction percentages (%) between different Building Elements.

Total EC Results per Building Element: Bricolla House & Business-As-Usual case

Building Element:	Bricolla House		Buisness-As-Usual Case
	Total EC ($kgCO_2eq$)	Reduction compared to B-A-U case (%):	Total EC ($kgCO_2eq$)
Roof	8 971,40	**-8%**	9 747,56
Ground Floor	14 304,54	**-31%**	20 633,86
Intermediate Floor	8 753,80	**-38%**	14 023,52
Ground Floor Wall	2 363,30	**-18%**	2 880,57
Retaining Wall	24 806,67	**-18%**	30 168,63
First Floor Wall	3 164,30	**-31%**	4 601,43
Internal Partition	1 462,53	**-17%**	1 765,09
Steel Frame	28 352,83	**-15%**	33 509,05
Concrete Foundations	14 088,48	**-19%**	17 390,42
Concrete Coloumns & Beams	1 874,42	**-20%**	2 357,14
Doors & Windows	1 569,23	**0%**	1 569,23
Steel Rebar	43 252,65	**0%**	43 252,65
Total	**152 964,15**	**-17%**	**183 338,96**

Figure 104: Table displaying Total Embodied Carbon (kgCO2eq) per Building Element of Bricolla House and Business-As-Usual Case. Reference: Author.

4.9.2. Comparison of Roof Envelope of Bricolla House and Business-As-Usual Case:

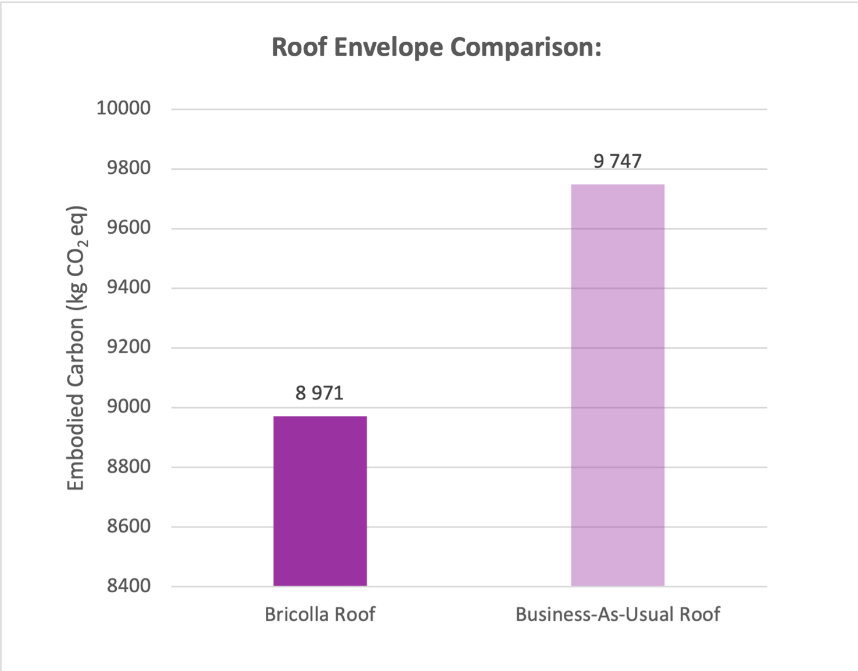


Figure 105: Embodied Carbon of the Bricolla and Business-As-Usual Case Roof Envelope. Reference: Author.

Figure 107 (above) shows the Total EC ($kgCO_2eq$) for the Roof Envelope of the Bricolla House and the Business-As-Usual case, that of the Bricolla House being lower than the Business-As-Usual case (as seen in the graph above). The total EC ($kgCO_2eq$) for the Bricolla house roof envelope is 8 971 $kgCO_2eq$ and for the Business-As-Usual case it is 9 747 $kgCO_2eq$.

As can be seen in the drawings of the Roof stratigraphy (Figure's 110 and 111) the material components that differ between the Bricolla House and the Business-As-Usual case are highlighted in pink. The Bricolla House has Corten steel roof sheeting and the Business-As-Usual case has clay tiles. Bricolla has PAN40 Lime-Hemp insulation and the Business-As-Usual case has EPS insulation.

R.01.Bri

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	Density (kg/m³)	Thickness (m)	Weight (kg/m²)	EC (CO_2/kg)	EC (CO_2/m²)	EC ($kgCO_2eq$)	EC ($kgCO_2eq$)	EC ($kgCO_2eq$)	EC Total ($kgCO_2eq$)
Corten Steel Sheeting	7850,00	0,001	7,85	2,73	21,43	8 780,81	118,64	10,42	8 971,40
Okume Panel	700,00	0,02	12,60	0,31	3,91				
Lime Hemp Insulation	40,00	0,24	9,60	0,09	0,86				
OSB Panel	640,00	0,02	11,52	0,46	5,30				
Okume Panel	700,00	0,02	12,60	0,31	3,91				

Figure 106: LCI Bricolla Roof Envelope. Reference: Author.

R.01.Bau

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	Density (kg/m³)	Thickness (m)	Weight (kg/m²)	EC (CO_2/kg)	EC (CO_2/m²)	EC ($kgCO_2eq$)	EC ($kgCO_2eq$)	EC ($kgCO_2eq$)	EC Total ($kgCO_2eq$)
Clay Roof Tiles	1650,00	0,01	19,80	0,26	5,15	9544,85	179,96	22,19	9747
EPS Insulation	28,00	0,15	4,20	3,29	13,82				
Plasterboard	665,00	0,01	8,65	0,39	3,37				
Okume Panel	700,00	0,02	12,60	0,31	3,91				

Figure 107: LCI Business-As-Usual Roof Envelope. Reference: Author.

R.01.Bri

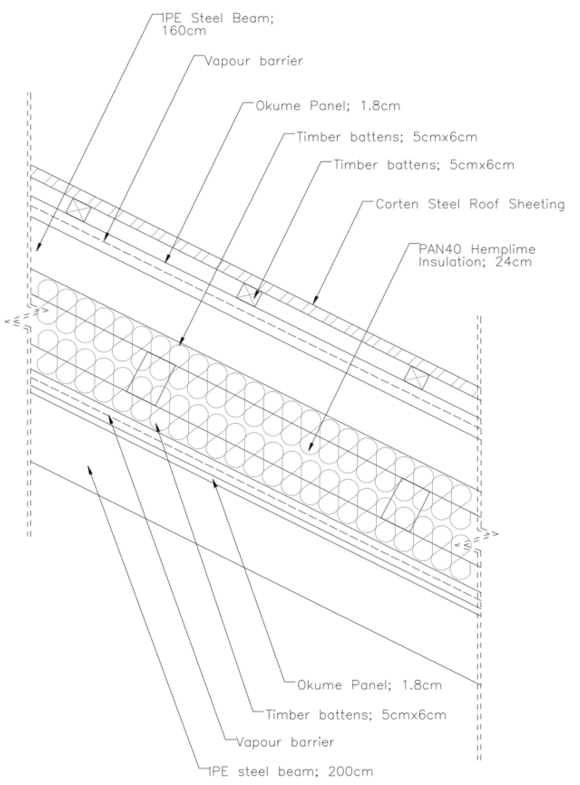


Figure 108: Bricolla Roof Envelope. Reference: Author.

R.01.Bau

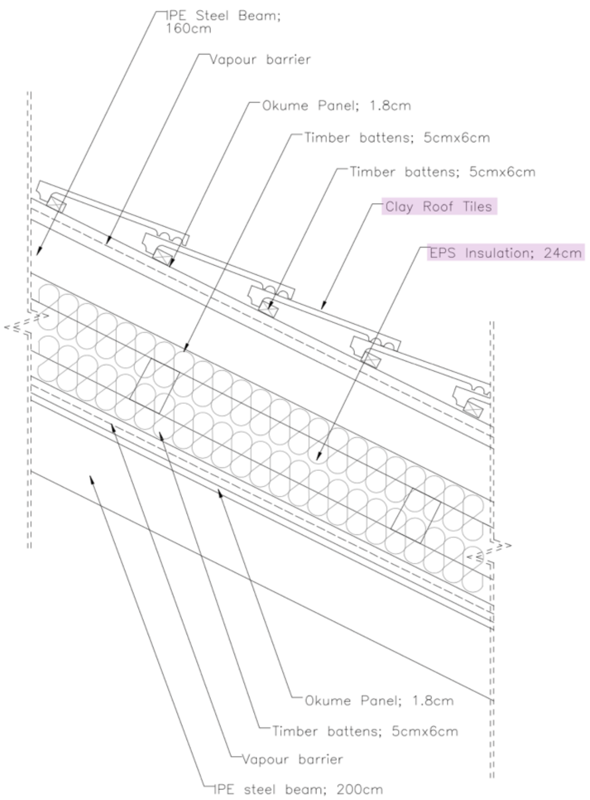


Figure 109: Business-As-Usual Roof Envelope. Reference: Author.

4.9.3. Comparison of Ground Floor of Bricolla House and Business-As-Usual Case:

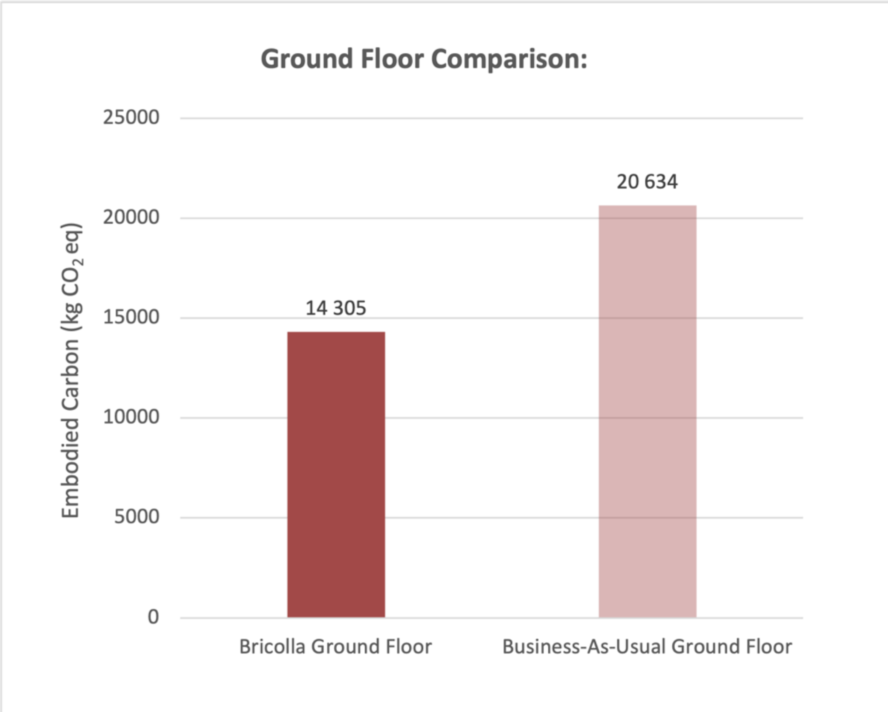


Figure 110: Embodied Carbon of the Bricolla and Business-As-Usual Case Ground Floor. Reference: Author.

Figure 112 (above) shows the total EC ($kgCO_2eq$) for the Ground Floor of the Bricolla house and the Business-As-Usual case, that of the Bricolla house being lower than the Business-As-Usual case (as seen in the graph). The total EC ($kgCO_2eq$) for the Bricolla house ground floor is 14 305 $kgCO_2eq$ and for the Business-As-Usual case it is 20 634 $kgCO_2eq$. There is a 30% reduction in EC from the Business-As-Usual case to the Bricolla house.

Figures 114 and 115 (below) show the stratigraphy of the Ground Floor for both Bricolla and the Business-As-Usual case. The difference in stratigraphy of the two cases differ as the Bricolla house slab is composed of Pozzolanic concrete (35% fly ash substation) and the Business-As-Usual case uses Ordinary Concrete. Bricolla house has XPS insulation under the screed and the Business-As-Usual case has EPS Insulation. The Bricolla house has a Hazelnut parquet floor finish and the Business-As-Usual case has Vinyl flooring.

GF.01.Bri

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Thickness (m)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC Total (kgCO_2eq)**
Hazulnut Parquet Flooring	660,00	0,02	9,90	0,81	8,02	14 017,15	177,11	110,28	14 304,54
Concrete Screed	1200,00	0,14	162,00	0,10	16,20				
XPS Insulation	35,00	0,12	4,20	0,71	2,98				
Pozzolanic Concrete	2380,00	0,10	238,00	0,12	28,56				

Figure 111: LCI Bricolla Ground Floor. Reference: Author.

GF.01.Bau

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Thickness (m)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC Total (kgCO_2eq)**
Vinyl Flooring	1330,00	0,01	6,65	3,19	21,21	20059,93	354,96	218,97	20 633,86
Concrete Screed	2000,00	0,10	200,00	0,10	20,00				
EPS Insulation	28,00	0,10	2,80	3,29	9,21				
Ordinary Concrete	2400,00	0,30	720,00	0,14	100,80				

Figure 114: LCI Business-As-Usual Ground Floor. Reference: Author.

GF.01.Bri

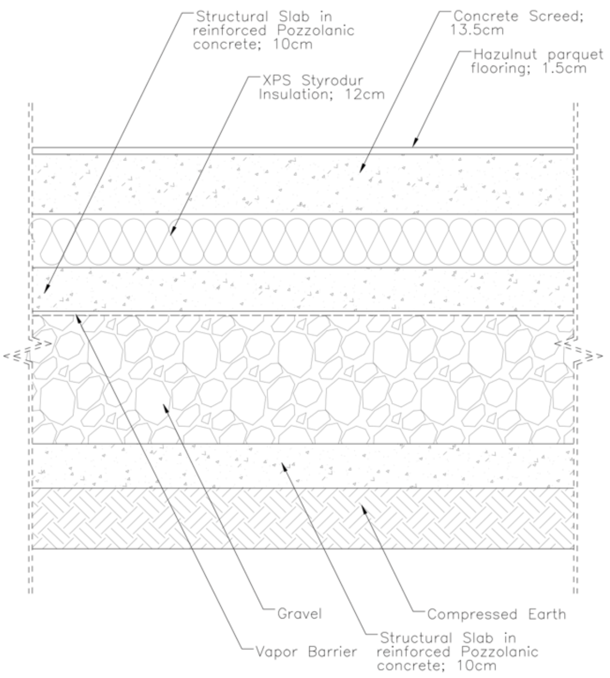


Figure 112: Business-As-Usual Ground Floor Stratigraphy. Reference: Author.

GF.01.Bau

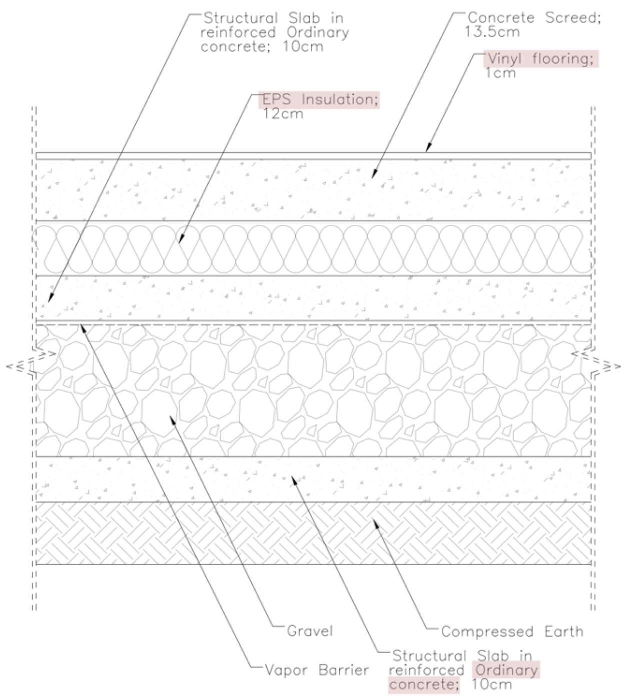


Figure 113: Bricolla Ground Floor Stratigraphy. Reference: Author.

4.9.4. Comparison of Intermediate Floor of Bricolla House and Business-As-Usual Case:

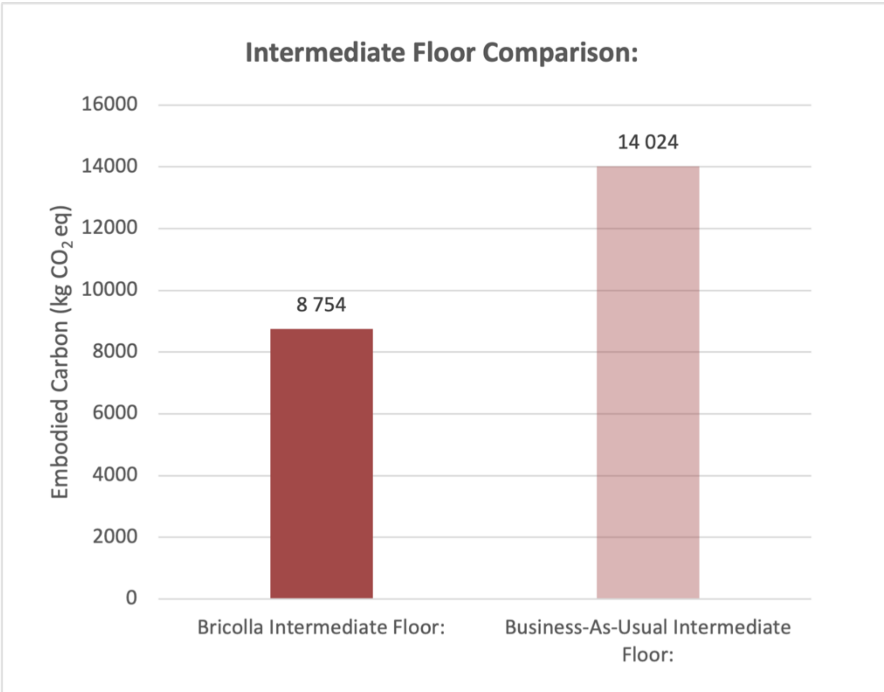


Figure 115: Embodied Carbon of the Bricolla and Business-As-Usual Case Intermediate Floor. Reference: Author.

Figure 117 (above) shows the total EC ($kgCO_2eq$) for the Intermediate Floor of the Bricolla house and the Business-As-Usual case, that of the Bricolla house being significantly lower than the Business-As-Usual case (as seen in the graph). The total EC ($kgCO_2eq$) for the Bricolla intermediate floor is 8756$kgCO_2eq$ and for the Business-As-Usual case it is 14025$kgCO_2eq$. There is a 38% reduction in Embodied Carbon from the Business-As-Usual case to the Bricolla house (similar to the reduction between Ground Floors of the Bricolla house and Business-As-Usual case).

In the drawings of the Intermediate Floor stratigraphy (Figures 120 and 121, below) the material components that differ between the Bricolla House and the Business-As-Usual case are highlighted. Bricolla has XPS Insulation while the Business-As-Usual case EPS Insulation. Bricolla uses Pozzolanic Concrete for the slab and the Business-As-Usual case uses Ordinary Concrete. Bricolla has a Hazelnut floor finish and the Business-As-Usual case has Vinyl Flooring.

FF.01.Bri

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Thickness (m)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC Total (kgCO_2eq)**
Hazulnut Parquet Flooring	660,00	0,02	9,90	0,81	8,02	8 461,63	170,05	122,81	8 753,80
Concrete Screed	1200,00	0,11	126,00	0,10	12,60				
XPS Insulation	35,00	0,10	3,50	0,71	2,49				
Pozzolanic Concrete	2380,00	0,15	357,00	0,12	42,84				

Figure 117: LCI Bricolla Intermediate Floor. Reference: Author.

FF.01.Bau

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Thickness (m)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC Total (kgCO_2eq)**
Vinyl Flooring	1330,00	0,01	6,65	3,19	21,21	13636,38	240,09	148,06	14024,53
Concrete Screed	2000,00	0,10	200,00	0,10	20,00				
EPS Insulation	28,00	0,09	2,52	3,29	8,29				
Ordinary Concrete	2400,00	0,20	480,00	0,12	57,60				

Figure 116: LCI Business-As-Usual Intermediate Floor. Reference: Author.

FF.01.Bri

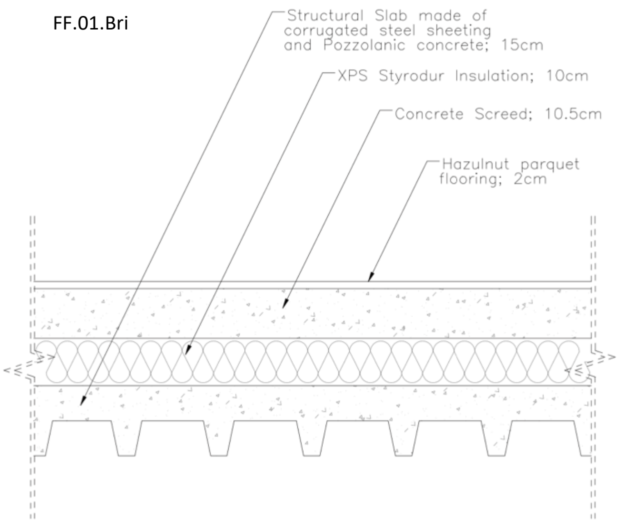


Figure 118: Bricolla Intermediate Floor. Reference: Author.

FF.01.Bau

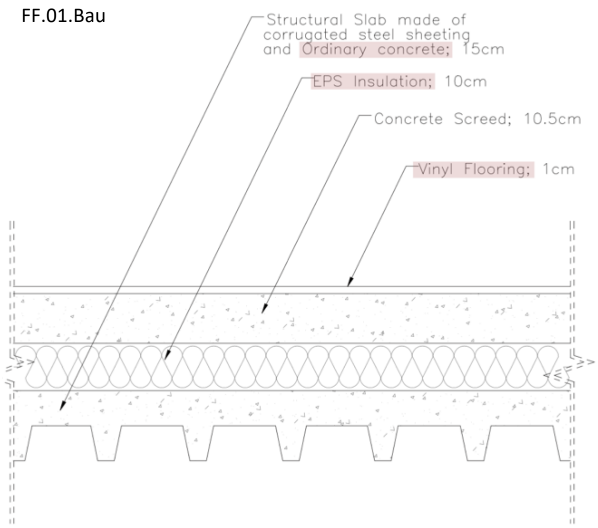


Figure 119: Business-As-Usual Intermediate Floor. Reference: Author.

4.9.5. Comparison of Ground Floor Wall of Bricolla House and Business-As-Usual Case:

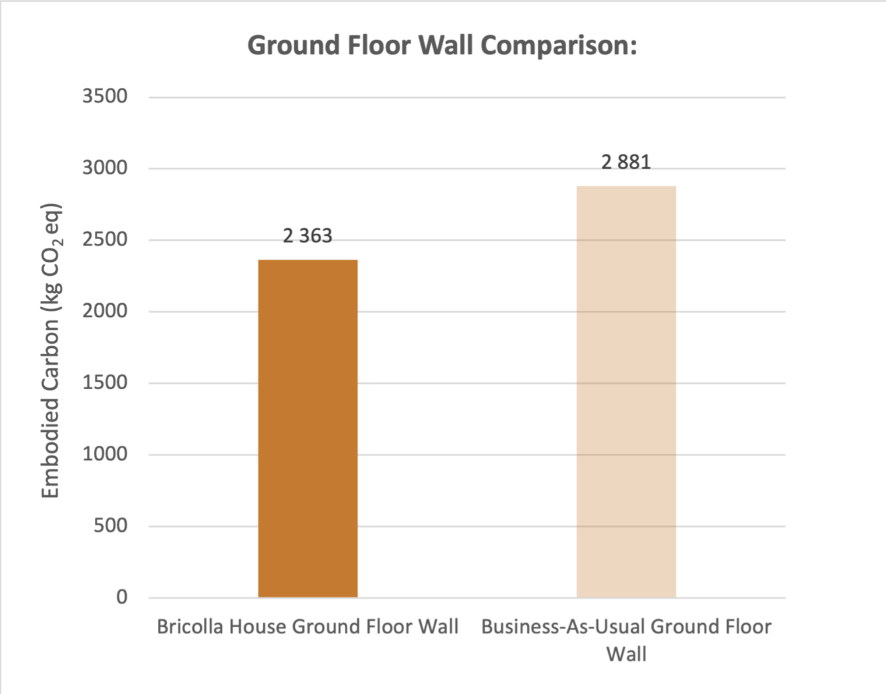


Figure 120: Embodied Carbon of the Bricolla and Business-As-Usual Case Ground Floor Wall. Reference: Author.

The graph above (Figure 122) shows the total EC (kgCO_2eq) for the Wall on the Ground Floor of the Bricolla house and the Business-As-Usual case, that of the Bricolla house being lower than the Business-As-Usual case. The Bricolla house wall (as seen in Figure 126) is a Cast Hemp-Lime wall (of 42cm thickness) with internal and external plaster (supported by Pozzolanic concrete coloumns). The Business-As-Usual wall is a double-skinned hollow brick wall with EPS insulation and internal and external plaster. The external brick layer is 12cm and the internal brick layer is 8cm (Figure 124).

The Total EC (kgCO_2eq) for the Bricolla house Hemp-lime wall 2 363 kgCO_2eq and the Business-As-Usual case Hollow Brick and Plaster wall is 2 881 kgCO_2eq. There is a 18% reduction in Total EC from the Business-As-Usual case wall to the Bricolla House wall.

W.02.Bri

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	Density (kg/m³)	Thickness (m)	Weight (kg/m²)	EC (CO_2/kg)	EC (CO_2/m²)	EC (kgCO_2eq)	EC (kgCO_2eq)	EC (kgCO_2eq)	EC Total (kgCO_2eq)
Plaster - lime	1300,00	0,02	26,00	0,39	10,14	2 290,84	50,47	21,99	2 363,30
Cast Hemp Lime	240,00	0,40	96,00	0,09	8,64				
Plaster - lime	1300,00	0,02	26,00	0,39	10,14				

Figure 121: LCI Bricolla Ground Floor Wall. Reference: Author.

W.02.Bau

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	Density (kg/m³)	Thickness (m)	Weight (kg/m²)	EC (CO_2/kg)	EC (CO_2/m²)	EC (kgCO_2eq)	EC (kgCO_2eq)	EC (kgCO_2eq)	EC Total (kgCO_2eq)
Plaster - lime	1300,00	0,02	26,00	0,39	10,14	2822,96	43,64	12,48	2 880,57
Hollow Brick	240,00	0,12	28,80	0,26	7,49				
EPS Insulation	28,00	0,08	2,24	3,29	7,37				
Hollow Brick	240,00	0,08	19,20	0,26	4,99				
Plaster - lime	1300,00	0,01	13,00	0,39	5,07				

Figure 122: LCI Business-As-Usual Ground Floor Wall. Reference: Author.

W.02.Bri

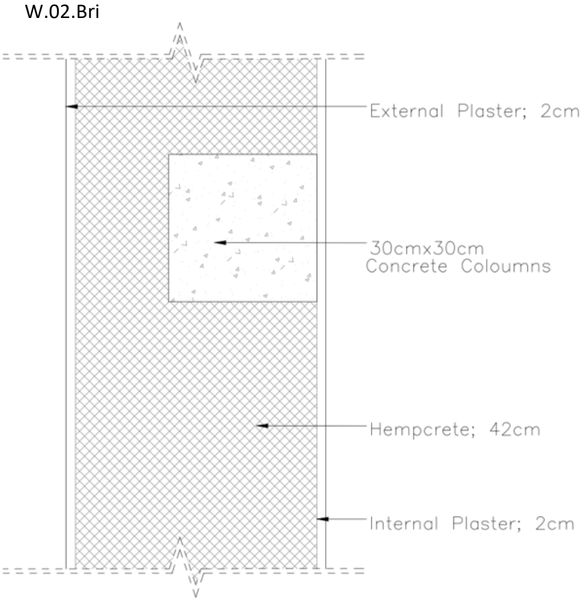


Figure 124: Bricolla Hemp-Lime Wall. Reference: Author.

W.02.Bau

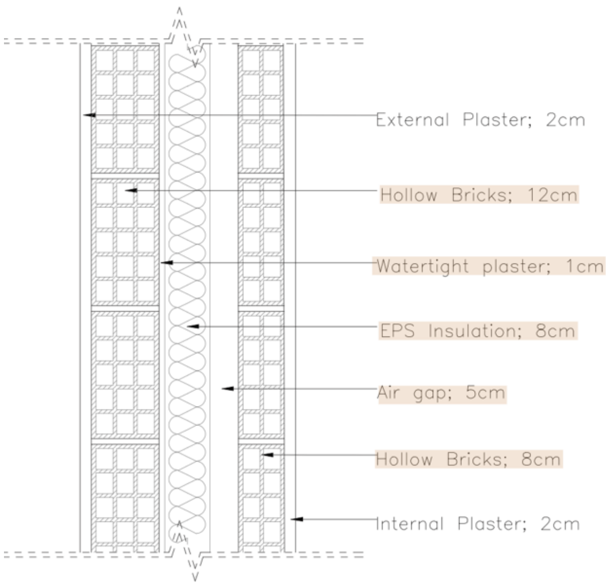


Figure 123: Business-As-Usual Hollow Bricks and Plaster. Reference: Author.

4.9.6. Comparison of Retaining Wall of Bricolla House and Business-As-Usual Case:

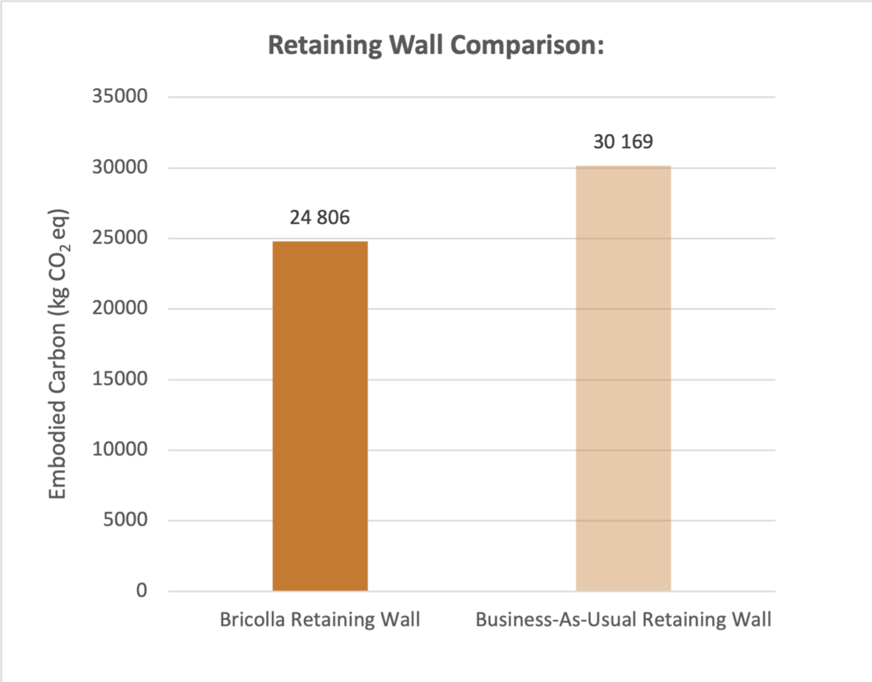


Figure 125: Embodied Carbon of the Bricolla and Business-As-Usual Case Retaining Wall. Reference: Author.

The graph above (Figure 127) shows the total EC (kgCO_2eq) for the Retaining Wall of the Bricolla house and the Business-As-Usual case. The total EC (kgCO_2eq) for the Bricolla Retaining Wall is 24 807 kgCO_2eq and for the Business-As-Usual case it is 30 169 kgCO_2eq.

The Bricolla house Retaining Wall is made of Pozzolanic concrete (with 30cm thickness) while the Business-As-Usual case is made from Ordinary concrete (with 30cm thickness). The Bricolla House retaining wall has XPS Insulation while the Business-As-Usual case retaining wall has EPS Insulation (as seen in Figures 128 and 129). Both the Bricolla House retaining wall and the Business-As-Usual case retaining wall have internal plaster of 2cm thick. There is a 18% reduction in Total EC from the Business-As-Usual case wall to the Bricolla House wall, this is largely due to the differing use of Pozzolanic concrete (with 35% fly ash substitution) for the Bricolla House versus Ordinary concrete (with Portland cement) for the Business-As-Usual case retaining wall.

W.01.Bri

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	Density (kg/m³)	Thickness (m)	Weight (kg/m²)	EC (CO_2/kg)	EC (CO_2/m²)	EC (kgCO_2eq)	EC (kgCO_2eq)	EC (kgCO_2eq)	EC Total (kgCO_2eq)
Plaster - lime	1300,00	0,02	26,00	0,39	10,14	24 191,87	265,14	349,66	24 806,67
Pozzolanic Concrete	2380,00	0,30	714,00	0,12	85,68				
XPS Insulation	35,00	0,12	4,20	0,71	2,98				

Figure 129: LCI Bricolla Retaining Wall. Reference: Author.

W.01.Bau

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	Density (kg/m³)	Thickness (m)	Weight (kg/m²)	EC (CO_2/kg)	EC (CO_2/m²)	EC (kgCO_2eq)	EC (kgCO_2eq)	EC (kgCO_2eq)	EC Total (kgCO_2eq)
Plaster - lime	1300,00	0,02	26,00	0,39	10,14	29460,23	361,81	346,59	30 168,63
Ordinary Concrete	2380,00	0,30	714,00	0,15	107,10				
EPS Insulation	28,00	0,09	2,52	3,29	8,29				

Figure 126: LCI Business-As-Usual Retaining Wall. Reference: Author.

W.01.Bri

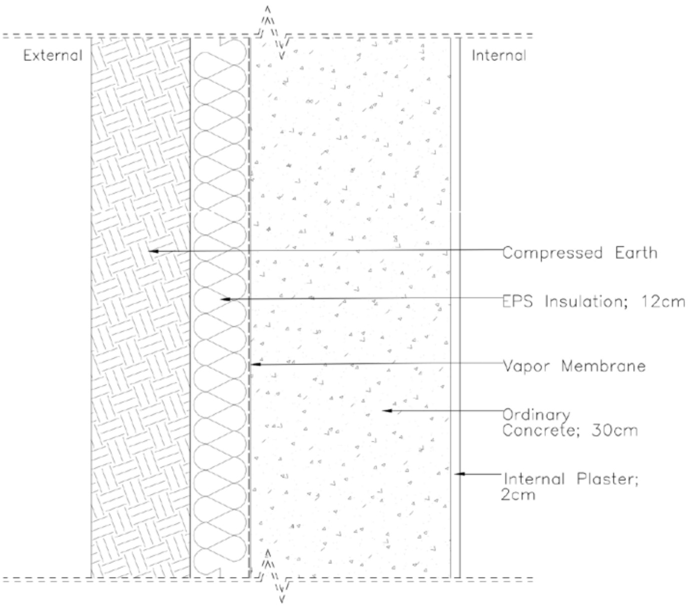


Figure 128: Bricolla Retaining Wall. Reference: Author.

W.01.Bau

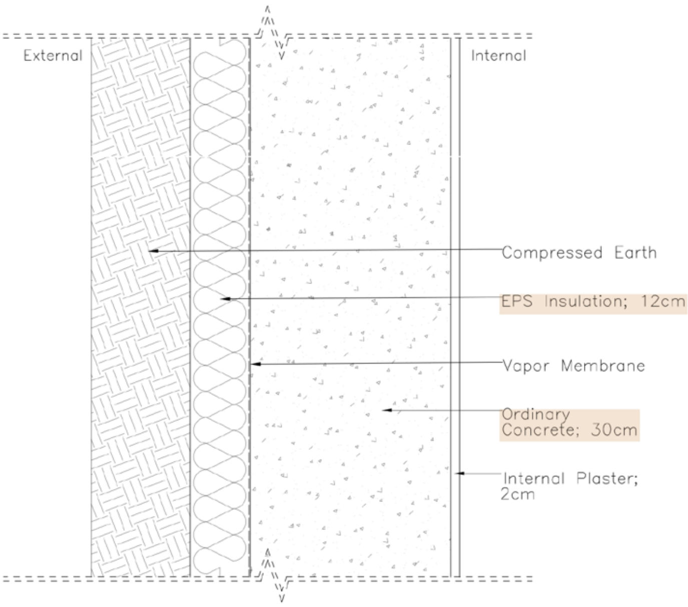


Figure 127: Business-As-Usual Retaining Wall. Reference: Author.

4.9.7. Comparison of First Floor Wall of Bricolla House and Business-As-Usual Case:

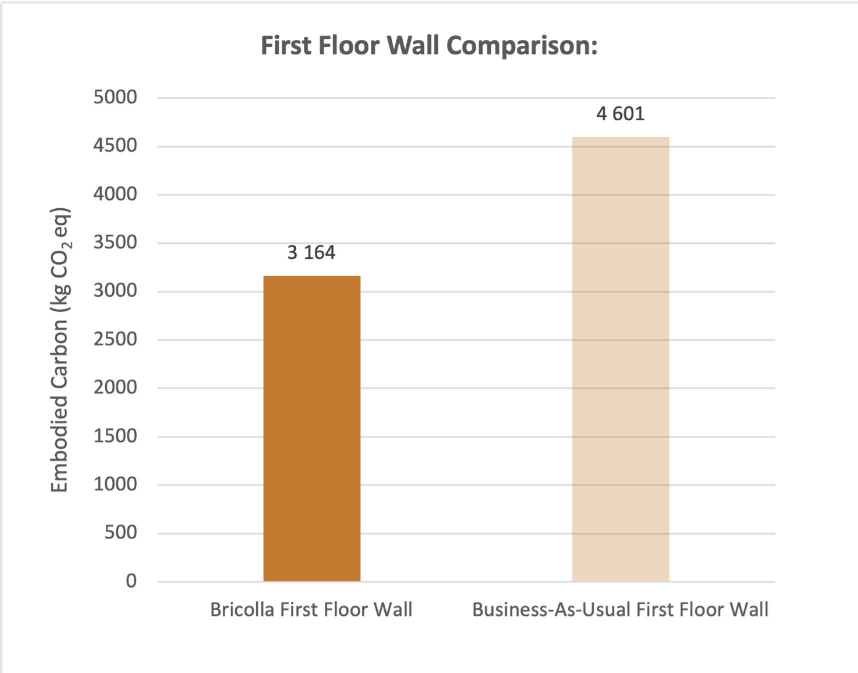


Figure 130: Embodied Carbon of the Bricolla and Business-As-Usual Case First Floor Wall. Reference: Author.

The graph above (Figure 132) shows the Total EC (kgCO_2eq) for the First Floor Wall of the Bricolla House and the Business-As-Usual case. The Bricolla House wall on the first floor is a timber drywall with PAN40 Hemp-Lime insulation (as seen in Figure 134). The Business-As-Usual wall is a double-skinned hollow brick wall with EPS insulation and internal and external plaster (Figure 135).

The Total EC (kgCO_2eq) for the Bricolla house Timber drywall is 3 164 kgCO_2eq and the Business-As-Usual case Hollow Brick wall is 4 601 kgCO_2eq.

W.03.Bri

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Thickness (m)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC ($kgCO_2eq$)**	**EC ($kgCO_2eq$)**	**EC ($kgCO_2eq$)**	**EC Total ($kgCO_2eq$)**
Doublesheet Plasterboard	665,00	0,03	16,63	0,39	6,48	2 819,98	87,26	97,64	3 164,30
Lime Hemp Insulation	40,00	0,15	6,00	0,09	0,54				
OSB Panel	640,00	0,02	12,80	0,46	5,89				
Wood Wool Panel	700,00	0,02	12,60	0,40	5,04				
Okume Panel	700,00	0,02	12,60	0,31	3,91				

Figure 134: LCI Bricolla Timber Dry-Wall. Reference: Author.

W.02.Bau

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Thickness (m)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC ($kgCO_2eq$)**	**EC ($kgCO_2eq$)**	**EC ($kgCO_2eq$)**	**EC Total ($kgCO_2eq$)**
Plaster - lime	1300,00	0,02	26,00	0,39	10,14	4509,40	69,70	12,48	4 601,43
Hollow Brick	240,00	0,12	28,80	0,26	7,49				
EPS Insulation	28,00	0,08	2,24	3,29	7,37				
Hollow Brick	240,00	0,08	19,20	0,26	4,99				
Plaster - lime	1300,00	0,01	13,00	0,39	5,07				

Figure 132: LCI Business-As-Usual Hollow Brick Wall. Reference: Author.

W.03.Bri

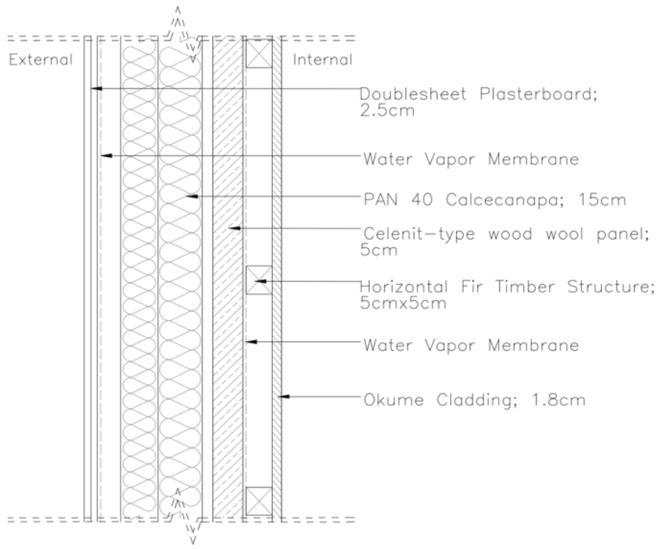


Figure 133: Bricolla Timber Dry-Wall. Reference: Author.

W.02.Bau

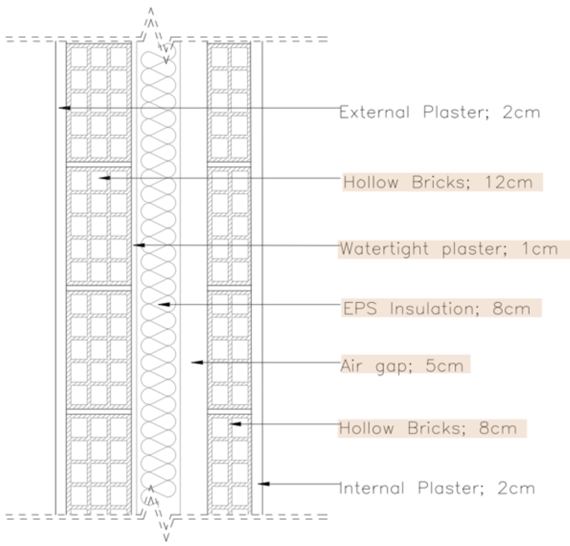


Figure 131: Business-As-Usual Hollow Brick Wall. Reference: Author.

4.9.8. Comparison of Internal Partition of Bricolla House and Business-As-Usual Case:

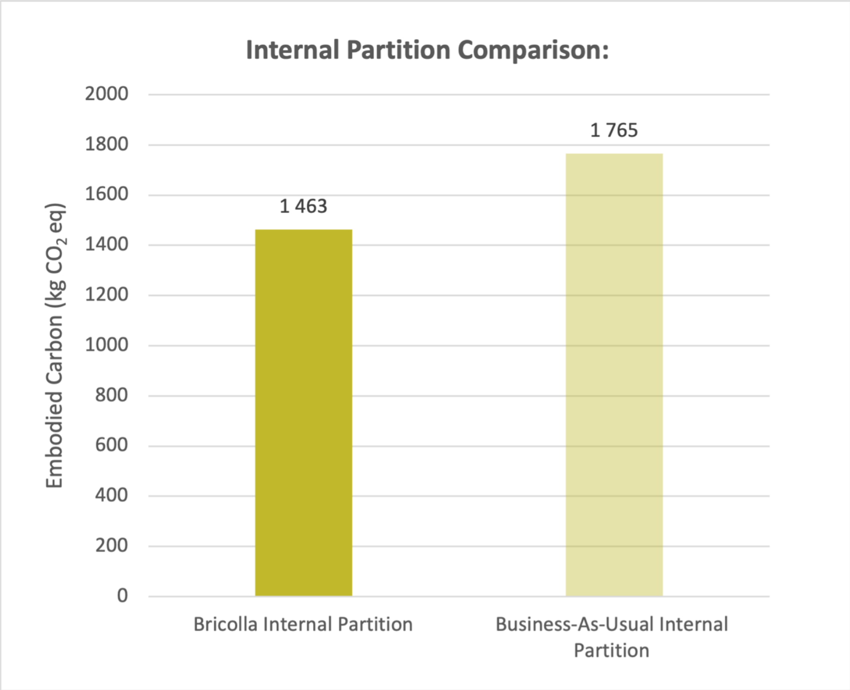


Figure 135: Embodied Carbon of the Bricolla and Business-As-Usual Case Internal Partition. Reference: Author.

The graph above (Figure 137) shows the Total EC ($kgCO_2eq$) for the Internal Partition of the Bricolla house and the Business-As-Usual case. The total EC ($kgCO_2eq$) for the Bricolla House Internal Partition is 1 463 $kgCO_2eq$ and for the Business-As-Usual case it is 1 765 $kgCO_2eq$. As seen in Figure 141, the Bricolla house Internal Partition is a timber drywall while the Business-As-Usual case internal partition is a single-skin hollow brick and plaster wall (Figure 140).

IP.01.Bri

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Thickness (m)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC ($kgCO_2eq$)**	**EC ($kgCO_2eq$)**	**EC ($kgCO_2eq$)**	**EC Total ($kgCO_2eq$)**
Doublesheet Plasterboard	665,00	0,03	16,63	0,39	6,48	1 305,09	150,44	6,99	1 462,53
Lime Hemp Insulation	40,00	0,15	6,00	0,09	0,54				
Doublesheet Plasterboard	665,00	0,03	16,63	0,39	6,48				

Figure 137: LCI Bricolla Internal Partition. Reference: Author.

IP.01.Bau

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Thickness (m)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC ($kgCO_2eq$)**	**EC ($kgCO_2eq$)**	**EC ($kgCO_2eq$)**	**EC Total ($kgCO_2eq$)**
Plaster - lime	665,00	0,02	13,30	0,39	5,19	1725,83	29,39	9,87	1 765,09
Hollow Brick	240,00	0,12	28,80	0,26	7,49				
Plaster - lime	665,00	0,02	13,30	0,39	5,19				

Figure 136: LCI Business-As-Usual Internal Partition. Reference: Author.

IP.01.Bri

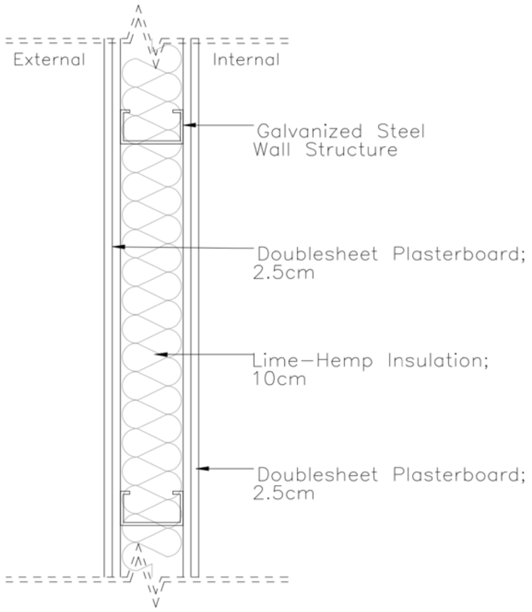


Figure 139: Bricolla Internal Partition. Reference: Author.

IP.01.Bau

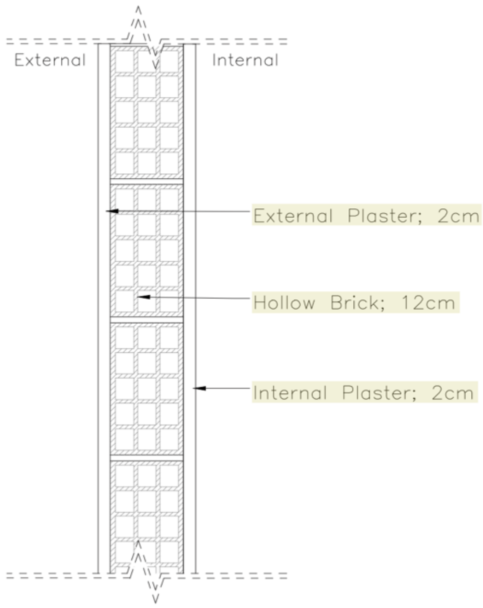


Figure 138: Business-As-Usual Internal Partition. Reference: Author.

4.9.9. Comparison of Steel Frame of Bricolla House and Business-As-Usual Case:

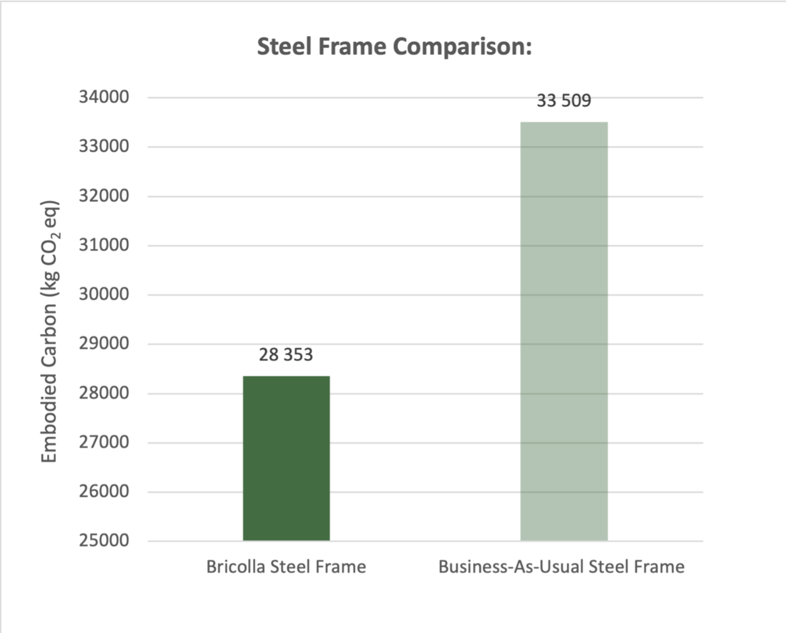


Figure 140: Embodied Carbon of the Bricolla and Business-As-Usual Case Steel Frame. Reference: Author.

Figure 142 above shows the total EC (kgCO_2eq) for the Steel Frame of the Bricolla house and the Business-As-Usual case, that of Bricolla House being less than the Business-As-Usual case.. The Bricolla house steel frame is comprised of steel with varying percentages of recycled content. The HEB 200 steel and the IPE 300 steel have a recycled content of 92% and the IPE 400 has a recycled content of 95%. The recycled content of IPE 160 Steel is not known but is assumed to be 92%. The Business-As-Usual steel frame is assumed to have a recycled content of 50% for all steel types.

The total EC (kgCO_2eq) for the Bricolla house Steel is 33 509 kgCO_2eq and the Business-As-Usual case embodied carbon for steel is 28 353 kgCO_2eq. There is a 15% reduction in Total EC from the Business-As-Usual case Steel Frame to the Bricolla House Steel Frame due to the differing percentages of recycled content in steel used in the Bricolla House and Business-As-Usual case.

	INITIAL PHASE					TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Area Section (m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC Total (kgCO_2eq)**
IPE 160 Steel	7850,00	0,008	1,04	65,53	28449,91	43,59	50,45	17 856,32
HEB 200 Steel	7850,00	0,010	1,04	81,60	7754,36	182,07	13,75	6 585,45
IPE 300 Steel	7850,00	0,017	1,04	64,75	1249,09	580,49	2,22	1 831,80
IPE 400 Steel	7850,00	0,024	1,04	199,93	2079,73	37,91	3,61	2 079,26
								28 352,83

Figure 141: LCI Bricolla Steel Frame. Reference: Author.

	INITIAL PHASE					TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Area Section (m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC Total (kgCO_2eq)**
IPE 160 Steel	7850,00	0,008	1,21	76,20	21515,24	43,59	50,45	21 668,02
HEB 200 Steel	7850,00	0,010	1,21	93,35	7222,97	182,07	13,75	7 412,33
IPE 300 Steel	7850,00	0,017	1,21	161,47	1453,27	580,49	2,22	2 016,35
IPE 400 Steel	7850,00	0,024	1,21	227,96	2370,83	37,91	3,61	2 412,35
								33 509,05

Figure 142: LCI Business-As-Usual Steel Frame. Reference: Author.

4.9.10. Comparison of Concrete Foundations of Bricolla House and Business-As-Usual Case:

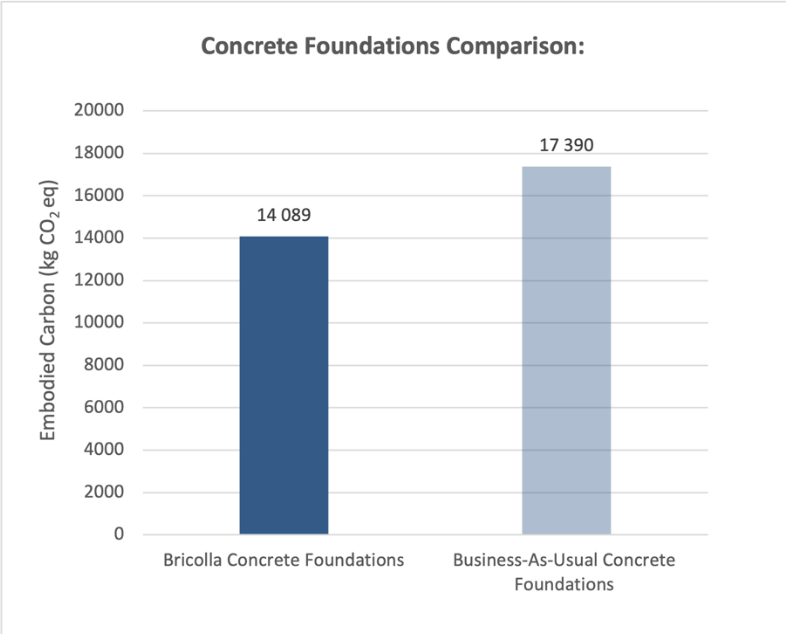


Figure 143: Embodied Carbon of the Bricolla and Business-As-Usual Case Concrete Foundations. Reference: Author.

The graph above (Figure 145) shows the total EC ($kgCO_2eq$) for the Foundations of the Bricolla house and the Business-As-Usual case. The total EC ($kgCO_2eq$) for the Bricolla Foundations is 14088,48 $kgCO_2eq$ and for the Business-As-Usual case it is 17390,42$kgCO_2eq$. The Bricolla house Foundations are made of Pozzolanic concrete (with 35% fly ash substitution) while the Business-As-Usual case Foundations are made from Ordinary concrete.

F.01.Bri

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	Density (kg/m^3)	Thickness (m)	Weight (kg/m^2)	EC (CO_2/kg)	EC (CO_2/m^2)	EC ($kgCO_2eq$)	EC ($kgCO_2eq$)	EC ($kgCO_2eq$)	EC Total ($kgCO_2eq$)
Pozzolanic Concrete	2350,00	0,40	940,00	0,12	112,80	13736,22	141,15	211,12	14 088,48

Figure 144: LCI Bricolla Concrete Foundations. Reference: Author.

F.01.Bau

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	Density (kg/m^3)	Thickness (m)	Weight (kg/m^2)	EC (CO_2/kg)	EC (CO_2/m^2)	EC ($kgCO_2eq$)	EC ($kgCO_2eq$)	EC ($kgCO_2eq$)	EC Total ($kgCO_2eq$)
Ordinary Concrete	2400,00	0,40	960,00	0,15	144,00	17314,56	214,15	212,89	17 390,42

Figure 145: LCI Business-As-Usual Concrete Foundations. Reference: Author.

4.9.11. Comparison of Concrete Coloumns & Beams of Bricolla House and Business-As-Usual Case:

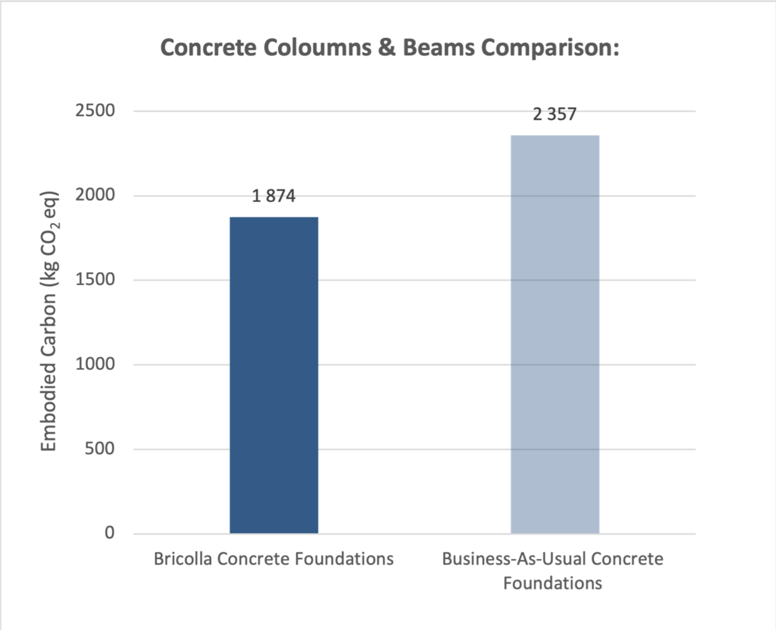


Figure 146: Embodied Carbon of the Bricolla and Business-As-Usual Case Concrete Coloumns & Beams. Reference: Author.

Figure 148 shows the total EC (kgCO_2eq) for the Concrete Coloumns and Beams in the Bricolla house and the Business-As-Usual case. The Bricolla house uses Pozzolanic concrete (35% fly ash substitution) while the Business-As-Usual case uses ordinary concrete. The total EC (kgCO_2eq) for the Bricolla house Concrete coloumns and beams is 1874,42 kgCO_2eq and the Business-As-Usual is 2357,14kgCO_2eq. The only difference between the two cases is the type of concrete used.

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Area Section (m²)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC Total (kgCO_2eq)**
Pozzolanic Concrete	2350,00	0,09	211,50	0,12	25,38	1 827,55	18,78	28,09	1 874,42

Figure 147: LCI Bricolla Concrete Coloumns & Beams. Reference: Author.

	INITIAL PHASE						TRANSPORT	END-OF-LIFE	ALL PHASES
Component	**Density (kg/m³)**	**Area Section (m²)**	**Weight (kg/m²)**	**EC (CO_2/kg)**	**EC (CO_2/m²)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC (kgCO_2eq)**	**EC Total (kgCO_2eq)**
Ordinary Concrete	2400,00	0,09	216,00	0,15	32,40	2300,4	28,45	28,28	2 357,14

Figure 148: LCI Business-As-Usual Concrete Coloumns & Beams. Reference: Author.

4.18. Comparison between Bricolla House and Business-As-Usual Case Conclusion

The analysis above comparing the LCA results per technical element between the Bricolla House and the Business-As-Usual case show, in all cases, that the Bricolla House solution is favourable (with lower EC value's). It is clear that the use of Pozzolanic Concrete (with 35% fly ash substitution) in the Bricolla House yields lower EC results than the Ordinary Concrete (Portland cement) as used in the Business-As-Usual case. As there is a large quantity of concrete in this design, largely due to the foundations and material intensive retaining wall (as a result of the building's position on site), the impact of concrete choice largely affects the LCA result. There is a 19% reduction in EC emissions for the Concrete Retaining Wall, Concrete Foundations and Concrete Coloumns & Beams between the Bricolla House and the Business-As-Usual case (with the Bricolla House result being lower).

Embedded in the reinforced concrete is the 'steel rebar', another large contributor to the overall EC value of both the Bricolla House and the Business-As-Usual case. Again, the high EC values for the steel rebar are due to large quantity of concrete used in this project. As there is no recycled content in the steel rebar for both Bricolla House and the Business-As-Usual case, the two cases have the same EC value for steel rebar (there is no reduction from the Business-As-Usual case to the Bricolla House).

The structural steel frame is another large contributor to the overall EC of both the Bricolla House and the Business-As-Usual case. There is a 15% reduction in EC emissions from the Business-As-Usual case to the Bricolla House. This is due to the Bricolla House using steel with an average recycled content of 90%. The recycled content of the Business-As-Usual case is 50%.

4.19. LEED Materials & Resources Scorecard's for Bricolla House; Scenario 1 & 2

MATERIAL & RESOURCES		AWARDED: 5 / 13
Prereq	Storage and Collection of Recyclables	0 / 0
Prereq	Construction and Demolition Waste Mgmt Planning	0 / 0
Credit	Building Life-Cycle Impact Reduction	3 / 5
Credit	Environmental Product Declarations	0 / 2
Credit	Sourcing of Raw Materials	0 / 2
Credit	Material Ingredients	0 / 2
Credit	Construction and Demolition Waste Mgmt	2 / 2

Figure 149: LEED MR Scorecard for Bricolla House, Scenario 1. Reference: Author.

Scenario 1: The above LEED Scorecard for the Materials & Resources (MR) category is a hypothetical scorecard for the Bricolla House. As seen, the Bricolla House scores 5/13 points for the MR category, with 3/5 points for the 'Building Life-Cycle Impact Reduction' and 2/2 points for 'Construction and Demolition Waste Management'. This scorecard (Figure 151) is titled 'Scenario 1' as it is 1 of 2 options for the Bricolla House LEED MR score. This scenario considers that the Bricolla House scores 0/0 for the categories 'Environmental Product Declarations' and 'Sourcing of Raw Materials'. This is due to Bricolla House not achieving the requirement of "20 EPD's" for the 'Environmental Product Declarations' category and not achieving the requirement of "five different manufacturers that meet at least one of the responsible sourcing and extraction criteria below for at least 30%, by cost, of the total value of building products" for the 'Sourcing of Raw Materials'. Although the Bricolla House prioritizes Hemplime products (Hempcrete Wall and Hemplime insulation) as well as responsibly sourced timber, this does not account to 30% of the project by cost (as per the category requirements). It is assumed that the Bricolla House scores 0/2 for the 'Materials Ingredients' category as this is very hard to achieve in a residential project (more applicable to a commercial/public building).

MATERIAL & RESOURCES		AWARDED: 9 / 13
Prereq	Storage and Collection of Recyclables	0 / 0
Prereq	Construction and Demolition Waste Mgmt Planning	0 / 0
Credit	Building Life-Cycle Impact Reduction	3 / 5
Credit	Environmental Product Declarations	2 / 2
Credit	Sourcing of Raw Materials	2 / 2
Credit	Material Ingredients	0 / 2
Credit	Construction and Demolition Waste Mgmt	2 / 2

Figure 150: LEED MR Scorecard for Bricolla House, Scenario 2. Reference: Author.

Scenario 2: The above LEED Scorecard for the Materials & Resources (MR) category (Figure 152) is a hypothetical scorecard for the Bricolla House. As seen, the Bricolla House scores 9/13 points for the MR category, with 3/5 points for the 'Building Life-Cycle Impact Reduction', 2/2 points for 'Environmental Product Declarations', 2/2 points for 'Sourcing of Raw Materials' and 2/2 points for 'Construction and Demolition Waste Management'. This scorecard is titled 'Scenario 2' as it is the 2nd option for the Bricolla House score. This scenario considers that the Bricolla House scores 2/2 for the categories 'Environmental Product Declarations' and 'Sourcing of Raw Materials'. It is arguable that if the Bricolla House was designed with the intention of achieving a LEED certification, the designers would have been mindful to achieve "20 EPD's" for the 'Environmental Product Declarations' and achieve "five different manufacturers that meet at least one of the responsible sourcing and extraction criteria below for at least 30%, by cost, of the total value of building products" for the 'Sourcing of Raw Materials' category. Although these category requirements are reasonably stringent, it is possible, with initial design intention, that the Bricolla House could achieve them. It is assumed that the Bricolla House scores 0/2 for the 'Materials Ingredients' category as this is very hard to achieve in a residential project (more applicable to a commercial/public building).

INTERPRETATION OF BRICOLLA HOUSE LCA RESULTS AND CRITICAL CONSIDERATIONS ON LCA RESULTS & SOFTWARE COMPARABILITY

5.1. The role of Software in the Interpretation of LCA results

An important point of discussion to understand and interpret the results of this thesis is the role of software in the conduction of Whole Building Life Cycle Assessment (WBLCA). The software chosen to conduct the WBCLA in this thesis was EURECA, supported by data inputs from the ICE database (2019). EURECA, as discussed previously (Chapter 3) is an Excel application tool developed by the Department of Architecture and Design - DAD of the Politecnico di Torino. Different LCA tools and software utilize different methodologies, data input ranges, system boundaries, functional units and calculation methods, leading to differing LCA results and interpretations. It is important to consider these aspects when comparing LCA outcomes.

5.1.1. EURECA Possibilities & Limitations and Critical Considerations on alternative LCA software

The EURECA tool is advantageous as it allows for data specific inputs, leading to specialized and case study specific LCA results (with a high degree of accuracy). EURECA calls for the inclusion of data of the whole building, including but not limited to; ground floor, intermediate floor, roofs, external walls internal partitions, foundations, structure as well as any 'linear elements' (frames). As the user manually enters each of the data values for each building component and element stratigraphy, the data is project specific. However, small inaccuracies in naming the project elements can result in misleading results i.e. the tool requires very specific labels for material components and errors in spelling can cause large discrepancies in final results. It is also possible to incorrectly enter data values relating to material density, thickness, area, Embodied Carbon (ect.) and there is margin for human error. In the LCA results and report, it is not clear where the discrepancies lie and reviewing each data entry is time consuming. The software also consumes a lot of computer processing power and can frequently result in computer crashes, specifically when trying to access the LCA report.

In the Master's thesis titled "Life cycle planning: application of the LCA methodology and DfD good practices to the case study of the Circular Tower in Burgdorf (2022)", Masoero, A. & Paro, S. state the possibilities and limitations of alternative LCA software's; including ZPF-Tool, SimaPro and OneClickLCA. ZPF-Tool is a small-scale Switzerland based LCA conduction tool. Data inputs in the ZPF tool include only floor, internal partitions and vertical enclosures, leading to a simplified LCA result (with a lower degree of accuracy). In the ZPF-Tool, generic stratigraphy's are available for selection, choosing that which most accurately corresponds to your building's condition. In EURECA, stratigraphy's are entered manually by the user and are building-specific, leading to a much higher degree of accuracy. SimaPro, another tool used in the thesis by Masoero, A. & Paro, S. (2022) and is a globally recognized and highly utilized tool, following standards of EU, US and Australia. Like EURECA, SimaPro allows for building specific stratigraphy input and material selection, alluding to a high degree of accuracy.

Another factor crucial to LCA software is the definition of system boundaries. The ZPF-Tool does not indicate specific system boundaries (as defined by ISO 21930) as the tool is Swedish and follows different standards. EURECA follows system boundaries (as defined by ISO 21930) and considers phases A1-A3 (Initial), B1-B5 (Recurring, not considered in Bricolla case study), C2-C4 (End-of-Life) and A4, C2 (Transport). Like EURECA, SimaPro as well as OneClickLCA can access the LCA impact of the entire life-span. OneClickLCA is a widely used and internationally recognized LCA tool. System boundaries are important to consider when comparing results across software's as it is important that the system boundaries in the assessment are constant in order to effectively compare LCA outcomes.

Another difference that arises across software's relates to the insertion of the building's life-span. The ZPF-Tool does not allow for manual entering of the building's life span and assumes a life-span of 30 years. EURECA allows the user to enter the building's life span but suggests a life span of 50 years. The user may also enter the building's life-span in the SimaPro tool as well as OneClickLCA. This is important to consider as the building's life span greatly impacts the results of EC per m^2 per year.

In conclusion, and as discussed above, comparisons between LCA results from different software's are complex and often mis-leading as data inputs, data selection (as well as system boundaries) in different software's vary dramatically, limiting effective comparability and interpretations. When conducting a comparison of LCA results obtained from varying software (as will be done in the section 5.1 following), it is important to consider the effective comparability of software's and to note the limitations of the comparison.

5.2. Data Analysis comparing LCA results of the Bricolla House to existing literature

In this section, the Whole Building LCA results achieved from the EURECA software for the Bricolla House and Business-As-Usual case (Chapter Four) will be elaborated upon. These results will also be contextualized by comparing them to research-found Whole Building LCA results of similar interest (with consideration of the comparability of LCA across software as discussed above).

The Bricolla house received a total EC value of 147,75tCO_2eq for the whole building LCA. This results in a total EC per 'heated floor area value' of 600,33 kgCO_2eq/m^2. When considering the 'total floor area', this results in 310,84 kgCO_2eq/m^2. Considering a building life-span of 50 years this results in 12,01 kgCO_2eq/m^2/year and considering a life span of 100 years this results in 6,00 kgCO_2eq/m^2/year (as depicted in Figure 89, pg. 149).

The Business-As-Usual case received a total EC value of 183,61 tCO_2eq for the whole building LCA. This results in a total EC value per 'heated floor area' of 719,54 kgCO_2eq/m^2. Considering a building life-span of 50 years this results in 14,39 kgCO_2eq/m^2/yr and considering a life span of 100 years this results in 7,20 kgCO_2eq/m^2/yr.

According to the "Embodied Carbon Benchmark for European Building's (2021)" produced by One Click LCA, Western European buildings have an average EC range from 510 to 600 kgCO_2eq/m^2. This range is in line with the EC value obtained for the Bricolla House (600,33 kgCO_2eq/m^2). The EC value of Business-As-Usual case is slightly higher than this benchmark (719,54 kgCO_2eq/m^2).

The scope of the One Click LCA benchmark for Western European building's is similar to the LCA conducted in this study (making the EC results comparable). The only differentiation between the LCA scope in One Click LCA Benchmark (2021) is that the One Click LCA Benchmark includes Use Stages B4 (Replacement) and B5 (Refurbishment). One Click LCA Benchmark (2021) scope does not include all Use Stage's (B1-B7) but only B4, B5. The functional unit of the One Click LCA (2021) scope is the same as that conducted in this study; heated floor area and the selected building life-span for the Benchmark study by One Click LCA is 60 years.

As a means of improvement, in order to lessen the EC emissions of the Bricolla House, attention can be placed on the large quantity of Steel and Concrete used in this building. Although the recycled content of the Steel nears 90% and the Concrete contains 35% fly-ash substitution, these are still the greatest EC contributors (relating to the building's structure). The largely quantity of concrete required is largely due to the buildings position on site (and the subsequently heavy retaining wall). In order to reduce this requirement, a possible different position on site could have been selected. A possibility for the reduction in EC emissions of the Steel frame could be to replace steel with timber glulam coloumns and beams.

Another consideration on the LCA results of the Bricolla house is the decision for the selection of data input values of timber to be 'Without Carbon Storage'. This is the suggested input for the EURECA software. With the inclusion of timber carbon storage, the overall EC value could be reduced.

5.3. Critical Consideration of LEED Rating System and it's distribution of credits in the Materials & Resources category

On page 162 and 163 above, a LEED score for the MR category is assigned for the Bricolla House. In Scenario 1, the Bricolla House achieved a score of 5/13 points and in Scenario 2, achieved 9/13 credits for the MR category (as described in detail on pages 162 and 163 above). The total achievable points in LEED v4.1 is 110 points. The category which considers LCA ('Building Impact Life Cycle Reduction') only consists of 5 available points. In relation to the total points, conducting a Whole Building LCA contributes a maximum of 4,5% to the overall score. This is problematic as the quantity of work of conducting a Whole Building LCA does not proportionality relate to it's allocation in the overall LEED score. This is discouraging for architects, designs and project teams to conduct a LCA.

As hypnotized in previous chapters of this thesis, GBRS's disproportionally prioritize OC over EC emissions and fail to accurately consider a building's entire lifecycle. As highlighted in this thesis, this is true for the LEED Rating System, the most popular and widely utilized rating system in the world. If the built environment is to decarbonise at the rate needed to meet reduction target goals by 2030 of greenhouse gas reduction of at least 40% by 2030 (as defined in the Paris agreement goals), it is essential that GBRS's grant a greater distribution of available credits to LCA. As designers, architects and other project stakeholders wish to conform to sustainable design, those that guide them (including GBRS's) need to accurately encourage designer's in the right direction.

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List of Figures:

Annexure

ANNEX 01: This annexure contains screenshots from the EURECA software of the Bricolla House LCA.

ANNEX 02: This annexure contains screenshots from the EURECA software of the Business-As-Usual LCA.

ANNEX 01: This annexure contains screenshots from the EURECA software of the Bricolla House LCA.

HOME | PROJECT DATA | TECHNICAL ELEMENTS | DOORS AND WINDOWS | PLANTS | TRANSPORTS | END OF LIFE | RESULTS SYSTEM | RESULTS MATERIALS | DATABASE | REPORT | SAVE

Project name:	Bricolla House
Building location:	Briaglia
Project designer/s:	PAT
Inteded use :	Residential
Building life cycle:	50 Years (Insert expected life cycle)
Recurring EE:	Enabled
Assessment of UNHEATED spaces EE:	Enabled ◉ / Disabled ○
Assessment of plants EE :	Disabled

Measurements of HEATED spaces of the building

Roof system – Type	Area [m²]
Roof	107,45
Name of element	0
Name of element	0
Name of element	0
Name of element	0
Total	107,45

Floor on the ground – Type	Area [m²]
Ground Floor	144,4
Foundations	117
Concrete Plinth	4,32
Name of element	0
Name of element	0
Total	265,72

Floor over unheated spaces – Type	Area [m²]
Name of element	0
Name of element	0
Name of element	0
Name of element	0
Name of element	0
Total	0

External wall – Type	Area [m²]
Perimeter Wall Cast Hemp-lime	80,55
Perimeter Concrete Retaining Wall	53,9
Perimeter Timber Drywall	128,59
Name of element	0
Name of element	0
Total	263,04

Partitioning – Type	Area [m²]
Internal Partition	96,62
Internal Concrete Wall	1,47
Name of element	0
Name of element	0
Name of element	0
Total	98,09

Horizontal partition – Type	Area [m²]
Intermediate Floor	97,2
Name of element	0
Name of element	0
Name of element	0
Name of element	0
Total	97,2

Linear element (Length / Front width)

Type	Front width [m]	Total length [m]	Area [m²]	Installation
Steel Wall Frame	0,2	51,84	10,368	Visible
Steel Roof Frame	0,2	46,08	9,216	Visible
Steel Frame Long-Beam	0,2	89,1	17,82	Visible
Steel Roof Substructure	0,16	346,5	55,44	Visible
Timber Roof Members	2,4	29,7	71,28	Visible
Timber Dry-Wall Members	0,3	3,24	0,972	Visible
Concrete Coloumns	0,3	71,1	21,33	Visible
Steel Beam Kitchen	0,4	10,4	4,16	Visible
	0	0	0	Visible
Outside Steek Beam	0,3	9	2,7	Visible
Total			193,286	

Measurements of UNHEATED spaces of the building

Roof systems – Type	Area [m²]
Roof Outside	174,7
Name of element	0
Name of element	0
Total	174,7

Floors on the ground – Type	Area [m²]
Ground Floor Patio Outside	121,56
Name of element	0
Name of element	0
Total	121,56

Floors over unheated spaces – Type	Area [m²]
Name of element	0
Name of element	0
Name of element	0
Total	0

External wall – Type	Area [m²]
Retaining Wall Patio	139,72
Name of element	0
Name of element	0
Total	139,72

Partitioning – Type	Area [m²]
Name of element	0
Name of element	0
Name of element	0
Total	0

Horizontal partition – Type	Area [m²]
Intermediate Floor Outside	82,5
Name of element	0
Name of element	0
Total	82,5

Linear element

Type	Front width [m]	Total length [m]	Area [m²]	Installation
Name of element	0	0	0	Visible
Name of element	0	0	0	Visible
Name of element	0	0	0	Visible
Name of element	0	0	0	Visible
Name of element	0	0	0	Visible
Total			0	

HOME | PROJECT DATA | TECHNICAL ELEMENTS | DOORS AND WINDOWS | PLANTS | TRANSPORTS | END OF LIFE | RESULTS SYSTEM | RESULTS MATERIALS | DATABASE | REPORT | SAVE

Roof system — Type: Weight per square meter — Heated space — Roof

Stratigraphy		Density	Thickness	Weight per square meter	Replac. cycles	Embodied Energy Totale		Embodied Energy Rinnovabile		Embodied Carbon		
#	Name of component	[kg/m³]	[m]	[kg/m2]	[n°]	EE_{tot} [MJ/kg]	EEtot [MJ/m2]	EE_{RS} [MJ/kg]	EErs [MJ/m2]	EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Corten Steel Sheet	7850,00	0,001	6,28			0,00		0,00	0,00	2,73	17,14
2	Okume Panel	700,00	0,018	12,60			0,00		0,00	0,00	0,31	3,91
3	Lime Hemp Insulation	40,00	0,240	9,60			0,00		0,00	0,00	0,09	0,86
4	OSB Panel	640,00	0,018	11,52			0,00		0,00	0,00	0,46	5,24
5	Okume Panel	700,00	0,018	12,60			0,00		0,00	0,00	0,31	3,91
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
5	Components		0,295				0,00		0,00	0,00	3,90	31,06

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

Floor on the ground — Type: Weight per square meter — Heated space — Ground Floor

Stratigraphy		Density	Thickness	Weight per square meter	Replac. cycles	Embodied Energy Totale		Embodied Energy Rinnovabile		Embodied Carbon		
#	Name of component	[kg/m³]	[m]	[kg/m2]	[n°]	EE_{tot} [MJ/kg]	EEtot [MJ/m2]	EE_{RS} [MJ/kg]	EErs [MJ/m2]	EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Hazulnut Parquet Flooring	660,00	0,015	9,90			0,00		0,00	0,00	0,81	8,02
2	Concrete Screed	1200,00	0,135	162,00			0,00		0,00	0,00	0,10	16,20
3	XPS Insulation	35,00	0,120	4,20			0,00		0,00	0,00	0,71	2,98
4	Pozzolanic Concrete	2380,00	0,100	238,00			0,00		0,00	0,00	0,12	28,32
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
4	Components		0,370				0,00		0,00	0,00	1,74	55,52

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

Horizontal partition — Type: Weight per square meter — Heated space — Intermediate Floor

Stratigraphy		Density	Thickness	Weight per square meter	Replac. cycles	Embodied Energy Totale		Embodied Energy Rinnovabile		Embodied Carbon		
#	Name of component	[kg/m³]	[m]	[kg/m2]	[n°]	EE_{tot} [MJ/kg]	EEtot [MJ/m2]	EE_{RS} [MJ/kg]	EErs [MJ/m2]	EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Hazulnut Parquet Flooring	660,00	0,015	9,90			0,00		0,00	0,00	0,81	8,02
2	Concrete Screed	1200,00	0,105	126,00			0,00		0,00	0,00	0,10	12,60
3	XPS Insulation	35,00	0,100	3,50			0,00		0,00	0,00	0,71	2,49
4	Pozzolanic Concrete	2380,00	0,090	214,20			0,00		0,00	0,00	0,12	25,49
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
4	Components		0,310				0,00		0,00	0,00	1,74	48,59

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

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Horizontal partition — Type: Weight per square meter — Heated space — Intermediate Floor

Stratigraphy		Density	Thickness	Weight per square meter	Replac. cycles	Embodied Energy Totale		Embodied Energy Rinnovabile		Embodied Carbon		
#	Name of component	[kg/m³]	[m]	[kg/m2]	[n°]	EE_{tot} [MJ/kg]	EEtot [MJ/m2]	EE_{RS} [MJ/kg]	EErs [MJ/m2]	EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Hazulnut Parquet Flooring	660,00	0,015	9,90			0,00		0,00	0,00	0,81	8,02
2	Concrete Screed	1200,00	0,105	126,00			0,00		0,00	0,00	0,10	12,60
3	XPS Insulation	35,00	0,100	3,50			0,00		0,00	0,00	0,71	2,49
4	Pozzolanic Concrete	2380,00	0,090	214,20			0,00		0,00	0,00	0,12	25,49
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
4	Components		0,310				0,00		0,00	0,00	1,74	48,59

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

External wall — Type: Weight per square meter — Heated space — Perimeter Wall Cast Hemp-lime

Stratigraphy		Density	Thickness	Weight per square meter	Replac. cycles	Embodied Energy Totale		Embodied Energy Rinnovabile		Embodied Carbon		
#	Name of component	[kg/m³]	[m]	[kg/m2]	[n°]	EE_{tot} [MJ/kg]	EEtot [MJ/m2]	EE_{RS} [MJ/kg]	EErs [MJ/m2]	EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Plaster - lime	1300,00	0,020	26,00			0,00		0,00	0,00	0,39	10,14
2	Cast Hemp Lime	240,00	0,400	96,00			0,00		0,00	0,00	0,09	8,16
3	Plaster - lime	1300,00	0,020	26,00			0,00		0,00	0,00	0,39	10,14
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
3	Components		0,440				0,00		0,00	0,00	0,87	28,44

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

External wall — Type: Weight per square meter — Heated space — Perimeter Concrete Retaining Wall

Stratigraphy		Density	Thickness	Weight per square meter	Replac. cycles	Embodied Energy Totale		Embodied Energy Rinnovabile		Embodied Carbon		
#	Name of component	[kg/m³]	[m]	[kg/m2]	[n°]	EE_{tot} [MJ/kg]	EEtot [MJ/m2]	EE_{RS} [MJ/kg]	EErs [MJ/m2]	EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Plaster - lime	1300,00	0,020	26,00			0,00		0,00	0,00	0,39	10,14
2	Pozzolanic Concrete	2380,00	0,400	952,00			0,00		0,00	0,00	0,12	113,29
3	XPS Insulation	35,00	0,120	4,20			0,00		0,00	0,00	0,71	2,98
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
3	Components		0,540				0,00		0,00	0,00	1,22	126,41

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

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Horizontal partition — Type: Weight per square meter — Unheated space — Intermediate Floor Outside

#	Stratigraphy: Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m^2]
1	Stone Floor Finish		0,020	0,00			0,00		0,00	0,00	0,00	0,00
2	Concrete Screed	600,00	0,050	30,00			0,00		0,00	0,00	0,00	0,00
3	XPS Insulation	35,00	0,100	3,50			0,00		0,00	0,00	0,71	2,49
4	Pozzolanic Concrete	2380,00	0,150	357,00			0,00		0,00	0,00	0,12	42,84
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
4	Components		0,320				0,00		0,00	0,00	0,83	45,33

Renewability Index: EE_{NRS} 0,00 — EE_{RS} 0,00 — $RI = EE_{RS}/EE_{tot}$ = 0%

External wall — Type: Weight per square meter — Unheated space — Retaining Wall Patio

#	Stratigraphy: Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m^2]
1	Plaster - lime	1300,00	0,020	26,00			0,00		0,00	0,00	0,39	10,14
2	Pozzolanic Concrete	2380,00	0,400	952,00			0,00		0,00	0,00	0,12	114,24
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
2	Components		0,420				0,00		0,00	0,00	0,51	124,38

Renewability Index: EE_{NRS} 0,00 — EE_{RS} 0,00 — $RI = EE_{RS}/EE_{tot}$ = 0%

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m^2]
1	HE 200 Steel	7850,00	0,008	62,80			0,00		0,00	0,00	1,04	65,31
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,008				0,00		0,00	0,00	1,04	65,31

EE_{NRS} 0,00 — EE_{RS} 0,00 — $RI = EE_{RS}/EE_{tot}$ = 0%

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Linear element — Type: Weight per meter — Heated space — Steel Frame Long-Beam

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m^2]
1	IPE 160 Steel	7850,00	0,005	39,25			0,00		0,00	0,00	1,04	40,82
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,005				0,00		0,00	0,00	1,04	40,82

Renewability Index: EE_{NRS} 0,00 — EE_{RS} 0,00 — $RI = EE_{RS}/EE_{tot}$ = 0%

Linear element — Type: Weight per meter — Heated space — Steel Roof Substructure

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m^2]
1	IPE 160 Steel	7850,00	0,005	39,25			0,00		0,00	0,00	1,04	40,82
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,005				0,00		0,00	0,00	1,04	40,82

Renewability Index: EE_{NRS} 0,00 — EE_{RS} 0,00 — $RI = EE_{RS}/EE_{tot}$ = 0%

Linear element — Type: Weight per meter — Heated space — Steel Beam Kitchen

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m^2]
1	IPE 400 Steel	7850,00	0,024	188,40			0,00		0,00	0,00	1,04	195,94
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,024				0,00		0,00	0,00	1,04	195,94

Renewability Index: EE_{NRS} 0,00 — EE_{RS} 0,00 — $RI = EE_{RS}/EE_{tot}$ = 0%

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Floor on the ground — Type: Weight per square meter — Heated space — Foundations

#	Stratigraphy Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Pozzolanic Concrete	2380,00	0,400	952,00			0,00		0,00	0,00	0,12	114,24
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,400				0,00		0,00	0,00	0,12	114,24

Renewability Index

EENRS · EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

Floor on the ground — Type: Weight per square meter — Heated space — Concrete Plinth

#	Stratigraphy Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Pozzolanic Concrete	2380,00	0,300	714,00			0,00		0,00	0,00	0,12	85,68
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,000				0,00		0,00	0,00	0,12	85,68

Renewability Index

EENRS · EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

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Linear element — Type: Weight per meter — Heated space — Outside Steek Beam

#	Stratigraphy Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	IPE 300 Steel	7850,00	0,017	133,45			0,00		0,00	0,00	1,04	138,79
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,017				0,00		0,00	0,00	1,04	138,79

Renewability Index

EENRS · EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot}$ = 0%

Insert average distance from the disposal site:

Distance from the disposal site:	50 km

Doors and windows

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Wood frame	170201 Wood	0,27	Recycle	100%	0,27	Recycle	0,00	0,00	6,44	0,41	0,49	-5825,45	27,23	-203,71
2	PVC frame	170203 Plastic	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	Aluminium frame	170407 Mixed metals	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	Aluminium and wood frame - WOOD	170201 Wood	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5	Aluminium and wood frame - ALUMINIUM	170407 Mixed metals	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		170407 Mixed metals	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7	Single glazed	170202 Glass	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8	Double glazed	170202 Glass	0,67	Recycle	100%	0,67	Recycle	0,00	0,00	16,30	1,05	1,24	-5427,47	93,95	-225,44
9	Triple glazed	170202 Glass	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		170202 Glass	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8	Components									22,73		1,74	-11 252,92	121,18	-429,15

Plants

		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Type	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Heating and cooling	160214 Discarded equipment	0,00	Landfill	100%	0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	Controlled mechanical ventilation	160214 Discarded equipment	0,00	Landfill	100%	0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	Renewable energy	160214 Discarded equipment	0,00	Landfill	100%	0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4															
3	Components									0,00		0,00	0,00	0,00	0,00

Roof system

Heated space | Roof

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Corten Steel Sheet	170407 Mixed metals	0,67	Reuse	90%	0,61	Reuse	0,07	0,00	16,29	1,05	1,24	-57282,58	-2381,99	-2 381,99
2	Okume Panel	170201 Wood	1,35	Reuse	90%	1,22	Reuse	0,14	0,00	32,69	2,10	2,50	-41360,73	-1556,95	-1 556,95
3	Lime Hemp Insulation	170604 Insulation materials	1,03	Reuse	90%	0,93	Reuse	0,10	0,00	24,90	1,60	1,90	-67585,19	-1557,60	-1 557,60
4	OSB Panel	170802 Gypsum-based construction n	1,24	Recycle	100%	1,24	Recycle	0,00	0,00	29,88	1,92	2,28	-1278,67	127,23	207,95
5	Okume Panel	170201 Wood	1,35	Reuse	90%	1,22	Reuse	0,14	0,00	32,69	2,10	2,50	-41360,73	-1556,95	-1 556,95
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5	Components									136,45		10,42	-208 867,90	-6 926,26	-6 845,54

Floor on the ground

Heated space | Ground Floor

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Hazulnut Parquet Flooring	170201 Wood	1,43	Reuse	90%	1,29	-	0,14	0,00	34,51	2,22	2,64	-39305,75	-1479,59	-1 479,59
2	Concrete Screed	170101 Concrete	23,39	Recycle	100%	23,39	-	0,00	0,00	564,76	36,25	43,14	-42574,90	30,15	-22 340,12
3	XPS Insulation	170604 Insulation materials	0,61	Recycle	100%	0,61	-	0,00	0,00	14,64	0,94	1,12	-19725,16	234,88	-659,24
4	Pozzolanic Concrete	170101 Concrete	34,37	Recycle	100%	34,37	-	0,00	0,00	829,71	53,26	63,38	-62548,30	44,30	-32 820,68
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	Components									1 443,63		110,28	-164 154,11	-1 170,26	-57 299,64

Horizontal partition

Heated space | Intermediate Floor

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Hazulnut Parquet Flooring	170201 Wood	0,96	Reuse	90%	0,87	Reuse	0,10	0,00	23,23	1,49	1,77	-29397,65	-1106,62	-1 106,62
2	Concrete Screed	170101 Concrete	12,25	Recycle	100%	12,25	Recycle	0,00	0,00	295,68	18,98	22,59	-22289,90	15,79	-11 696,08
3	XPS Insulation	170604 Insulation materials	0,34	Recycle	100%	0,34	Reuse	0,00	0,00	8,21	0,53	0,63	-11064,66	131,75	-369,80
4	Pozzolanic Concrete	170101 Concrete	20,82	Recycle	100%	20,82	Recycle	0,00	0,00	502,65	32,27	38,40	-37892,84	26,84	-19 883,33
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	Componenti									829,78		63,39	-100 645,06	-932,24	-33 055,82

External wall

Heated space | Perimeter Wall Cast Hemp-lime

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Nome	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Plaster - lime	170107* mixtures of, or separate fracti	2,09	Recycle	100%	2,09	Recycle	0,00	0,00	50,56	3,25	3,86	-10178,30	2,70	-2 000,06
2	Cast Hemp Lime	170107* mixtures of, or separate fracti	7,73	Recycle	100%	7,73	Recycle	0,00	0,00	186,69	11,98	14,26	-37581,41	9,97	-7 384,82
3	Plaster - lime	170107* mixtures of, or separate fracti	2,09	Recycle	100%	2,09	Recycle	0,00	0,00	50,56	3,25	3,86	-10178,30	2,70	-2 000,06
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	Components									287,81		21,99	-57 938,00	15,37	-11 384,94

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External wall — **Heated space** — **Perimeter Concrete Retaining Wall**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [kgCO_2eq]	EC_{TOT} [kgCO_2eq]	EE [MJ]		EC [kgCO_2eq]
1	Plaster - lime	170107* mixtures of, or separate fracti	1,40	Recycle	100%	1,40	Recycle	0,00	0,00	33,83	2,17	2,58	-6810,80	1,81	-1 338,34
2	Pozzolanic Concrete	170101 Concrete	51,31	Recycle	100%	51,31	Recycle	0,00	0,00	1 238,82	79,52	94,64	-93389,30	66,14	-49 003,72
3	XPS Insulation	170604 Insulation materials	0,23	Recycle	100%	0,23	Recycle	0,00	0,00	5,47	0,35	0,42	-7362,78	87,67	-246,08
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	Components									1 278,12		97,64	-107 562,88	155,62	-50 588,14

External wall — **Heated space** — **Perimeter Timber Drywall**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [kgCO_2eq]	EC_{TOT} [kgCO_2eq]	EE [MJ]		EC [kgCO_2eq]
1	Doublesheet Plasterboard	170802 Gypsum-based construction n	2,14	Recycle	100%	2,14	Recycle	0,00	0,00	51,61	3,31	3,94	-2208,36	219,73	359,15
2	Lime Hemp Insulation	170604 Insulation materials	0,77	Recycle	100%	0,77	Recycle	0,00	0,00	18,63	1,20	1,42	-25093,57	298,81	-838,66
3	OSB Panel	170802 Gypsum-based construction n	1,65	Recycle	100%	1,65	Recycle	0,00	0,00	39,74	2,55	3,04	-1700,27	169,17	276,52
4	Wood Wool Panel	170802 Gypsum-based construction n	1,62	Recycle	100%	1,62	Recycle	0,00	0,00	39,12	2,51	2,99	-1673,70	166,53	272,20
5	Okume Panel	170201 Wood	1,62	Reuse	90%	1,46	Reuse	0,16	0,00	39,12	2,51	2,99	-49498,15	-1863,27	-1 863,27
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5	Components									188,21		14,38	-80 174,04	-1 009,03	-1 794,06

Partitioning — **Heated space** — **Internal Partition**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [kgCO_2eq]	EC_{TOT} [kgCO_2eq]	EE [MJ]		EC [kgCO_2eq]
1	Doublesheet Plasterboard	170802 Gypsum-based construction n	1,61	Recycle	100%	1,61	Recycle	0,00	0,00	38,78	2,49	2,96	-1659,32	165,10	269,86
2	Lime Hemp Insulation	170604 Insulation materials	0,58	Recycle	100%	0,58	Reuse	0,00	0,00	14,00	0,90	1,07	-18854,81	224,52	-630,16
3	Doublesheet Plasterboard	170802 Gypsum-based construction n	1,61	Recycle	100%	1,61	Recycle	0,00	0,00	38,78	2,49	2,96	-1659,32	165,10	269,86
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	Components									91,56		6,99	-22 173,44	554,72	-90,44

HOME | PROJECT DATA | TECHNICAL ELEMENTS | DOORS AND WINDOWS | PLANTS | TRANSPORTS | END OF LIFE | RESULTS SYSTEM | RESULTS MATERIALS | DATABASE | REPORT | SAVE

Linear element — **Heated space** — **Steel Wall Frame**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [kgCO_2eq]	EC_{TOT} [kgCO_2eq]	EE [MJ]		EC [kgCO_2eq]
1	HE 200 Steel	170407 Mixed metals	3,26	Reuse	90%	2,93	Reuse	0,33	0,00	78,60	5,05	6,00	-276363,81	-11492,10	-11 492,10
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									78,60		6,00	-276 363,81	-11 492,10	-11 492,10

Linear element — **Heated space** — **Steel Roof Frame**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [kgCO_2eq]	EC_{TOT} [kgCO_2eq]	EE [MJ]		EC [kgCO_2eq]
1	HE 200 Steel	170407 Mixed metals	2,89	Reuse	90%	2,60	Reuse	0,29	0,00	69,86	4,48	5,34	-245656,72	-10215,20	-10 215,20
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									69,86		5,34	-245 656,72	-10 215,20	-10 215,20

Linear element — **Heated space** — **Steel Frame Long-Beam**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [kgCO_2eq]	EC_{TOT} [kgCO_2eq]	EE [MJ]		EC [kgCO_2eq]
1	IPE 160 Steel	170407 Mixed metals	3,50	Reuse	90%	3,15	Reuse	0,35	0,00	84,43	5,42	6,45	-296875,19	-12345,03	-12 345,03
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									84,43		6,45	-296 875,19	-12 345,03	-12 345,03

Linear element | Heated space | Steel Roof Substructure

	Stratigraphy	EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	IPE 160 Steel	170407 Mixed metals	13,60	Reuse	90%	12,24	Reuse	1,36	0,00	328,34	21,08	25,08	-1154514,61	-48008,44	-48 008,44
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									**328,34**		**25,08**	**-1 154 514,61**	**-48 008,44**	**-48 008,44**

Linear element | Heated space | Steel Beam Kitchen

	Stratigraphy	EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	IPE 400 Steel	170407 Mixed metals	1,96	Reuse	90%	1,76	Reuse	0,20	0,00	47,30	3,04	3,61	-166330,07	-6916,54	-6 916,54
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									**47,30**		**3,61**	**-166 330,07**	**-6 916,54**	**-6 916,54**

Linear element | Heated space | Concrete Coloumns

	Stratigraphy	EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Pozzolanic Concrete	170101 Concrete	15,23	Recycle	100%	15,23	Recycle	0,00	0,00	367,68	23,60	28,09	-27717,91	19,63	-14 544,29
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									**367,68**		**28,09**	**-27 717,91**	**19,63**	**-14 544,29**

Roof system | Unheated space | FALSE

	Stratigraphy	EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Corten Steel Sheet	170407 Mixed metals	1,37	Reuse	90%	1,23	Reuse	0,14	0,00	33,11	2,13	2,53	-116417,72	-4841,02	-4 841,02
2	Okume Panel	170201 Wood	2,20	Reuse	90%	1,98	-	0,22	0,00	53,14	3,41	4,06	-60522,54	-2278,26	-2 278,26
3	OSB Panel	170802 Gypsum-based construction n	2,01	Recycle	100%	2,01	-	0,00	0,00	48,59	3,12	3,71	-2078,96	206,85	338,11
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	Components									**134,84**		**10,30**	**-179 019,22**	**-6 912,43**	**-6 781,18**

Floor on the ground | Unheated space | FALSE

	Stratigraphy	EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Hazulnut Parquet Flooring	170201 Wood	1,20	Reuse	90%	1,08	Reuse	0,12	0,00	29,05	1,87	2,22	-36765,21	-1383,96	-1 383,96
2	Concrete Screed	170101 Concrete	9,85	Recycle	100%	9,85	Recycle	0,00	0,00	237,72	15,26	18,16	-17920,38	12,69	-9 403,27
3	XPS Insulation	170604 Insulation materials	0,51	Recycle	100%	0,51	Reuse	0,00	0,00	12,33	0,79	0,94	-16605,19	197,73	-554,97
4	Pozzolanic Concrete	170101 Concrete	28,93	Recycle	100%	28,93	Recycle	0,00	0,00	698,47	44,84	53,36	-52654,93	37,29	-27 629,37
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	Components									**977,57**		**74,68**	**-123 945,71**	**-1 136,25**	**-38 971,58**

Horizontal partition | Unheated space | FALSE

	Stratigraphy	EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Stone Floor Finish	170103 Bricks	0,00	Reuse	90%	0,00	Reuse	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	Concrete Screed	170101 Concrete	2,48	Recycle	100%	2,48	Recycle	0,00	0,00	59,75	3,84	4,56	-4504,50	3,19	-2 363,63
3	XPS Insulation	170604 Insulation materials	0,29	Recycle	100%	0,29	Reuse	0,00	0,00	6,97	0,45	0,53	-9391,31	111,83	-313,87
4	Pozzolanic Concrete	170101 Concrete	29,45	Recycle	100%	29,45	Recycle	0,00	0,00	711,06	45,64	54,32	-53603,55	37,96	-28 127,14
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	Components									**777,78**		**59,42**	**-67 499,36**	**152,98**	**-30 804,63**

External wall | Unheated space | FALSE

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Plaster - lime	170107* mixtures of, or separate fracti	3,63	Recycle	100%	3,63	Recycle	0,00	0,00	87,70	5,63	6,70	-17655,02	4,68	-3 469,25
2	Pozzolanic Concrete	170101 Concrete	133,01	Recycle	100%	133,01	Recycle	0,00	0,00	3 211,28	206,14	245,32	-242084,46	171,45	-127 027,84
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	Components									**3 298,98**		**252,02**	**-259 739,48**	**176,14**	**-130 497,08**

Floor on the ground | Heated space | Foundations

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Pozzolanic Concrete	170101 Concrete	111,38	Recycle	100%	111,38	Recycle	0,00	0,00	2 689,09	172,62	205,43	-202718,88	143,57	-106 371,72
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									**2 689,09**		**205,43**	**-202 718,88**	**143,57**	**-106 371,72**

Floor on the ground | Heated space | Concrete Plinth

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	Pozzolanic Concrete	170101 Concrete	3,08	Recycle	100%	3,08	Recycle	0,00	0,00	74,47	4,78	5,69	-5613,75	3,98	-2 945,68
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									**74,47**		**5,69**	**-5 613,75**	**3,98**	**-2 945,68**

Linear element | Heated space | Outside Steek Beam

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon		Avoided impactcs		
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]	EE [MJ]		EC [$kgCO_2eq$]
1	IPE 300 Steel	170407 Mixed metals	1,20	Recycle	100%	1,20	Recycle	0,00	0,00	29,00	1,86	2,22	-47352,60	640,91	-1 818,39
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	Components									**29,00**		**2,22**	**-47 352,60**	**640,91**	**-1 818,39**

ANNEX 02: This annexure contains screenshots from the EURECA software of the Business-As-Usual LCA.

HOME | PROJECT DATA | TECHNICAL ELEMENTS | DOORS AND WINDOWS | PLANTS | TRANSPORTS | END OF LIFE | RESULTS SYSTEM | RESULTS MATERIALS | DATABASE | REPORT | SAVE

Project name:	Bricolla House	Inteded use :	Residential	Assessment of UNHEATED spaces EE:	Enabled / Disabled
Building location:	Briaglia	Building life cycle:	50 Years (Insert expected life cycle)		
Project designer/s:	PAT	Recurring EE:	Enabled	Assessment of plants EE :	Disabled

Measurements of HEATED spaces of the building

Roof system

Type	Area [m²]
Roof	107,45
Name of element	0
Name of element	0
Name of element	0
Name of element	0
Total	107,45

Floor on the ground

Type	Area [m²]
Ground Floor	144,4
Foundations	117
Concrete Plinth	4,32
Name of element	0
Name of element	0
Total	265,72

Floor over unheated spaces

Type	Area [m²]
Name of element	0
Name of element	0
Name of element	0
Name of element	0
Name of element	0
Total	0

External wall

Type	Area [m²]
Perimeter Wall Hollow Brick	209,14
Perimeter Concrete Retaining Wall	53,88
Name of element	0
Name of element	0
Name of element	0
Total	263,02

Partitioning

Type	Area [m²]
Internal Partition	96,62
Internal Concrete Wall	1,47
Name of element	0
Name of element	0
Name of element	0
Total	98,09

Horizontal partition

Type	Area [m²]
Intermediate Floor	97,45
Name of element	0
Name of element	0
Name of element	0
Name of element	0
Total	97,45

Linear element

Type	Front width [m]	Total length [m]	Area [m²]	Installation
Steel Wall Frame	0,2	51,84	10,368	Visible
Steel Roof Frame	0,2	46,08	9,216	Visible
Steel Frame Long-Beam	0,2	89,1	17,82	Visible
Steel Roof Substructure	0,16	346,5	55,44	Visible
Timber Roof Members	2,4	29,7	71,28	Visible
Steel Beam Kitchen	0,4	10,4	4,16	Visible
Concrete Coloumns	0,3	71	21,3	Visible
Outside Steel Beam	0,3	9	2,7	Visible
Steel Frame Long-Beam	0,6	29,7	17,82	Visible
Name of element	0	0	0	Visible
Total			210,104	

Measurements of UNHEATED spaces of the building

Roof systems

Type	Area [m²]
Roof outside	174,7
Name of element	0
Name of element	0
Total	174,7

Floors on the ground

Type	Area [m²]
Ground Floor Patio Outside	121,56
Name of element	0
Name of element	0
Total	121,56

Floors over unheated spaces

Type	Area [m²]
Intermediate Floor Outside	0
Name of element	0
Name of element	0
Total	0

External wall

Type	Area [m²]
Retaining Wall Patio	140,72
Name of element	0
Name of element	0
Total	140,72

Partitioning

Type	Area [m²]
Name of element	0
Name of element	0
Name of element	0
Total	0

Horizontal partition

Type	Area [m²]
Intermediate Floor Out	82,5
Name of element	0
Name of element	0
Total	82,5

Linear element

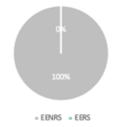
Type	Front width [m]	Total length [m]	Area [m²]	Installation
Name of element	0	0	0	Visible
Name of element	0	0	0	Visible
Name of element	0	0	0	Visible
Name of element	0	0	0	Visible
Name of element	0	0	0	Visible
Total			0	

HOME | PROJECT DATA | TECHNICAL ELEMENTS | DOORS AND WINDOWS | PLANTS | TRANSPORTS | END OF LIFE | RESULTS SYSTEM | RESULTS MATERIALS | DATABASE | REPORT | SAVE

Linear element — Type: Weight per meter — Heated space — Steel Wall Frame

#	Stratigraphy Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	HEB 200 Steel	7850,00	0,008	62,80		21,50	1350,20		0,00	0,00	1,21	75,99
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,008				1350,20		0,00	0,00	1,21	75,99

Renewability Index



EE_{NRS}	EE_{RS}
1350,20	0,00
RI = EE_{RS}/EE_{tot} = 0%	

Linear element — Type: Weight per meter — Heated space — Steel Frame Long-Beam

#	Stratigraphy Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	IPE 160 Steel	7850,00	0,005	40,82			0,00		0,00	0,00	1,21	49,39
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,005				0,00		0,00	0,00	1,21	49,39

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00
RI = EE_{RS}/EE_{tot} = 0%	

Floor on the ground — Type: Weight per square meter — Heated space — Foundations

#	Stratigraphy Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Ordinary Concrete	2400,00	0,300	720,00			0,00		0,00	0,00	0,15	108,00
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,300				0,00		0,00	0,00	0,15	108,00

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00
RI = EE_{RS}/EE_{tot} = 0%	

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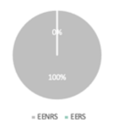
External wall — Type: Weight per square meter — Heated space — Perimeter Wall Hollow Brick

#	Stratigraphy Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Plaster - lime	1300,00	0,020	26,00			0,00		0,00	0,00	0,39	10,14
2	Hollow Brick	240,00	0,120	28,80			0,00		0,00	0,00	0,26	7,49
3	EPS Insulation	28,00	0,080	2,24		88,60	198,46		0,00	0,00	3,29	7,37
4	Hollow Brick	240,00	0,080	19,20			0,00		0,00	0,00	0,26	4,99
5	Plaster - lime	1300,00	0,010	13,00			0,00		0,00	0,00	0,39	5,07
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
5	Components		0,310				198,46		0,00	0,00	4,59	35,06

Renewability Index



EE_{NRS}	EE_{RS}
198,46	0,00
RI = EE_{RS}/EE_{tot} = 0%	

External wall — Type: Weight per square meter — Heated space — Perimeter Concrete Retaining Wall

#	Stratigraphy Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Plaster - lime	1300,00	0,020	26,00			0,00		0,00	0,00	0,39	10,14
2	Ordinary Concrete	2380,00	0,400	952,00			0,00		0,00	0,00	0,15	142,80
3	EPS Insulation	28,00	0,090	2,52			0,00		0,00	0,00	3,29	8,29
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
3	Components		0,510				0,00		0,00	0,00	3,83	161,23

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00
RI = EE_{RS}/EE_{tot} = 0%	

Partitioning — Type: Weight per square meter — Heated space — Internal Partition

#	Stratigraphy Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Plaster - lime	665,00	0,020	13,30			0,00		0,00	0,00	0,39	5,19
2	Hollow Brick	240,00	0,120	28,80			0,00		0,00	0,00	0,26	7,49
3	Plaster - lime	665,00	0,020	13,30			0,00		0,00	0,00	0,39	5,19
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
3	Components		0,160				0,00		0,00	0,00	1,04	17,86

Renewability Index

EENRS EERS

EE_{NRS}	EE_{RS}
0,00	0,00
RI = EE_{RS}/EE_{tot} = 0%	

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Roof system — Type: Weight per square meter — Unheated space — Roof outside

#	Stratigraphy: Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Clay Roof Tiles	1650,00	0,012	19,80			0,00		0,00	0,00	0,26	5,15
2	Plasterboard	665,00	0,013	8,65			0,00		0,00	0,00	3,29	28,44
3	Okume Panel	700,00	0,018	12,60			0,00		0,00	0,00	0,39	4,91
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
3	Components		0,043				0,00		0,00	0,00	3,94	38,50

Renewability Index

EE_{NRS}	EE_{RS}
0,00	0,00

RI = EE_{RS}/EE_{tot} = 0%

Floor on the ground — Type: Weight per square meter — Heated space — Concrete Plinth

#	Stratigraphy: Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Ordinary Concrete	2400,00	0,300	720,00			0,00		0,00	0,00	0,15	108,00
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,300				0,00		0,00	0,00	0,15	108,00

Renewability Index

EE_{NRS}	EE_{RS}
0,00	0,00

RI = EE_{RS}/EE_{tot} = 0%

External wall — Type: Weight per square meter — Unheated space — Retaining Wall Patio

#	Stratigraphy: Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Ordinary Concrete	2400,00	0,400	960,00			0,00		0,00	0,00	0,15	144,00
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,400				0,00		0,00	0,00	0,15	144,00

Renewability Index

EE_{NRS}	EE_{RS}
0,00	0,00

RI = EE_{RS}/EE_{tot} = 0%

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Horizontal partition — Type: Weight per square meter — Unheated space — Intermediate Floor Out

#	Stratigraphy: Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Concrete Screed	2000,00	0,100	200,00			0,00		0,00	0,00	0,10	20,00
2	EPS Insulation	28,00	0,090	2,52			0,00		0,00	0,00	3,29	8,29
3	Ordinary Concrete	2400,00	0,100	240,00			0,00		0,00	0,00	0,15	36,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
3	Components		0,290				0,00		0,00	0,00	3,54	64,29

Renewability Index

EE_{NRS}	EE_{RS}
0,00	0,00

RI = EE_{RS}/EE_{tot} = 0%

Floor on the ground — Type: Weight per square meter — Unheated space — Ground Floor Patio Outside

#	Stratigraphy: Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Concrete Screed	2000,00	0,100	200,00			0,00		0,00	0,00	0,10	20,00
2	EPS Insulation	28,00	0,100	2,80			0,00		0,00	0,00	3,29	9,21
3	Ordinary Concrete	2400,00	0,100	240,00			0,00		0,00	0,00	0,15	36,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
3	Components		0,300				0,00		0,00	0,00	3,54	65,21

Renewability Index

EE_{NRS}	EE_{RS}
0,00	0,00

RI = EE_{RS}/EE_{tot} = 0%

Linear element — Type: Weight per meter — Heated space — Steel Roof Frame

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	HEB 200 Steel	7580,00	0,008	59,12			0,00		0,00	0,00	1,21	71,54
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,008				0,00		0,00	0,00	1,21	71,54

Renewability Index

EE_{NRS}	EE_{RS}
0,00	0,00

RI = EE_{RS}/EE_{tot} = 0%

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Linear element — Type: Weight per meter — Heated space — Concrete Coloumns

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Ordinary Concrete	2400,00	0,090	216,00			0,00		0,00	0,00	0,15	32,40
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,090				0,00		0,00	0,00	0,15	32,40

Renewability Index

EENRS · EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot} =$ 0%

Linear element — Type: Weight per meter — Heated space — Steel Beam Kitchen

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	IPE 400 Steel	7850,00	0,024	188,40			0,00		0,00	0,00	1,21	227,96
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,024				0,00		0,00	0,00	1,21	227,96

Renewability Index

EENRS · EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot} =$ 0%

Linear element — Type: Weight per meter — Heated space — Outside Steel Beam

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	IPE 300 Steel	7850,00	0,017	133,45			0,00		0,00	0,00	1,21	161,47
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,017				0,00		0,00	0,00	1,21	161,47

Renewability Index

EENRS · EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot} =$ 0%

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Partitioning — Type: Weight per square meter — Heated space — Internal Concrete Wall

#	Stratigraphy: Name of component	Density [kg/m³]	Thickness [m]	Weight per square meter [kg/m2]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m2]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EErs [MJ/m2]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	Ordinary Concrete	2400,00	0,300	720,00			0,00		0,00	0,00	0,15	108,00
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,000				0,00		0,00	0,00	0,15	108,00

Renewability Index

EENRS · EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot} =$ 0%

Linear element — Type: Weight per meter — Heated space — Steel Roof Substructure

#	Stratigraphy: Name of component	Density [kg/m³]	Sezione O. [m2]	Weight per meter [kg/m]	Replac. cycles [n°]	Embodied Energy Totale: EE_{tot} [MJ/kg]	EEtot [MJ/m]	Embodied Energy Rinnovabile: EE_{RS} [MJ/kg]	EEfr [MJ/m]	Embodied Carbon: EC_{indir} [CO_2/kg]	EC_{tot} [CO_2/kg]	EC_{tot} [CO_2/m²]
1	IPE 160 Steel	7850,00	0,005	40,82			0,00		0,00	0,00	1,21	49,39
2				0,00			0,00		0,00	0,00	0,00	0,00
3				0,00			0,00		0,00	0,00	0,00	0,00
4				0,00			0,00		0,00	0,00	0,00	0,00
5				0,00			0,00		0,00	0,00	0,00	0,00
6				0,00			0,00		0,00	0,00	0,00	0,00
7				0,00			0,00		0,00	0,00	0,00	0,00
8				0,00			0,00		0,00	0,00	0,00	0,00
9				0,00			0,00		0,00	0,00	0,00	0,00
10				0,00			0,00		0,00	0,00	0,00	0,00
1	Components		0,005				0,00		0,00	0,00	1,21	49,39

Renewability Index

EENRS · EERS

EE_{NRS}	EE_{RS}
0,00	0,00

$RI = EE_{RS}/EE_{tot} =$ 0%

Insert average distance from the disposal site:

Distance from the disposal site:	50 km

Doors and windows

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Wood frame	170201 Wood	0,27	Landfill	100%	0,27	Landfill	0,00	0,00	6,44	0,41	0,49
2	PVC frame	170203 Plastic	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3	Aluminium frame	170407 Mixed metals	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
4	Aluminium and wood frame - WOOD	170201 Wood	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5	Aluminium and wood frame - ALUMINIUM	170407 Mixed metals	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		170407 Mixed metals	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7	Single glazed	170202 Glass	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8	Double glazed	170202 Glass	0,68	Landfill	100%	0,68	Landfill	0,00	0,00	16,30	1,05	1,25
9	Triple glazed	170202 Glass	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		170202 Glass	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8	Components									**22,74**		**1,74**

Plants

		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Type	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Heating and cooling	160214 Discarded equipment	0,00	Landfill	100%	0,00	-	0,00	0,00	0,00	0,00	0,00
2	Controlled mechanical ventilation	160214 Discarded equipment	0,00	Landfill	100%	0,00	-	0,00	0,00	0,00	0,00	0,00
3	Renewable energy	160214 Discarded equipment	0,00	Landfill	100%	0,00	-	0,00	0,00	0,00	0,00	0,00
4												
3	Components									**0,00**		**0,00**

Roof system — Heated space — Roof

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Clay Roof Tiles	170107* mixtures of, or separate fraction	2,13	Recycle	100%	2,13	Recycle	0,00	0,00	51,36	3,30	3,92
2	EPS Insulation	170604 Insulation materials	0,45	Landfill	100%	0,45	Landfill	0,00	0,00	10,90	0,70	0,83
3	Plasterboard	170802 Gypsum-based construction mat	0,93	Recycle	100%	0,93	Recycle	0,00	0,00	22,43	1,44	1,71
4	Okume Panel	170201 Wood	1,35	Recycle	100%	1,35	Recycle	0,00	0,00	32,69	2,10	2,50
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
4	Components									**117,37**		**8,97**

Floor on the ground — Heated space — Ground Floor

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Vinyl Flooring	170203 Plastic	0,96	Recycle	100%	0,96	Recycle	0,00	0,00	23,18	1,49	1,77
2	Concrete Screed	170101 Concrete	28,88	Landfill	100%	28,88	Landfill	0,00	0,00	697,24	44,76	53,26
3	EPS Insulation	170604 Insulation materials	0,40	Landfill	100%	0,40	Landfill	0,00	0,00	9,76	0,63	0,75
4	Ordinary Concrete	170101 Concrete	34,66	Landfill	100%	34,66	Landfill	0,00	0,00	836,68	53,71	63,92
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00

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Horizontal partition — Heated space — Intermediate Floor

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Vinyl Flooring	170203 Plastic	0,65	Recycle	100%	0,65	Recycle	0,00	0,00	15,65	1,00	1,20
2	Concrete Screed	170101 Concrete	19,49	Landfill	100%	19,49	Landfill	0,00	0,00	470,54	30,20	35,95
3	EPS Insulation	170604 Insulation materials	0,25	Landfill	100%	0,25	Landfill	0,00	0,00	5,93	0,38	0,45
4	Ordinary Concrete	170101 Concrete	23,39	Landfill	100%	23,39	Landfill	0,00	0,00	564,64	36,25	43,13
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
4	Componenti									**1 056,76**		**80,73**

External wall — Heated space — Perimeter Wall Hollow Brick

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Nome	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Plaster - lime	170107* mixtures of, or separate fraction	5,44	Landfill	100%	5,44	Landfill	0,00	0,00	131,28	8,43	10,03
2	Hollow Brick	170103 Bricks	6,02	Landfill	100%	6,02	Landfill	0,00	0,00	145,42	9,33	11,11
3	EPS Insulation	170604 Insulation materials	0,47	Landfill	100%	0,47	Landfill	0,00	0,00	11,31	0,73	0,86
4	Hollow Brick	170103 Bricks	4,02	Landfill	100%	4,02	Landfill	0,00	0,00	96,94	6,22	7,41
5	Plaster - lime	170107* mixtures of, or separate fraction	2,72	Landfill	100%	2,72	Landfill	0,00	0,00	65,64	4,21	5,01
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5	Components									**450,59**		**34,42**

External wall — Heated space — Perimeter Concrete Retaining Wall

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Plaster - lime	170107* mixtures of, or separate fraction	1,40	Landfill	100%	1,40	Landfill	0,00	0,00	33,82	2,17	2,58
2	Ordinary Concrete	170101 Concrete	51,29	Landfill	100%	51,29	Landfill	0,00	0,00	1 238,36	79,49	94,60
3	EPS Insulation	170604 Insulation materials	0,14	Landfill	100%	0,14	Landfill	0,00	0,00	3,28	0,21	0,25
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3	Components									**1 275,46**		**97,44**

Partitioning — Heated space — Internal Partition

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Plaster - lime	170107* mixtures of, or separate fraction	1,29	Landfill	100%	1,29	Landfill	0,00	0,00	31,02	1,99	2,37
2	Hollow Brick	170103 Bricks	2,78	Landfill	100%	2,78	Landfill	0,00	0,00	67,18	4,31	5,13
3	Plaster - lime	170107* mixtures of, or separate fraction	1,29	Landfill	100%	1,29	Landfill	0,00	0,00	31,02	1,99	2,37
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3	Components									**129,23**		**9,87**

Floor on the ground — **Heated space** — **Concrete Plinth**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Ordinary Concrete	170101 Concrete	3,11	Landfill	100%	3,11	Landfill	0,00	0,00	75,09	4,82	5,74
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
1	Components									**75,09**		**5,74**

External wall — **Unheated space** — **FALSE**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Ordinary Concrete	170101 Concrete	135,09	Landfill	100%	135,09	Landfill	0,00	0,00	3 261,44	209,35	249,15
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
1	Components									**3 261,44**		**249,15**

Horizontal partition — **Unheated space** — **FALSE**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Concrete Screed	170101 Concrete	16,50	Landfill	100%	16,50	Landfill	0,00	0,00	398,35	25,57	30,43
2	EPS Insulation	170604 Insulation materials	0,21	Landfill	100%	0,21	Landfill	0,00	0,00	5,02	0,32	0,38
3	Ordinary Concrete	170101 Concrete	19,80	Landfill	100%	19,80	Landfill	0,00	0,00	478,02	30,68	36,52
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3	Components									**881,39**		**67,33**

Floor on the ground — **Unheated space** — **FALSE**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Concrete Screed	170101 Concrete	24,31	Landfill	100%	24,31	Landfill	0,00	0,00	586,95	37,68	44,84
2	EPS Insulation	170604 Insulation materials	0,34	Landfill	100%	0,34	Landfill	0,00	0,00	8,22	0,53	0,63
3	Ordinary Concrete	170101 Concrete	29,17	Landfill	100%	29,17	Landfill	0,00	0,00	704,34	45,21	53,81
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3	Components									**1 299,51**		**99,27**

Linear element — **Heated space** — **Steel Roof Frame**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	HEB 200 Steel	170407 Mixed metals	2,72	Recycle	100%	2,72	Recycle	0,00	0,00	65,77	4,22	5,02
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
1	Components									**65,77**		**5,02**

Linear element — **Heated space** — **Concrete Coloumns**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	Ordinary Concrete	170101 Concrete	15,34	Landfill	100%	15,34	Landfill	0,00	0,00	370,25	23,77	28,28
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
1	Components									**370,25**		**28,28**

Linear element — **Heated space** — **Steel Beam Kitchen**

Stratigraphy		EWC CODE	Weight	Disposal	Amount 1		Disposal	Amount 2	Embodied Energy		Embodied Carbon	
#	Name	[-]	[t]	[-]	[%]	[t]	[-]	[t]	EE_{FR} [MJ]	EE_{TOT} [MJ]	EC_{IND} [$kgCO_2eq$]	EC_{TOT} [$kgCO_2eq$]
1	IPE 400 Steel	170407 Mixed metals	1,96	Recycle	100%	1,96	Recycle	0,00	0,00	47,30	3,04	3,61
2		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
3		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
4		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
5		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
6		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
7		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
8		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
9		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
10		-	0,00	-		0,00	-	0,00	0,00	0,00	0,00	0,00
1	Components									**47,30**		**3,61**