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MASTERARBEIT

Life Cycle Assessment of a Wooden High-Rise Building in Comparison to a Conventional Construction

unter der Leitung von

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KURZFASSUNG

Durch neue Technologien werden die Grenzen der Leistungsfähigkeit von Holzfabrikaten als Bauteile immer weiter ausgedehnt. Solche Holzbauteile werden entsprechend immer mehr zu High-Tech Produkten. Während gleichermaßen ein Streben nach höheren vertikalen Grenzen im Sinne von Hochhäusern basierend auf Holzkonstruktionen mit der Entwicklung dieser Materialien Hand in Hand geht, ist ein Ende dieses Voranstrebens nicht in Sicht. Es stellt sich jedoch die Frage, ob den daraus entstehenden neuen Konstruktionen ein praktikabler und nachhaltiger neuer Ansatz gegenüber der Verdichtung unserer urbanen Landschaft innewohnt. Um Klarheit über dies zu schaffen werden die Komponenten eines der welthöchsten Holzgebäudes mithilfe des Ökobilanz-Ansatzes analysiert und die Auswertung sowie zusätzliche Daten und Faktoren mit einem konventionell konstruierten, gleichwertigen Gebäude verglichen.

Obgleich volumetrisch größer als Stahlbetonkonstruktionen, bieten Holzhochhäuser eine nachhaltige Lösung zu den Verdichtungs- sowie Verstädterungsproblematiken unserer Zeit. Da Holz CO_2 inkorporiert kann der Erderwärmungsfaktor eines solchen Holzhochhauses tatsächlich bis zu zwei Dritteln der negativen Emissionen eines äquivalenten Stahlbetongebäudes kompensieren. Durch Wiederverwertung kann die Lebensspanne sowie energetische Rückgewinnung der Ressource Holz einen weiteren Pluspunkt im Vergleich zu Beton nachweisen. Der Bauprozess mit vorgefertigten Holzkomponenten ist zeiteffizient und generiert eine vergleichsweise geräuscharme Baustelle. Die Planungsphasen solcher Großbauvorhaben sind jedoch im Moment noch fernab von konventionellen Projekten und benötigen daher auch länger. Durch weitere Projekterfahrungen mit dieser neuen Bauweise wird diese Problematik jedoch auch verringert werden..

Forschung und Entwicklung sollten der optimierten Materialnutzung weiter nachgehen. Zusätzlich muss die Industrie sich einer erweiterten Produktion neuer und effizienter Holzbauteile widmen um diese Komponenten realisierbar, wirtschaftlich, preiseffizient und damit wettbewerbsfähig gegenüber Stahlbeton und anderen Konstrutkionsformen zu machen.

Als nächster Schritt ist es denkbar die Effizienz verschiedener Performanceparameter von unterschiedlichenHolzhochhäusern zu analysieren. Der Fokus kann hierbei beispielsweise auf unterschiedlichen Gebäudetypen, Nutzungen oder Konstruktionsformen liegen. Individuelle Lösungen können helfen Vergleichswerte für zukünftige Entwicklungen zu kreieren. Mit dem weltweiten Aufkommen einer Vielzahl an Holzhochhäusern existiert dann Substanz für solche Forschungsbemühungen.

Stichworte

Vergleichende Ökobilanz, Bauteile, Hochhaus, Tree Gebäude, Stahlbeton, Bezugswert, ökologischer Fußabdruck

ABSTRACT

New technologies in timber technology emerge and have an innovation effect onto the performance of wooden building components. As such, components made from this material – which is generally known to be a sustainable material – are becoming more and more of high-tech products. Currently, a growing number of high-rise buildings is constructed based on timber. Thereby, these building compete against each other regarding the technological limits of timber construction in view of construction height. However, it has to be critically questioned, if such high-rise structure offer a feasible and sustainable approach toward densification of the urban landscapes, given the amount of knowledge, and technological skills required to use the material for high-rise construction. In order to investigate in this direction, one of the world's current highest timber construction buildings and its components are to be analyzed via life-cycle-assessment methods. Subsequently, the outcome of these efforts are compared with corresponding data of conventionally constructed buildings of similar size, layout, and usage.

Although the structures and volumetric dimensions of timber high-rise buildings are usually larger than those of comparable concrete buildings, timber buildings offer a rather sustainable solution to the densification and urbanization problems of recent times. The capability to store CO_2 can be considered as a big advantage: The global warming potential of a timber high-rise compensates up to two thirds of emissions connected with an equivalent concrete structure. Moreover, additional benefits include the recycling of wood, their long lifespan and energetic payback of the resource wood. Furthermore, the construction time required to erect a timber construction building can be considered as time-efficient, and construction-related noise is moderate compared to other building sites. However, while the construction time is short, the planning of timber high-rise buildings currently requires more time than conventional projects. This might be due to the fact that the technology is still not very common throughout the planning practice. This, most likely, will change with an increased number of high-rise timber constructions to be built and the establishment of corresponding knowledge-bases.

Future Research and Development efforts need to further investigate the optimization of the material use. In addition, the industry has to adapt toward a broader manufacturing practice of new and efficient wooden elements in order to make the components more feasible, cost-efficient and competitive to concrete and other construction forms. The next steps in investigation thus should encompass a critical comparison between different construction methods for timber high-rise construction.

The different individual solutions and build use cases will contribute to create benchmarks for future developments. Given the increasing number of timber constructions in planning, building, or even in use, such comparison efforts can offer substantive improvements for the design, planning, and construction of timber high-rise buildings.

Keywords

Comparative LCA, Building Materials, High-Rise, the Tree Building, Concrete, Benchmark, ecological footprint

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To my mother who gave everything for me, I owe it all to you.

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1 INTRODUCTION

1.1 Overview

With the occurring shift in population dispersion, the world is witnessing an unprecedented growth of cities in recent decades. A majority of people on this planet now live in urban areas. This urbanization is largely accompanied by housing shortage which remains one of the big problems to be solved by policy makers and urban planners of our time. Yet, this is merely one of two issues tied to the building industry (Bugliarello, G. 2006).

Moreover, buildings are considered as one of major contributors to CO_2 emission and pollution of the environment. As shown in Figure 1, up to 6% of global GHG (greenhouse gas) emissions (up to 19% including electricity related emissions, Lucon et al. 2014) are linked to buildings onsite energy generation. Excluded from this are emissions of electricity use and the production/transport of building components.

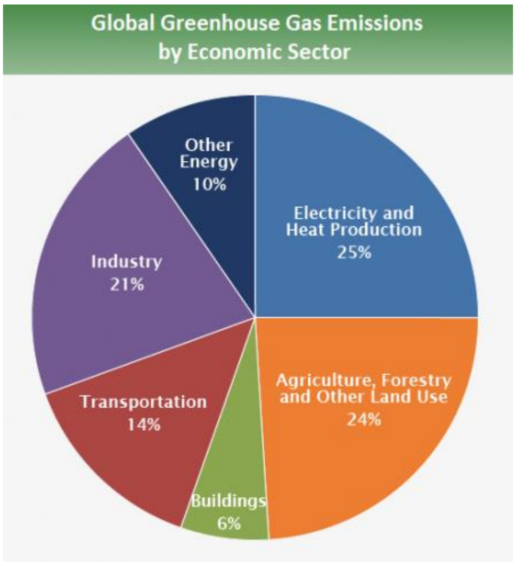


Figure 1: Global greenhouse gas emissions (EPA 2014)

Materials used to construct our living space play a substantial role on the impact we create towards the environment. Cement for concrete production as an example accounts for up to 8% of global CO_2 emissions. This value does not even consider the reinforcement steel production (Oliver et al. 2015).

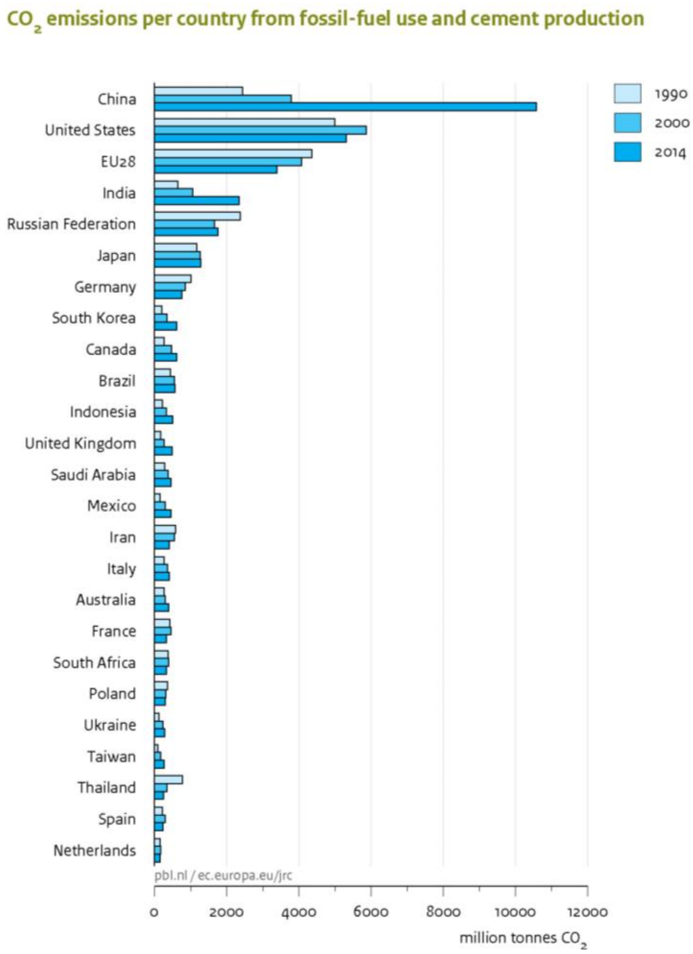


Figure 2: CO_2 emissions per country from fossil-fuel use and cement production (Oliver et al. 2015).

This situation calls for new design proposals and material compositions that improve sustainability, energy efficiency and decrease the GWP (global warming potential) of our built environment (GWP-data is usually referred to as the equivalent of $CO_2.kg^{-1}$).

One approach for urban densification is maximizing the construction height of buildings up to high-rise level. Such buildings typically are made of reinforced concrete and steel. Smart design using sustainable material solutions and state of the art engineering offer new approaches to the skyscraper construction. Recent trends reveal the increased use of timber as construction material for high-rise buildings. Experimenting with the capabilities of wood has led to the realization of the first wooden high-rise buildings, combining the endeavor to save CO_2 and realizing a densified urban structure. In order to clarify the differences and benefits of the new approach (timber construction) versus the conventional construction approaches (concrete, steel), this research was performed in order conduct a semantic comparison between wood and reinforced concrete high-rise constructions.

1.2 Motivation

One requirement to establish a fundamental improvement regarding sustainability and enhanced building design is the creation and availability of know-ledge-bases and detailed reference documentation of lighthouse projects. In an effort to quantify energy consumption and GWP of materials and processes, various methods have been developed. One of the most prominent methods hereby is the Life-Cycle-Assessment (LCA). This method offers a rather clear and structured analysis of affiliated data. Results from LCAs can be used for decision support in design and planning processes. Building with timber regularly is connected as a way to healthy living. Moreover it offers a possible sustainable approach to tackle the problems concerning urban densification. Within the scientific community different studies have been conducted in this domain: Durlinger et al 2013, have previously evaluated building materials as used in realized constructions, focusing on wooden high-rises. Clarifying the enormous reduction in $CO_2.kg^{-1}$ equivalent these constructions offer. Skullestad et al. 2016 established comparative LCA in order to measure climate change mitigation deferring from conventional to alternative structural systems in high-rise timber buildings. Here the data was estimated through simulation/calculation and focusing on CC only. There is a lack of real life data comparison in case studies for these constructions, though various examples are already built and inhabited. With a progressing market, investors are coming more to terms with the idea of climate change mitigation in the building process. Aim of this thesis is to assess a built example of one of the largest wooden residential buildings of our time concerning its GWP. Furthermore, to establish a case study in which the construction is exchanged with conventional reinforced concrete, with the goal to clarify differences in costs, building process and impact on the environment.

1.3 Background

1.3.1 Life Cycle Assessment

Following the effort to confine and reduce the impact of operations on climate change and health, in 1996 ISO 14000 was drafted as a family of standards. Mainly to provide *“practical tools for companies and organizations of all kinds looking to manage their environmental responsibilities”* as stated by ISO. The concrete founding points for this development are these:

- Minimization of negative environmental affect.
- Correspond to regulations, laws and additional environmental requirements
- Being prone to continuous improvement

This basis paved the way towards the implementation of important standards like the ISO 14001 that largely affects the EU’s eco-management. One year after the creation of ISO 14000 in 1997 a new process for ecological analysis was built on its foundation. This instrument was Life Cycle Assessment as described by the ISO 14040. Being reviewed and edited to its current state in 2006, LCA provides a framework and rules for calculation.

According to ISO 14040: 2006:

“LCA can assist in:

- *Identifying opportunities to improve the environmental performance of products at various point in their life cycle,*
- *Informing decision-makers (…), e.g. for the purpose of strategic planning, priority setting, product or process design or redesign,*
- *The selection of relevant indicators of environmental performance,*
- *Marketing (e.g. implementing an ecolabelling scheme, making an environmental claim, or producing an environmental product declaration).”*

This is achieved by numerically assessing the GWP and incorporated energy via material type and quantity. Following the procedure allows a comparison between product types and can aid to deliver an optimized decision.

To apply an LCA on a product or process, four phases are considered (ISO 14040: 2006):

- **Goal and scope**
  Identifying the objectives and intention, the designation of the LCA is clarified. With the objectives in view it is part of this phase to specify which products are taken into account and how the system boundaries are set. Question to be answered in this part are: “What is the intended information I want to excerpt? Who is this information for? What life cycle stages are taken into account? Where are the limits?”

- **Inventory analysis (LCI)**
  This phase deals with the determination and quantification of the ecological qualities of the assessed object. Intrinsic part are the in- and outputs of raw material, energy, water, waste and emission. An inventory is created for the entire life cycle of a product or only for certain life cycle stages. Often depictions of indirect and direct process flows are added in diagrams for revised legibility.
- **Life cycle impact assessment (LCIA)**
  Taking the numeric values of the LCI and evaluating them into their characteristic impact on the environment. This is grouped into these steps:
  - Impact category selection and definition
  - LCI result classification
  - Category characterization
  - Normalization

  Table 1: Example for the required data of an LCA

Impact Category	Definition	LCI data results	Characterization
Global Warming	Increase in average global temperature	CO_2, N_2O, CH_4, O_3,…	GWP (CO_2 equivalent)

  Via normalization the results are divided by a specified benchmark in order to compare between different impact categories. The impact categories are then grouped according to a chosen sorting criteria and weighted by their perceived importance.
- **Interpretation**
  Important factors of the preceding steps are identified and the results evaluated. This happens according to the aims and goals that were set in the beginning. Possible conclusions are drawn in this part and limitations of the analysis explained. Suggestions derive here from in order to lower the negative effects of the assessed system on the environment.

As shown in Figure 4, the process of LCA is iterative. While data is obtained, interpretation runs throughout all stages, thereby the entire process is constantly prone to reevaluation.

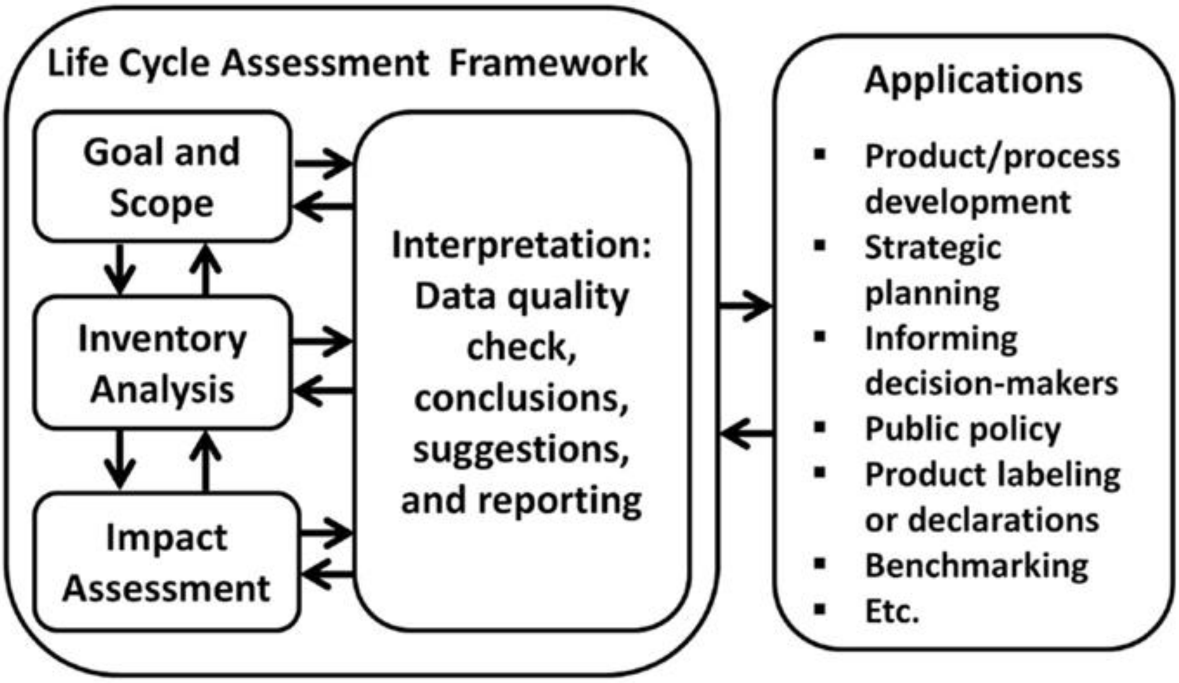


Figure 3: Four main steps for LCA (ISO 2006; Guinee et al. 2010)

A complete LCA will consider the entire life cycle of a product. It is however important in the goal and scope step to designate which variant of limitation is chosen as this will determine the focus of the assessment. Usual variations are the following:

- **Cradle-to-grave**
  Analysis of the complete life cycle of a product, from raw material extraction (cradle) to the designated end-of-life or disposal (grave).
- **Cradle-to cradle**
  This specific LCA method can be selected for a product that can be reused or recycled into a new product at the end of its life.
- **Cradle-to-gate**
  This method runs from the raw material extraction up to the end of a certain stage in the life cycle of a product.
- **Gate-to-gate**
  Here only one process step is taken into account. Gate-to-gate parts can later be connected in order to form a limited selective assessment.

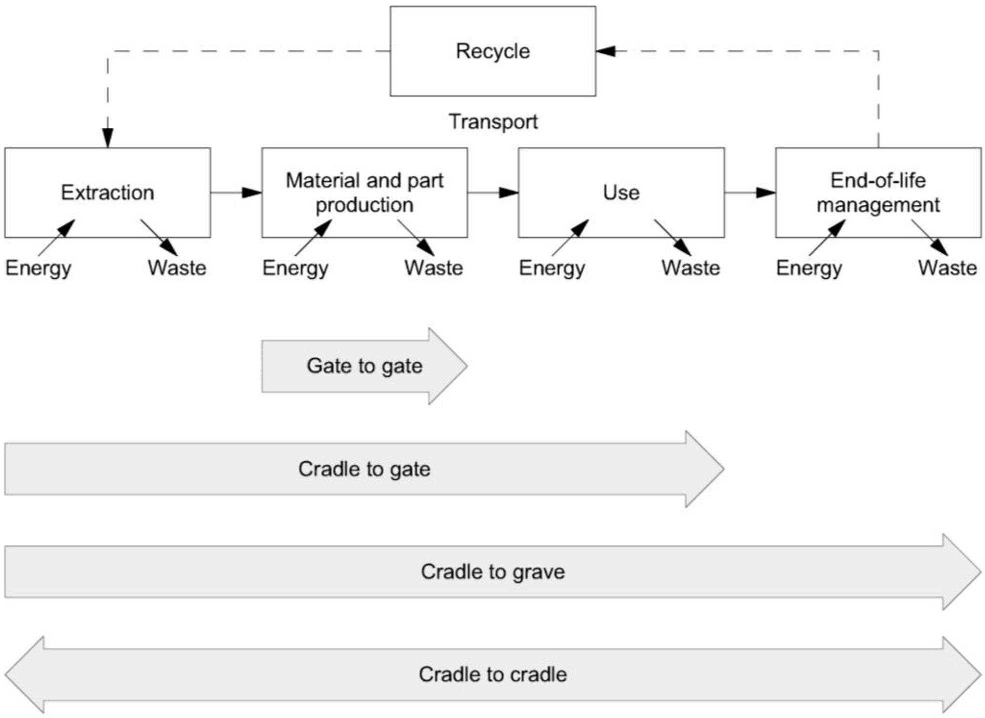


Figure 4: Goal and scope (illustration by author)

To produce the LCA for a building, the same described procedure is followed. Deferring hereby though is that the manufacturing of parts and materials can sometimes be split into two categories. Namely the manufacturing of the base parts and the assembly for larger prefabricated components such as doors, walls or slabs. The “use” step then consists of the on-site construction and the occupancy during which maintenance plays a role. Another necessary addition is the demolition of the building, preceding the disposal of the material.

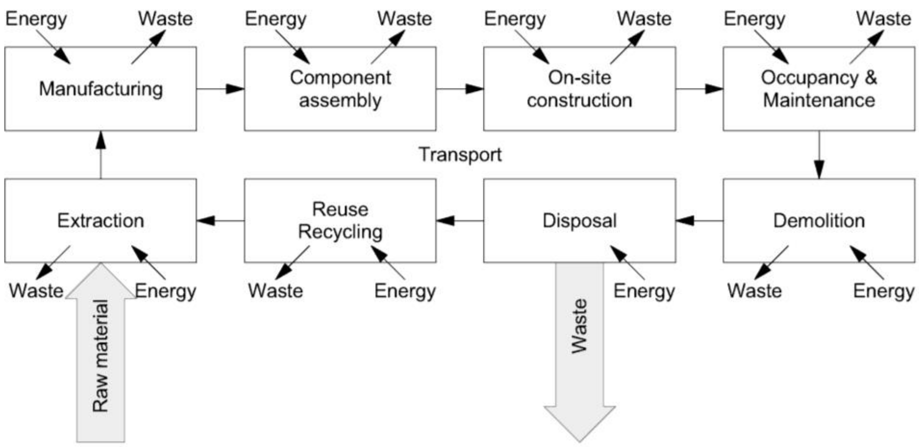


Figure 5: Complete LCA of a building (illustration by author)

A building requires energy for every life cycle process stage. While the entire sums of energy needed/used for the utilization of building products is denoted as “embodied energy”, all use applications that require energy during the occupancy stage are termed “operating energy”.

Embodied energy is calculated by adding together the energy needs of extraction, manufacturing, assembly, construction, demolition, disposal and transportation.

Operating energy is a subjective term and can either be measured during occupation or estimated in advance.

Putting these two terminologies side by side according to their energetic impact: *“Results show that operating (80-90%) and embodied (10-20%) phases of energy use are significant contributors to building’s life cycle energy demand” (Ramesha et al. 2010).* As regulations and new developments push forward in reducing the operating energy demand of buildings, the implication of more sustainable materials with lower embodied energy becomes even more important. According to Thormark (2001) up to 45% of the entire energy demand of a low energy building with a life span of 50 years is linked to embodied energy.

1.3.2 Wooden High-Rise Structures

In order to encircle the special constructions of wooden high-rise buildings, the first enquiry is to clarify the term “high-rise”. According to Emporis “*a high-rise building is a structure whose architectural height is between 35 and 100 meters. A structure is automatically listed as a high-rise when it has a minimum of 12 floors, whether or not the height is known. If it has fewer than 40 floors and the height is unknown, it is also classified automatically as a high-rise.” (ESN 18727).* This definition states that there is a certain range to which a building is considered being a “high-rise”. Taking this further, a limit is set at 100 meters of height, marking the distinguishing terminological line between *“high-rise”* and *“skyscraper” (ESN 24419).* To get a good overview on the scale of the group of high buildings we are investing, Figure 6 shows them in the global contemporary context.

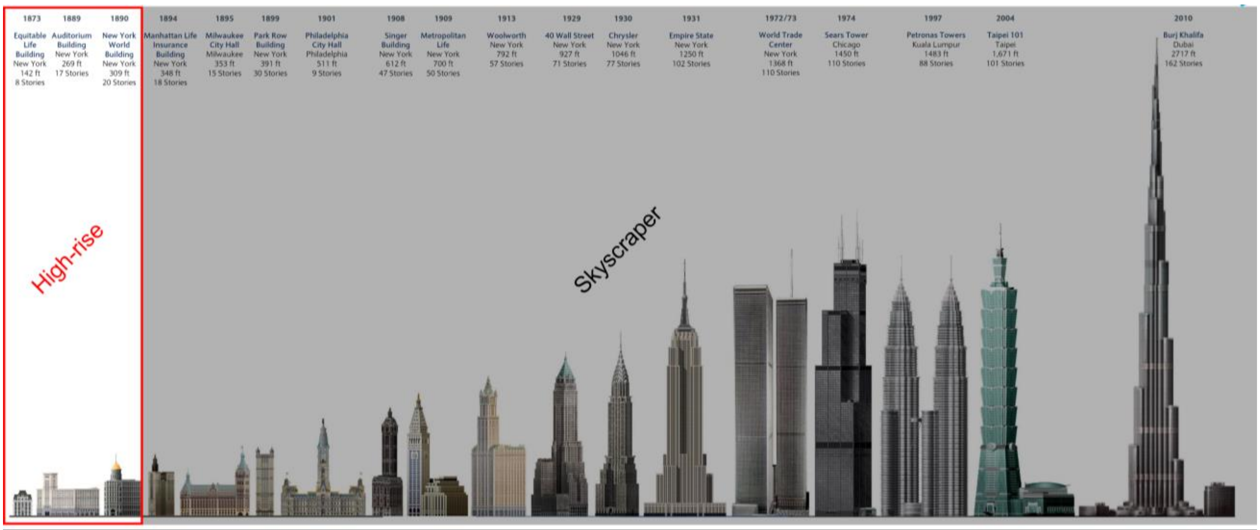


Figure 6: Skyscraper Index (Ritholtz 2012, edited)

The conventional materials for the assembly of these large structures are man-made substances like fired bricks, concrete or steel. With the invention and hype of RC in the 1900s a material was found to push building limits even higher. A large factor for this development was not only the sturdy nature of the materials but also their ability to resist fire.

By the end of the 20th century it became more and more necessary for design solutions to respond to environmental issues. Global warming and sustainability of resources was marking the beginning of a change in the market and the search for alternative materials. Having the idea in mind to address also the issues of densification these materials were in need to possess certain qualities. Wood as a great example has the benefit of being a CO_2 binding, sustainable substance that grows naturally. Therefore effort was undertaken to improve and harness the maximum capabilities of the material. Though various examples can be named and assessed here, the focus will lie on glulam and CLT. Glulam as a wooden composite was already used for over 100 years when research and implementation of CLT started in Austria and Germany in the early 1990s. These components are assembled by gluing layers of wood together, thereby producing a material that can bear large loads. While glulam pieces are glued in parallel direction, CLT binds solid-sawn panels in perpendicular layers.

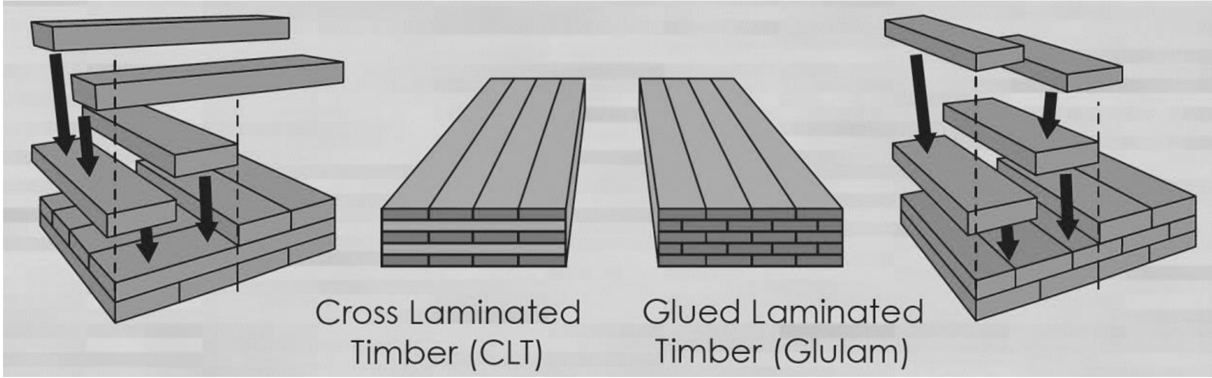


Figure 7: What is Cross Laminated Timber (CLT)/ Glued Laminated Timber (Glulam) (BuildableDesign 2017)

Glulam can be produced as a structural member for columns, beams and arched shapes. A big positive feature to glulam is that building parts can be produced from small tress rather than old growth and solid-sawn timbers. This adds the advantage of selectively cancelling out negative effects of defects or knots. CLT is a very flexible material in comparison. It can be used for walls, roofs and ceilings and combines the effectiveness of carrying loads as a solid building element with the perks of the material wood.

Using these elements different projects have been undertaken to test and further the boundaries of vertical limitation while building with wood. In recent years this has led to somewhat of a race in order to build ever higher wooden structures.

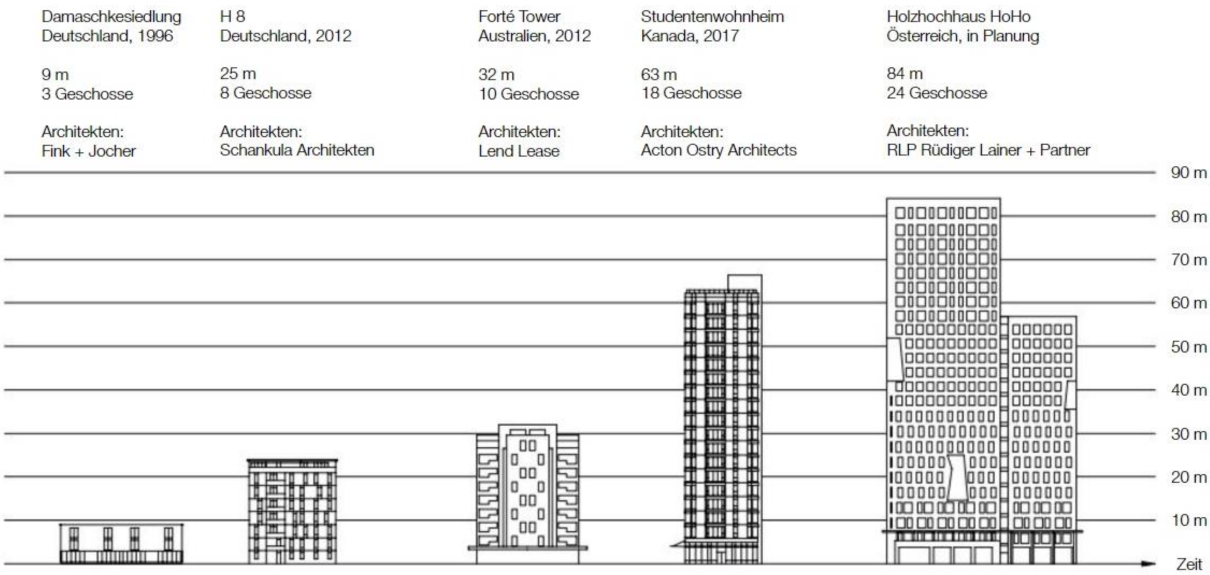


Figure 8: Development of multi-story wooden constructions (Atlas Mehrgeschossiger Holzbau 2017)

As depicted in Figure 8 the rally of wooden high-rise buildings is about to take the step towards the next category of skyscrapers after reaching heights of over 100m. Currently the tallest wooden construction is “Brock Commons” in Vancouver with 53m.

Table 2: Tallest wooden buildings, past, present and future development (Wikipedia 2018, edited)

Name	Height (m)	Floors	City	Date	Status
W 350 Sumitomo	350	70	Tokyo, Japan	2041	Planned
Oakwood Tower	304.8	80	London, England	/	Planned
River Beech Tower	228	80	Chicago, USA	/	Proposed
Trätoppen	133	40	Stockholm, Sweden	/	Proposed
HoHo	84	24	Vienna, Austria	2018	Under Construction
Mjøsa Tower	80	18	Brumunddal, Norway	2019	Under Construction
Brock Commons	53	18	Vancouver, Canada	2017	Completed
Treet	52.8	14	Bergen, Norway	2015	Completed
Forté	32	10	Melbourne, Australia	2012	Completed

1.3.3 Case Study Building: The Tree Tower

To select an adequate wooden high-rise project some boundaries and qualities of the building had to be set first. In order to make an assessment concerning densification, the category residential building was picked. This had the effect that any mixed-use and office building was already excluded from the beginning.

In a first advance, the “Forté” wooden apartment complex in Melbourne, Australia offered a good example for study. This building was constructed in the end of 2012, using CLT elements exclusively produced and exported from Austria. Including the transportation impact for these components would have obviously been necessary in the LCA. This building with its 32m and 10 stories held the title of being the largest wooden construction in the world.

Figure 9: Forté, Melbourne (Forte-Living 2012)

Due to the fact that the Forté was already overtaken in height by another wooden housing, it was decided however to select the “Tree Tower” in Bergen, Norway. At the time of writing, the preceding highest wooden construction in the world. “Treet” (“Tree” in Norwegian), is a 14 story residential building with a height of 45m (respectively 52,8m, total building height – comma is used as a separator in this written work). Built in accordance to the passive-house standard, occupation of the structure started in December 2015. Setting of this building is next to a sea channel in the central urban area of Bergen. Being the second largest city in Norway it is located on the countries west coast. To understand the structure of this building let us take a step back to consider the ideological development.

Figure 10: Bergen, location for Treet

Figure 11: Tree, 3D view (Timber-design and Technology 2015)

Construction with wood has a long tradition in Norway. The national interest in this material is not only marked in the heritage of boat manufacturing but also its culmination in form of the stave churches. In the light of this past, Norwegian engineering projects have been undertaken, reevaluating the importance of wood toward its structural use in bridges.

Figure 12: Wooden bridge, Flisa brua, Norway (Moelven 2013)

Taking the framework from these modern bridges, the concept for "Treet" was developed. The idea was to turn the side elevation of the specific wooden construction from a horizontal into a vertical load bearing system, as shown in Figure 12.

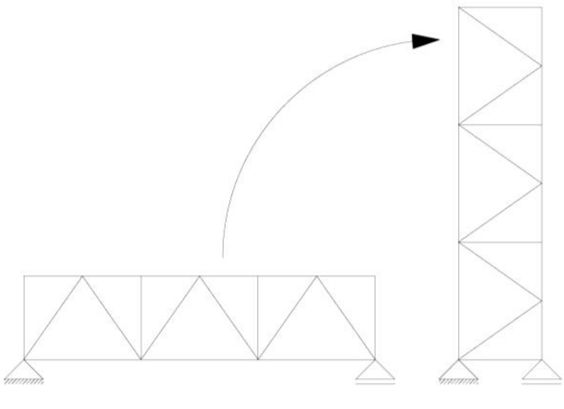


Figure 13: Structural concept (illustration by author)

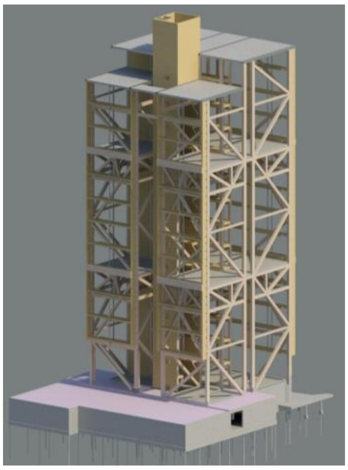


Figure 14: 3D view of structural model (Structural Design and Assembly of "Treet" – A 14-Storey Timber Residential Building in Norway)

The design of the building was conducted by companies ARTEC (ARTEC 2018) and BOB BBL (BOB 2018), taking from 2011 until 2013 to finalize. These approximately two years of development were additionally supported by the Norwegian University of Science and Technology and the Norwegian Institute of Wood Technology.

A rig consisting mainly of glulam and some CLT panels for the elevator shaft serves as skeleton for the residential modules. Abrahamsen and Malo (2014) state that this might be explained as *"an analogy to a cabinet rack filled with drawers"*. The whole wooden construction is erected on a basis of reinforced concrete which also serves as the buildings cellar and car park.

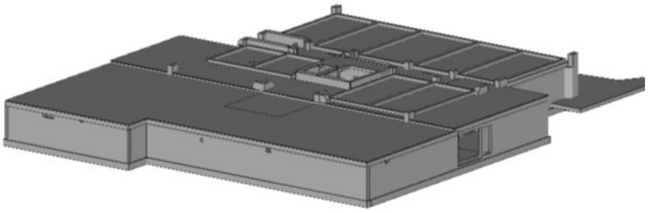


Figure 15: Step 1: Building foundation (ARTEC 2015)

Considered as "drawers", the modules make up the volume of the building. Four stories can be stacked on-top of another and three of these packs exist. Complying with the passive house standard, these modules were prefabricated and delivered to Bergen from a factory in Estonia.

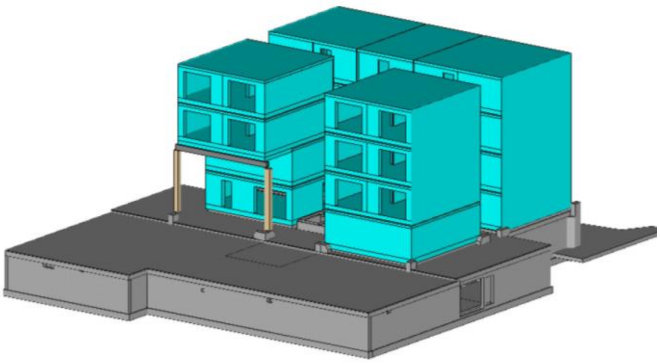


Figure 16: Step 2: Module pack (ARTEC 2015)

Through the large trusses that run across the facades, the necessary stiffness of the structure is achieved. The CLT parts have next to no effect on the static performance of the whole building and are used for the elevator shaft, staircase, balconies and a minority of inner walls.

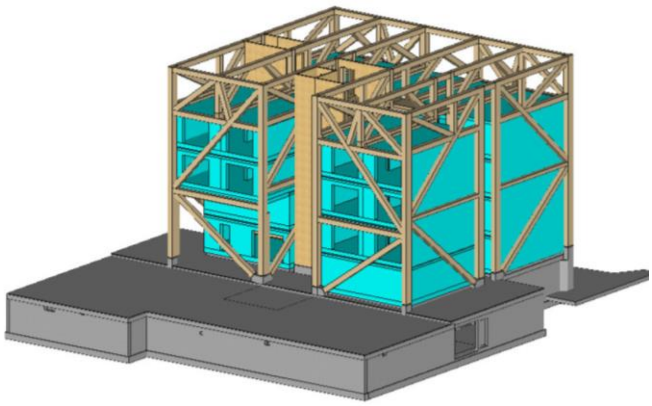


Figure 17: Step 3: Glulam frame and CLT panels (ARTEC 2015)

So called “power storeys” separate the stacks of modules and make up for the 5th and 10th floors. Special modules are worked into these load bearing stabilizing layers that carry a prefabricated, reinforced concrete slab on top. The concrete here is not only to function as a foundation of the next module stack, but also to stabilize the light wooden construction through its weight.

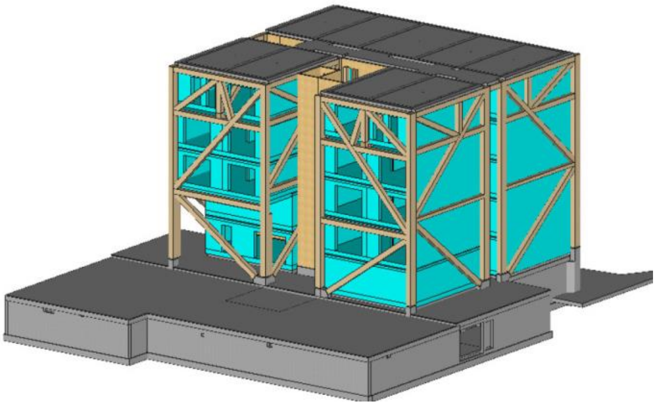


Figure 18: Step 4: Power storey (ARTEC 2015)

This process of stacking modules and wrapping them in a glulam frame is repeated two more times, leading to 14 stories in total. 62 apartments are located on a net area of 5830 m^2 with a gym and a rooftop terrace.

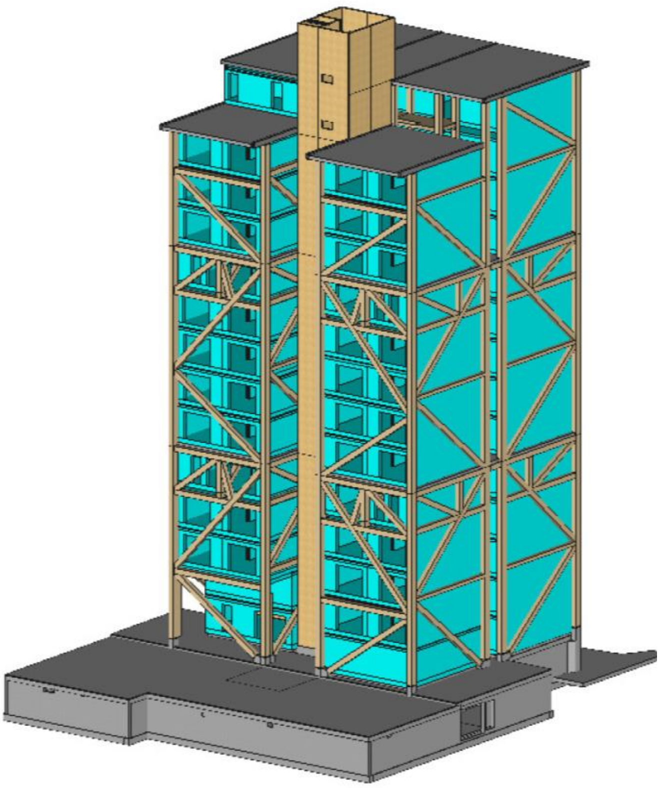


Figure 19: Step 5: Repetition of the steps (ARTEC 2015)

Adding balconies and finishing the building façades, two materials were chosen: A ventilated cor-ten steel facade for the sides to the north-west and south east, a curtain wall (steel/glass) on the other two, covering the balconies. The integration of the structure behind the facades protects the wood against exterior influences and therefore lowers the maintenance intensity.

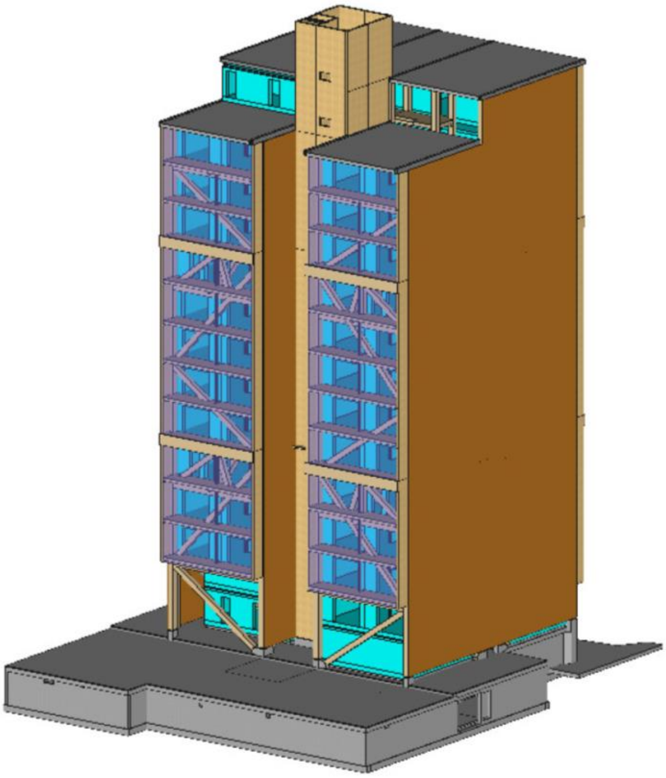


Figure 20: Step 6: Façade finalization (ARTEC 2015)

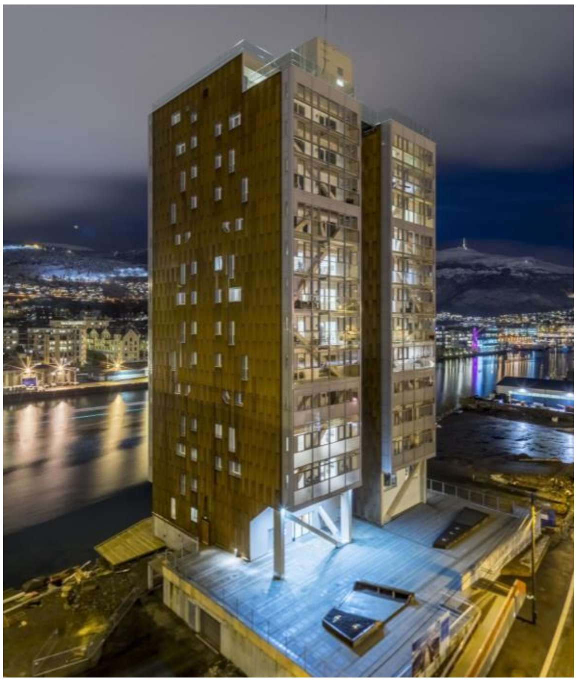


Figure 21: Finished construction (BOB 2015)

Two staircases, the main one with the elevator and one planned as fire escape make up for the buildings circulation. The resulting floor plan has five apartments per story. These are four equally cut two-bedroom apartments with a net area of 62 m^2 and a one-bedroom apartment with 43 m^2. Main window opening sides are North and South facing with balconies in front.

Figure 22: Typical floor plan (ARTEC 2013)

A visitation on-site clarified that the implementation of the glulam frame is visible and in some cases to the harm of the spacial flow. For example, in some floors the beams run diagonally in front of balcony doors, which puts into question the architectonic concept in combination to the structural equivalent.

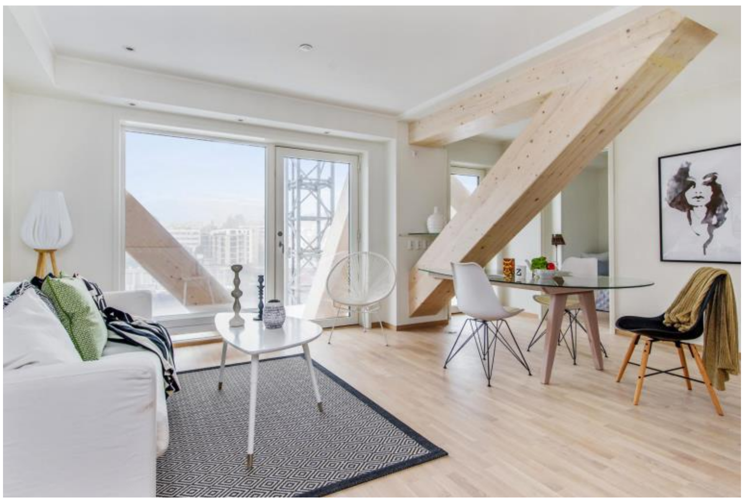


Figure 23: Interior view of an apartment (BOB 2015)

As mentioned the concept for the main structure stems from modern Norwegian bridge constructions. Typical for these is their connection using slotted-in steel plates and dowels. These joints are located inside the beams and columns, therefore not viewable. This grants them the characteristics of elegance, simplicity, durability and good fire resistance.

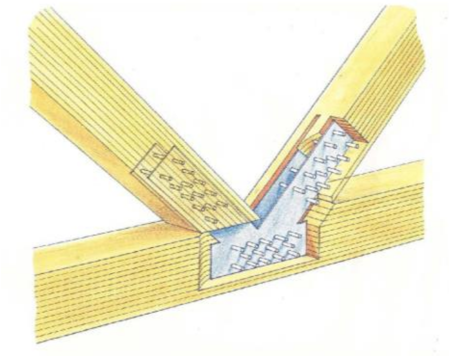
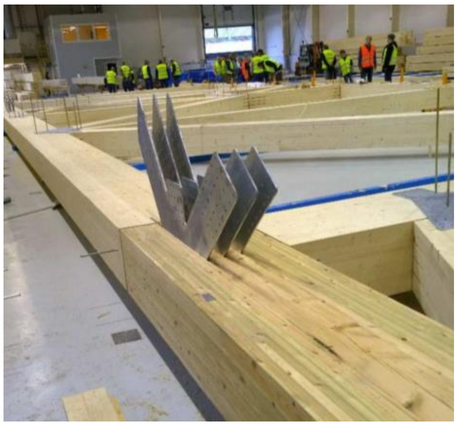



Figure 24/25: Slotted-in steel plates with dowels (ARTEC 2013)

The basic calculation for the evaluation of connection stiffness was executed in accordance to the simple design guidelines in Eurocode 5 (CEN 1995-1-1 2004). K_{ser}, the stiffness modulus depends on the chosen connection type, ρ_{mean} the mean density and d the diameter in mm. When calculating a dowel fastener connection between timber and steel K_{ser} is given per dowel and shear plane via this formula:

$$K_{ser} = 2\rho_{mean}^{1.5}d/23 \qquad (1)$$

2 METHOD

2.1 Overview

It seems clear to further engage in the utilization of sustainable materials with a low GWP. Yet conventional construction methods that might implement a higher impact on the environment, are still rigidly integrated into global building processes. This state creates a circle in which new solutions are only involuntarily accepted. Not allowing learning, improvement and in the end standardization of new practices take place, is the result of sticking to the safe and calculable.

Objective of this project is to deliver quantification and a numeric comparison between the obsolescent use of RC and the built example of a wooden glulam structure. The main part is split into three subcategories, the result gathering which is subdivided into: LCA of the "Treet" and LCA of a RC equivalent; then numeric comparison and conclusion of the results.

Crucial part for the execution is an according collection of data. Marking the verifiability and in the end determining the scientific worth of this study. Furthermore it is important to create a statically correct benchmark to read out the adequate values.

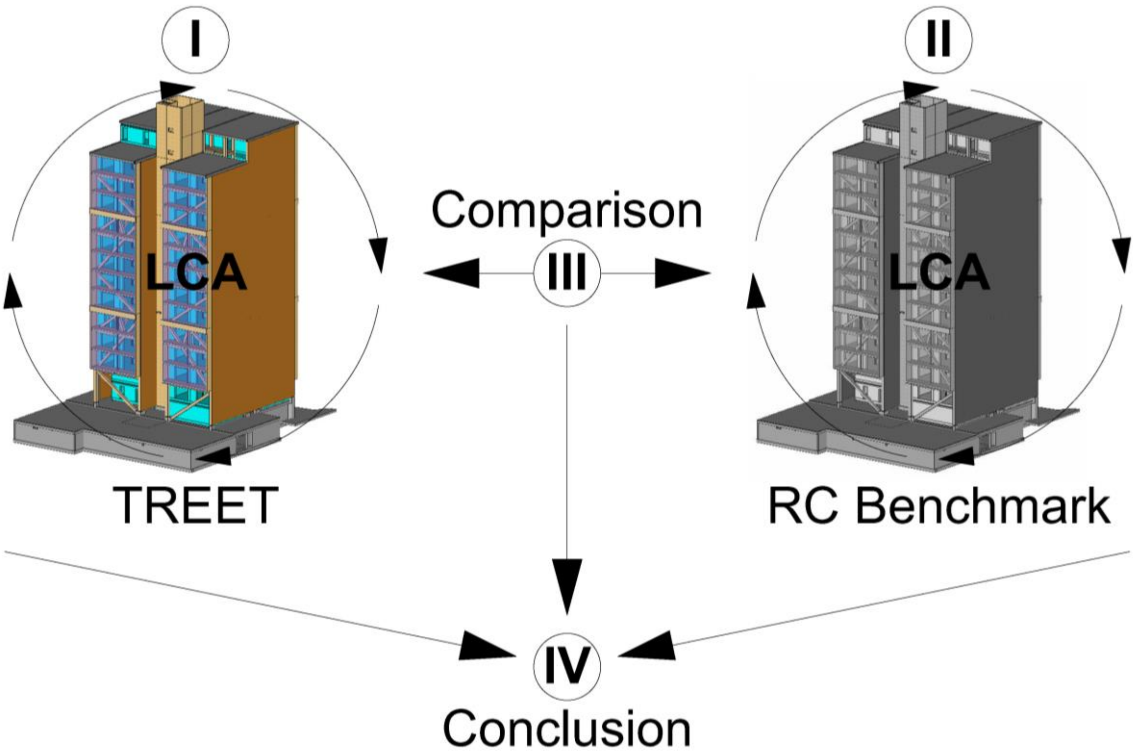


Figure 26: Methodology (ARTEC 2015, edited)

- **I. Treet**

  In entirety, the first of four parts is the selection of the building and performing an LCA. As stated in the previous chapter it is necessary to initially clarify the boundaries of the LCA in the goal and scope phase. After the selection of the building, the range of building materials to be taken into account in the LCI is considered. Following as the next step is the LCIA, in which is determined under which factors the products are analyzed. Quantification and calculation is then used to obtain the numeric values as a first result of the evaluated object.
- **II. Conventional Construction**

  Following this, it is then necessary to produce a RC-benchmark-building via simulation. This building is required to function and deliver the same amount of net floor space as the original. Special importance is assigned to the calculation and implementation of static capabilities and delivering an insulation quality in passive house standard. Using this building a LCA is performed, again aiming at the acquisition of designated values and focusing on selected materials.
- **III. Comparison**

  After gathering the two distinguished semantic datasets, a comparison can take place. This shall produce an outlook on characteristic performance in regard to selected values for the different types of building materials.
- **IV. Conclusion**

  Finally the results are concluded in order to excerpt the knowledge that was gained.

2.2 Hypothesis

In consideration of CO_2-equivalent quantification, the qualities of wood are unprecedented. Not only incorporating and locking away large amounts of the chemical within its fibers, it is also harvested and processed efficiently in energetic and environmental terms. Additionally, wood products possess a beneficial recycling output after the end-of-life stage. In comparison, concrete that needs cement as a high energy demanding substance is becoming more and more outdated.

This research and study aids the decision making process for future developments. Magnifying regards towards sustainability, expected GWP and costs of used building components.

2.3 Scope

The research is dedicated to distinguish use of RC and wood in high-rise structures, in order to assess certain qualities of both materials. In accordance to this strive the clarification of what will be considered in the LCA as building components has to be trimmed. A big point is also choosing the LCA limitation for the life-cycle stages, to make the outcome more readable. To answer these questions the final goal has to be kept in mind. The gathered data for “Treet” is ground on plans by the architect. Material data calculations are performed with environmental product declarations (EPD) and Austrian supplier price lists.

- **Building parts**

  Creating the ramifications of the building can be seen as the initial part. It is assigned which parts of the building shall be taken into consideration:
  Declaring the cellar as a subjective element that can vary in size, it is required in both construction types only according to luxurious needs such as car park and extra storage. To obtain a qualitative assessment with focus only on the aboveground construction, the building shall be reduced to its bare minimum: a foundation with the necessary dimensions without bore piles.
  The façade is seen as an exchangeable element with next to no impact to the structure. It is considered subjective and therefore not taken into account for the LCA of the building. For simplicity, windows and doors are also left out of the assessment. Walls are seen without openings/holes.
  Walls inside the apartments are also excluded, they are not relevant for the study.
  The building is stripped to its meaningful qualities, delivering the basis of an object that creates living space. Consisting of a foundation, the static structure and the inhabitable floor area with the modules, yet without building systems.

- **Materials**

  Narrowing down the materials of the assessment is separated into the two building types.
  For “Treet”: Glulam, CLT, construction wood, insulation and RC
  For the conventional construction: RC and insulation
  The concrete and insulation type shall be determined to be the same for comparability.

- **Material dimensions/mass**

  In distinction, the data for "Treet" states certain material quantities that were used. All building masses are acquired through official statements, datasheets, interviews and plan measurements.

  For the simulation of the RC construction only the minimum amount of RC according to statics and necessary insulation according to passive house standard are implemented and read out via software.

- **Time/Timeframe**

  Construction time of the tree tower is given and an educated estimation for the RC structure is established. For both buildings 50 years in service at full capability is the timeframe. This is the minimum lifespan of building structures in the EU (according to Eurocode 0, Category 4).

- **Assessed Values**

  Four different aspects make up the material analysis.

  Utilizing the "*simplified LCA profile" (Marsh 2015),* three LCA related fields are determined:

  - For the impact on global warming (GWP), the assessed chemical of the research is carbon dioxide (CO_2) in its' kg equivalent.
  - Total use of non-renewable primary energy (TNRPE) resources for production is determined in Megajoule (MJ)
  - The acidification potential (AP) of soil and water is listed in kg of sulfur dioxide (SO_2) equivalent.

  Finally the material costs for the buildings are calculated. Setting for the estimation is Austria, prices are noted in Euro (€). The data is excerpted from Austrian supplier price lists.

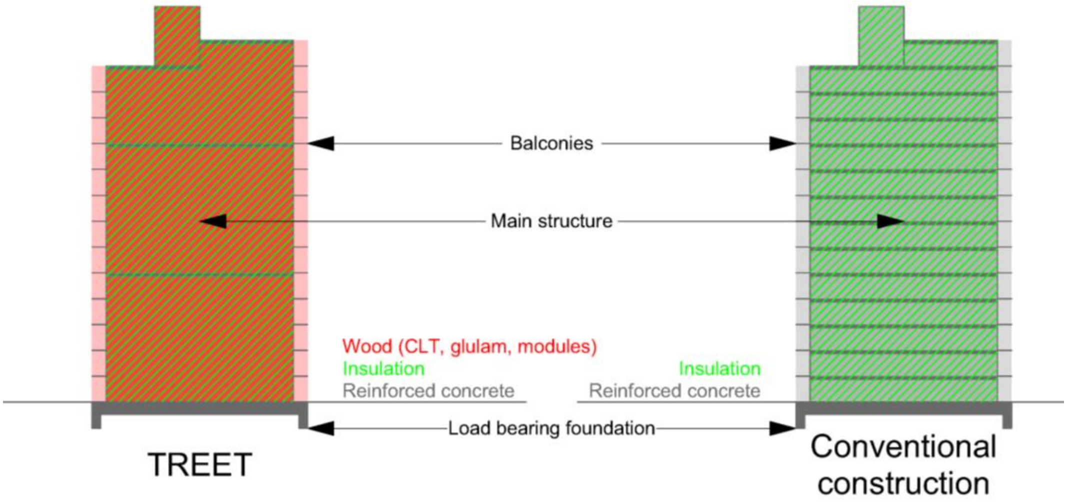


Figure 27: Scope of the building assessment (illustration by author)

The assessment for the building-products impact is founded on the Environmental Product Declaration or EPD that stands in accordance to ISO standard 14025. Datasheets provide the product specific GWP and TNRPE for certain life cycle stages for the value of 1 m^3/1 t of material which are focus of this study. Via multiplication of the m^3 of the individual materials with the EPD data, the finally resulting total numeric sums are gained.

In regards to the boundaries of the LCA, defined gate-to-gate procedures are utilized. Excluding transport from manufacturer to the construction site and from demolishment to waste processing, the center of attention is to be kept on the materials. This means the product creation (cradle) is considered, from extraction of the raw material to manufacture. The use stage is left out as various factors like construction and/or maintenance make it incalculable. For the end-of-life assessment the same is to be said. Different disassembly procedures amount to different value outputs, this section is therefore left out. In the end, the benefits and loads beyond the system boundary of the materials are taken into account. This sheds some light on the further use as buildings today are not assembled to last forever. It is important to realize the potential of reuse.

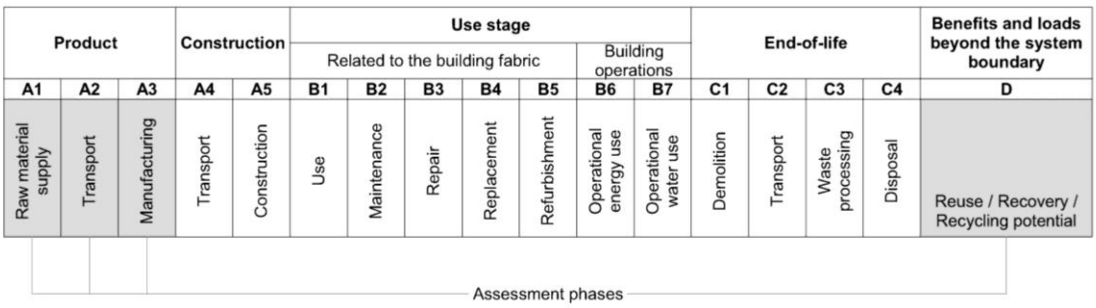


Figure 28: Selection of assessment phases for the study (ISO 14025, edited)

EPD shortages

Not all original EPD sheets are accessible, and not all deliver the necessary data.

Following original data for “Treet” is not provided by the officials:

- RC, concrete: EPD stage D, rebar: entire EPD
- OSB and construction wood: entire EPD
- Insulation: entire EPD

For the missing values of the original material EPD, an alternative with the same/approximated material specifications is used.

Following replacement values are selected:

- RC, concrete: EPD of concrete with the same durability class C45, rebar: EPD of carbon steel reinforcing bar
- OSB: Alternative EPD, construction wood: Alternative EPD
- Insulation: Rockwool EPD (German)

Cost estimation

The material cost estimation supplies statements to the theory of financing such a building in Austria. The according price lists of Austrian material suppliers are located in the appendix. For the RC, the values used are the same in both buildings for comparability.

Additional Information

In the comparison section, other viable semantic differences of the constructions are mentioned. Included here will be two additional aspects:

- Noise during the construction
- Soundproofing issues

3 RESULTS

3.1 The Tree Tower

Starting with the assessment of the wooden high-rise, the building components involved are glulam, CLT, RC and the prefabricated modules.

3.1.1 Components

The principle goes from interior to exterior. This means the habitable modules are reviewed first.

Altogether there are 132 modules used in the building. Two different floor slabs serve as the difference between the modules. 68 of them are considered as standard slab modules, 64 as wet area slab modules.

Figure 29: 3D building model, only modules (ARTEC 2013)

As seen in figures 30-32, the modules are prefabricated, done by the company “Kodumaja” (Estonia) and delivered as whole to the building site. There they are only lifted in place via crane and attached.

Figure 30/31/32: Basic set-up, 2x2 modules (BOB 2015)

These components consist of a timber-frame wall and slab construction, filled with mineral-wool as insulation. Though there are many more materials mentioned, for the LCA only the wood and mineral wool is used for the calculation. That makes up the module material composition. In the end it is needed to excerpt the individual material masses. This can be done by working with the floor plan, and section first. Measuring out the lengths/widths/heights of walls/slabs and then calculating the areas. For the height assessment it is necessary to mention that the highest points of the building are chosen, the top of the 14. (resp. 13.) floor. Walls are considered to run through without slab separation, slab areas are measured including areas under/above walls.

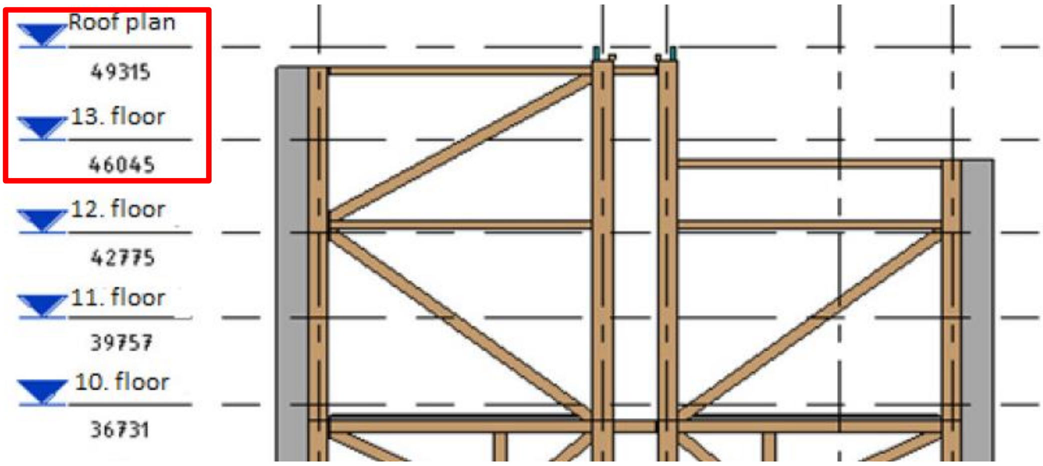


Figure 33: Partial section for height assessment (SWECO 2013, edited)

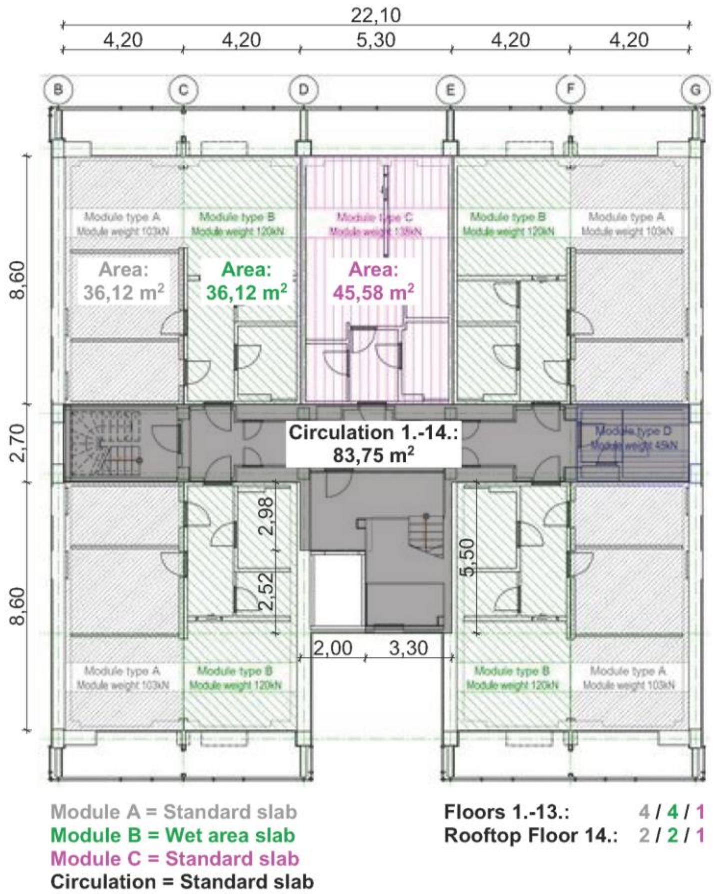


Figure 34: Area and module floor plan (ARTEC 2013, edited)

The modules are enclosed in insulated walls, making the circulation space a non-heated area. In between modules B/C a separating interior wall is used. These are the two wall types used in the assessment. Stating again: The interior walls inside the apartments are not taken into account. Though there are different slabs and a roof it is only necessary here to obtain the specific floor areas of the modules as the values are the same. The circulation area is considered to consist completely of standard slab. In case of the walls, the height is measured from ground floor to maximum height. These are the outputs for single module elements, therefore have to be multiplied accordingly in the next part. To have a brief overview, the information is sorted and collected in table 3 (appendix).

It is now consequential to multiply the parts to obtain the total amounts. This is done in table 4 (appendix).

The obtained total areas are listed in short form below:

Building Part	**Area**
Exterior wall	6163,22 m^2
Interior wall	848,30 m^2
Wet area slab, ground floor	144,48 m^2
Wet area slab, upper floors	1806,00 m^2
Standard slab, ground floor/circulation	1362,56 m^2
Standard slab, upper floors	2398,54 m^2
Roof area	418,28 m^2

Being the most sophisticated part of the entire building, it makes sense to elaborate the details. In the following, the affiliated details are put in order: First the modular walls, then the slabs and finally the roof.

Detailing of the prefabricated modules:

Walls

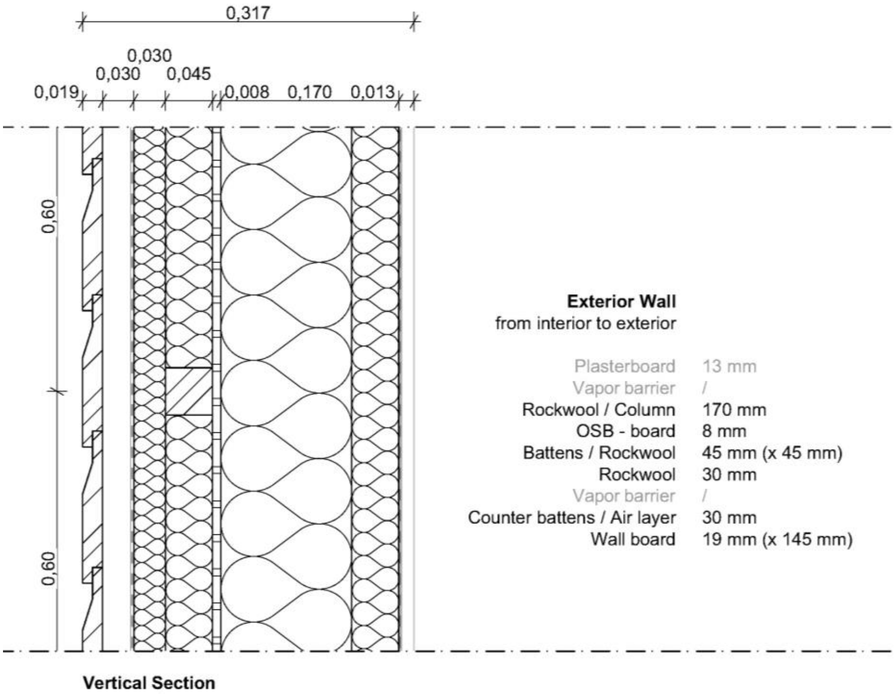


Figure 35: Vertical section of exterior module wall (based on illustration by ARTEC)

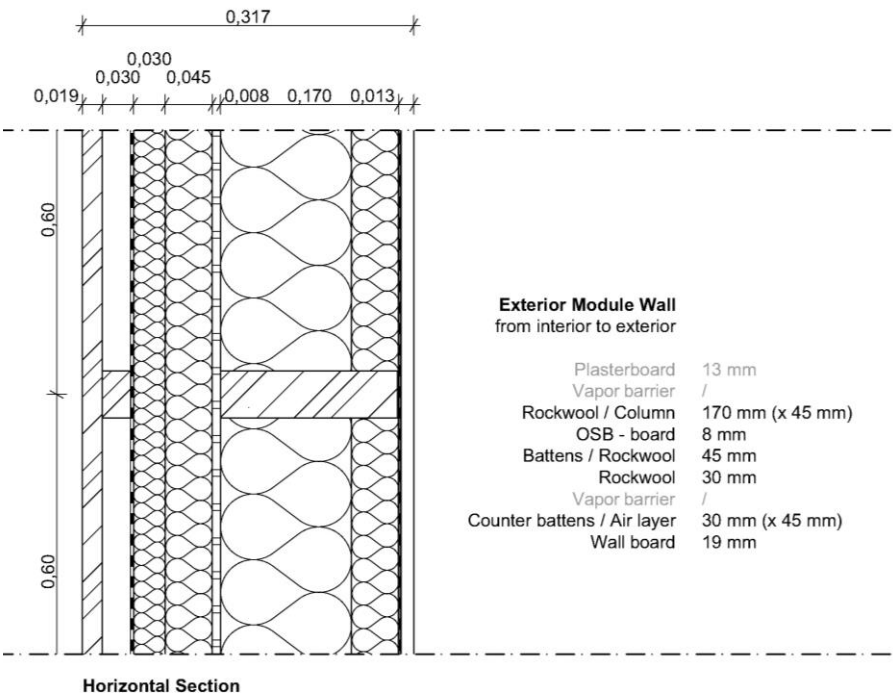


Figure 36: Horizontal section of exterior module wall (based on illustration by ARTEC)

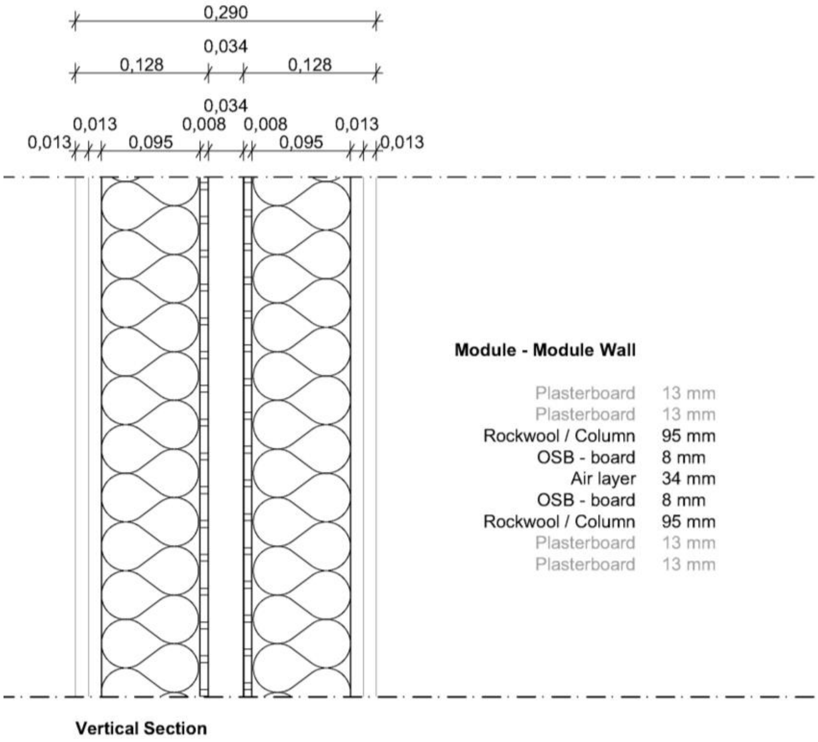


Figure 37: Vertical section of interior module wall (based on illustration by ARTEC)

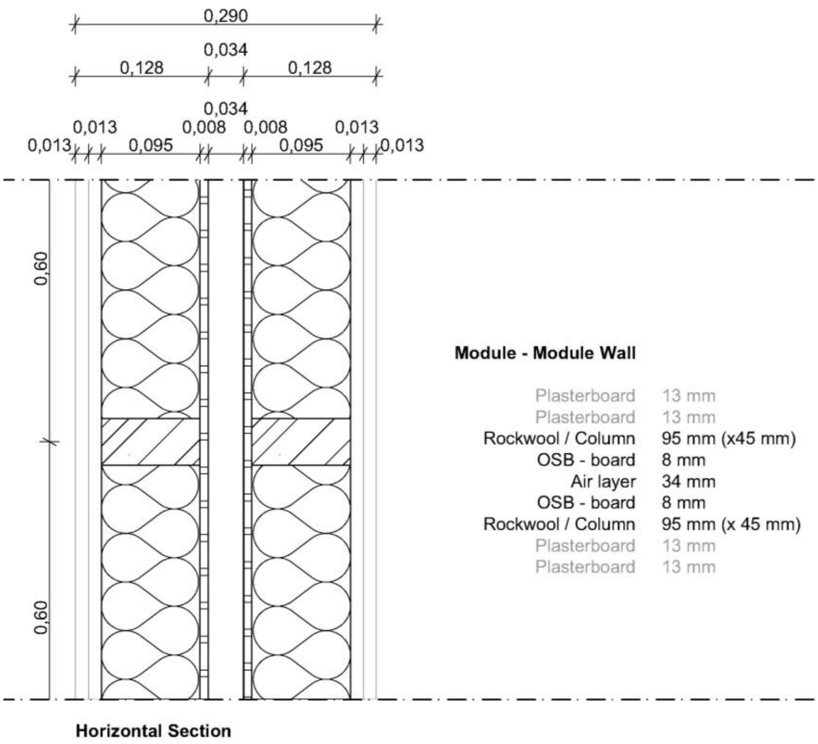


Figure 38: Horizontal section of interior module wall (based on illustration by ARTEC)

As mentioned before, the interior walls inside the modules are not relevant for this study and therefore left out.

Slabs

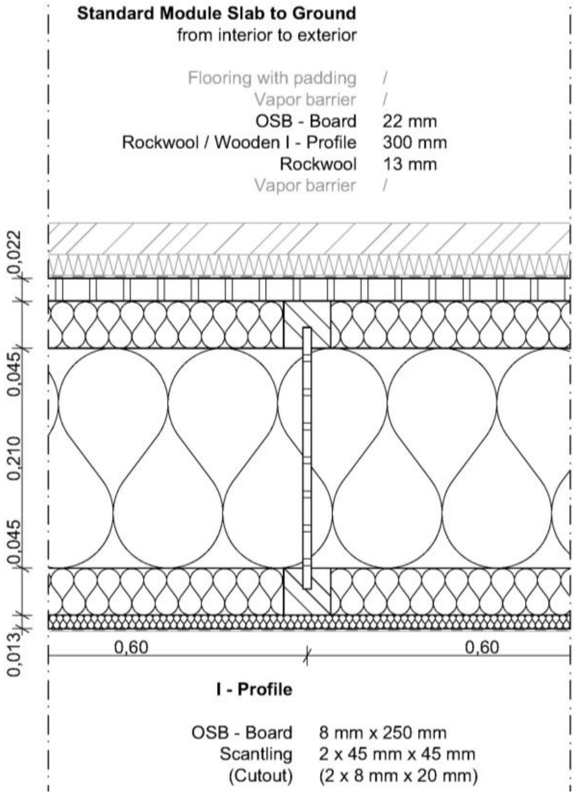


Figure 39: Slab to ground for standard module (based on illustration by ARTEC)

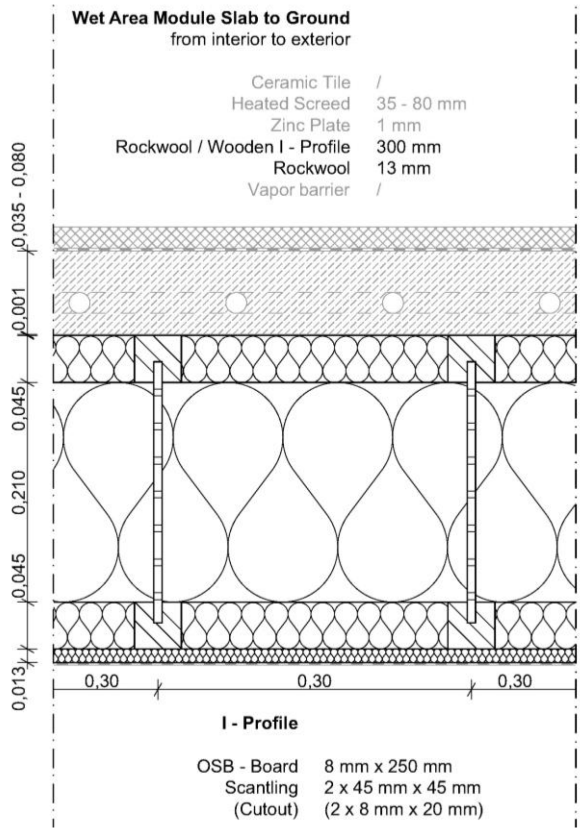


Figure 40: Slab to ground for wet area module (based on illustration by ARTEC)

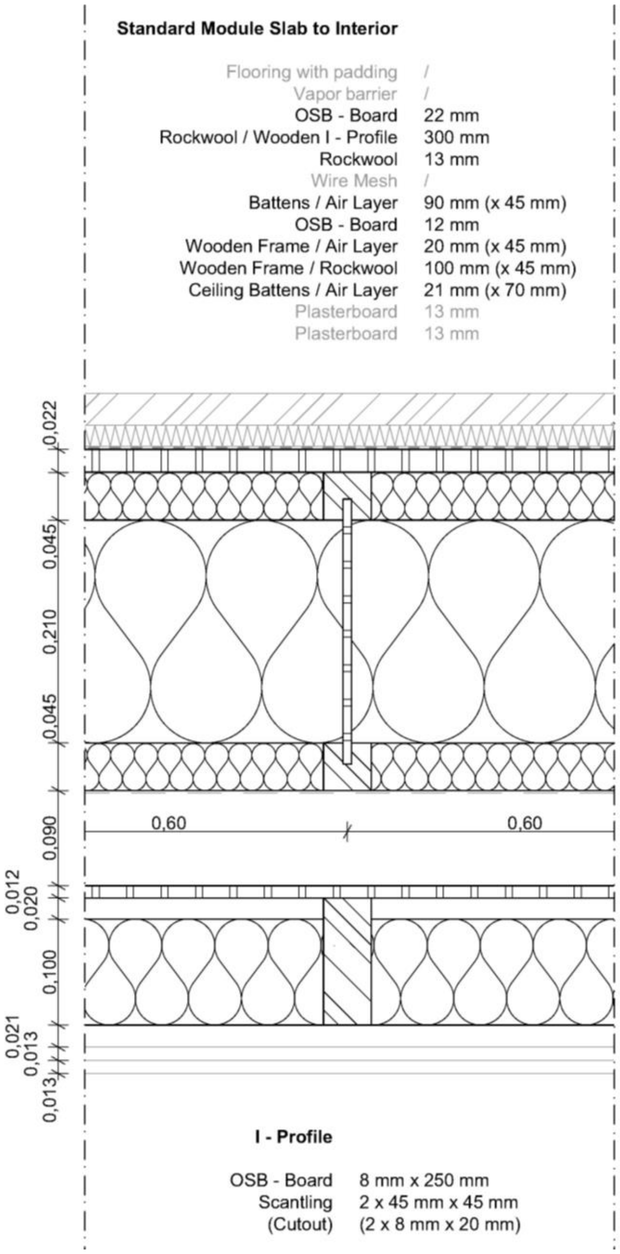


Figure 41: Slab to interior for standard module (based on illustration by ARTEC)

For the two air layers that include wooden battens, the distance in between battens is 0,60 m.

Important to mention about the slabs is, that there are two module types using either the standard or the wet area slab. As depicted in figure 35, the standard module works with distances between the I – profiles of 0,60 m. The wet area module slab, depicted in figure 36 places the I – profiles at 0,30 m separation.

Roof

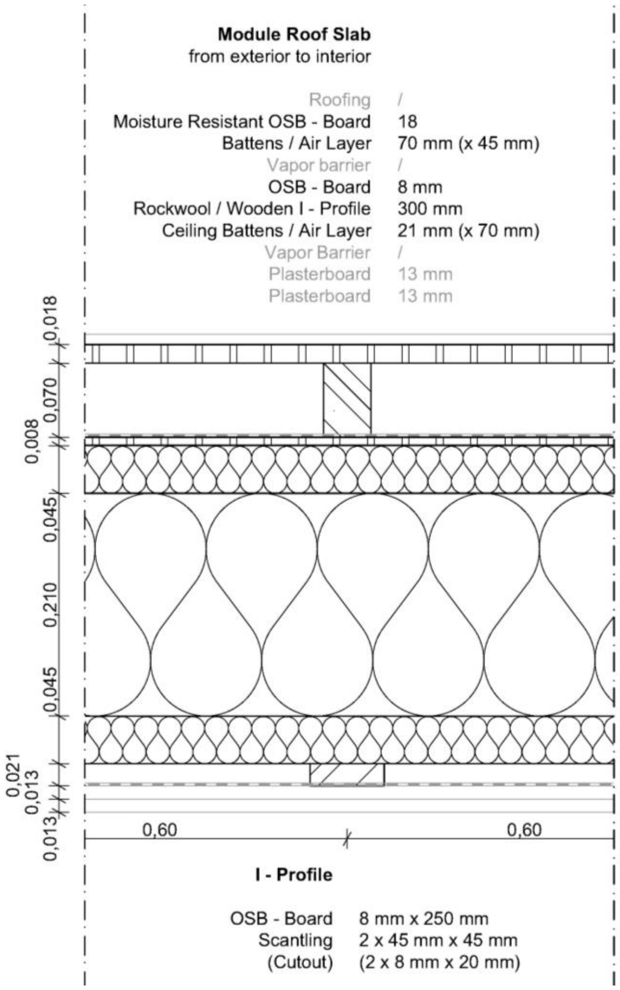


Figure 42: Module roof slab (based on illustration by ARTEC)

In this section the wooden I – profiles are not visible. They are oriented in a perpendicular manner with the usual distance between elements of 0,60 m.

Analyzing the details in regards to viable materials for the assessment, focus lies on wood and insulation. Summarizing the different types and sizes gives a brief overview of all components.

Walls

- Rockwool: 30 mm / 45 mm / 95 mm / 170 mm
- OSB – Board: 8 mm
- Battens / Scantlings: 30 mm x 45 mm / 45 mm x 45 mm / 45 mm x 95 mm / 45 mm x 170 mm

  Consecutive distance between battens/scantlings: 0,60 m
- Wall Board: 19 mm (perceived as one solid layer)

Slabs

- Rockwool: 13 mm / 100 mm / 300 mm
- OSB – Board: 8 mm / 12 mm / 18 mm / 22 mm
- Battens / Scantlings: 21 mm x 70 mm / 45 mm x 70 mm / 45 mm x 90 mm / 45 mm x 120 mm

  Consecutive distance between battens/scantlings: 0,60 m
- I – profiles:

  OSB – Board: 8 mm x 250 mm

  → Cross-section: 20,00 x 10^{-5} m^2

  Scantling: 2 x (45 mm x 45 mm), Cutout: 2 x (8 mm x 20 mm)

  → One scantling cross-section: 18,65 x 10^{-5} m^2

  Consecutive distance between I – profiles:

  0,30 m (wet area module) / 0,60 m (standard module)
- Wall Board: 19 mm (perceived as one solid layer)

Module material mass

For the final output of material masses, the modules have to be separated into their constituents. This is done via the total component areas and maximum length/height/width. Herein the distribution of battens/scantlings and I – profiles is measured to qualitatively determine the m^3 of wood and insulation.

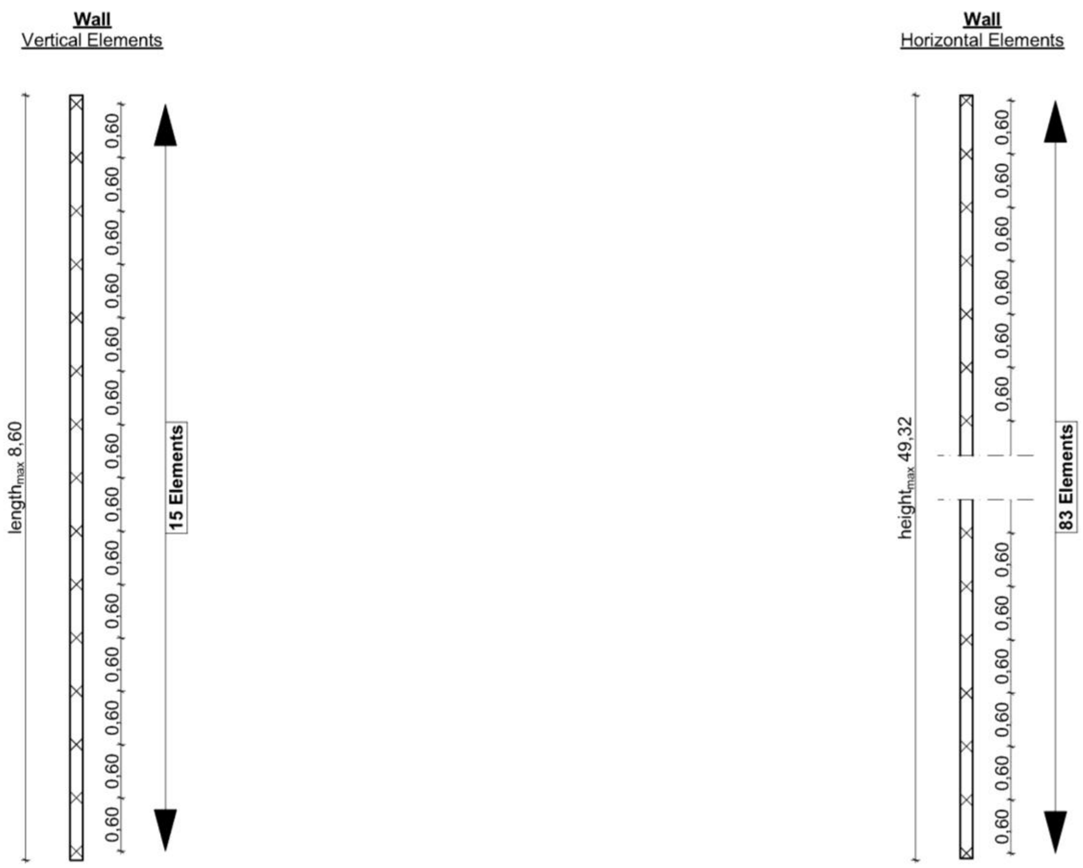


Figure 43: Wall, wooden frame elements (illustration by author)

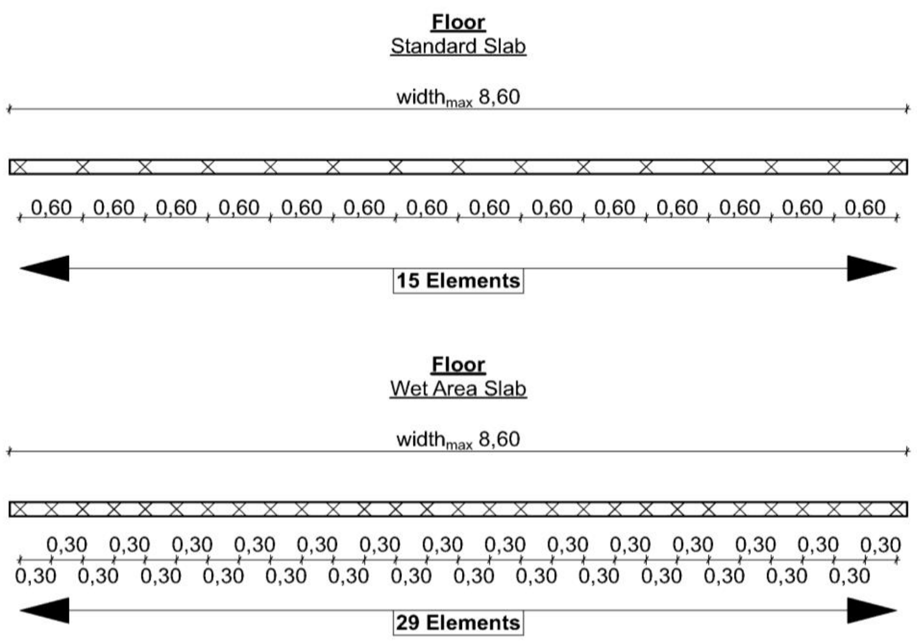


Figure 44: Slab, wooden frame elements (illustration by author)

For the calculation the component areas are divided through the maximum values of height/length/width in order to get the theoretic 2-dimensional layouts of the building parts.

Using the resulting counts from figures 43/44 and the theoretic expansions from table 5 (appendix), the running lengths of the wooden frame elements are calculated in table 6 (appendix).

Taking the running lengths and the cross-sections of the elements, the frame element volumes are gained.

Finally, the (gross) volumes of the planar elements in the modules are calculated. This is done by multiplying the areas of the module components with the material thicknesses. Afterwards the according frame volumes are deducted from the insulation volumes.

For subtraction of the wooden frame elements from the insulation, the scantlings of the following sizes are not considered as they are located in air layers. These are the affiliated total material volumes of the scantling sizes:

- 20 mm x 45 mm: 0,92 m^3
- 30 mm x 45 mm: 1,45 m^3
- 21 mm x 71 mm: 0,72 m^3
- 45 mm x 90 mm: 4,16 m^3

In sum: 7,25 m^3

Deducting this sum from the total mass of KVH: 16,61 m^3, table 7 (appendix), we acquire a volume of 9,36 m^3.

Rockwool (gross) – (OSB (I-profile) + KVH (frame)) = Rockwool (net)

$4004{,}83\ m^3 - (2{,}30\ m^3 + 9{,}36\ m^3) = \underline{3993{,}17\ m^3}$

The total material volumes of the modules are displayed in table 9.

Table 9: Module material volumes

Material	Frame Volume	Planar Volume	Total Volume
KVH	16,61 m^3	117,10 m^3	**133,71 m^3**
OSB	2,30 m^3	183,77 m^3	**186,07 m^3**
Rockwool	-11,66 m^3	4004,83 m^3	**3993,17 m^3**

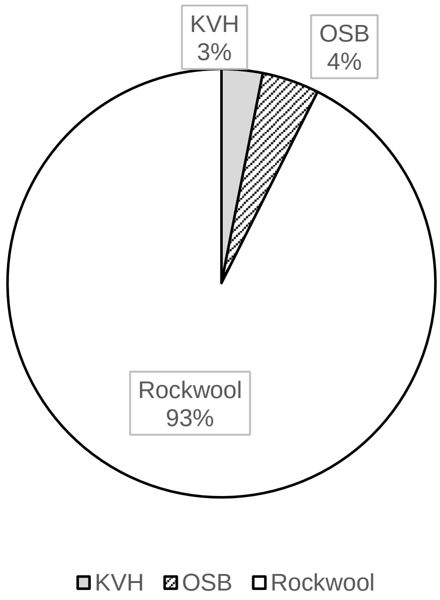


Figure 45: Module material distribution, percentage (illustration by author)

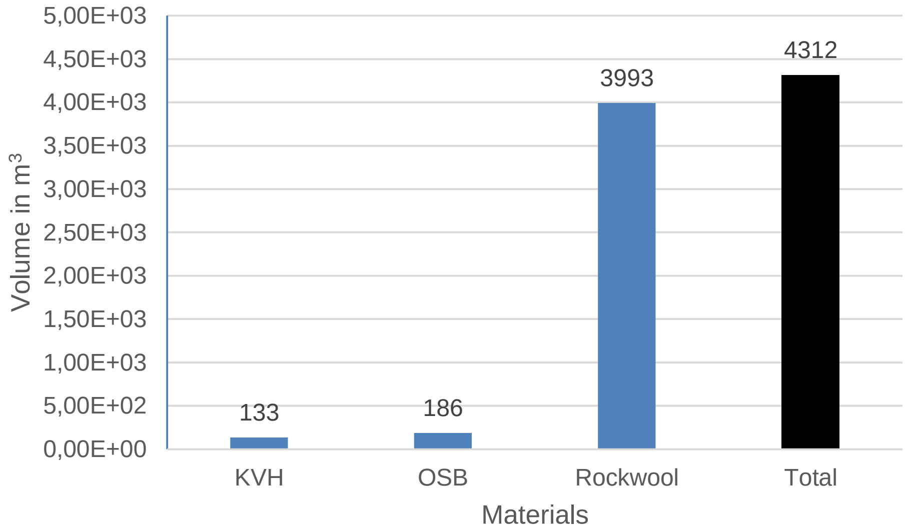


Figure 46: Module material distribution, absolute values (illustration by author)

CLT

For the amount of CLT used in the building we can apply the amounts declared by the developers.

Figure 47: CLT building parts (ARTEC 2013)

Table: 10 CLT used in “Treet”

Construction Element	Amount
Walls	143,77 m^3
Roof	39,12 m^3
Balcony Walls	42,08 m^3
Balcony Slab	111,03 m^3
Total	**336,00 m^3**

Glulam

Equal to the amount of CLT, the official data for the glulam elements is utilized.

Figure 48: Glulam building parts (ARTEC 2013)

Table 11: Glulam used in “Treet”

Construction Element	Volume
Main Timber Frame	531,74 m^3
Secondary Structure	31,14 m^3
Total	**562,88 m^3**

Reinforced Concrete

Though not relying on concrete for vertical construction, it is used as a stabilizing element against wind and earthquakes, in the foundation, the power floors and on the roof. All RC elements are prefabricated. For the dimension of the foundation, the measured value of the original is used, not taking the cellar with its walls into account. The standard floor plan area is used for determination of the volume, as seen in table 12. To determine the mass of rebar steel inside the RC, we apply the average engineering values for 1,00 m^3 per building part and use the mean, as shown:

- Walls: 80-120 kg/m^3 → 100 kg/m^3
- Slabs: 110-160 kg/m^3 → 135 kg/m^3
- Foundation: 120-130 kg/m^3 → 125 kg/m^3

Table 12: Concrete used in “Treet”

Construction Element	Area	Thickness	Concrete Volume	Rebar Quotient	Steel Mass
Concrete Foundation	423,34 m^2	0,45 m	190,50 m^3	125 kg/m^3	23,81 t
Concrete Slab, Power Story 1	423,34 m^2	0,20 m	84,67 m^3	135 kg/m^3	11,43 t
Concrete Slab, Power Story 2	423,34 m^2	0,20 m	84,67 m^3	135 kg/m^3	11,43 t
Concrete Slab, Roof	423,34 m^2	0,20 m	84,67 m^3	135 kg/m^3	11,43 t
Total			**444,51 m^3**		**58,10 t**

Material Summary

Table 13: Material summary

Material	Volume
KVH	133,71 m^3
OSB	186,07 m^3
Rockwool	3993,17 m^3
CLT	336,00 m^3
Glulam	562,88 m^3
Concrete	444,51 m^3
Rebar Steel	58,10 t

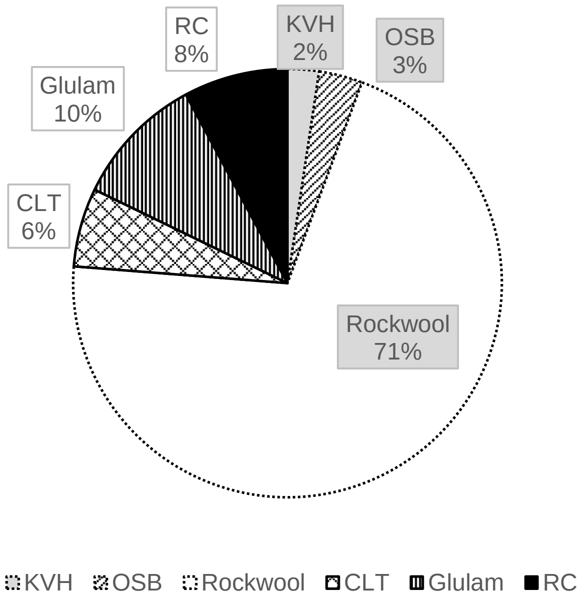


Figure 49: Total material distribution, percentage (illustration by author)

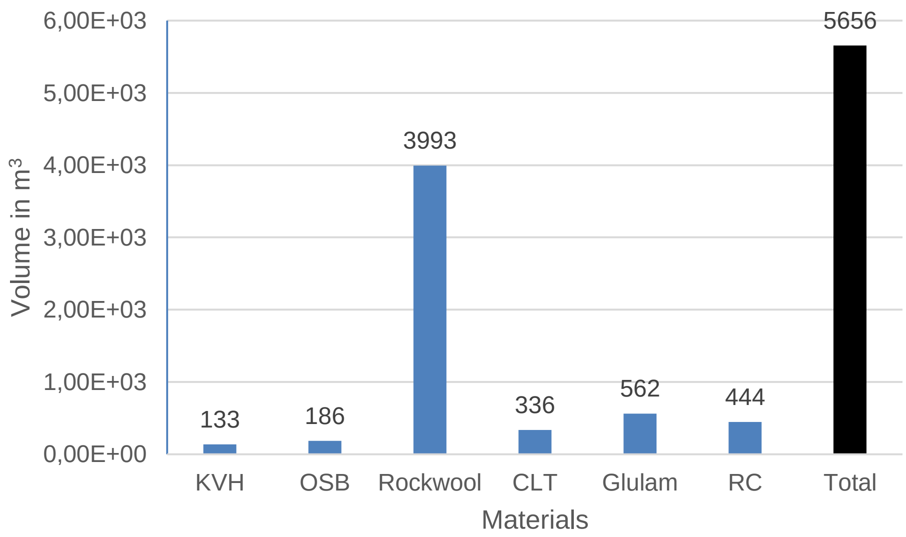


Figure 50: Total material distribution, absolute values (illustration by author)

3.1.2 Quantification

In the beginning of this chapter, the basic GWP and TNRPE values of the selected LCA stages, and the gross material costs for the chosen materials of “Treet” are gathered (table 14/15/16, appendix). To obtain the amounts of affiliated CO_2, MJ and €, the material volumes are multiplied with the EPD stage values, resp. the prices.

The price assessment proceeds with company prices from Austria in order to establish a gross overview of local material costs for the structure. Chosen prices were selected for the largest amounts and sizes. This considers that the different products are bought in large amounts and therefore listed on a lower cost level.

Table 18: "Treet" EPD, GWP production only

Material	Amount	GWP, production only Per $1m^3$/1 t	GWP Total
KVH	133,71 m^3	-729,85 kg CO_2/m^3	-97,59 t CO_2
OSB	186,07 m^3	-760,00 kg CO_2/m^3	-141,41 t CO_2
Rockwool	3993,17 m^3	82,64 kg CO_2/m^3	330,00 t CO_2
CLT	336,00 m^3	-601,77 kg CO_2/m^3	-202,20 t CO_2
Glulam	562,88 m^3	-663,00 kg CO_2/m^3	-373,19 t CO_2
Concrete	444,51 m^3	252,87 kg CO_2/m^3	112,40 t CO_2
Rebar Steel	58,10 t	839,00 kg CO_2/t	48,75 t CO_2
"Treet", total building GWP for production			**-323,24 t CO_2**

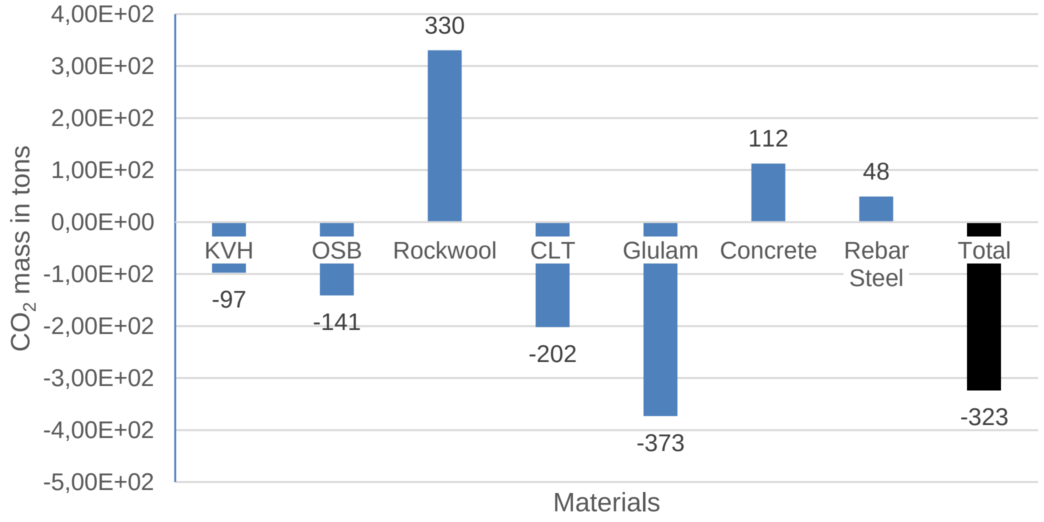


Figure 51: "Treet" GWP, production (illustration by author)

Table 19: “Treet” EPD, GWP including recycling

Material	Amount	GWP, production & recycling Per $1m^3/1$ t	GWP Total
KVH	133,71 m^3	-1087,85 kg CO_2/m^3	-145,46 t CO_2
OSB	186,07 m^3	-1409,00 kg CO_2/m^3	-262,17 t CO_2
Rockwool	3993,17 m^3	76,72 kg CO_2/m^3	306,36 t CO_2
CLT	336,00 m^3	-961,77 kg CO_2/m^3	-323,16 t CO_2
Glulam	562,88 m^3	-1001,00 kg CO_2/m^3	-563,44 t CO_2
Concrete	444,51 m^3	229,79 kg CO_2/m^3	102,14 t CO_2
Rebar Steel	58,10 t	1189,00 kg CO_2/t	69,08 t CO_2
“Treet”, total building GWP for production & recycling			**-815,65 t CO_2**

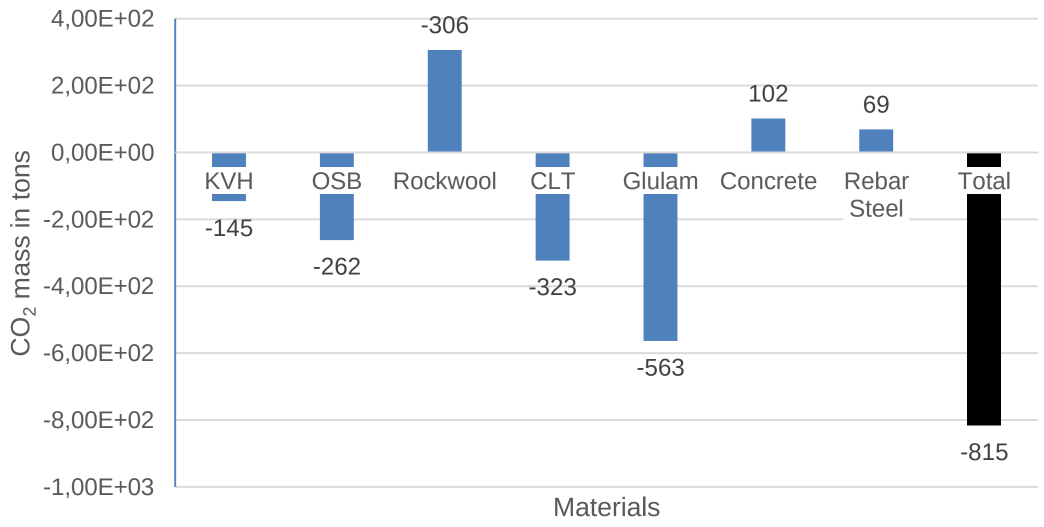


Figure 52: “Treet” GWP, production & recycling (illustration by author)

Table 20: “Treet” EPD, TNRPE production only

Material	**Amount**	**TNRPE, production only** **Per 1m³/1 t**	**TNRPE** **Total**
KVH	133,71 m³	1178,00 MJ/m³	157,51 GJ
OSB	186,07 m³	4810,00 MJ/m³	895,00 GJ
Rockwool	3993,17 m³	1184,90 MJ/m³	4731,51 GJ
CLT	336,00 m³	2493,00 MJ/m³	837,65 GJ
Glulam	562,88 m³	1510,00 MJ/m³	849,95 GJ
Concrete	444,51 m³	1531,27 MJ/m³	680,67 GJ
Rebar Steel	58,10 t	10700,00 MJ/t	621,67 GJ
“Treet”, total building TNRPE for production			**8773,95 GJ**

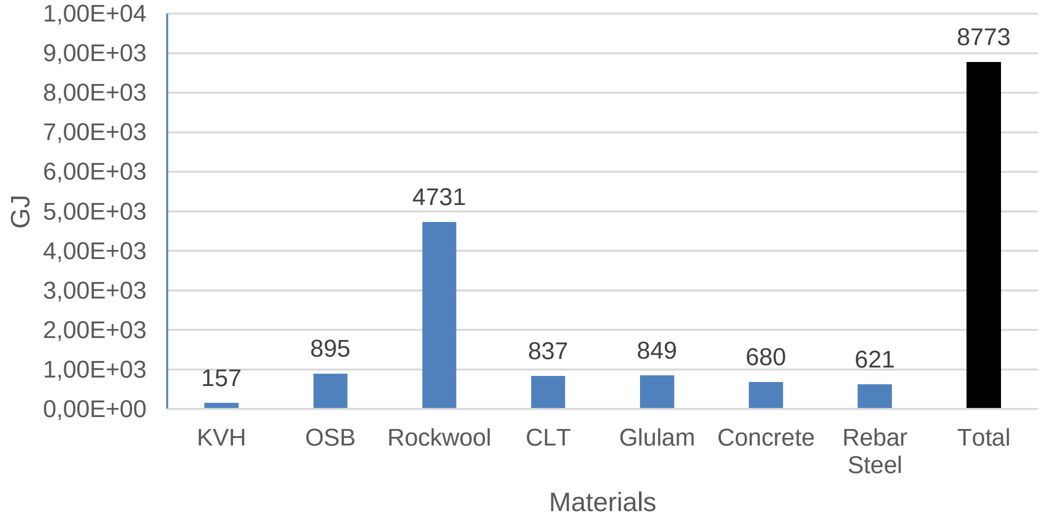


Figure 53: “Treet” TNRPE, production (illustration by author)

Table 21: “Treet” EPD, TNRPE including recycling

Material	Amount	TNRPE, production & recycling Per 1m³/1 t	TNRPE Total
KVH	133,71 m^3	-5912,00 MJ/m^3	-790,49 GJ
OSB	186,07 m^3	-5690,00 MJ/m^3	-1058,74 GJ
Rockwool	3993,17 m^3	1085,47 MJ/m^3	4334,47 GJ
CLT	336,00 m^3	-4897,00 MJ/m^3	-1645,39 GJ
Glulam	562,88 m^3	-2900,00 MJ/m^3	-1632,35 GJ
Concrete	444,51 m^3	1212,27 MJ/m^3	538,87 GJ
Rebar Steel	58,10 t	13830,00 MJ/t	803,52 GJ
“Treet”, total building TNRPE for production & recycling			**549,88 GJ**

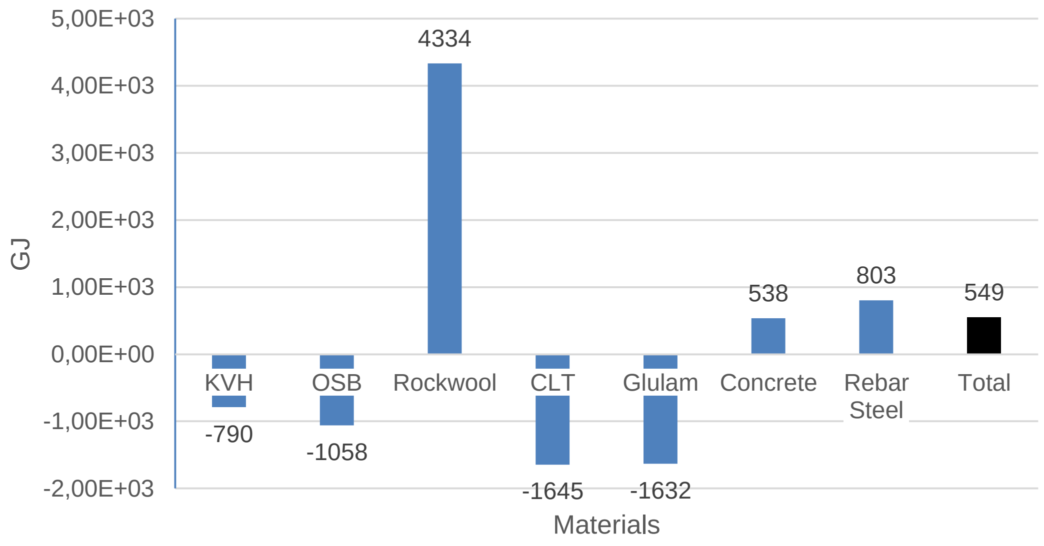


Figure 54: “Treet” TNRPE, production & recycling (illustration by author)

Table 22: "Treet" EPD, AP production only

Material	Amount	AP, production only Per 1m³/1 t	TNRPE Total
KVH	133,71 m^3	39,72 x 10^{-2} kg SO_2/m^3	5,31 kg SO_2
OSB	186,07 m^3	1,04 kg SO_2/m^3	193,51 kg SO_2
Rockwool	3993,17 m^3	6,24 x 10^{-1} kg SO_2/m^3	2491,74 kg SO_2
CLT	336,00 m^3	6,72 x 10^{-1} kg SO_2/m^3	225,79 kg SO_2
Glulam	562,88 m^3	7,43 x 10^{-1} kg SO_2/m^3	418,22 kg SO_2
Concrete	444,51 m^3	3,64 x 10^{-1} kg SO_2/m^3	161,80 kg SO_2
Rebar Steel	58,10 t	3,46 kg SO_2/t	201,03 kg SO_2
"Treet", total building AP for production			**3697,40 kg SO_2**

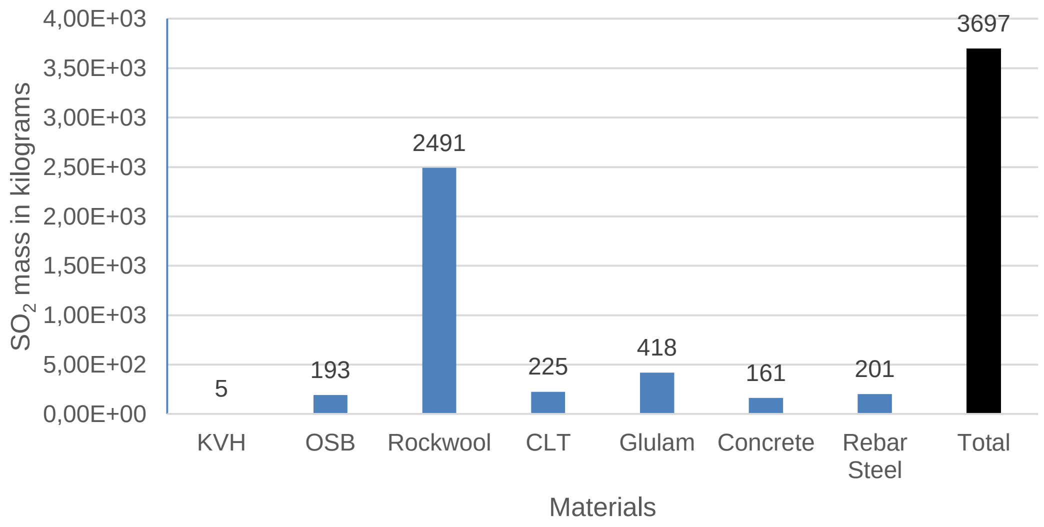


Figure 55: "Treet" AP, production (illustration by author)

Table 23: “Treet” EPD, AP including recycling

Material	Amount	AP, production & recycling Per 1m³/1 t	TNRPE Total
KVH	133,71 m^3	2,82 x 10^{-2} kg SO_2/m^3	3,77 kg SO_2
OSB	186,07 m^3	6,54 x 10^{-1} kg SO_2/m^3	121,69 kg SO_2
Rockwool	3993,17 m^3	6,18 x 10^{-1} kg SO_2/m^3	2467,78 kg SO_2
CLT	336,00 m^3	3,02 x 10^{-1} kg SO_2/m^3	101,47 kg SO_2
Glulam	562,88 m^3	-8,87 x 10^{-1} kg SO_2/m^3	-499,27 kg SO_2
Concrete	444,51 m^3	3,23 x 10^{-1} kg SO_2/m^3	143,58 kg SO_2
Rebar Steel	58,10 t	4,80 kg SO_2/t	278,88 kg SO_2
“Treet”, total building AP for production & recycling			**2617,90 kg SO_2**

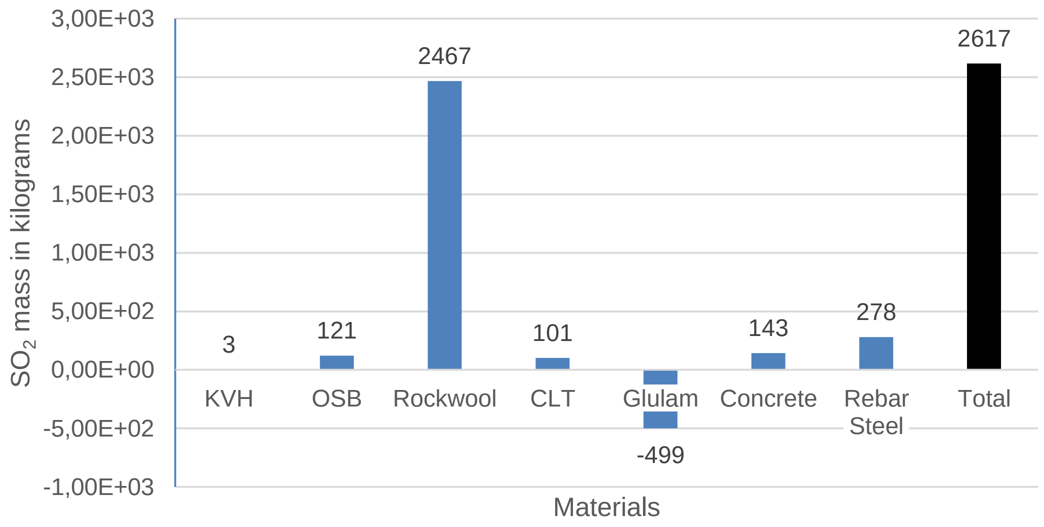


Figure 56: “Treet” AP, production & recycling (illustration by author)

Table 24: “Treet” material cost

Material	Amount	Price, gross Per 1m³/1 t	Price, gross Total
KVH	133,71 m³	283,86 €/m³	37954,92 €
OSB	186,07 m³	306,80 €/m³	57086,28 €
Rockwool	3993,17 m³	108,67 €/m³	433937,78 €
CLT	336,00 m³	795,00 €/m³	267120,00 €
Glulam	562,88 m³	367,83 €/m³	207044,15 €
Concrete	444,51 m³	111,00 €/m³	49340,61 €
Rebar Steel	58,10 t	919,00 €/t	53393,90 €
“Treet”, total building material cost			**1105877,64 €**

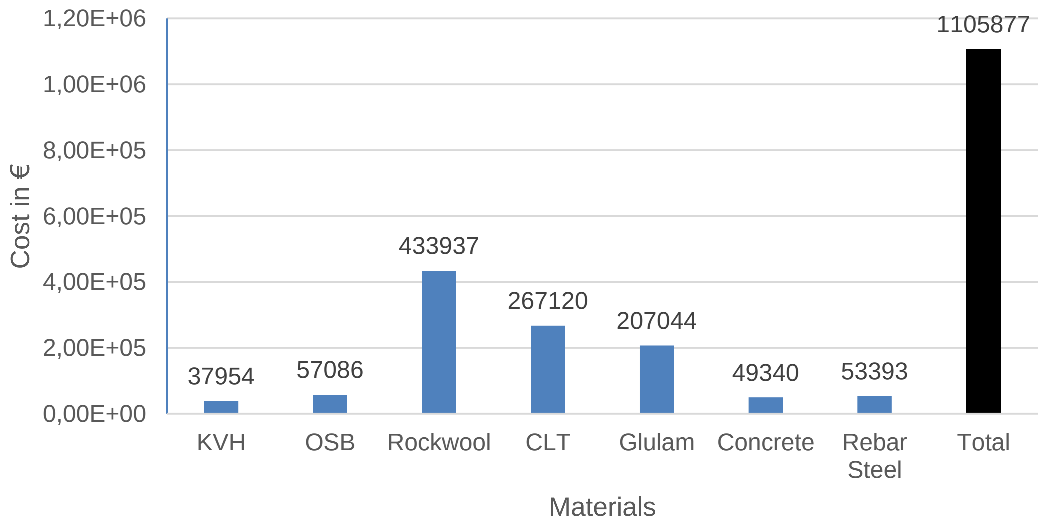


Figure 57: “Treet” material cost (illustration by author)

3.2 Conventional Construction

3.2.1 Overview

Goal is to create a reinforced concrete benchmark with the same plan setup as "Treet". Minimal structural material dimensions are pursued. In using the static analysis program RFEM the necessary RC values are obtained as a first step. Following this, the insulation requirements are calculated for the building hull via ArchiPHSYIK. The total material mass is then assessed and multiplied with the EPDs / price lists to generate the numeric output.

3.2.2 Components

Structural Dimensions

To receive the same net area and floor plans as the wooden structure, the interior horizontal and vertical measurements of the "Treet" room sizes are incorporated in the simulation.

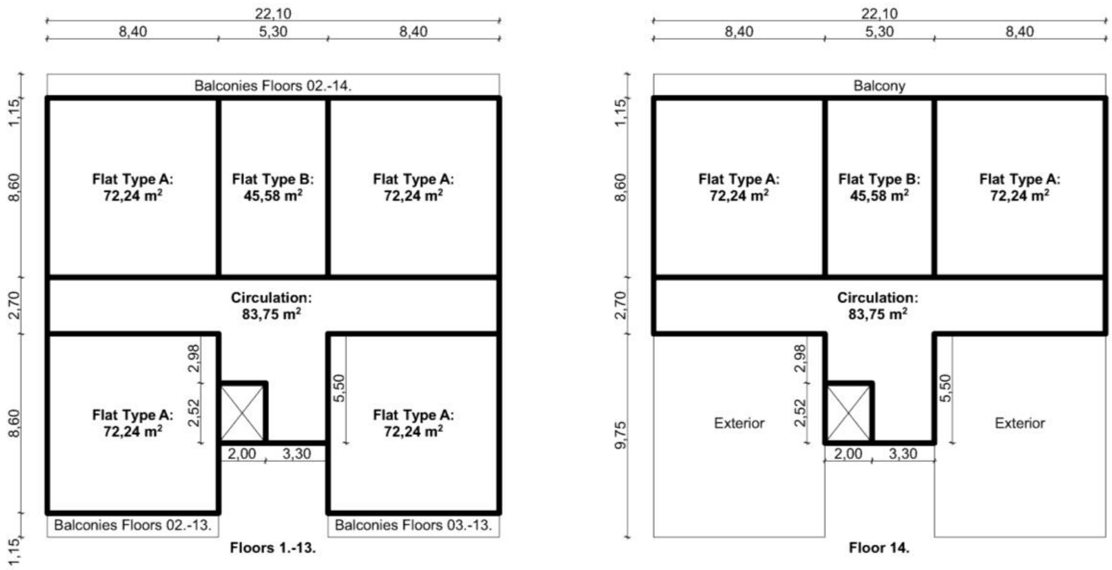


Figure 58: RC benchmark, floor plan, basic setup (illustration by author)

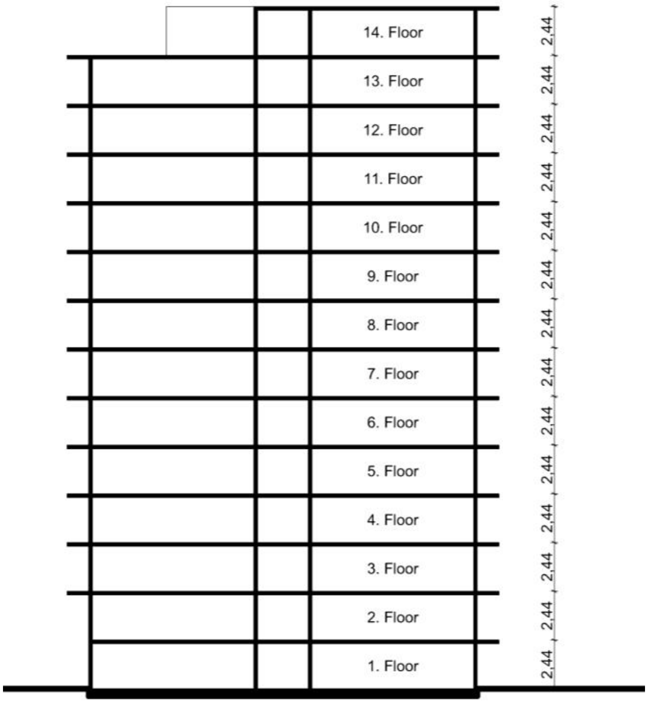


Figure 59: RC benchmark, section, basic setup (illustration by author)

As shown in figures 58 and 59 the dimensions of the original building are used as initial setup for the RFEM simulation. This is a program used for basic static analysis. In this study it helps to determine the material quantities of RC in walls and slabs. The calculations done by the program take into account dead, live and environmental loads.

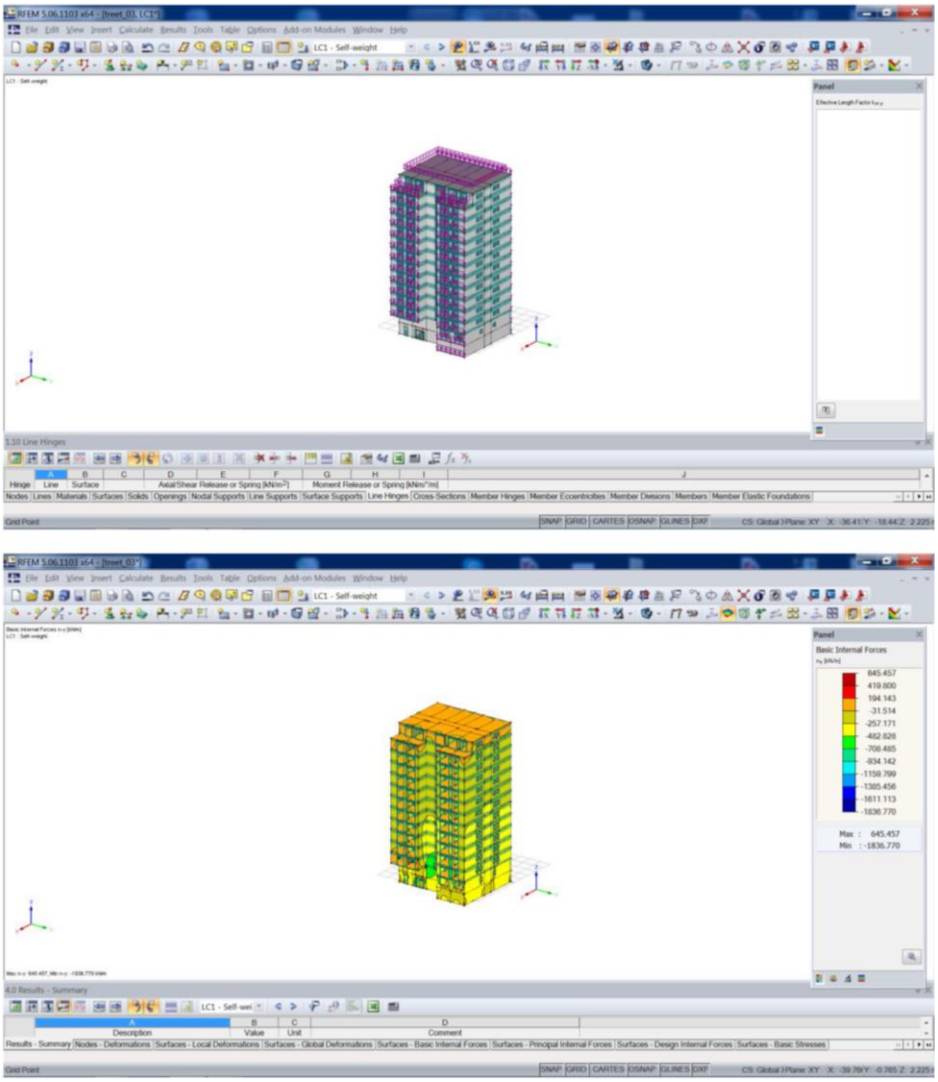


Figure 60: RC benchmark, RFEM, static analysis (illustration by author)

From the analysis we can excerpt definite material dimensions. In order to keep the construction simple / feasible, the RC wall thickness and slab strength throughout the building are calculated to be the same.

These are the determined RC building element dimensions:

- Foundation: 0,40 m
- All slabs: 0,25 m
- All walls: 0,20 m

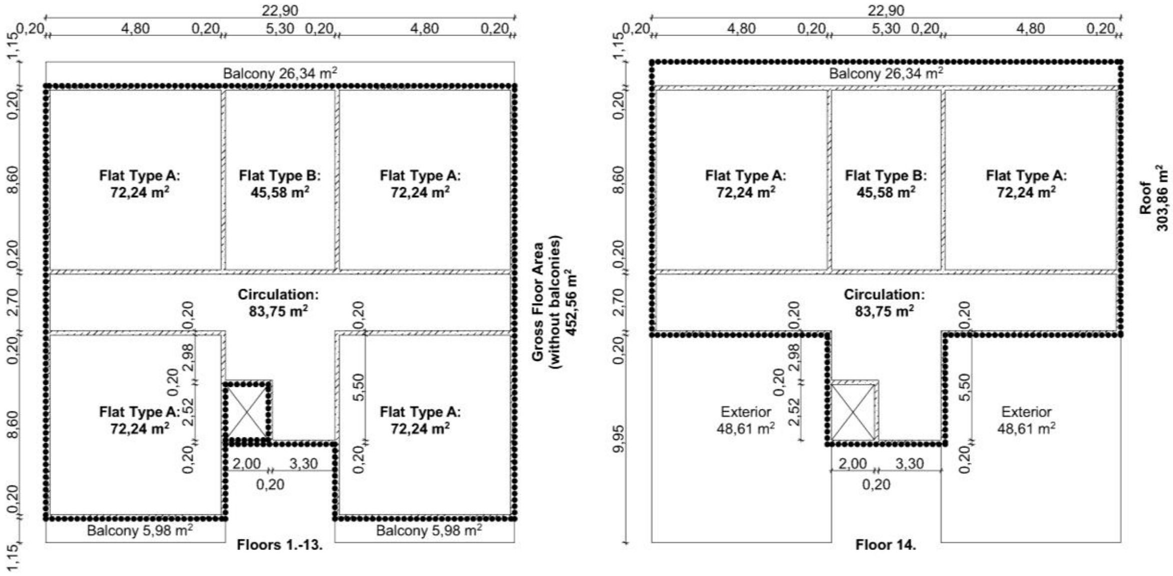


Figure 61: RC benchmark, floor plan (illustration by author)

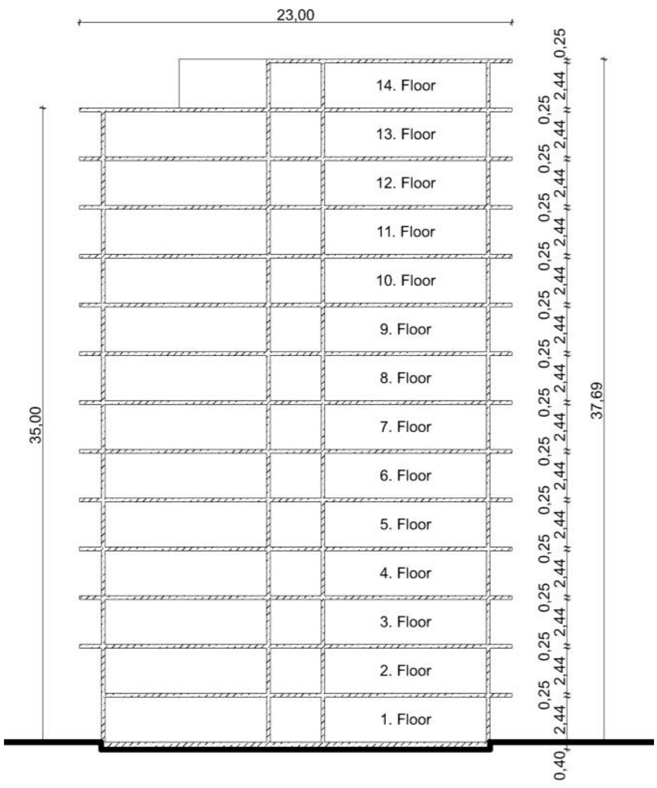


Figure 62: RC benchmark, section (illustration by author)

Thermal Envelope

The numeric output of the RC skeleton allows calculation of the minimum insulation thicknesses with the program ArchiPHYSIK. This is an energy certification and building physics software, licensed for use in Austria according to local norms. The maximum U-values are set according to the passive house standard, in congruence with the tree tower. For calculation purposes this is the standard which defines the capacity.

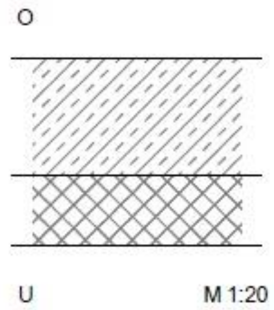
This is the max. U-value for opaque building parts according to passive house standard:

0,15 W/(m^{2}K)

In the RC construction this affects the components slab-to-ground, exterior walls and roof.

The following figures depict the definition of the rockwool insulation amounts:

Bauteilbezeichnung	Bauteil Nr.
Slab to Ground - Passive House RC Benchmark	**01**
Bauteiltyp: **Erdanliegende Bodenplatte bis 1,5 m unter Erde**	**EBu**
Wärmedurchgangskoeffizient U-Wert 0,14	W/m²K
erforderlich 0,40	W/m²K



Konstruktionsaufbau und Berechnung

Nr	Baustoffschichten (von außen nach innen) Bezeichnung	ID kurz	berücksichtigen	Bestand	d Dicke m	λ Leitfähigkeit W/m K	R = d/λ Durchlassw. m²K/W	ρ Dichte kg/m³	ρ · d Flächengewicht kg/m²
1	ROCKWOOL Durock Austria 035	bauboo	☒		0,2400	0,035	6,857	150,0	36,0
2	Stahlbeton 120 kg/m³ Armierungsstahl (1	bauboo	☒		0,4000	2,400	0,167	2.350,0	940,0
Dicke des Bauteils					0,640				
Flächenbezogene Masse des Bauteils									976,0
Summe der Wärmedurchlasswiderstände	ΣRt						7,024	m²K/W	

		Koeffizient	Rsi, Rse Widerstand	
Wärmeübergangskoeffizient/widerstand	innen	5,882	0,170	
Wärmeübergangskoeffizient/widerstand	außen			
Summe der Wärmeübergangswiderstände	Rsi + Rse		0,170	m²K/W
Wärmedurchgangswiderstand	RT = Rsi + ΣRt + Rse		7,194	m²K/W
Wärmedurchgangskoeffizient	U = 1/ RT		0,139	W/m²K

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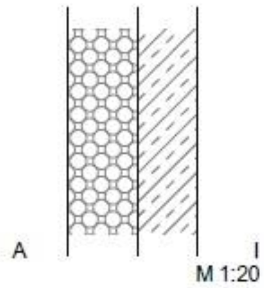
Figure 63: Slab-to-ground, U-value assessment (illustration by author)

Bauteilbezeichnung	Bauteil Nr.
Exterior Wall - Passive House RC Benchmark	02
Bauteiltyp Außenwand	AW
Wärmedurchgangskoeffizient U-Wert 0,14	W/m²K
erforderlich 0,35	W/m²K



Konstruktionsaufbau und Berechnung

Nr	Baustoffschichten von außen nach innen Bezeichnung	ID kurz	berücksichtigen	Bestand	d Dicke m	λ Leitfähigkeit W/m K	R = d/λ Durchlassw. m²K/W	ρ Dichte kg/m³	ρ · d Flächengewicht kg/m²
1	ROCKWOOL Fixrock 035 Austria (6-24c		☒		0,2400	0,035	6,857	50,0	12,0
2	Stahlbeton-Wand (20cm)	WSK	☒		0,2000	2,300	0,087	2.400,0	480,0
Dicke des Bauteils					0,440				
Flächenbezogene Masse des Bauteils									492,0
Summe der Wärmedurchlasswiderstände	ΣRt						6,944	m²K/W	

		Koeffizient	Rsi, Rse Widerstand	
Wärmeübergangskoeffizient/widerstand	innen	7,692	0,130	
Wärmeübergangskoeffizient/widerstand	außen	25,000	0,040	
Summe der Wärmeübergangswiderstände	Rsi + Rse		0,170	m²K/W
Wärmedurchgangswiderstand	RT = Rsi + ΣRt + Rse		7,114	m²K/W
Wärmedurchgangskoeffizient	U = 1/ RT		**0,141**	W/m²K

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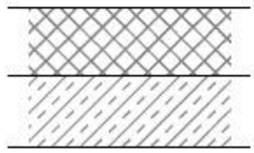
Figure 64: Exterior wall, U-value assessment (illustration by author)

Bauteilbezeichnung	Bauteil Nr.	
Roof - Passive House RC Benchmark	03	O
Bauteiltyp Außendecke	AD	
Wärmedurchgangskoeffizient U-Wert 0,14 W/m²K		
erforderlich 0,20 W/m²K		U M 1:20



Konstruktionsaufbau und Berechnung

	Baustoffschichten	ID	berücksichtigen	Bestand	d	λ	R = d/λ	ρ	ρ · d
	von außen nach innen				Dicke	Leitfähigkeit	Durchlassw.	Dichte	Flächengewicht
Nr	Bezeichnung	kurz			m	W/m K	m²K/W	kg/m³	kg/m²
1	ROCKWOOL Durock Austria 035	bauboo	☒		0,2400	0,035	6,857	150,0	36,0
2	Stahlbeton 140 kg/m³ Armierungsstahl (1	bauboo	☒		0,2500	2,500	0,100	2.375,0	593,7
Dicke des Bauteils					0,490				
Flächenbezogene Masse des Bauteils									629,7
Summe der Wärmedurchlasswiderstände	ΣRt						6,957	m²K/W	

		Koeffizient	Rsi, Rse Widerstand	
Wärmeübergangskoeffizient/widerstand	innen	10,000	0,100	
Wärmeübergangskoeffizient/widerstand	außen	25,000	0,040	
Summe der Wärmeübergangswiderstände	Rsi + Rse		0,140	m²K/W
Wärmedurchgangswiderstand	RT = Rsi + ΣRt + Rse		7,097	m²K/W
Wärmedurchgangskoeffizient	U = 1/ RT		**0,141**	W/m²K

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Figure 65: Roof, U-value assessment (illustration by author)

Through the analysis it becomes clear that the RC elements have next to no impact on the total U-value. Therefore the insulation thickness throughout the building hull is 0,24 m of rockwool.

Final Component dimensions:

- Slab-to-ground: 0,40 m RC / 0,24 m rockwool
- Interior slabs and balconies: 0,25 m RC
- Exterior walls: 0,20 m RC / 0,24 m rockwool
- Interior walls: 0,20 m RC
- Roof: 0,25 m RC / 0,24 m rockwool

3.2.3 Quantification

Using the floor plans and section the material masses are calculated. Rebar steel mass inside the RC is determined per 1,00 m³ of volume, as done in chapter 3.1.1.

Table 29: RC benchmark, material amounts

Type	Volume/Mass
Rockwool	1046,29 m^3
Concrete	2926,52 m^3
Rebar Steel	355,62 t

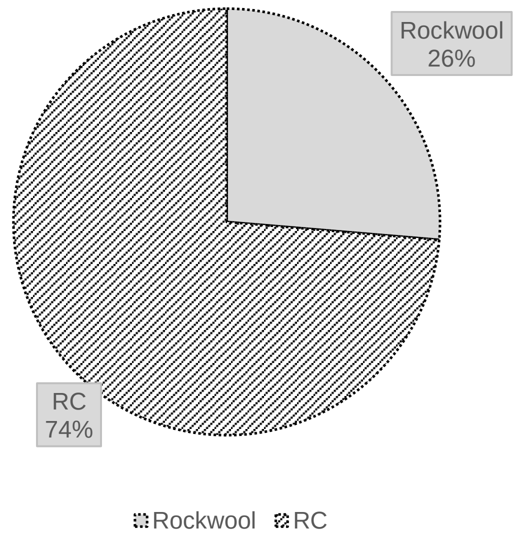

Figure 66: Volumetric material distribution, percentage (illustration by author)

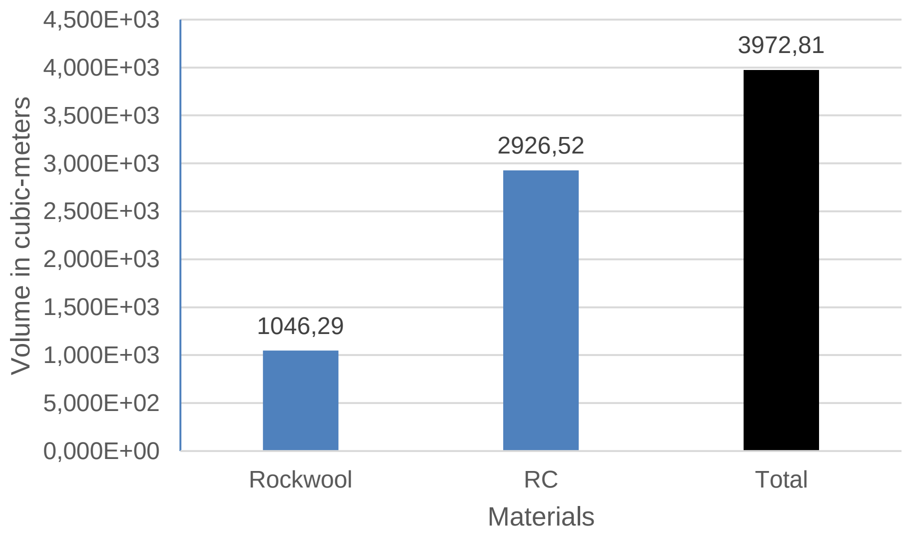

Figure 67: Volumetric material distribution, absolute values (illustration by author)

Using these quantities, the GWP, TNRPE, AP and material prices are calculated.

Table 30: RC benchmark, GWP production only

Material	**Amount**	**GWP, production only** **Per 1m³/1 t**	**GWP** **Total**
Rockwool	1046,29 m^3	82,64 kg CO_2/m^3	86,47 t CO_2
Concrete	2926,52 m^3	252,87 kg CO_2/m^3	740,03 t CO_2
Rebar Steel	355,62 t	839,00 kg CO_2/t	214,47 t CO_2
RC benchmark, total building GWP for production			**1040,97 t CO_2**

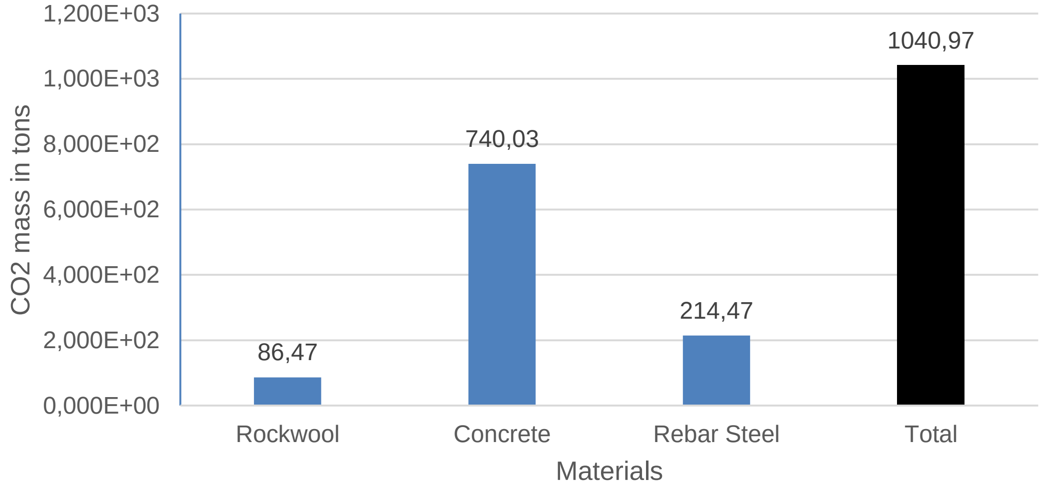

Figure 68: RC benchmark, GWP, production (illustration by author)

Table 31: RC benchmark, GWP including recycling

Material	**Amount**	**GWP, production & recycling** **Per 1m³/1 t**	**GWP** **Total**
Rockwool	1046,29 m^3	76,72 kg CO_2/m^3	80,27 t CO_2
Concrete	2926,52 m^3	229,79 kg CO_2/m^3	672,49 t CO_2
Rebar Steel	355,62 t	1189,00 kg CO_2/t	422,83 t CO_2
RC benchmark, total building GWP for production & recycling			**1175,59 t CO_2**

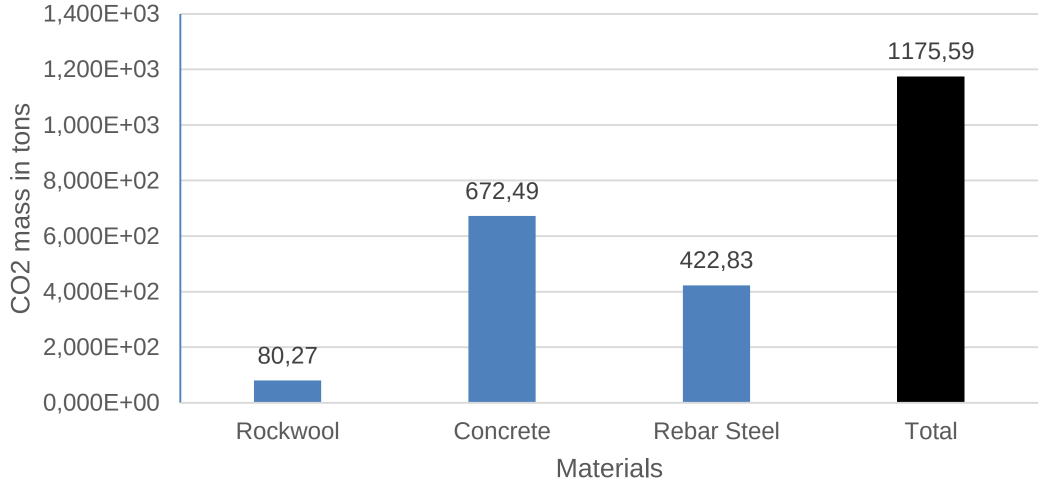

Figure 69: RC benchmark, GWP, production & recycling (illustration by author)

Table 32: RC benchmark, TNRPE production only

Material	Amount	TNRPE, production only Per 1m³/1 t	TNRPE Total
Rockwool	1046,29 m^3	1184,90 MJ/m^3	1239,75 GJ
Concrete	2926,52 m^3	1531,27 MJ/m^3	4481,29 GJ
Rebar Steel	355,62 t	10700,00 MJ/t	3805,13 GJ
RC benchmark, total building TNRPE for production			**9526,17 GJ**

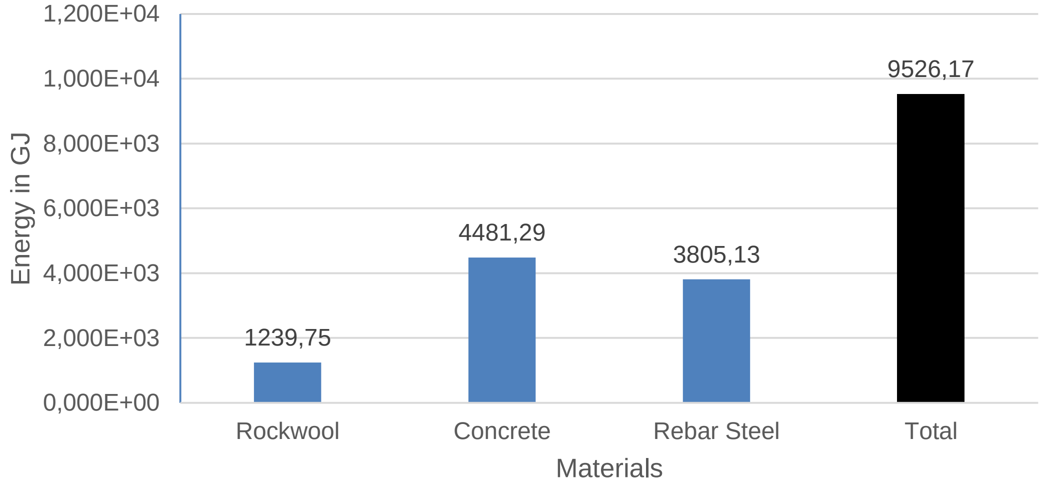

Figure 70: RC benchmark, TNRPE, production (illustration by author)

Table 33: RC benchmark, TNRPE including recycling

Material	Amount	TNRPE, production & recycling Per $1m^3$/1 t	TNRPE Total
Rockwool	1046,29 m^3	1085,47 MJ/m^3	1135,72 GJ
Concrete	2926,52 m^3	1212,27 MJ/m^3	3547,73 GJ
Rebar Steel	355,62 t	13830,00 MJ/t	4918,23 GJ
RC benchmark, total building TNRPE for production & recycling			**9601,68 GJ**

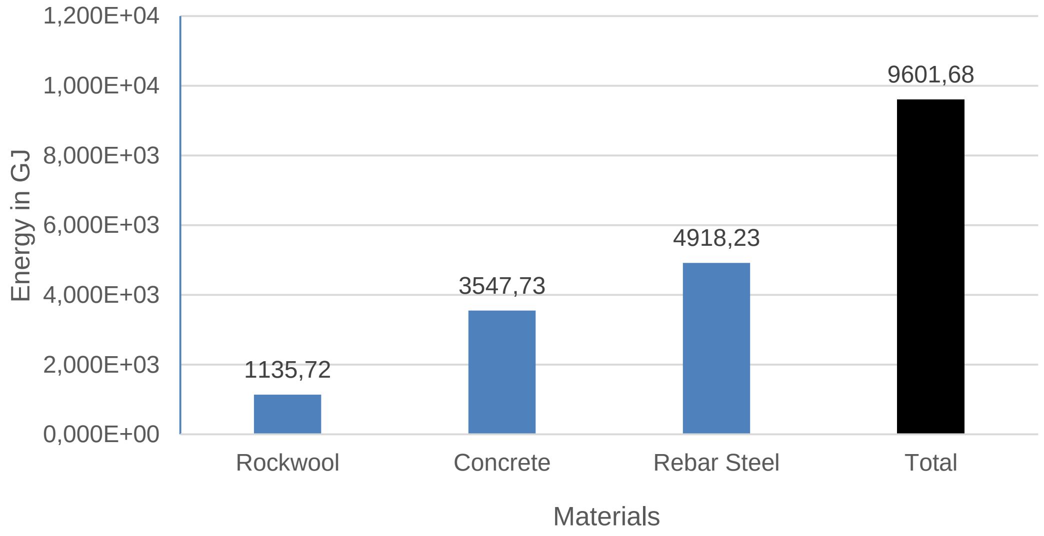

Figure 71: RC benchmark, TNRPE, production & recycling (illustration by author)

Table 34: RC benchmark, AP production only

Material	Amount	AP, production only Per $1m^3/1$ t	AP Total
Rockwool	1046,29 m^3	6,24 x 10^{-1} kg SO_2/m^3	652,88 kg SO_2
Concrete	2926,52 m^3	3,64 x 10^{-1} kg SO_2/m^3	1065,25 kg SO_2
Rebar Steel	355,62 t	3,46 kg SO_2/t	1230,45 kg SO_2
RC benchmark, total building AP for production			**2948,58 kg SO_2**

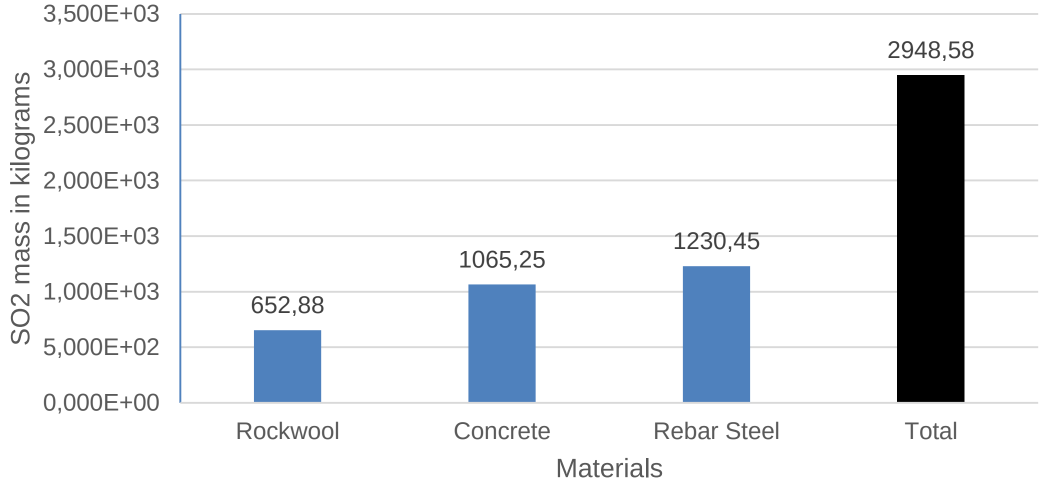

Figure 72: RC benchmark, AP, production (illustration by author)

Table 35: RC benchmark, AP including recycling

Material	**Amount**	**AP, production & recycling** **Per 1m^3/1 t**	**AP** **Total**
Rockwool	1046,29 m^3	6,18 x 10^{-1} kg SO_2/m^3	646,61 kg SO_2
Concrete	2926,52 m^3	3,23 x 10^{-1} kg SO_2/m^3	945,27 kg SO_2
Rebar Steel	355,62 t	4,80 kg SO_2/t	1706,98 kg SO_2
RC benchmark, total building AP for production & recycling			**3298,86 kg SO_2**

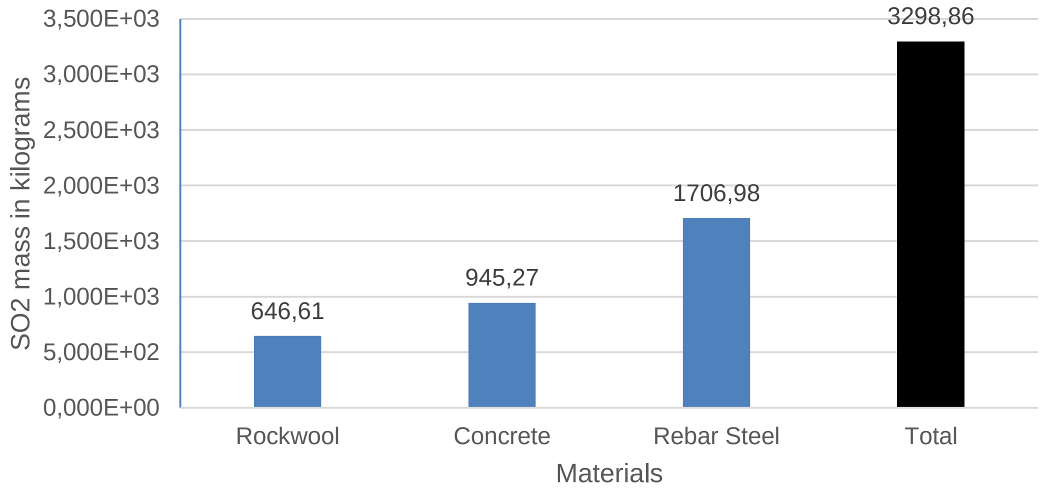

Figure 73: RC benchmark, AP, production & recycling (illustration by author)

Table 36: RC benchmark, material cost

Material	**Amount**	**Price, gross** **Per 1m³/1 t**	**Price, gross** **Total**
Rockwool	1046,29 m³	108,67 €/m³	113700,33 €
Concrete	2926,52 m³	111,00 €/m³	324843,72 €
Rebar Steel	355,62 t	919,00 €/t	326814,78 €
RC benchmark, total building TNRPE for production			**765358,83 €**

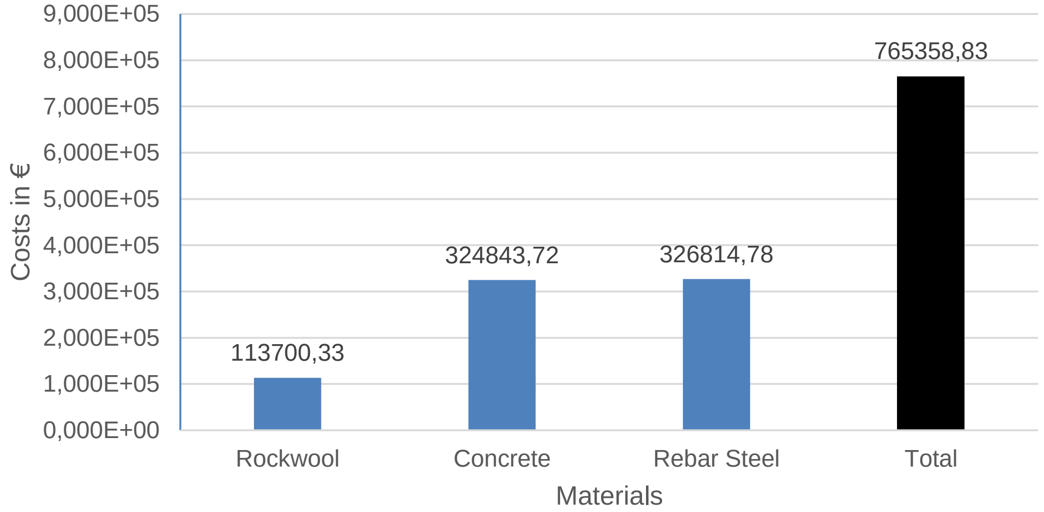

Figure 74: RC benchmark, material cost (illustration by author)

4 COMPARISON & ANALYSIS

Overview

This chapter compares and relativizes the values of the results. In a comparative manner “Treet” and the RC construction are numerically placed next to one another in terms of their building volumes, total mass, GWP, TNRPE, AP and material costs. The amounts and resulting difference are then compared with benchmarks in order to make them more readable.

Table 39: Comparison, overview

Aspect	Treet	RC Construction	Difference
Volume	5656,34 m^3	3972,81 m^3	1683,53 m^3
Mass	2115,62 t	7619,76 t	5504,14 t
GWP, prod.	-323,24 t CO_2	1040,97 t CO_2	1364,21 t CO_2
GWP, prod. & rec.	-815,65 t CO_2	1175,59 t CO_2	1991,24 t CO_2
TNRPE, prod.	8773,95 GJ	9526,17 GJ	752,22 GJ
TNRPE, prod. & rec.	549,88 GJ	9601,68 GJ	9051,80 GJ
AP, prod.	3697,40 kg SO_2	2948,58 kg SO_2	748,82 kg SO_2
AP, prod. & rec.	2617,90 kg SO_2	3298,86 kg SO_2	680,96 kg SO_2
Material Cost	1105877,64 €	765358,83 €	340518,81 €

Building Volume

In direct comparison, the RC structure is more compact. This is due to the increased use of dense concrete mass, which leads to a reduction of stuffed insulation material in frame spacing, as in “Treet”.

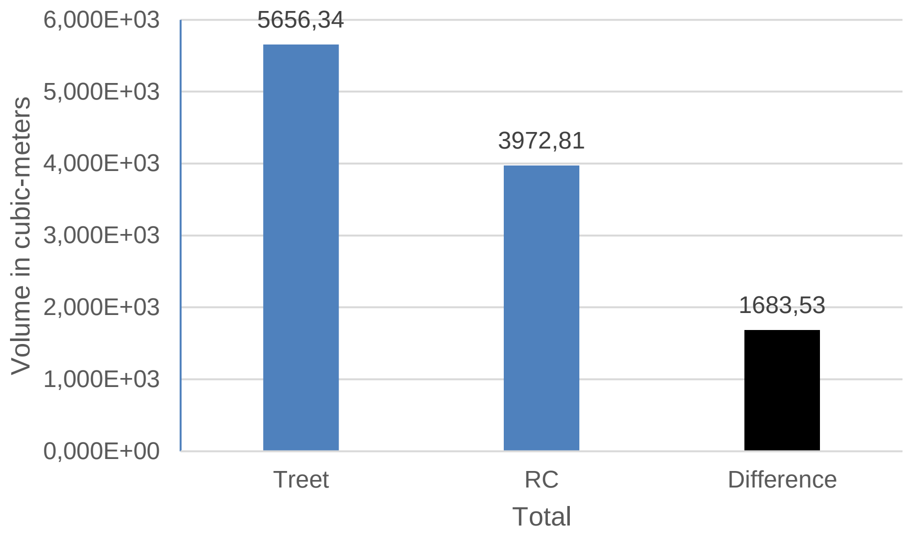

Figure 75: Volumetric comparison (illustration by author)

The saved volume of the RC benchmark stands at 1683,53 m^3. This space is enough to hold a housing unit of 100 m^2 gross area with approximately 5 stories and a flat roof. In a rough estimation this story size would fit the popular 80 m^2 apartment and leave 20 m^2 for walls and circulation, making a total of 400 m^2 of net living space. Dividing this by an average living space of 45 m^2 per person, we have to assume habitable area for nearly 9 people was lost by the construction of “Treet”.

Building Mass

The weight of “Treet” is far lighter than it’s RC counterpart. Though stretching out far more in three dimensions this underlines the stabilizing necessity of the RC layers on top of its’ power stories.

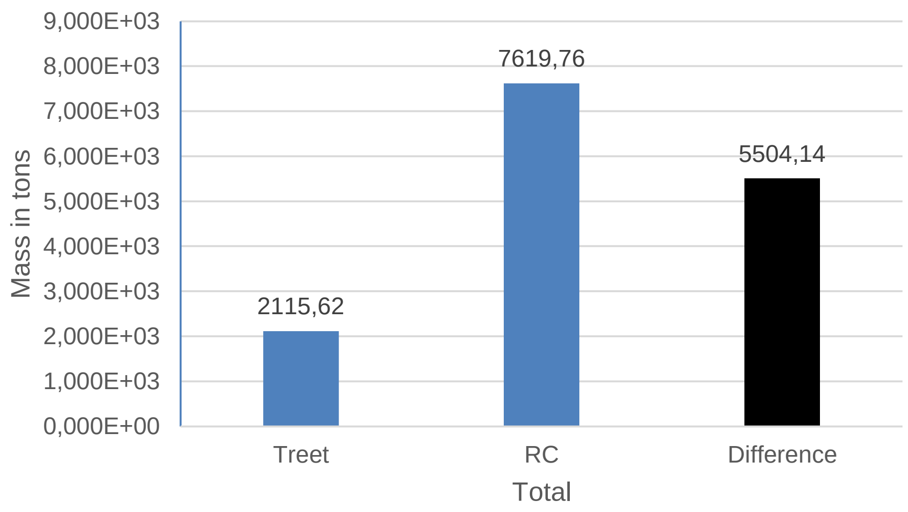

Figure 76: Mass comparison (illustration by author)

With the RC construction being far more massive, the question arises how the transportation of building parts for the two buildings would function. Considering a truck transportation with a loading capacity of 27 t per truck and the 5504,14 t of difference, this means: For the theoretic building site of the RC benchmark an additional 204 trucks have to deliver components. This is assuming the trucks are all loaded perfectly efficient and to the maximum of their capacities.

GWP

Deriving from the CO_2 saving capabilities of wood, the outcome of this assessment underlines the up to positive effect when using this material in buildings. Storing away the CO_2 rather than releasing it into the air by combustion. RC as a building component lacks the sustainable approach and even emits an excess of CO_2 when recycled, due to the reshaping process of its' steel reinforcements.

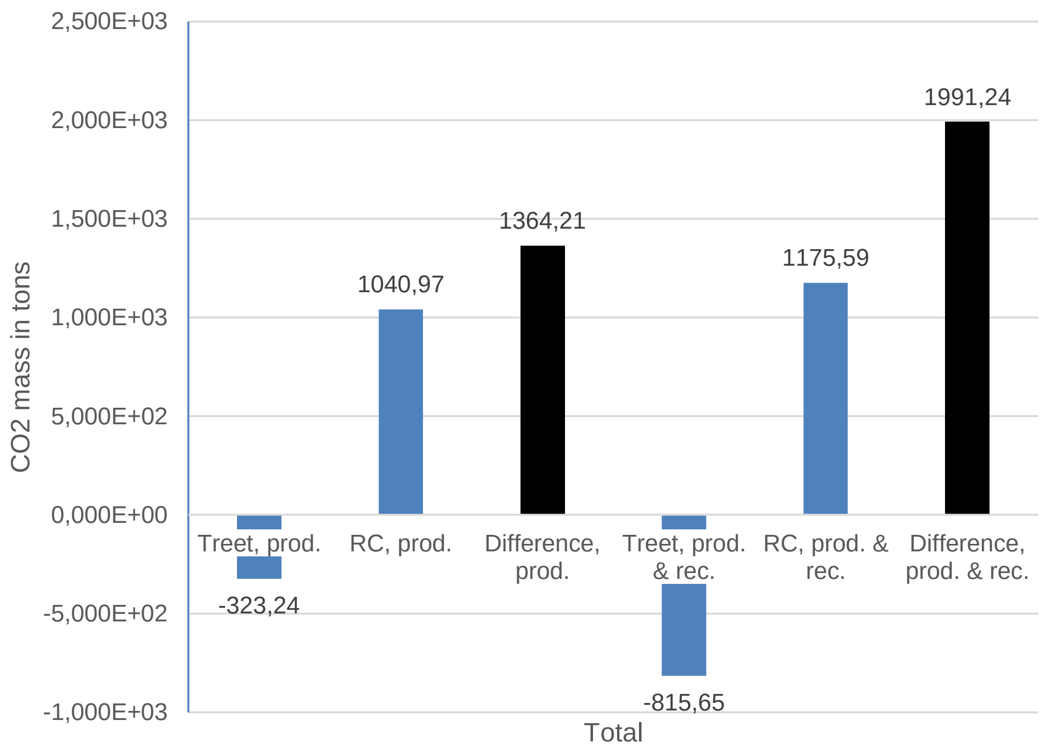

Figure 77: GWP comparison (illustration by author)

EU Regulation No 443/2009 states that a newly produced car should average an emittance 130 g CO_2/km. If every one of the 113 possible inhabitants of "Treet" used such a car, they could all drive an average of around 22000 km until they reached the potential their building saves in CO_2 by the material production alone.

1991 tons of CO_2 mark the disposition in GWP when recycling the two building types. A plane on a short distance flight will produce approximately 260 g CO_2/km. Rather than building in RC, the inhabitants of “Treet” all go on holidays after their building has been recycled. They could all travel 27762 km, or from Bergen to Bali and back before negating the CO_2 balance their building has provided them with.

TNRPE

The primary energy content signifies the necessary resources required to produce a product or a service. Specified to non-renewable resources, this means substances like crude oil or coal and the harvested energy of their combustion. Both buildings lie close to one another for the energy requirements in the production stage, though the difference in materials creates a large impact when including recycling.

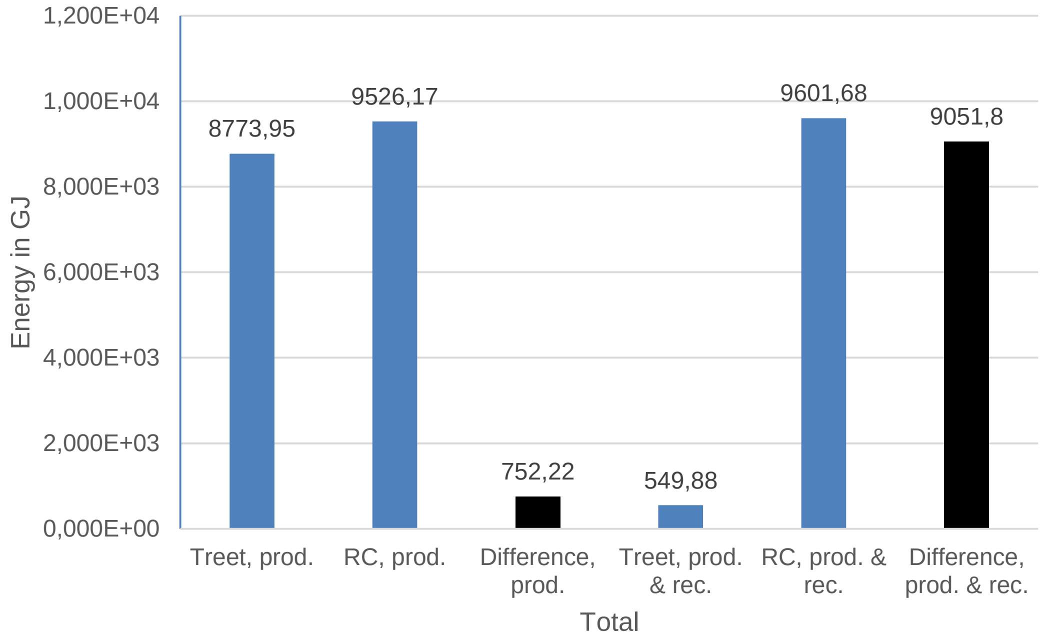

Figure 78: TNRPE comparison (illustration by author)

Taking the energy one liter of gasoline and one kilogram of coal incorporate, we can more clearly state the amount of saved energy of “Treet”:

Energy differentiation after recycling of both buildings: 9051,80 GJ

Gasoline: 34,20 MJ/l

264672,51 l of gasoline saved in favor of “Treet”

Coal: 30 MJ/kg

301726,67 kg of coal saved in favor of “Treet”

AP

Assessment of the AP means quantification of the SO_2 mass. This molecule is historically tied to the industrialization and the occurring poisoning of the air. In this impact category both buildings seem to shake hands. In the production process, the RC construction emits less than “Treet”, after recycling the tables are turned.

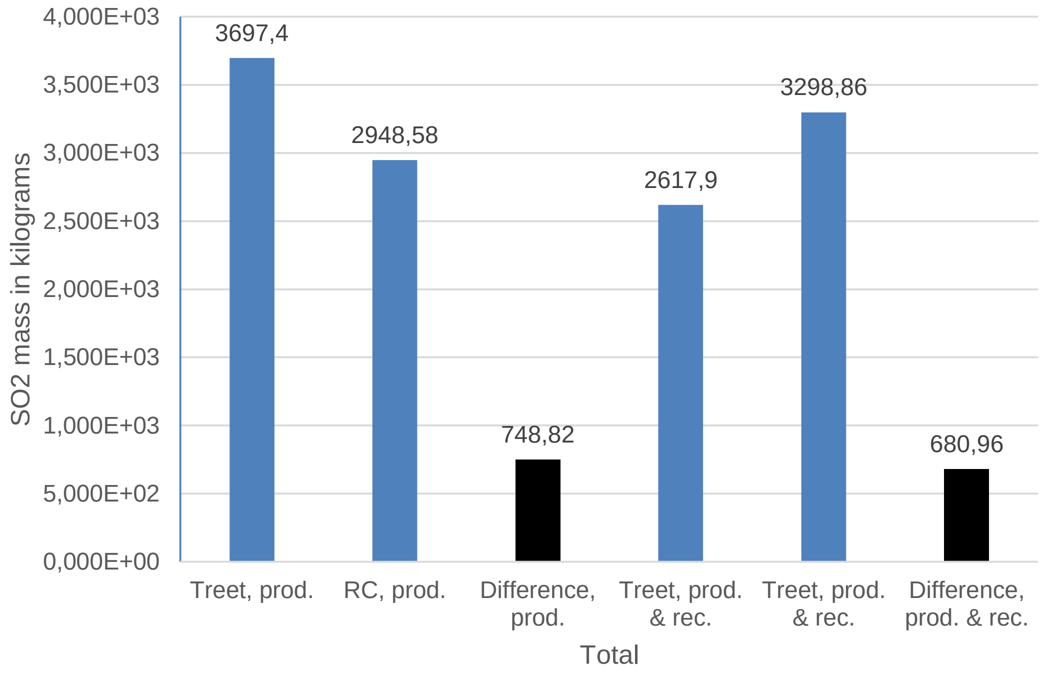

Figure 79: AP comparison (illustration by author)

Around 260 mg of SO_2/m^3 poison one cubic meter of air to a level that is immediately dangerous to life or health, according to the National Institute for Occupational Safety and Health in the US. Taking 3697,40 kg SO_2, the AP of “Treet” in the component production phase, 14,22 km^3 were poisoned.

SO_2 is used in wine making, here around 10 milligrams are used to produce a liter. After recycling of “Treet”, 680,96 kg SO_2 are available before reaching the emissions of the RC benchmark. With these savings 68096000 liters of wine could be produced. That would be around a fourth of the entire wine production of the year 2014/15 in the country of Greece.

Material Costs

To have an estimation of what only the building material costs could be in Austria, the results highlight a strong indication in favor of the RC benchmark. This is most likely linked to subsiding concrete prices where the market is rivaling and in contrast, the not as well distributed new market of CLT production where prices are still high.

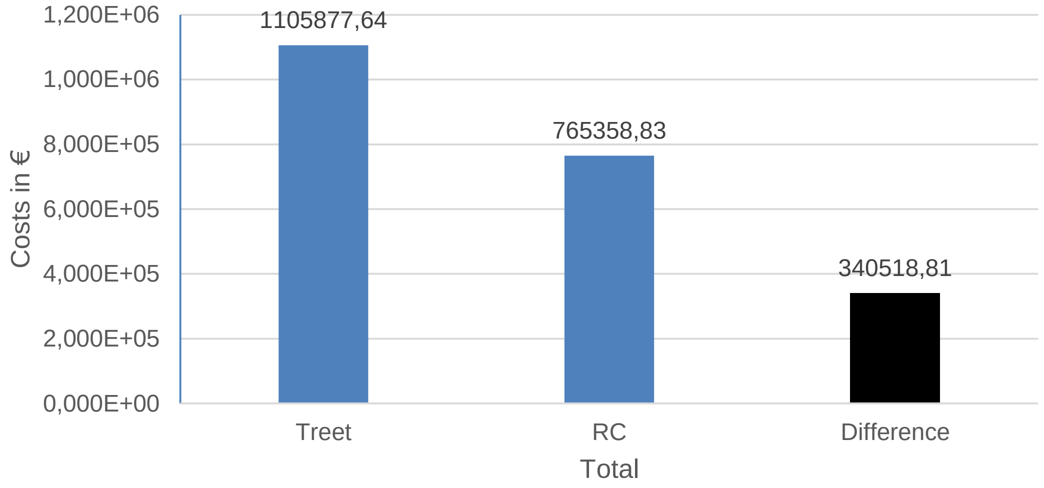

Figure 80: Material cost comparison (illustration by author)

In total the difference between the structures is 340518,81 €. This would be enough to finance approximately 45% of another RC benchmark structure. As this study does not take other aspects like transport to the building site into consideration, actual costs would definitely be a lot higher for the concrete construction. Only to encircle the before mentioned excessive truck loads.

Other Aspects

A planning period of four years was necessary to develop “Treet”. In approximation, due to the simplicity of the RC structure it is clear that through highly optimized engineering teams in aspects of concrete and rebar constructions its’ timeframe would be a lot shorter. As both constructions are entirely prefabricated, the actual building times are estimated to be similar.

Regarding noise on the building site of “Treet”, neighbors, developers and builders themselves found it to be on a very quiet and convenient level. There were no complaints. Comparing this to a RC building site with a lot of loud drilling and machinery the benefits of the wooden construction are highlighted.

A more problematic aspect with acoustics are the soundproofing issues between floors when building with wood. The massive setup necessary between levels for noise regulation between neighbors is far more elegantly solved with a filigree RC slab.

5 CONCLUSION

This study examined different aspects of a timber high-rise construction and a comparable conventional building (conventional hereby means the use of traditional reinforced-concrete construction technologies). The observed aspects include CO_2- and SO_2-emissions, TNRPE-demand, cost implications and a rough statement towards construction time and aspects of building acoustics.

Results can be summarized as follows: The timber-construction building performs well in terms of Global Warming Potential, while the concrete-construction suffers from the material-related energy- and emission-intensive generation processes. However, the RC-building shows a higher area-efficiency (construction elements are considerably smaller than in the timber building). Moreover, in cost comparison it turns out the concrete construction still features lower investment cost.

If recycling possibilities are integrated into the evaluation, the wooden construction shows a higher feasibility. In detail, the different cradle-to-cradle processes that are possible for timber constructions provide very long lifespans for used resources.

Limitations of the Presented Study

It is important to outline the limits of this study:

- Data used for evaluation, both in the cost estimation and the LCA can be considered as secondary data, partly taken from catalogues. It is very difficult to assess the uncertainties connected with the approach, however, it is important to mention that there might be some uncertainty connected with both input data and results.
- The approach was followed up by a specific case study building. While results can be considered to be very interesting for this case study building, the results cannot automatically be considered as meaningful for all other buildings.

The ongoing pushing-the-limits process regarding the maximum construction heights of buildings undoubtedly will enlarge the possibilities for urban densification in vertical direction. However, it has to be considered that the availability of sustainable high-rise construction alone is just an element in the ongoing discourse about city growth and urbanization of the 21st century, which requires a holistic approach.

Needless to say, the usage of timber construction for high-rise buildings still is the exception, not the rule. Thus, the level of experience amongst all involved stakeholders (governmental bodies, planers, engineers, etc.) still requires improvement and standardization. Improved spatial planning within the buildings, and facility management optimization could be utilized to mitigate the space-cutting effect of the larger construction elements. A real “skyscraper” comparable to the highest buildings of the world yet has to be constructed.

Future research should encompass investigation toward the efficiency of different timber-construction forms. Different approaches and building types can be assessed, towards the impact of the material on the quality of the created space. Here the mixed-use Viennese “HoHo”- wooden high-rise (Hoho 2018), which is set to be completed by the end of 2018, offers a fruitful opportunity for further research.

6 INDEX

6.1 List of Abbreviations and Characterizations

A1	Raw Material Supply
A2	Transport
A3	Manufacturing
C1	Demolition
C3	Waste Processing
C4	Disposal
CC	Climate Change Impact
CLT	Cross Laminated Timber
CO_2	Carbon Dioxide
d	Diameter
D	Reuse / Recovery / Recycling Potential
EPD	Environmental Product Declaration
€	Euro
GHG	Greenhouse Gases
GJ	Gigajoule
Glulam	Glued Laminated Timber
GWP	Global Warming Potential
ISO	International Organization for Standardization
kg	Kilogramm
K_{ser}	Stiffness Modulus
KVH	“Konstruktionsvollholz” Constructional Wood
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory Analysis
LCIA	Life Cycle Impact Assessment

MJ	Megajoule
OSB	Oriented Strand Board
PE	Primary Energy
ρ_{mean}	Mean Density
RC	Reinforced Concrete
Resp.	Respectively
SO_2	Sulfur Dioxide
t	Metric Ton
TNRPE	Total Non-Renewable Primary Energy

6.2 List of Figures

6.3 List of Tables

6.4 List of Equations

7 LITERATURE

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8 APPENDIX

8.1 Text documents

8.1.1 EPDs

KVH


UMWELT-PRODUKTDEKLARATION
nach ISO 14025 und EN 15804

Deklarationsinhaber	**Überwachungsgemeinschaft Konstruktionsvollholz e.V.**
Herausgeber	Institut Bauen und Umwelt (IBU)
Programmhalter	Institut Bauen und Umwelt (IBU)
Deklarationsnummer	EPD-ÜKH-2012111-DE
Ausstellungsdatum	20.09.2017
Gültigkeit	19.09.2018

Konstruktionsvollholz KVH®
Überwachungsgemeinschaft Konstruktionsvollholz e.V.

www.ibu-epd.com / https://epd-online.com

Institut Bauen und Umwelt e.V.

2.4 Inverkehrbringung/Anwendungsregeln

Konstruktionsvollholz KVH® ohne Keilzinkenverbindungen muss die bauaufsichtlichen Anforderungen an Vollholz nach DIN EN 14081-1:2011-05, Holzbauwerke - Nach Festigkeit sortiertes Bauholz für tragende Zwecke mit rechteckigem Querschnitt - Teil 1: Allgemeine Anforderungen, erfüllen.

Für eine Anwendung in Deutschland sind anwendungsbezogenen Regelungen aus DIN 20000-5:2012-03, Anwendung von Bauprodukten in Bauwerken - Teil 5: Nach Festigkeit sortiertes Bauholz für tragende Zwecke mit rechteckigem Querschnitt, zu beachten.

Konstruktionsvollholz KVH® mit Keilzinkenverbindungen muss die bauaufsichtlichen Anforderungen an keilgezinktes Vollholz nach DIN 1052: 2008 erfüllen.

Darüber hinaus müssen alle Konstruktionsvollhölzer KVH® die ergänzenden privatrechtlichen Vorgaben der Vereinbarung über Konstruktionsvollholz KVH® erfüllen.

2.5 Lieferzustand

Die Produkte werden in folgenden Vorzugsmaßen hergestellt:

Min Höhe:	100 mm
Max Höhe:	240 mm
Min. Breite:	60 mm
Max. Breite:	140 mm
Lagerlängen:	13 m (für keilgezinktes KVH®, größere Längen auf Anfrage möglich)

2.6 Grundstoffe/Hilfsstoffe

Keilgezinktes Konstruktionsvollholz KVH® besteht aus faserparallel miteinander verklebten technisch getrockneten Bohlen oder Kanthölzern aus Nadelholz. Für die grundsätzlich duroplastische Verklebung werden im Wesentlichen Polyurethan-Klebstoffe (PUR) oder Melamin-Harnstoff–Formaldehyd-Klebstoffe (MUF) eingesetzt. In sehr selten Fällen kommen Phenol-Resorzin-Formaldehyd Klebstoffe (PRF) zum Einsatz.

Die für die Umwelt-Produktdeklaration gemittelten Anteile an Inhaltsstoffen je m³ Konstruktionsvollholz KVH® betragen (gerundet auf 2 Stellen):

- Nadelholz, vorwiegend Fichte ca. 89,20%
- Wasser ca. 10,70%
- PUR Klebstoffe ca. 0,04%
- MUF Klebstoffe ca. 0,06%

Das Produkt hat eine durchschnittliche Rohdichte von 492,71 kg/m³.

Bei nicht-keilgezinktem Konstruktionsvollholz KVH® wird kein Klebstoff verwendet. Die Rohdichte liegt bei 490,13 kg/m³ bei einem Wasseranteil von 10,71 %.

2.7 Herstellung

Für die Herstellung von Konstruktionsvollholz KVH ® wird konventionelles Schnittholz zunächst auf weniger als 18% Holzfeuchte getrocknet, vorgehobelt und visuell bzw. maschinell nach der Festigkeit sortiert. Identifizierte Bereiche mit festigkeitsmindernden Stellen werden abhängig von der erwünschten Festigkeitsklasse ausgekappt. Bei keilgezinktem Konstruktionsvollholz KVH® werden die entstandenen Schnittholzabschnitte durch Keilzinkenverbindung zu endlos langen Lamellen gestoßen. Nach Aushärtung bzw. bei nicht-keilgezinktem Konstruktionsvollholz KVH® nach dem Auskappen der Fehlstellen, werden die Querschnitte gehobelt, gefast, abgebunden und verpackt. Bei Bedarf kann eine Behandlung mit Holzschutzmitteln erfolgen.

2.8 Umwelt und Gesundheit während der Herstellung

Die entstehende Abluft wird gemäß der gesetzlichen Bestimmungen gereinigt. Es entstehen keine Belastungen von Wasser und Boden. Die entstehenden Abwässer werden in das lokale Abwassersystem eingespeist.

2.9 Produktverarbeitung/Installation

Konstruktionsvollholz KVH® kann mit den üblichen für die Vollholzbearbeitung geeigneten Werkzeugen bearbeitet werden.

Die Hinweise zum Arbeitsschutz sind auch bei der Verarbeitung/Montage zu beachten.

2.10 Verpackung

Es werden Polyethylen (AVV 15 01 02), Metalle (AVV 15 01 04), Vollholz (AVV 15 01 03), Papier und Pappe (AVV 15 01 01) sowie zu kleinen Anteilen andere Kunststoffe verwendet (AVV 15 01 02).

2.11 Nutzungszustand

Die Zusammensetzung für den Zeitraum der Nutzung entspricht der Grundstoffzusammensetzung nach Abschnitt 2.6. „Grundstoffe".

Während der Nutzung sind in dem Produkt etwa 219 kg Kohlenstoff gebundenen. Dies entspricht bei einer vollständigen Oxidation etwa 805 kg CO_2.

2.12 Umwelt und Gesundheit während der Nutzung

Umweltschutz: Gefährdungen für Wasser, Luft und Boden können bei bestimmungsgemäßer Anwendung der Produkte nach heutigem Erkenntnisstand nicht entstehen.
Gesundheitsschutz: Nach heutigem Erkenntnisstand sind keine gesundheitlichen Schäden und Beeinträchtigungen zu erwarten.
Im Hinblick auf Formaldehyd ist Konstruktionsvollholz KVH® auf Grund seines Klebstoffgehaltes, seiner Struktur und seiner Verwendungsform emissionsarm.

Mit MUF-Klebstoffen verklebtes Konstruktionsvollholz KVH ® gibt nachträglich Formaldehyd ab. Gemessen am Grenzwert der Chemikalienverbotsverordnung von 0,1 ml/m³ sind die Werte nach Prüfung (prEN 15497:2011-09, Keilzinkenverbindungen im Bauholz - Leistungsanforderungen und Mindestanforderungen an die Herstellung; Deutsche Fassung prEN 15497:2011) als sehr niedrig einzustufen.

Mit PUR-Klebstoffen oder EPI Klebstoffen verklebtes Konstruktionsvollholz KVH® oder Konstruktionsvollholz KVH® ohne Keilzinkenverbindungen weist Formaldehydemissionswerte nach prEN 15497: 2011 im Bereich des naturbelassenen Holzes auf (um 0,004 ml/m³)

5 LCA: Ergebnisse

Nicht-keilgezinktes Konstruktionsvollholz KVH®

ANGABE DER SYSTEMGRENZEN (X = IN ÖKOBILANZ ENTHALTEN; MND = MODUL NICHT DEKLARIERT)																
Produktionsstadium			Stadium der Errichtung des Bauwerks		Nutzungsstadium							Entsorgungsstadium				Gutschriften und Lasten außerhalb der Systemgrenze
Rohstoffversorgung	Transport	Herstellung	Transport zur Baustelle	Einbau ins Gebäude	Nutzung / Anwendung	Instandhaltung	Reparatur	Ersatz	Erneuerung	Energieeinsatz für das Betreiben des Gebäudes	Wassereinsatz für das Betreiben des Gebäudes	Rückbau / Abriss	Transport	Abfallbehandlung	Deponierung	Wiederverwendungs-, Rückgewinnungs- oder Recyclingpotenzial
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	X	X	X	X

ERGEBNISSE DER ÖKOBILANZ UMWELTAUSWIRKUNGEN: 1m³ KVH, nicht keilgezinkt

		Produktion			Entsorgung			Gutschrift
Parameter	**Einheit**	**A1**	**A2**	**A3**	**C2**	**C3**	**C4**	**D**
GWP	[kg CO_2-Äq.]	-7,77E+02	9,45E+00	3,77E+01	4,39E-01	8,06E+02	0,00E+00	-3,58E+02
ODP	[kg CFC11-Äq.]	2,01E-06	3,27E-08	7,61E-06	8,78E-10	1,19E-06	0,00E+00	-8,17E-05
AP	[kg SO_2-Äq.]	1,48E-01	4,12E-02	2,08E-01	1,89E-03	6,98E-03	0,00E+00	-3,69E-01
EP	[kg PO_4^{3-} - Äq.]	3,20E-02	9,44E-03	4,05E-02	4,37E-04	5,89E-04	0,00E+00	-3,78E-03
POCP	[kg Ethen Äq.]	2,94E-02	4,24E-03	6,40E-02	2,04E-04	4,64E-04	0,00E+00	-2,49E-02
ADPE	[kg Sb Äq.]	2,63E-04	2,76E-07	7,19E-04	9,27E-09	1,23E-07	0,00E+00	-1,95E-05
ADPF	[MJ]	3,01E+02	1,32E+02	4,17E+02	6,20E+00	4,62E+01	0,00E+00	-4,05E+03

Legende	GWP = Globales Erwärmungspotenzial; ODP = Abbau Potential der stratosphärischen Ozonschicht; AP = Versauerungspotenzial von Boden und Wasser; EP = Eutrophierungspotenzial; POCP Bildungspotential für troposphärisches Ozon; ADPE = Potenzial für den abiotischen Abbau nicht fossiler Ressourcen; ADPF = Potenzial für den abiotischen Abbau fossiler Brennstoffe

ERGEBNISSE DER ÖKOBILANZ RESSOURCENEINSATZ: 1 m³ KVH, nicht keilgezinkt

		Produktion			Entsorgung			Gutschrift
Parameter	**Einheit**	**A1**	**A2**	**A3**	**C2**	**C3**	**C4**	**D**
PERE	[MJ]	4,03E+02	2,15E-01	1,05E+03	8,21E-03	4,70E+00	0,00E+00	-3,34E+02
PERM	[MJ]	8,43E+03	0,00E+00	7,51E+01	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PERT	[MJ]	8,84E+03	2,15E-01	1,12E+03	8,21E-03	4,70E+00	0,00E+00	-3,34E+02
PENRE	[MJ]	3,69E+02	1,33E+02	6,76E+02	6,23E+00	8,78E+01	0,00E+00	-7,09E+03
PENRM	[MJ]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
PENRT	[MJ]	3,69E+02	1,33E+02	6,76E+02	6,23E+00	8,78E+01	0,00E+00	-7,09E+03
SM	[kg]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
RSF	[MJ]	3,08E+01	0,00E+00	3,11E+02	0,00E+00	0,00E+00	0,00E+00	4,25E+03
NRSF	[MJ]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
FW	[m^3]	6,09E+02	3,08E+00	4,17E+02	1,17E-01	4,99E+01	0,00E+00	3,34E+03

Legende	PERE = Erneuerbare Primärenergie als Energieträger; PERM = Erneuerbare Primärenergie zur stofflichen Nutzung; PERT = Total erneuerbare Primärenergie; PENRE = Nicht-erneuerbare Primärenergie als Energieträger; PENRM = Nicht-erneuerbare Primärenergie zur stofflichen Nutzung; PENRT = Total nicht erneuerbare Primärenergie; SM = Einsatz von Sekundärstoffen; RSF = Erneuerbare Sekundärbrennstoffe; NRSF = Nicht erneuerbare Sekundärbrennstoffe; FW = Einsatz von Süßwasserressourcen

ERGEBNISSE DER ÖKOBILANZ OUTPUT-FLÜSSE UND ABFALLKATEGORIEN: 1 m³ KVH, nicht keilgezinkt

		Produktion			Entsorgung			Gutschrift
Parameter	**Einheit**	**A1**	**A2**	**A3**	**C2**	**C3**	**C4**	**D**
HWD	[kg]	8,15E-03	0,00E+00	2,52E-02	0,00E+00	0,00E+00	0,00E+00	1,47E+00
NHWD	[kg]	1,14E-02	0,00E+00	1,70E-02	0,00E+00	0,00E+00	0,00E+00	1,37E-02
RWD	[kg]	2,44E-02	4,09E-04	9,26E-02	1,10E-05	1,49E-02	0,00E+00	-1,01E+00
CRU	[kg]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
MFR	[kg]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	4,90E+02	0,00E+00	0,00E+00
MER	[kg]	0,00E+00	0,00E+00	3,90E+00	0,00E+00	4,90E+02	0,00E+00	-4,94E+02
EE Strom	[MJ]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
EE Wärme	[MJ]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Legende	HWD = Gefährlicher Abfall zur Deponie; NHWD = Entsorgter nicht gefährlicher Abfall; RWD = Entsorgter radioaktiver Abfall; CRU = Komponenten für die Wiederverwendung; MFR = Stoffe zum Recycling; MER = Stoffe für die Energierückgewinnung; EE = Exportierte Energie je Typ

OSB

UMWELT-PRODUKTDEKLARATION
nach ISO 14025 und EN 15804

Deklarationsinhaber	**SWISS KRONO Tec AG**
Herausgeber	Institut Bauen und Umwelt e.V. (IBU)
Programmhalter	Institut Bauen und Umwelt e.V. (IBU)
Deklarationsnummer	EPD-KRO-20150067-IBD2-DE
ECO EPD Ref. No.	ECO-00000188
Ausstellungsdatum	15.06.2015
Gültig bis	14.06.2020

SWISS KRONO OSB-Platten

SWISS KRONO Tec AG

Institut Bauen und Umwelt e.V.

www.bau-umwelt.com / https://epd-online.com

ECO PLATFORM EPD EN 15804 VERIFIED

SWISS KRONO

1. Allgemeine Angaben

SWISS KRONO Tec AG	SWISS KRONO OSB-Platten
Programmhalter IBU - Institut Bauen und Umwelt e.V. Panoramastr. 1 10178 Berlin Deutschland	**Inhaber der Deklaration** KRONOTEC AG Haldenstraße 12 6006 Luzern - Schweiz
Deklarationsnummer EPD-KRO-20150067-IBD2-DE	**Deklariertes Produkt/deklarierte Einheit** 1 Kubikmeter OSB Platte
Diese Deklaration basiert auf den Produktkategorienregeln: Holzwerkstoffe, 07.2014 (PCR geprüft und zugelassen durch den unabhängigen Sachverständigenrat) **Ausstellungsdatum** 15.06.2015 **Gültig bis** 14.06.2020	**Gültigkeitsbereich:** Dieses Dokument bezieht sich auf alle OSB-Platten, welche in folgenden Werken der SWISS KRONO GROUP hergestellt werden: SWISS KRONO GmbH, Heiligengrabe, Deutschland SWISS KRONO Sp. z o.o, Zary, Polen Der Inhaber der Deklaration haftet für die zugrundeliegenden Angaben und Nachweise; eine Haftung des IBU in Bezug auf Herstellerinformationen, Ökobilanzdaten und Nachweise ist ausgeschlossen.
Prof. Dr.-Ing. Horst J. Bossenmayer (Präsident des Instituts Bauen und Umwelt e.V.)	**Verifizierung** Die CEN Norm /EN 15804/ dient als Kern-PCR Verifizierung der EPD durch eine/n unabhängige/n Dritte/n gemäß /ISO 14025/ ☐ intern ☒ extern
Dr. Burkhart Lehmann (Geschäftsführer IBU)	Matthias Schulz, Unabhängige/r Prüfer/in vom SVR bestellt

2. Produkt

2.1 Produktbeschreibung

OSB-Platten (Oriented Strand Board – SWISS KRONO OSB) sind klebstoffgebundene, dreischichtig aufgebaute Holzwerkstoffplatten (Flachpressplatten) aus orientiert gestreuten, länglichen Holzspänen (120 - 160 mm lange Kiefernholz Furnierstreifen), sog. Strands gemäß /EN13986/ bzw. /EN 300/ „OSB". „Strands" aus einer definierten Dicke und Form, vornehmlich aus Rundhölzern, werden in mehreren Schichten verleimt. Die Orientierung der Mittelschicht erfolgt dabei im 90° Winkel zu den Deckschichten. Die OSB-Platten werden mit einem PMDI-Harz verleimt und in Dicken von 8 bis 40 mm hergestellt.
Für die schwer entflammbare SWISS KRONO OSB/SF-B wird ein Flammschutzmittel zugesetzt.
Das deklarierte Produkt stellt einen massengewichteten Durchschnitt der hergestellten Sortimente dar. Bei der Berechnung des Durchschnittes wird berücksichtigt, dass in den beiden Werken unterschiedliche Mengen mit unterschiedlichen Dichten produziert werden.

2.2 Anwendung

Die SWISS KRONO OSB entsprechen der Nutzungsklasse 1 und 2 nach EC5 und dürfen daher in Feuchtbereich bzw. nicht bewitterten Außenbereich verwendet werden. OSB-Platten können in tragenden und aussteifenden Bauteilen eingesetzt werden.

2.3 Technische Daten

Bautechnische Daten

Bezeichnung	Wert	Einheit
Rohdichte nach /EN 323/	600 - 620	kg/m³
Elastizitätsmodul (längs)	4930 - 7500	N/mm²
Elastizitätsmodul (quer)	1980 - 3500	N/mm²
Biegezugfestigkeit (längs)	14,8 - 28,5	N/mm²
Biegezugfestigkeit (quer)	7,4 - 20	N/mm²
Wärmeleitfähigkeit	0,13	W/(mK)
Wasserdampfdiffusionswiderstandszahl	200 - 300	-

2.4 Inverkehrbringung/Anwendungsregeln

Für das Inverkehrbringen in der EU/EFTA (mit Ausnahme der Schweiz) gilt die Verordnung (EU) Nr. 305/2011 vom 9. März 2011. Die Produkte benötigen eine Leistungserklärung unter Berücksichtigung von /EN 13986:2004
Holzwerkstoffe zur Verwendung im Bauwesen — Eigenschaften, Bewertung der Konformität und Kennzeichnung/ und die CE-Kennzeichnung.
Für die Verwendung gelten die jeweiligen nationalen Bestimmungen, in Deutschland die /Allgemeine bauaufsichtliche Zulassung:

SWISS KRONO

5. LCA: Ergebnisse

Die folgenden Tabellen zeigen die Ergebnisse der Umweltwirkungsanalyse differenziert nach den CML-Umweltkategorien, Ressourceneinsatz, Output-Flüssen und Abfallkategorien skaliert auf die funktionelle Einheit von 1 m³ OSB Platte. In Modul C3 wird die Freisetzung des biogenen CO_2 und die stoffliche Primärenergie, die in den Platten enthalten ist, deklariert. Lasten aus der Verbrennung (außer biogenen CO_2) und Gutschriften werden in D deklariert.

ANGABE DER SYSTEMGRENZEN (X = IN ÖKOBILANZ ENTHALTEN; MND = MODUL NICHT DEKLARIERT)

Produktionsstadium			Stadium der Errichtung des Bauwerks		Nutzungsstadium							Entsorgungsstadium				Gutschriften und Lasten außerhalb der Systemgrenze
Rohstoffversorgung	Transport	Herstellung	Transport vom Hersteller zum Verwendungsort	Montage	Nutzung / Anwendung	Instandhaltung	Reparatur	Ersatz	Erneuerung	Energieeinsatz für das Betreiben des Gebäudes	Wassereinsatz für das Betreiben des Gebäudes	Rückbau / Abriss	Transport	Abfallbehandlung	Beseitigung	Wiederverwendungs-, Rückgewinnungs- oder Recyclingpotenzial
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
X	X	X	MND	MND	MND	MND	MNR	MNR	MNR	MND	MND	MND	MND	X	MND	X

ERGEBNISSE DER ÖKOBILANZ UMWELTAUSWIRKUNGEN: 1 m³ OSB Platte (617 kg)

Parameter	Einheit	A1-A3	C3	D
Globales Erwärmungspotenzial	[kg CO_2-Äq.]	-7,60E+2	1,04E+3	-6,49E+2
Abbau Potential der stratosphärischen Ozonschicht	[kg CFC11-Äq.]	1,36E-4	0,00E+0	-2,97E-7
Versauerungspotenzial von Boden und Wasser	[kg SO_2-Äq.]	1,04E+0	0,00E+0	-3,86E-1
Eutrophierungspotenzial	[kg $(PO_4)^{3-}$-Äq.]	1,39E-1	0,00E+0	2,88E-4
Bildungspotential für troposphärisches Ozon	[kg Ethen-Äq.]	1,50E-1	0,00E+0	5,21E-2
Potenzial für den abiotischen Abbau nicht fossiler Ressourcen	[kg Sb-Äq.]	1,28E-4	0,00E+0	-7,82E-5
Potenzial für den abiotischen Abbau fossiler Brennstoffe	[MJ]	4,61E+3	0,00E+0	-8,41E+3

ERGEBNISSE DER ÖKOBILANZ RESSOURCENEINSATZ: 1 m³ OSB Platte (617 kg)

Parameter	Einheit	A1-A3	C3	D
Erneuerbare Primärenergie als Energieträger	[MJ]	8,99E+2	0,00E+0	1,04E+4
Erneuerbare Primärenergie zur stofflichen Nutzung	[MJ]	1,19E+4	-1,19E+4	0,00E+0
Total erneuerbare Primärenergie	[MJ]	1,28E+4	-1,19E+4	1,04E+4
Nicht-erneuerbare Primärenergie als Energieträger	[MJ]	4,27E+3	0,00E+0	-1,05E+4
Nicht-erneuerbare Primärenergie zur stofflichen Nutzung	[MJ]	5,37E+2	-5,37E+2	0,00E+0
Total nicht erneuerbare Primärenergie	[MJ]	4,81E+3	-5,37E+2	-1,05E+4
Einsatz von Sekundärstoffen	[kg]	0,00E+0	0,00E+0	0,00E+0
Erneuerbare Sekundärbrennstoffe	[MJ]	2,12E+2	0,00E+0	1,14E+4
Nicht erneuerbare Sekundärbrennstoffe	[MJ]	0,00E+0	0,00E+0	0,00E+0
Einsatz von Süßwasserressourcen	[m³]	7,21E-1	0,00E+0	-2,16E+0

ERGEBNISSE DER ÖKOBILANZ OUTPUT-FLÜSSE UND ABFALLKATEGORIEN: 1 m³ OSB Platte (617 kg)

Parameter	Einheit	A1-A3	C3	D
Gefährlicher Abfall zur Deponie	[kg]	1,70E-3	0,00E+0	-3,89E-3
Entsorgter nicht gefährlicher Abfall	[kg]	3,06E+0	0,00E+0	1,27E+0
Entsorgter radioaktiver Abfall	[kg]	8,13E-2	0,00E+0	-1,07E+0
Komponenten für die Wiederverwendung	[kg]	0,00E+0	0,00E+0	IND
Stoffe zum Recycling	[kg]	0,00E+0	0,00E+0	IND
Stoffe für die Energierückgewinnung	[kg]	IND	6,05E+2	IND
Exportierte elektrische Energie	[MJ]	IND	0,00E+0	IND
Exportierte thermische Energie	[MJ]	IND	0,00E+0	IND

6. LCA: Interpretation

Die folgende Interpretation enthält eine Zusammenfasssung der Ökobilanzergebnisse bezogen auf eine funktionelle Einheit von 1 m³ OSB Platte.
Der abiotische Verbrauch elementarer Ressourcen **(ADPE)** ist hauptsächlich von der Rohstoffbereitstellung dominiert. Hier spielt das Klebersystem die entscheidende Rolle.
Beim abiotischen Verbrauch fossiler Ressourcen **(ADPF)** geht etwa die Hälfte der Wirkung auf die Bereitstellung thermischer Energie zurück. Der Einsatz von Erdgas wirkt sich hier stark aus.

Versauerungs- und Eutrophierungspotential **(AP, EP)** werden teils durch die Rohstoffbereitstellung, teils durch Energieerzeugung und teils durch Prozessemissionen verursacht.

Das Treibhauspotential **(GWP)** nimmt eine besondere Stellung ein, da durch die Sequestrierung von Kohlenstoffdioxid im Holz negative Werte in der Bilanz in den Modulen A1-A3 entstehen.
Die Speicherung des Kohlenstoffs während des Baumwachstums schlägt sich in der Rohstoffbereitstellung nieder. Dieser gespeicherte

Rockwool

UMWELT-PRODUKTDEKLARATION
nach ISO 14025 und EN 15804

Deklarationsinhaber	Deutsche ROCKWOOL Mineralwoll GmbH & Co. OHG
Herausgeber	Institut Bauen und Umwelt (IBU)
Programmhalter	Institut Bauen und Umwelt (IBU)
Deklarationsnummer	EPD-DRW-2012121-D
Ausstellungsdatum	18.12.2012
Gültigkeit	17.12.2017

Steinwolle-Dämmstoffe im mittleren Rohdichtebereich
Deutsche ROCKWOOL Mineralwoll GmbH & Co. OHG

www.bau-umwelt.com

Institut Bauen und Umwelt e.V.

ROCKWOOL
DÄMMT PERFEKT & BRENNT NICHT

2.3 Technische Daten

- Nennwert Wärmeleitfähigkeit λ_D nach /DIN EN 13162/: 0,032 bis 0,048 [W/m·K]
- Bemessungswert Wärmeleitfähigkeit λ gemäß allgemeiner bauaufsichtlicher Zulassung: 0,032 bis 0,048 [W/m·K]
- Wasserdampfdiffusionswiderstandszahl nach /EN 12086/ μ = 1
- Wasserdampfdiffusionsäquivalente Luftschichtdicke = μ x Bauteildicke in [m];
  (bei 1 m Dicke wäre diese 1)
- Rohdichte gem. /DIN 1602/: 61 bis 120 kg/m³
- Druckspannung gem. /EN 826/: 0,5 bis 40 kPa
- Schallabsorptionsgrade α_S in Abhängigkeit von der Frequenz nach /DIN EN ISO 354/ sind den Datenblättern für die entsprechenden Produkte zu entnehmen. Beispiel Schallschluckplatte RAF (30- mm-Platte mit 200 mm Luftraum):

F [Hz]	125	250	500	1000	2000	4000
α_S	0,34	0,73	0,93	0,81	0,92	0,94

2.4 Inverkehrbringung/Anwendungsregeln

Produktnorm: DIN EN 13162: 2009-02, Wärmedämmstoffe für Gebäude - Werkmäßig hergestellte Produkte aus Mineralwolle (MW) - Spezifikation; Deutsche Fassung EN 13162:2008.

Allgemeine bauaufsichtliche Zulassung des DIBt für Wärmedämmstoffe aus Mineralwolle (MW) nach /DIN EN 13162: 2009-02/.

Für Steinwolle-Dämmstoffe der Gesellschaft Deutsche ROCKWOOL Mineralwoll GmbH & Co. OHG gilt die Zulassung Nr. Z-23.15-1468 vom 16. April 2012.

Voraussetzung für die Zulassung:

Seit 01.06.2000 gilt in Deutschland ein Verbot des Herstellens, Inverkehrbringens und Verwendens von Mineralwolle-Dämmstoffen, die nicht die Freizeichnungskriterien des Anhangs IV, Nr. 22, Absatz 2 der Gefahrstoffverordnung sowie des Anhangs 1 Abschnitt 23 zu § 1 Chemikalien-Verbotsverordnung erfüllen.

2.5 Lieferzustand

Die Steinwolledämmstoffe sind in verschiedenen Längen und Breiten erhältlich als Matten, Bahnen, Platten, Zöpfe und Formteile, wobei Dicken bis zu 350 mm möglich sind.

Rohdichte: 61 kg/m³ bis einschließlich 120 kg/m³

2.6 Grundstoffe/Hilfsstoffe

Rohstoffe sind die natürlich vorkommenden Gesteine Diabas/Basalt (27–50 Masse-%) sowie zementgebundene Formsteine (50–73 Masse-%). Hinzu kommt bis max. 3,5 % TM Bindemittel (harnstoffmodifiziertes Phenol-Formaldehyd-Harz mit Glukose) sowie max. 0,2 % aliphatisches Mineralöl und max. 0,1 % Haftvermittler (Siloxanol). Weitere Hilfsstoffe oder Zusatzmittel werden nicht verwendet.

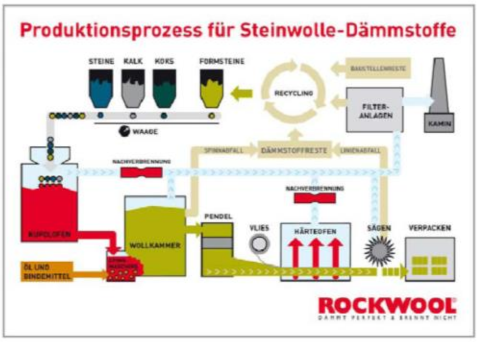
2.7 Herstellung

Diabas/Basalt sowie Betonformsteine werden mittels Koks als Energieträger im Kupolofen bei ca. 1.400–1.500 °C geschmolzen und im Walzenspinnerverfahren zerfasert. Gleich danach werden Schmelzmittel (Mineralöle) und Bindemittel (harnstoffmodifiziertes Phenol-Formaldehyd-Harz) in wässriger Lösung aufgesprüht. Das Bindemittel dient der Gewährleistung von Bindung und Formstabilität, das Schmelzmittel der Staubminderung und Hydrophobierung. Der in der wässrigen Lösung ebenfalls enthaltene Haftvermittler unterstützt die Anhaftung des Bindemittels an den Fasern. Die Rohwolle wird in Sammelkammern, welche unter Unterdruck stehen, auf Transportbändern abgelegt. Das Rohvlies wird kontinuierlich ausgetragen und Härteöfen zugeführt, in denen 200–300 °C heiße Luft durch die Wollmasse gesaugt wird, wobei sich die Bindemittel zu Duroplasten vernetzen. Anschließend werden Kaschierungen aufgebracht oder das Vlies wird mit Drahtgeflecht versteppt. Dies ist jedoch nicht Teil der vorliegenden Deklaration.

Schließlich wird das Produkt mittels Sägen in Form gebracht.

Die während des Produktionsbetriebes entstehenden Abluftmengen werden mechanisch gefiltert und überwiegend thermisch nachverbrannt. Über Wärmetauscher wird der hierbei freigesetzte Wärmeinhalt zur Vorwärmung des Ofenwindes verwendet. Die abgeschiedenen Stäube werden als Rohstoff erneut genutzt.

Das Prozesswasser wird intern gereinigt und zu einem erheblichen Teil wieder in den Prozess zurückgeführt.



Gütesicherung:

Eigen- und Fremdüberwachung nach Bauregelliste, Teil B, Zulassung Nr. Z 23.15-1468 bzw. CE-Kennzeichnung nach europäischen Vorschriften.

Für Produkte der technischen Isolierung nach VDI 2055 entsprechend AGI Q 132.

Alle Produkte nach RAL-GZ 388.

Qualitätsmanagementsystem gemäß /DIN EN ISO 9001/.

2.8 Umwelt und Gesundheit während der Herstellung

Gesundheitsschutz Herstellung:

Für Mineralwolle-Dämmstoffe gelten in Deutschland folgende spezielle Vorschriften:

Verbot des Herstellens und Verwendens biopersistenter Fasern (Gefahrstoffverordnung, Anhang IV, Nr. 22)

Verbot des Inverkehrbringens biopersistenter Fasern (Chemikalien-Verbotsverordnung, Nr. 23 des Anhangs zu § 1)

Neben den gesetzlichen Vorgaben sind keine weiteren besonderen Maßnahmen erforderlich.

ROCKWOOL
DÄMMT PERFEKT & BRENNT NICHT

5 LCA: Ergebnisse

Es folgt die Darstellung der Umweltwirkungen für 1 m³ Steinwolle mit einer durchschnittlichen Rohdichte von 94 kg/m³, hergestellt von der Deutschen ROCKWOOL Mineralwoll GmbH & Co. OHG. Die folgenden Tabellen zeigen die Ergebnisse der Indikatoren der Wirkungsabschätzung, des Ressourceneinsatzes sowie zu Abfällen und sonstigen Output-Strömen bezogen auf 1 m³ Steinwolledämmstoff. Die mit „x“ gekennzeichneten Module nach /DIN EN 15804/ werden hierbei adressiert.

ANGABE DER SYSTEMGRENZEN (X = IN ÖKOBILANZ ENTHALTEN; MND = MODUL NICHT DEKLARIERT)

Produktstadium			Stadium der Errichtung des Bauwerks		Nutzungsstadium							Entsorgungsstadium				Gutschriften und Lasten außerhalb der Systemgrenze
Rohstoffversorgung	Transport	Herstellung	Transport zur Baustelle	Einbau ins Gebäude	Nutzung / Anwendung	Instandhaltung	Reparatur	Ersatz	Erneuerung	Energieeinsatz für das Betreiben des Gebäudes	Wassereinsatz für das Betreiben des Gebäudes	Rückbau / Abriss	Transport	Abfallbehandlung	Deponierung	Wiederverwendungs-, Rückgewinnungs- oder Recyclingpotential
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
x	x	x	MND	x	MND	MND	MND	MND	MND	MND	MND	MND	x	MND	x	x

ERGEBNISSE DER ÖKOBILANZ UMWELTAUSWIRKUNGEN: 1 m³ Steinwolle, 94 kg/m³

		Produktion	Einbau	Transport	Deponierung	Gutschrift
Parameter	**Einheit**	**A1-A3**	**A5**	**C2**	**C4**	**D**
Globales Erwärmungspotential	[kg CO_2-Äq.]	82,64	11,11	0,40	7,38	-5,92
Abbau Potential der stratosphärischen Ozonschicht	[kg CFC11-Äq.]	3,10E-06	8,19E-09	7,03E-10	2,40E-08	-2,89E-07
Versauerungspotential von Boden und Wasser	[kg SO_2-Äq.]	6,24E-01	2,29E-03	1,31E-03	8,16E-03	-5,83E-03
Eutrophierungspotential	[kg PO_4^{3-}- Äq.]	8,49E-02	5,64E-04	2,85E-04	2,36E-02	-7,18E-04
Bildungspotential für troposphärisches Ozon	[kg Ethen Äq.]	3,39E-02	2,02E-04	1,71E-04	2,48E-03	-6,16E-04
Potential für den abiotischen Abbau nicht fossiler Ressourcen	[kg Sb Äq.]	2,28E-05	4,32E-07	1,34E-08	4,07E-08	-3,59E-07
Potential für den abiotischen Abbau fossiler Brennstoffe	[MJ]	1073,10	5,47	5,55	16,64	-89,20

ERGEBNISSE DER ÖKOBILANZ RESSOURCENEINSATZ: 1 m³ Steinwolle, 94 kg/m³

		Produktion	Einbau	Transport	Deponierung	Gutschrift
Parameter	**Einheit**	**A1-A3**	**A5**	**C2**	**C4**	**D**
Erneuerbare Primärenergie als Energieträger	[MJ]	140,51	0,04	0,01	1,06	-3,69
Erneuerbare Primärenergie zur stofflichen Nutzung	[MJ]	13,61	n/a	n/a	n/a	n/a
Total erneuerbare Primärenergie	[MJ]	154,12	0,04	0,01	1,06	-3,69
Nicht-erneuerbare Primärenergie als Energieträger	[MJ]	1072,44	5,77	5,58	17,52	-99,43
Nicht-erneuerbare Primärenergie zur stofflichen Nutzung	[MJ]	112,45	n/a	n/a	n/a	n/a
Total nicht erneuerbare Primärenergie	[MJ]	1184,90	5,77	5,58	17,52	-99,43
Einsatz von Sekundärstoffen	[kg]	30,6	n/a	n/a	n/a	n/a
Erneuerbare Sekundärbrennstoffe	[MJ]	2,50	0,00	0,00	0,00	0,00
Nicht erneuerbare Sekundärbrennstoffe	[MJ]	56,66	0,00	0,00	0,00	0,00
Einsatz von Süßwasserressourcen	[m³]	0,311	0,011	0,000	0,029	-0,019

ERGEBNISSE DER ÖKOBILANZ OUTPUT-FLÜSSE UND ABFALLKATEGORIEN: 1 m³ Steinwolle, 94 kg/m³

		Produktion	Einbau	Transport	Deponierung	Gutschrift
Parameter	**Einheit**	**A1-A3**	**A5**	**C2**	**C4**	**D**
Gefährlicher Abfall zur Deponie*	[kg]	3,32E-02	2,28E-01	0,00E+00	3,28E-03	-1,71E-05
Entsorgter nicht gefährlicher Abfall	[kg]	324,82	0,24	0,03	96,00	-10,15
Entsorgter radioaktiver Abfall	[kg]	3,86E-02	9,23E-05	8,75E-06	1,02E-04	-3,63E-03
Komponenten für die Wiederverwendung	[kg]	n/a	n/a	n/a	n/a	n/a
Stoffe zum Recycling	[kg]	n/a	n/a	n/a	n/a	n/a
Stoffe für die Energierückgewinnung	[kg]	n/a	n/a	n/a	n/a	n/a
Exportierte Energie [Strom]	[MJ]	n/a	6,81	0,00	3,43	n/a
Exportierte Energie [Therm.E.]	[MJ]	n/a	67	0,00	0,00	n/a

CLT

ENVIRONMENTAL PRODUCT DECLARATION

in accordance with ISO 14025 and EN 15804

Declaration holder	**Studiengemeinschaft Holzleimbau e.V.**
Publisher	Institut Bauen und Umwelt (IBU)
Programme holder	Institut Bauen und Umwelt (IBU)
Declaration number	EPD-SHL-2012211-EN
Issue date	20.09.2014
Validity	19.09.2015

Cross-laminated timber (X-Lam)

Studiengemeinschaft Holzleimbau e.V.

Institut Bauen und Umwelt e.V.

www.bau-umwelt.com

BSP Holz

Institut für Bautechnik or European technical approvals (ETAs) which contain information on manufacturing, quality control and marking as well as the product features and design.

2.5 Delivery status

The products can be manufactured in the following sizes. The permissible sizes can vary depending on the manufacturer and the respective abZ or ETA:

Min. thickness: 51 mm

Max. thickness: 500 mm (standard thickness to 300 mm)

Max. width 2.95 m – 4.80 m

Max. length 16 m – 20 m

2.6 Base materials / Auxiliaries

X-Lam comprises at least three layers of kiln-dried coniferous wood boards or plank laminations glued together crosswise. Polyurethane (PUR) or melamine-urea-formaldehyde adhesives (MUF) are used for basic duroplastic gluing as well as smaller quantities of emulsion-polymer-isocyanate (EPI) adhesives.

The percentage averages of ingredients per cubic metre of X-Lam established for the Environmental Product Declaration:

- Coniferous wood, primarily spruce: approx. 87.5%
- Water: approx. 10.5%
- PUR adhesives: approx. 0.5%
- MUF adhesives: approx. 1.4%
- EPI adhesives: approx. 0.1%

The product has an average gross density of 491.65 kg/m³.

2.7 Manufacture

The manufacture of X-Lam involves drying coniferous boards and timbers to less than 15% moisture content, followed by pre-planing and visual or machine-strength grading. Board sections identified as having strength-reduced areas are removed depending on the requisite strength class and the ensuing board sections jointed by finger-joints to form lamellas of infinite length.

During the subsequent pre-planing process, the lamellas are planed on four sides to thicknesses ranging from 17 mm to 45 mm. Some manufacturers use edge gluing to glue the lamellas to form a single-layered solid wood panel.

If the X-Lam manufacturer produces single-layered solid wood panels first, they are planed after hardening, glued and then arranged crosswise in the press.

Manufacturers working without edge gluing directly arrange the lamellas crosswise in the press.

Depending on the manufacturer, individual layers can be manufactured from wood-based panels which can be jointed.

After pressing and hardening, the blank is planed, bevelled, bound and packed. Preservative treatment is possible if necessary.

2.8 Environment and health during manufacturing

Waste air generated during production is cleaned in accordance with statutory specifications. Water and soil do not incur any pollution. The process waste water incurred is fed into the local waste water system. Noise-intensive machinery is encapsulated accordingly by way of structural measures.

2.9 Product processing / Installation

X-Lam can be processed using the standard tools suitable for processing solid wood.

The information concerning industrial safety must also be observed during processing/assembly.

2.10 Packaging

Polyethylene foils are used.

2.11 Condition of use

Composition for the period of use complies with the compilation of base materials in accordance with section 2.6. "Base materials".

During usage, around 216 kg of carbon are bound in the product. This complies with approx. 789 kg of CO_2 for full oxidation.

2.12 Environment and health during use

Environmental protection: In accordance with the current state of knowledge, no hazards are incurred for water, air or soil when the products are used as designated.
Health protection: In accordance with the current state of knowledge, no damage to or impairments of health are to be anticipated.
With regard to formaldehyde, X-Lam is low-emission thanks to its adhesive content, structure and form of use.

X-Lam glued with PUR or EPI adhesives displays formaldehyde emission values in the range of natural wood (around 0.004 ml/m³). MDI emissions by X-Lam glued with PUR or EPI adhesives can not be measured within the framework of the detection limit of 0.05 µg/m³. On account of the high reactivity of MDI towards water (air and wood moisture), it can be assumed that X-Lam glued this way already displays MDI emissions in the zero-value range shortly after manufacture.

X-Lam glued with MUF adhesives emits formaldehyde subsequently. Measured at the limit value of 0.1 ml/m³ of the Chemical Restriction Regulation, the values can be classified as low after testing (DIN EN 717-1). Average emissions are 0.04 ml/m³. In individual cases, they can account for approx. 0.06 ml/m³.

2.13 Reference service life

X-Lam complies with glued laminated timber in terms of its components and manufacturing process. Glued laminated timber has been used for more than 100 years. When used as designated, there is no known or anticipated limit to its durability.

The service life of X-Lam is therefore in line with the service life of the respective building when used as designated.

2.14 Extraordinary effects

Fire

- Fire class D in accordance with DIN EN 13501-1
- Smoke class s2 – normal smoke development
- d0 – non-dripping

BSP Holz

5 LCA: Results

SYSTEM LIMITS (X = INCLUDED IN LCA; MND = MODULE NOT DECLARED)																
Production stage			Building construction stage		Usage phase							Disposal stage				Credits and encumbrances outside the system limit
Provision of raw materials	Transport	Manufacture	Transport to the site	Installation in the building	Use / Application	Maintenance	Repairs	Substitution	Renewal	Energy used for operating the building	Water used for operating the building	Rebuilding / Demolition	Transport	Waste treatment	Landfilling	Reuse, recovery or recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	X	X	X	X

LIFE CYCLE ASSESSMENT RESULTS - ENVIRONMENTAL EFFECTS: 1m³ X-Lam

		Production			Disposal			Credit
Parameter	Unit	A1	A2	A3	C2	C3	C4	D
GWP	[kg CO_2 equiv.]	-7.31E+02	7.23E+00	1.22E+02	4.45E-01	7.93E+02	0.00E+00	-3.60E+02
ODP	[kg CFC11 equiv.]	4.29E-06	7.71E-08	2.84E-05	8.89E-10	1.19E-06	0.00E+00	-8.23E-05
AP	[kg SO_2 equiv.]	2.41E-01	3.12E-02	4.00E-01	1.91E-03	6.98E-03	0.00E+00	-3.70E-01
EP	[kg PO_4^{3-} equiv.]	5.83E-02	7.10E-03	6.75E-02	4.42E-04	5.89E-04	0.00E+00	-3.55E-03
POCP	[kg ethene equiv.]	5.19E-02	3.18E-03	8.01E-02	2.07E-04	4.64E-04	0.00E+00	-2.48E-02
ADPE	[kg Sb equiv.]	4.97E-04	2.23E-07	1.19E-04	9.39E-09	1.23E-07	0.00E+00	-6.23E-06
ADPF	[MJ]	8.55E+02	1.00E+02	1.32E+03	6.28E+00	4.62E+01	0.00E+00	-4.05E+03

Legend	GWP = Global Warming Potential; ODP = Ozone Depletion Potential; AP = Acidification Potential; EP = Eutrification Potential; POCP Ozone Creation Potential; ADPE = Abiotic Depletion Potential for Non-fossil Resources; ADPF = Abiotic Depletion Potential for Fossil Fuels

LIFE CYCLE ASSESSMENT RESULTS - USE OF RESOURCES: 1m³ X-Lam

		Production			Disposal			Credit
Parameter	Unit	A1	A2	A3	C2	C3	C4	D
PERE	[MJ]	8.29E+02	3.67E-01	1.69E+03	8.31E-03	4.70E+00	0.00E+00	-3.28E+02
PERM	[MJ]	8.29E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PERT	[MJ]	9.12E+03	3.67E-01	1.69E+03	8.31E-03	4.70E+00	0.00E+00	-3.28E+02
PENRE	[MJ]	9.04E+02	1.03E+02	2.29E+03	6.31E+00	8.78E+01	0.00E+00	-7.39E+03
PENRM	[MJ]	9.95E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PENRT	[MJ]	1.00E+03	1.03E+02	2.29E+03	6.31E+00	8.78E+01	0.00E+00	-7.39E+03
SM	[kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF	[MJ]	6.39E+01	0.00E+00	3.84E+00	0.00E+00	0.00E+00	0.00E+00	4.28E+03
NRSF	[MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW	[m³]	8.06E+02	4.51E+00	1.42E+03	1.18E-01	4.99E+01	0.00E+00	3.36E+03

Legend	PERE = Primary Energy, Renewable; PERM = Primary energy, non-renewable; PERT = Primary energy, renewable, total; PENRE = Primary energy, non-renewable; PENRM = Primary energy, non-renewable, for material usage; PENRT = Primary energy, non-renewable, total; SM = Use of secondary materials; RSF = Renewable secondary fuels; NRSF = Non-renewable secondary fuels; FW = Use of fresh water resources

LIFE CYCLE ASSESSMENT RESULTS - OUTPUT FLOWS AND WASTE CATEGORIES: 1m³ X-Lam

		Production			Disposal			Credit
Parameter	Unit	A1	A2	A3	C2	C3	C4	D
HWD	[kg]	9.02E-02	0.00E+00	6.32E-02	0.00E+00	0.00E+00	0.00E+00	1.47E+00
NHWD	[kg]	2.36E-02	0.00E+00	5.83E-03	0.00E+00	0.00E+00	0.00E+00	4.46E-05
RWD	[kg]	5.22E-02	9.67E-04	3.47E-01	1.11E-05	1.49E-02	0.00E+00	-1.03E+00
CRU	[kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MFR	[kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.93E+02	0.00E+00	0.00E+00
MER	[kg]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.93E+02	0.00E+00	-4.93E+02
EE electricity	[MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EE heat	[MJ]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Legend	HWD = Hazardous waste for landfilling; NHWD = Non-hazardous waste disposed of; RWD = Radioactive waste disposed of; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EE = Exported energy per type

Glulam

Ver. 4 2014

ENVIRONMENTAL PRODUCT DECLARATION

in accordance with ISO 14025, ISO 21930 and EN 15804

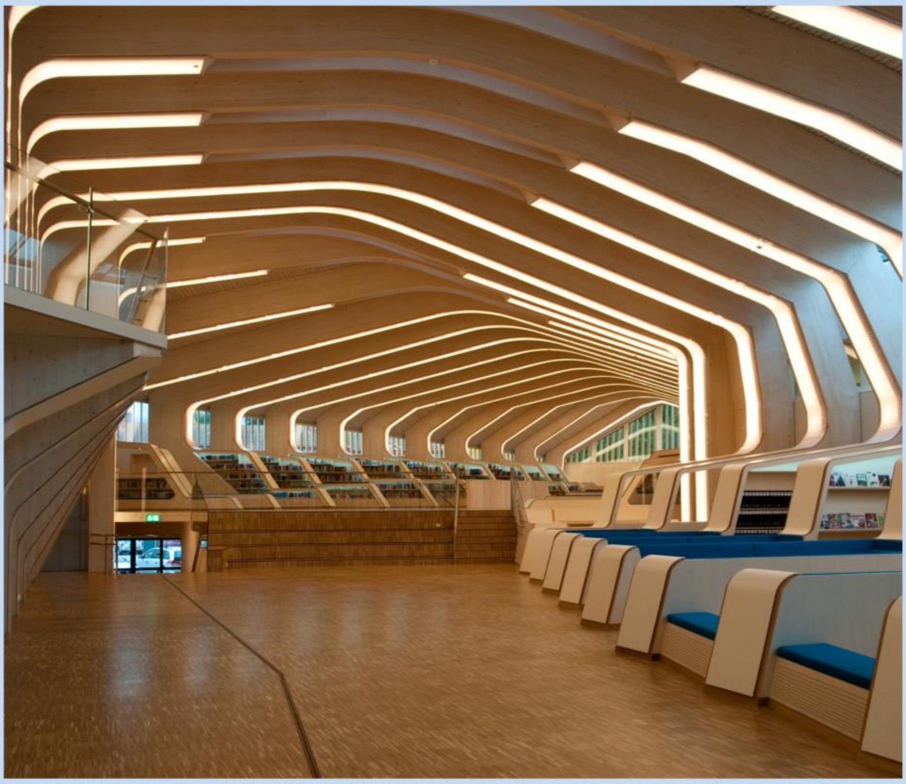
epd-norge.no
The Norwegian EPD Foundation

Eier av deklarasjonen:	Moelven Limtre AS
Program operatør:	Næringslivets Stiftelse for Miljødeklarasjoner
Utgiver:	Næringslivets Stiftelse for Miljødeklarasjoner
Deklarasjon nummer:	NEPD-336-222-NO
Godkjent dato:	01.07.2015
Gyldig til:	01.07.2020

Standard limtrebjelke

Moelven Limtre AS

www.epd-norge.no



NEPD-336-222-NO Standard Limtrebjelke, Moelven Limtre AS 1

Produkt

Produktbeskrivelse:
Limtre er oppbygd av trelameller som er sammenbundet med lim. Fiberretningen i lamellene går parallelt med bjelkens lengderetning. Bruksområde er takbjelker, kantbjelker, bjelkelag, sperrer, hallkonstruksjoner, bruer.

Tekniske data:
GL30c styrkeklassen. Produsert etter EN 14080:2013. Limtre har en densitet på 470 kg/m^3 og en fuktighet på 12%.

Produktspesifikasjon:
Lameltykkelsen er 45mm for standard dimensjoner. Bjelkens høyde er multipel av dette, f.eks. 225, 270, 315 osv. Spesialprodukter og buer med små radier kan/må produseres med andre lamelltykkelser.

Materialer	kg	%
Høvellast av gran eller furu	461,22	98,13
Lim	8,78	1,87
Totalt for produktet	470	100,00
Plastemballasje	1	
Totalt med emballasje	471	

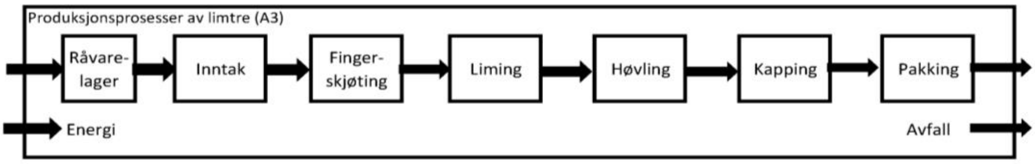
Markedsområde:
Norge og Sverige

Levetid:
Referanselevetid er den samme som for byggverket, som regel settes denne til 60 år.

LCA: Beregningsregler

Deklarert enhet:
Produksjon av 1 m3 standard limtrebjelke av gran eller furu

Systemgrenser:
Flytskjema for produksjonen (A3) av limtre er vist under, mens resten av modulene er vist på side 5. Modul D er beregnet med energisubstitusjon og er nærmere forklart under scenarioene.



Datakvalitet:
Data for produksjonen av limtre ble hentet inn i 2014 og representerer et snitt for 2013. Data for skurlast et hentet fra norsk EPD med data representativt for 2013. Data for produksjon av lim er hentet fra de spesifikke leverandørene. Andre data er hentet fra Ecoinvent v3.1 som ble lansert i 2014. Data for fjernvarme er hentet fra Statistisk sentralbyrå og er representative for et gjennomsnitt i 2013.

Cut-off kriterier:
Alle viktige råmaterialer og all viktig energibruk er inkludert. Produksjonsprosessen for råmaterialene og energistrømmer som inngår med veldig små mengder (<1%) er ikke inkludert. Disse cut-off kriteriene gjelder ikke for farlige materialer og stoffer.

Allokering:
Allokering er gjort i henhold til bestemmelser i EN 15804. Inngående energi, vann, avfall og interntransport er allokert etter volum mellom alle produktene. Påvirkning for primærproduksjonen av resirkulerte materialer er allokert til hovedproduktet der materialet ble brukt. I verdikjeden av trevirke er det brukt økonomisk allokering.

Beregning av biogent karboninnhold:
Opptak og utslipp av karbondioksid fra biologisk opphav er beregnet basert på NS-EN 16485:2014. Denne metoden er basert på modularitetsprinsippet i EN 15804:2012, og hvor utslipp skal telles med i den livsløpsmodulen hvor det faktisk skjer. Mengden karbondioksid er beregnet i henhold til NS-EN 16449:2014. Med en gjennomsnittlig densitet på 461 kg/m^3 for limtre, så vil karboninnholdet omregnet til karbondioksid gi 755 kg CO_2 per m^3 trevirke.

Estimater og antakelser:
Nøkkelestimater og antakelser er enten presentert i EPD eller finnes i NPCR015 (08/2013).

LCA: Resultater

Resultatene for global oppvarming i A1-A3 gir store utslag for opptaket av karbondioksid gjennom fotosyntesen under trevirkets vekst. Den samme mengden karbondioksid slippes ut ved avfallsforbrenning i C3.

Systemgrenser (X = inkludert, MID = modul ikke deklarert, MIR = modul ikke relevant)

Produktfase			Konstruksjon installasjon fase		Bruksfase							Sluttfase				Etter endt levetid
Råmaterialer	Transport	Tilvirkning	Transport	Konstruksjon installasjon fase	Bruk	Vedlikehold	Reparasjon	Utskiftinger	Renovering	Operasjonell energibruk	Operasjonell vannbruk	Demontering	Transport	Avfallsbehandling	Avfall til sluttbehandling	Gjenbruk-gjenvinning-resirkulering-potensiale
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Miljøpåvirkning

Parameter	Unit	A1-A3	A4	A5	C1	C2	C3	B1-B7, C4	D
GWP	kg CO_2-ekv	-6,63E+02	1,19E+01	7,11E+00	7,02E-03	9,31E+00	7,84E+02	0	-3,38E+02
ODP	kg CFC11-ekv	1,19E-05	2,20E-06	8,16E-07	6,09E-10	1,64E-06	5,89E-07	0	-5,14E-05
POCP	kg C_2H_4-ekv	5,34E-02	2,05E-03	3,09E-03	1,87E-06	1,74E-03	4,69E-03	0	-8,63E-02
AP	kg SO_2-ekv	7,43E-01	4,84E-02	4,82E-02	3,93E-05	5,01E-02	1,22E-01	0	-1,63E+00
EP	kg PO_4^{3-}-ekv	1,66E-01	8,13E-03	1,08E-02	8,77E-06	9,33E-03	3,20E-02	0	-1,15E-01
ADPM	kg Sb-ekv	2,72E-04	3,45E-05	1,72E-05	1,73E-07	2,36E-05	1,10E-05	0	-7,84E-05
ADPE	MJ	1,42E+03	1,82E+02	9,06E+01	6,29E-02	1,39E+02	7,46E+01	0	-2,43E+03

GWP Globalt oppvarmingspotensial; ODP Potensial for nedbryting av stratosfærisk ozon; POCP Potensial for fotokjemisk oksidantdanning; AP Forsurningspotensial for kilder på land og vann; EP Overgjødslingspotensial; ADPM Abiotisk uttømmingspotensial for ikke-fossile ressurser; ADPE Abiotisk uttømmingspotensial for fossile ressurser

Ressursbruk

Parameter	Unit	A1-A3	A4	A5	C1	C2	C3	B1-B7, C4	D
RPEE	MJ	3,22E+03	2,37E+00	5,58E+02	1,13E+00	2,27E+00	7,91E+03	0	-1,58E+03
RPEM	MJ	7,91E+03	INA	-1,22E-14	INA	INA	-7,91E+03	0	INA
TPE	MJ	1,11E+04	2,37E+00	5,58E+02	1,13E+00	2,27E+00	1,80E+00	0	-1,58E+03
NRPE	MJ	1,35E+03	1,83E+02	9,52E+01	8,99E-02	1,40E+02	2,26E+02	0	-4,41E+03
NRPM	MJ	1,56E+02	INA	-1,01E-16	INA	INA	-1,56E+02	0	INA
TRPE	MJ	1,51E+03	1,83E+02	9,52E+01	8,99E-02	1,40E+02	7,05E+01	0	-4,41E+03
SM	kg	INA	INA	INA	INA	INA	INA	0	INA
RSF	MJ	INA	INA	INA	INA	INA	INA	0	INA
NRSF	MJ	INA	INA	INA	INA	INA	INA	0	INA
W	m^3	2,03E+02	-3,16E-03	1,02E+01	8,51E-03	-1,51E-02	2,50E-01	0	-4,60E+00

RPEE Fornybar primærenergi brukt som energibærer; RPEM Fornybar primærenergi brukt som råmateriale; TPE Total bruk av fornybar primærenergi; NRPE Ikke fornybar primærenergi brukt som energibærer; NRPM Ikke fornybar primærenergi brukt som råmateriale; TRPE Total bruk av ikke fornybar primærenergi; SM Bruk av sekundære materialer; RSF Bruk av fornybart sekundære brensel; NRSF Bruk av ikke fornybart sekundære brensel; W Netto bruk av ferskvann

Concrete

Ver 1114

ENVIRONMENTAL PRODUCT DECLARATION

ISO 14025 ISO 21930 EN 15804

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The Norwegian EPD Foundation

Eier av deklarasjonen	Velde Betong AS
Programoperatør	Næringslivets Stiftelse for Miljødeklarasjoner
Deklarasjonsnummer	NEPD-334-218-NO
Godkjent dato	08.06.2015
Gyldig til	08.06.2020

1 M3. B45 SV40 <200mm

Produkt

Velde Betong AS

Eier av deklarasjon

VELDE

NEPD-334-218-NO 1 M3. B45 SV40 <200mm, Velde Betong AS 1

Produkt

Produktbeskrivelse:
-Fabrikkblandet betong produsert i henhold til NS-EN 206-1.
-Produktene anvendes til støping av såle, gulv, dekker, vegger, søyler med mer.

Tekniske data:
-Fasthetsklasser B45. -Bestandighetsklasse SV40 - Egenvekt 2300-2600 kg.

Markedsområde:
Rogaland: Sandnes, Stavanger, Gjesdal, Hå, Klepp, Sola, Randaberg og Time Kommune

Levetid:
Som for bygninger

Produktspesifikasjon:
-Fabrikkblandet betong produsert i henhold til NS-EN 206-1.

Materials	Percent
Cement	16,17
Aggregate	76,00
Water	6,99
Chemicals	0,19
SCM	0,65

LCA: Beregningsregler

Deklarert enhet:
1 m3 1 M3. B45 SV40 <200mm

Cut-off kriterier:
Alle viktige råmaterialer og all viktig energibruk er inkludert. Produksjonsprosessen for råmaterialene og energistrømmer som inngår med veldig små mengder (<1%) er ikke inkludert.

Allokering:
Allokering er gjort I hht bestemmelser I EN 15804 Inngående energi og vann, samt produksjon av avfall i egen produksjon er allokert likt mellom alle produktene gjennom masseallokering. Påvirkning for primærproduksjonen av resirkulerte materialer er allokert til hovedproduktet der materialet ble brukt. Resirkuleringsprosessen og transport av materialet er allokert til denne analysen.

Datakvalitet:

Materials	Data quality	Source	Year
Cement	EPD	NEPD 154N	2013
Aggregate	Supplier data	Østfoldforskning	2013
Aggregate	Database	Modified EcoInvent	2012
Chemicals	European average	Efca	
Water			
Chemicals	European Average	Efca	
SCM	Waste		

Systemgrenser:
Alle prosesser fra råvareuttak til produktet ut fra fabrikkporten er inkludert i analysen.

Flytskjema:

LCA: Resultater

System boundaries (X=included, MND=module not declared, MNR=module not relevant)

Product stage				Construction installation stage	User stage							End of life stage				Beyond the system bondaries
Raw materials	Transport	Manufacturing	Transport	Construction/ Installation stage	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction/ demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	MNR	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

Miljøpåvirkning (Environmental impact)

Parameter	Unit	A1	A2	A3	A4	A5	C1	C2
GWP	kg CO_2 -eqv	2,52E+002	8,20E-001	4,87E-002	1,06E+001			
ODP	kg CFC11 -eqv	7,70E-006	0,00E+000	6,00E-009	0,00E+000			
POCP	kg C_2H_4-eqv	5,62E-001	1,04E-003	3,63E-004	1,40E-002			
AP	kg SO_2 -eqv	1,91E-001	4,53E-003	1,79E-004	6,90E-002			
EP	kg PO_4^{3-} -eqv	5,65E-002	7,18E-004	1,54E-005	1,36E-002			
ADPM	kg Sb -eqv	4,43E-005	0,00E+000	0,00E+000	0,00E+000			
ADPE	MJ	1,26E+003	1,08E+001	4,21E-001	1,42E+002			

GWP Globalt oppvarmingspotensial; **ODP** Potensial for nedbryting av stratosfærisk ozon; **POCP** Potensial for fotokjemisk oksidantdanning; **AP** Forsurningspotensial for kilder på land og vann; **EP** Overgjødslingspotensial; **ADPM** Abiotisk uttømmingspotensial for ikke-fossile ressurser; **ADPE** Abiotisk uttømmingspotensial for fossile ressurser

Ressursbruk (Resource use)

Parameter	Unit	A1	A2	A3	A4	A5	C1	C2
RPEE	MJ	5,93E+001	1,40E-002	0,00E+000	1,87E-001			
RPEM	MJ	2,28E-001	4,51E-003	1,33E-002	2,53E-002			
TRPE	MJ	5,95E+001	1,86E-002	1,33E-002	2,12E-001			
NRPEE	MJ	1,46E+003	1,08E+001	4,86E-001	1,42E+002			
NRPEM	MJ	6,13E+001	0,00E+000	0,00E+000	0,00E+000			
TNRPE	MJ	1,52E+003	1,08E+001	4,86E-001	1,42E+002			
SM	kg	2,03E+002	0,00E+000	0,00E+000	0,00E+000			
RSF	MJ	0,00E+000	0,00E+000	0,00E+000	0,00E+000			
NRSF	MJ	6,20E+002	0,00E+000	0,00E+000	0,00E+000			
W	m^3	2,19E+002	9,61E-002	1,73E-005	1,07E+000			

RPEE Fornybar primærenergi brukt som energibærer; **RPEM** Fornybar primærenergi brukt som råmateriale; **TRPE** Total bruk av fornybar primærenergi; **NRPEE** Ikke fornybar primærenergi brukt som energibærer; **NRPEM** Ikke fornybar primærenergi brukt som råmateriale; **TNRPE** Total bruk av ikke fornybar primærenergi; **SM** Bruk av sekundære materialer; **RSF** Bruk av fornybart sekundære brensel; **NRSF** Bruk av ikke fornybart sekundære brensel; **W** Netto bruk av ferskvann

Livsløpets slutt - Avfall (End of life - Waste)

Parameter	Unit	A1	A2	A3	A4	A5	C1	C2
HW	kg	2,89E-003	0,00E+000	2,39E-006	1,16E-004			
NHW	kg	2,19E+001	2,07E-003	7,10E-002	2,95E-002			
RW	kg	0,00E+000	0,00E+000	0,00E+000	0,00E+000			

HW Avhendet farlig avfall; **NHW** Avhendet ikke-farlig avfall; **RW** Avhendet radioaktivt avfall

Livsløpets slutt - Utgangsfaktorer (End of life - Output flow)

Parameter	Unit	A1	A2	A3	A4	A5	C1	C2
CR	kg	0,00E+000	0,00E+000	0,00E+000	0,00E+000			
MR	kg	5,43E-001	0,00E+000	0,00E+000	0,00E+000			
MER	kg	0,00E+000	0,00E+000	0,00E+000	0,00E+000			
EEE	MJ	0,00E+000	0,00E+000	0,00E+000	0,00E+000			
ETE	MJ	0,00E+000	0,00E+000	0,00E+000	0,00E+000			

CR Komponenter for gjenbruk; **MR** Materialer for resikulering; **MER** Materialer for energigjenvinning; **EEE** Eksportert elektrisk energi; ETE Eksportert termisk energi

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Es kommt drauf an,
was man draus macht.

www.beton.org

A4 Anhang

Ergebnisse der Ökobilanz für 1 m³ Konstruktionsbeton C35/45

LCA: Ergebnisse

Die Wirkungsabschätzungsergebnisse stellen nur relative Aussagen dar. Sie machen keine Aussagen über Endpunkte der Wirkungskategorien, Überschreitungen von Schwellenwerten, Sicherheitsmargen oder über Risiken.

ANGABE DER SYSTEMGRENZEN (X = IN ÖKOBILANZ ENTHALTEN; MND = MODUL NICHT DEKLARIERT)

Rohstoffversorgung	Transport	Herstellung	Transport zur Baustelle	Einbau ins Gebäude	Nutzung / Anwendung	Instandhaltung	Reparatur	Ersatz	Erneuerung	Energieeinsatz für das Betreiben des Gebäudes	Wassereinsatz für das Betreiben des Gebäudes	Rückbau / Abriss	Transport	Abfallbehandlung	Beseitigung	Wiederverwendungs-, Rückgewinnungs- oder Recyclingpotenzial
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
x	x	x	x	x	x	x	x	x	x	MND	MND	x	x	x	MND	x

ERGEBNISSE DER ÖKOBILANZ UMWELTAUSWIRKUNGEN: 1 m³ Konstruktionsbeton C 35/45

Parameter	Einheit	A1-A3	A4	A5	B1-B5	C1	C2	C3	D
Globales Erwärmungspotenzial (GWP)	[kg CO_2-Äq.]	265,1[1)]	5,5	1,35	0[2)]	3,02	0,47	1,38	-23,08[2)]
Abbau Potential der stratosphärischen Ozonschicht (ODP)	[kg CFC11-Äq.]	7,98E-7	2,98E-10	3,06E-9	0	1,63E-14	2,65E-11	7,45E-11	-9,57E-8
Versauerungspotenzial von Boden und Wasser (AP)	[kg SO_2-Äq.]	0,364	0,0179	9,18E-3	0	0,0288	4,74E-3	0,013	-0,041
Eutrophierungspotenzial (EP)	[kg $(PO_4)^{3-}$- Äq.]	0,0572	0,0041	1,86E-3	0	6,13E-3	1,02E-3	2,80E-3	-5,91E-3
Bildungspotential für troposphärisches Ozon (POCP)	[kg Ethen Äq.]	0,0442	0,0022	6,49E-4	0	3,73E-3	7,12E-4	1,70E-3	-4,05E-3
Potenzial f. d. abiotischen Abbau nicht fossiler Ressourcen (ADP_{el})	[kg Sb Äq.]	4,68E-4	2,54E-7	5,15E-8	0	1,39E-7	2,17E-8	6,34E-8	-1,90E-6
Potenzial für den abiotischen Abbau fossiler Brennstoffe (ADP_{foss})	[MJ]	958,1	76,4	18,14	0	41,9	6,5	19,1	-242,7

1) Hierin enthalten sind 34,8 kg CO_2-Äq. aus der Verbrennung von Abfällen bei der Herstellung von Zementklinker. Nach dem Verursacherprinzip (EN 15804) wären diese dem Produktsystem zuzuordnen, das den Abfall verursacht hat. Innerhalb dieser EPD wird jedoch von einer Subtraktion dieses Anteils abgesehen. So soll über Ländergrenzen hinweg die Vergleichbarkeit von berechneten Treibhauspotenzialen auch dann sichergestellt werden, falls die bei der Klinkerherstellung eingesetzten Sekundärbrennstoffe in anderen Ländern keinen Abfallstatus haben sollten.

2) Zu einem möglichen zusätzlichen negativen Treibhauspotenzial aus der Carbonatisierung von Beton vgl. Abschnitt 4

ERGEBNISSE DER ÖKOBILANZ RESSOURCENEINSATZ: 1 m³ Konstruktionsbeton C 35/45

Parameter	Einheit	A1-A3	A4	A5	B1-B5	C1	C2	C3	D
Erneuerbare Primärenergie als Energieträger	[MJ]	92,2	3,1	0,43	0	1,7	0,26	0,762	-47,1
Erneuerbare Primärenergie zur stofflichen Nutzung	[MJ]	0	0	0	0	0	0	0	0
Total erneuerbare Primärenergie (PE_{ern})	[MJ]	92,2	3,1	0,43	0	1,7	0,26	0,762	-47,1
Nicht-erneuerbare Primärenergie als Energieträger	[MJ]	1.116,0	77,0	19,0	0	42,0	6,55	19,2	-319,0
Nicht-erneuerbare Primärenergie zur stofflichen Nutzung	[MJ]	0	0	0	0	0	0	0	0
Total nicht erneuerbare Primärenergie (PE_{nern})	[MJ]	1.116,0	77,0	19,0	0	42,0	6,55	19,2	-319,0
Einsatz von Sekundärstoffen	[kg]	90,9	0	0	0	0	0	0	0
Erneuerbare Sekundärbrennstoffe	[MJ]	209,4	0	0	0	0	0	0	0
Nicht erneuerbare Sekundärbrennstoffe	[MJ]	408,2	0	0	0	0	0	0	0
Einsatz von Süßwasserressourcen	[m³]	0,229	0	0	0	0,044	0	0	0

ERGEBNISSE DER ÖKOBILANZ OUTPUT-FLÜSSE UND ABFALLKATEGORIEN: 1 m³ Konstruktionsbeton C 35/45

Parameter	Einheit	A1-A3	A4	A5	B1-B5	C1	C2	C3	D
Gefährlicher Abfall zur Deponie	[kg]	0,233	0	0	0	0	0	0	0
Entsorgter nicht gefährlicher Abfall	[kg]	0,001	0	0	0	0	0	0	0
Entsorgter radioaktiver Abfall	[kg]	0,062	0	0,001	0	0	0	0	0
Komponenten für die Wiederverwendung	[kg]	0	0	0	0	0	0	0	0
Stoffe zum Recycling	[kg]	0	0	0	0	0	0	2.400	2.400
Stoffe für die Energierückgewinnung	[kg]	0	0	0	0	0	0	0	0
Exportierte elektrische Energie	[MJ]	0	0	0	0	0	0	0	0
Exportierte thermische Energie	[MJ]	0	0	0	0	0	0	0	0

7 InformationsZentrum Beton GmbH – Beton C 35/45

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Rebar Steel

bre

Environmental Product Declaration

BREG EN EPD No.: 000125 Issue: 01

ECO EPD Ref. No.: 000454

This is to certify that this verified Environmental Product Declaration provided by:

UK CARES

Is in accordance with the requirements of:

EN 15804:2012+A1:2013

This declaration is for:

Carbon Steel Reinforcing Bar (secondary production route – scrap), Sector Average

Company Address

Pembroke House
21 Pembroke Road
Sevenoaks, Kent
TN13 1XR

SUSTAINABILITY

	Emma Baker	01 December 2016
Signed for BRE Global Ltd	Operator	Date of this Issue
01 December 2016		30 November 2019
Date of First Issue		Expiry Date

This verified Environmental Product Declaration is issued subject to terms and conditions (for details visit www.greenbooklive.com/terms).

To check the validity of this EPD please visit www.greenbooklive.com/check or contact us.

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ECO PLATFORM EPD EN 15804 VERIFIED

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LCA Results

(INA = Indicator not assessed, AGG = Aggregated, NA = Not Applicable)

Indicator	Unit	A1 Raw Material supply	A2 Transport to factory	A3 Manufacturing	A1-A3 Merged A1/A2/A3	A4 Transport to site	A5 Construction - installation	B1 Use	B2 Maintenance	B3 Repair
Environmental impacts per declared/functional unit										
GWP	kg CO_2 eq.	AGG	AGG	AGG	839	16.1	94.8	0.00	0.00	0.00
ODP	kg CFC 11 eq.	AGG	AGG	AGG	8.20E-07	7.39E-11	8.21E-08	0.00	0.00	0.00
AP	kg SO_2 eq.	AGG	AGG	AGG	3.46	0.0396	0.36	0.00	0.00	0.00
EP	kg $(PO_4)^{3-}$ eq.	AGG	AGG	AGG	0.339	0.00918	0.0382	0.00	0.00	0.00
POCP	kg C_2H_4 eq.	AGG	AGG	AGG	0.257	-0.0111	0.0212	0.00	0.00	0.00
ADPE	kg Sb eq.	AGG	AGG	AGG	0.000154	1.07E-06	2.22E-05	0.00	0.00	0.00
ADPF	MJ eq.	AGG	AGG	AGG	9870	221	1140	0.00	0.00	0.00
GWP = Global Warming Potential (Climate Change); ODP = Ozone Depletion Potential; AP = Acidification Potential for Soil and Water; EP = Eutrophication Potential; POCP = Photochemical Ozone Creation; ADPE = Abiotic Depletion Potential – Elements; ADPF = Abiotic Depletion Potential – Fossil Fuels										
Resource use										
PERE	MJ	AGG	AGG	AGG	1260	12.6	188	0.00	0.00	0.00
PERM	MJ	AGG	AGG	AGG	0.00	0.00	0.00	0.00	0.00	0.00
PERT	MJ	AGG	AGG	AGG	1260	12.6	188	0.00	0.00	0.00
PENRE	MJ	AGG	AGG	AGG	10700	222	1240	0.00	0.00	0.00
PENRM	MJ	AGG	AGG	AGG	0.00	0.00	0.00	0.00	0.00	0.00
PENRT	MJ	AGG	AGG	AGG	10700	222	1240	0.00	0.00	0.00
SM	kg	AGG	AGG	AGG	1120	0.00	112	0.00	0.00	0.00
RSF	MJ	AGG	AGG	AGG	-0.129	0.00	-0.0129	0.00	0.00	0.00
NRSF	MJ	AGG	AGG	AGG	-2.03	0.00	-0.203	0.00	0.00	0.00
FW	m^3	AGG	AGG	AGG	1.45	0.03	0.18	0.00	0.00	0.07
PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Net use of fresh water										
Waste to disposal										
HWD	kg	AGG	AGG	AGG	0.13	1.68E-05	0.098	0.00	0.00	0.00
NHWD	kg	AGG	AGG	AGG	106	0.0187	267	0.00	0.00	0.00
TRWD	kg	AGG	AGG	AGG	0.32	0.000318	0.0369	0.00	0.00	0.00
RWDHL	kg	AGG	AGG	AGG	0.000394	4.65E-07	5.40E-05	0.00	0.00	0.00
HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; TRWD = Total Radioactive waste disposed; RWDHL = Radioactive waste disposed (high-level nuclear waste)										
Other output flows										
CRU	kg	AGG	AGG	AGG	0.00	0.00	0.00	0.00	0.00	0.00
MFR	kg	AGG	AGG	AGG	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	AGG	AGG	AGG	0.00	0.00	0.00	0.00	0.00	0.00
EE	MJ	AGG	AGG	AGG	0.00	0.00	0.00	0.00	0.00	0.00
CRU = Components for reuse; MFR = Materials for recycling; MER = Materials for energy recovery; EE = Export energy										

LCA Results (continued)

(INA = Indicator not assessed, AGG = Aggregated, NA = Not Applicable)

Indicator	Unit	B4 Replacement	B5 Refurbishment	B6 Operational energy use	B7 Operational water use	C1 Demolition	C2 Transport	C3 Waste Processing	C4 Disposal	D Reuse/ Recovery/ Recycling Potential
Environmental impacts per declared/functional unit										
GWP	kg CO_2 eq.	0.00	0.00	0.00	0.00	2.06	38.9	0.00	1.28	350
ODP	kg CFC 11 eq.	0.00	0.00	0.00	0.00	7.78E-12	1.77E-10	0.00	1.41E-11	-1.56E-09
AP	kg SO_2 eq.	0.00	0.00	0.00	0.00	0.00316	0.126	0.00	0.0077	1.34
EP	kg $(PO_4)^{3-}$ eq.	0.00	0.00	0.00	0.00	0.000428	0.0299	0.00	0.00105	0.106
POCP	kg C_2H_4 eq.	0.00	0.00	0.00	0.00	0.000381	-0.0324	0.00	0.000749	0.196
ADPE	kg Sb eq.	0.00	0.00	0.00	0.00	6.21E-08	2.51E-06	0.00	4.43E-07	-2.88E-05
ADPF	MJ eq.	0.00	0.00	0.00	0.00	28.6	535	0.00	16.7	3270
GWP = Global Warming Potential (Climate Change); ODP = Ozone Depletion Potential; AP = Acidification Potential for Soil and Water; EP = Eutrophication Potential; POCP = Photochemical Ozone Creation; ADPE = Abiotic Depletion Potential – Elements; ADPF = Abiotic Depletion Potential – Fossil Fuels										
Resource use										
PERE	MJ	0.00	0.00	0.00	0.00	0.0709	28.8	0.00	1.96	-171
PERM	MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERT	MJ	0.00	0.00	0.00	0.00	0.0709	28.8	0.00	1.96	-171
PENRE	MJ	0.00	0.00	0.00	0.00	28.6	537	0.00	17.3	3130
PENRM	MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PENRT	MJ	0.00	0.00	0.00	0.00	28.6	537	0.00	17.3	3130
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FW	m^3	0.00	0.00	0.23	1.45	0.03	0.18	0.00	0.00	0.07
PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Net use of fresh water										
Waste to disposal										
HWD	kg	0.00	0.00	0.00	0.00	0.098	3.84E-05	0.00	3.95E-07	4.44E-06
NHWD	kg	0.00	0.00	0.00	0.00	267	0.0428	0.00	80.1	4.96
TRWD	kg	0.00	0.00	0.00	0.00	0.0369	0.000759	0.00	0.000241	-0.0564
RWDHL	kg	0.00	0.00	0.00	0.00	5.40E-05	1.11E-06	0.00	3.06E-07	-7.16E-05
HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; TRWD = Total Radioactive waste disposed; RWDHL = Radioactive waste disposed (high-level nuclear waste)										
Other output flows										
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MFR	kg	0.00	0.00	0.00	0.00	0.00	0.00	920	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CRU = Components for reuse; MFR = Materials for recycling; MER = Materials for energy recovery; EE = Export energy										

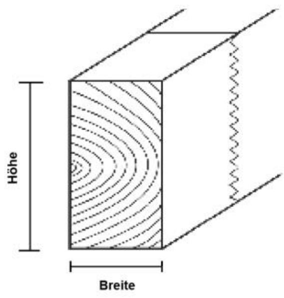
8.1.2 Price Lists

KVH

Konstruktionsvollholz Fichte "NSI"
NETTO

KVH besteht aus mehreren massiven Fichten- und Tannen-Kantholz-Stücken, die in der Länge keilgezinkt und kraftschlüssig verbunden werden.

Bezugsnorm:	ÖNORM DIN 4074-1
Güteklasse:	für nicht sichtbare Konstruktionen Festigkeitsklasse C24
Qualität:	NSI
Verleimung:	PUR-Kleber zugelassen nach DIN 68141 geprüft nach ÖNORM EN 385 helle Leimfuge
Holzfeuchte:	max. 18%
Oberfläche:	4-seitig gehobelt, Kanten gefast vereinzelt rauhe Stellen zulässig,
Längen:	Standardlänge 13 m



Breite	Preis/m³	ab m³	Preis	ab m³	Preis	ab m³	Preis
60 mm	435,00	5,21	371,00	20,00	339,00	50,00	310,00
80 mm	443,00	5,81	378,00	20,00	345,00	50,00	316,00
100 mm	450,00	5,82	384,00	20,00	351,00	50,00	321,00
120 mm	458,00	5,25	390,00	20,00	357,00	50,00	326,00
140 mm	465,00	6,12	397,00	20,00	363,00	50,00	332,00
160 mm	480,00	5,00	410,00	20,00	374,00	50,00	342,00

Die Preise für 50m³ gelten für das Liefergebiet Mittelsteiermark. Bei anderen Liefergebieten sind Frachtaufschläge möglich.

342,00 € Net = **283,86 € Gross/m³**

Lagerliste mit Stück/Paket:

Breite \ Höhe	80	100	120	140	160	200	240	280
60	98	77	63	56	49	35	28	
80					35	25	20	
100		44			28	20	16	16
120			27		21	20	15	
140				24				
160					14	12	10	

Andere Längen und Dimensionen auf Anfrage!

Lagerartikel RG Rabattgruppe A=Auslauf

OSB

OSB-Platten

OSB Platten (Oriented Strand Board) sind Grobspanplatten aus ausgerichteten Spänen. Für die Herstellung der Holzwerkstoffplatten werden lange, schlanke, relativ große Späne (strands) aus frischem Waldholz und zwar sowohl Nadelholz (Fichte, Kiefer) als auch Laubholz, verwendet.

Die Späne werden in den Deckschichten parallel zur Längsrichtung und in der Mittelschicht kreuzweise ausgerichtet („oriented"), wodurch sich für die Längs- und Querrichtung unterschiedliche Eigenschaften ergeben. Typische Anwendungsgebiete für OSB Platten sind Beplankungen aussteifender Wand und Deckenelemente im Holzbau, aber auch viele andere Bereiche des Hausbaus, z.B. Innen und Außenwände, Decken, Dächer und Böden. Die sichtbar oder nicht sichtbar gelassene Oberfläche bietet eine Vielzahl attraktiver Gestaltungsmöglichkeiten. Geschliffene Oberflächen können auf den jeweiligen Einsatzzweck abgestimmt, mit Lacken, Lasuren, Wachsen, Ölen und Beizen beschichtet werden.

OSB/3 Holzbauplatten ungeschliffen

NETTO

OSB 3 EN300. Baubiologisch unbedenkliche Holzbauplatte, deutlich unter E1.
Einsatz im Innenbereich bei normaler Feuchtigkeitsbelastung.

Format	Stärke	Preis/m²	ab m²	Preis	Stk./Pal.	Art.Nr.
2500 x 1250 mm	12 mm	5,20	250,00	4,10	68	272782
	15 mm	6,20	200,00	4,90	54	254390
	18 mm	7,50	168,50	5,90	44	260799
	22 mm	9,20	137,50	7,20	36	268973
	25 mm	10,80	121,88	8,40	32	279795
5000 x 1250 mm	15 mm	6,20	187,50	4,90	26	261314
	18 mm	7,50	162,50	5,90	20	254386
	22 mm	9,20	137,50	7,20	20	261556
	25 mm	9,20	118,75	7,50	20	279796

per 0,025 m³ | 9,20 € Net = **7,67€ Gross** | **→ 306,80 € Gross/m³**

OSB/3 Holzbauplatten ungeschliffen mit Nut + Feder

NETTO

OSB 3 EN300. Ungeschliffene Holzbauplatte, 4-seitige Nut + Feder, deutlich unter E1.

Format	Stärke	Preis/m²	ab m²	Preis	Stk./Pal.	Art.Nr.
2500 x 675 od. 2500 x 625 mm	12 mm	5,40	135,00	4,20	68	508852
	15 mm	6,50	108,00	5,10	54	284878
	18 mm	7,80	91,13	6,10	44	284880
	22 mm	9,50	74,25	7,40	36	284879
	25 mm	11,20	65,81	8,80	32	508851
2500 x 1250 mm	15 mm	6,50	200,00	5,10	54	502177
	18 mm	7,80	168,75	6,10	44	268222
	22 mm	9,50	137,50	7,40	36	266339
	25 mm	11,20	121,88	8,80	32	277218

Rohe Plattenwerkstoffe

Lagerartikel RG Rabattgruppe A=Auslauf

Rockwool

Flexirock®

Abmessungen mm (L x B x D)	Art.-Nr. Paket	ROCKPACK Pakete	Transp.m³	m²	EINZEL-PAKET m²	R_D (m²·K)/W	Preis €/m² exkl. MwSt.	inkl. MwSt.
1000 x 600 x **80**	110377	36	10,000	129,60	3,60	2,05	**8,77**	10,52
1000 x 600 x **100**	110378	36	10,000	108,00	3,00	2,55	**10,75**	12,90
1000 x 600 x **120**	110379	36	10,000	86,40	2,40	3,05	**13,01**	15,61
1000 x 600 x **140**	110380	32	10,000	76,80	2,40	3,55	**15,21**	18,25
1000 x 600 x **160**	110381	36	10,000	64,80	1,80	4,10	**17,20**	20,64
1000 x 600 x **180**	110382	32	10,000	57,60	1,80	4,60	**19,52**	23,42
1000 x 600 x **200**	107169	20	10,000	36,00	1,80	5,10	**21,72**	26,06
1000 x 600 x **220**	236695	24	10,000	28,80	1,20	5,60	**23,88**	28,66
1000 x 600 x **240**	110383	32	10,000	38,40	1,20	6,15	**26,08**	31,30

per 0,24 m³

Steinwolle-Dämmplatte mit elastischem Einbauverhalten. Ohne Zuschneiden, ohne Abfall einfach zwischen die Ständer der Außen- oder Trennwand einzubauen. Die Abmessungen sind ideal auf die Holzrahmenbauweise abgestimmt – die Breite kann um 5 cm komprimiert werden.

- Produktart MW-W nach ÖNORM B 6000.
- Euroklasse A1 nach ÖNORM EN 13501-1.
- Nennwert der Wärmeleitfähigkeit λ_D = 0,039 W/(m·K)

→ 108,67 € Gross/m³

CLT

BSP, BSH, Duobalken und KVH

01

Brettsperrholz

Brettsperrholz Fichte

Modern, ökologisch und flexibel – entwickelt für den Einsatz im konstruktiven Holzbau.
Ist ein massives, statisch wirksames und gleichzeitig raumbildendes Holzelement, das sich dank seiner flexiblen Abmessungen und hervorragenden bauphysikalischen Eigenschaften für jede bauliche Anforderung eignet.
Der kreuzweise Aufbau aus qualitativ hochwertigem Rohmaterial gewährleistet durch die dauerhafte Verklebung formstabile und steife Bauteile.
Vorteile:
Massive werthaltige Bauweise. Raumgewinn durch geringe Konstruktionsstärken. Flexible Gestaltung ohne Rasterbindung. Ausgezeichnete Formstabilität und Maßhaltigkeit. Hervorragende statische Eigenschaften. Vorgefertigte Elemente, exakte Montage. Kurze Bauzeit durch trockene Bauweise. Baubiologisch empfohlen. CO2 Speicher, Klima-positiv.
Decken- und Dachelemente DL Decklage längs laufend
Wandelemente DQ Decklage vertikal
Herstellung: nach Ö-Norm EN 386, DIN 1052-1/A1 gemäß Zulassung ETA-09/0036, Z-9.1-638
Holzart: heimische Fichte
Standardbreiten: 2400 mm, 2650 mm, 2750 mm, 2900 mm, 3000 mm
Länge: max. 16.5 m
Grundpreisbasis: Industriequalität, inkl. rechtwinkeligem Formatschnitt.
Verrechnungsbasis: kleinstes umschriebenes Rechteck gerechnet auf die nächstfolgende Standardbreite.

Ident-Nr.	Beschreibung	Stärke mm	VE	Preis €
21447617	3s, DL	60	m²	62,00
21448225	3s, DQ	60	m²	62,00
21448249	3s, DL	80	m²	72,00
21448256	3s, DQ	80	m²	72,00
21448263	3s, DL	90	m²	77,00
21448270	3s, DQ	90	m²	77,00
21448287	3s, DL	100	m²	80,00
21448294	3s, DQ	100	m²	80,00
21448300	3s, DL	120	m²	97,00
21448317	3s, DQ	120	m²	97,00
21448324	5s, DL	100	m²	87,00
21448331	5s, DQ	100	m²	87,00
21448348	5s, DL	120	m²	105,00
21448355	5s, DQ	120	m²	105,00
21448362	5s, DL	140	m²	115,00
21448379	5s, DQ	140	m²	115,00
21448386	5s, DL	160	m²	129,00
21448393	5s, DQ	160	m²	129,00
21448409	5s, DL	180	m²	144,00
21448416	5s, DQ	180	m²	144,00
21448423	5s, DL	200	m²	159,00
21448430	5s, DQ	200	m²	159,00
21448447	7ss, DL	200	m²	159,00
21448454	7ss, DQ	200	m²	159,00
21448461	7s, DL	220	m²	174,00
21448478	7s, DQ	220	m²	174,00
21448485	7ss, DL	220	m²	174,00
21448492	7ss, DQ	220	m²	174,00
21448508	7s, DL	240	m²	187,00

per 0,20 m³

795,00 € Gross/m³

Preise exkl. Mwst! Aktualisierungen und Preisänderungen vorbehalten!

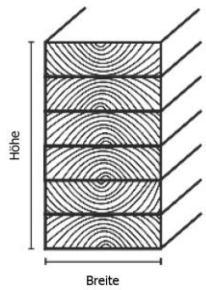
Glulam

Brettschichtholz Fichte „Sicht"

NETTO

Brettschichtholz besteht aus mindestens drei breitseitig-faser-parallel verleimten Brettern oder Brettlagen aus Nadelholz, die 4-seitig gehobelt werden.

Bezugsnorm:	EN 386, ON B 4100 T1, DIN 1052 T1, MUF EN 301
Güteklasse:	Güteklasse II gemäß DIN 1052 Festigkeitsklasse GL 24 Festigkeitsklasse GL 28; GL 32 oder GL 36 auf Anfrage.
Verleimung:	Leimprüfung nach ÖNORM DIN 68141 helle Leimfuge, BEWITTERUNGSBESTÄNDIG
Holzfeuchte:	12% (+/- 2%)
Oberfläche:	4-seitig gehobelt, mit Fase
Längen:	siehe Lagerliste (Halbstangen möglich)



Breite	Preis/m³	ab m³	Preis	ab m³	Preis	ab m³	Preis
80 mm	647,00	3,45	552,00	20,00	504,00	50,00	461,00
100 mm	632,00	4,32	539,00	20,00	493,00	50,00	451,00
120 mm	617,00	3,46	526,00	20,00	481,00	50,00	440,00
140 mm	617,00	4,03	526,00	20,00	481,00	50,00	440,00
160 mm	617,00	4,30	526,00	20,00	481,00	50,00	440,00

Die Preise für 50m³ gelten für das Liefergebiet Mittelsteiermark. Bei anderen Liefergebieten sind Frachtaufschläge möglich.

440,00 € Net = **367,83 € Gross/m³**

Höhe / Breite	80	100	120	140	160	180	200	240	280	300	320	360	400	440	480
80			12		12		12								
100		12		12	12 16		12	12							
120			12		12			12							
140				12			12								
160					12		12 16	12	12		12		16		

Andere Dimensionen und Längen auf Anfrage!

Zustellungen von Brettschichtholz mit einer Länge über 16 m erfordern ein Begleitfahrzeug. Transportbegleitung Pauschale Euro 200,00

Lagerartikel RG Rabattgruppe A=Auslauf

Concrete

BAUBETON

BAU BETON GmbH • Kleeblattgasse 43 • A-2601 Sollenau

Druckfestig-keitsklassen	Expositonsklassen	Kurzbez.	Kons.	Zement	€ / m³
C 30/37	XC2 (A)	XC2	bis F 45	CEM II 42,5 N	83,00
C 30/37	XW1 (A)	XW1	bis F 45	CEM II 42,5 N	86,00
C 30/37	XW2 (A)	XW2	bis F 45	CEM II 42,5 N	93,00
C 30/37	XC3/XW1 (A)	B1	bis F 45	CEM II 42,5 N	86,00
C 30/37	XC4/XW1/XD2/XF1/XA1L (A)	B2	bis F 45	CEM II 42,5 N	89,00
C 30/37	XC4/XW1/XD2/XF3/XA1L (A)	B3	bis F 45	CEM II 42,5 N	91,00
C 30/37	XC4/XW2/XD2/XF1/XA1L (A)	B4	bis F 45	CEM II 42,5 N	93,00
C 30/37	XC4/XW2/XD2/XF2/XF3/XA1L (A)	B5	bis F 45	CEM II 42,5 N	95,00
C 30/37 (56)	XC4/XW2/XD2/XF3/XA2L/XA2T (A)	B6 C3A-frei	bis F 45	CEM I 42,5 N C3A-frei	112,00
C 30/37	XC4/XW2/XD3/XF4/XA1L (A)	B7	bis F 45	CEM II 42,5 N	103,00
C 30/37 (56)	XC3/XW2/XD2/XF3/XA1T/XA1L (A)	BS1 A	bis F 45	CEM I 42,5 N C3A-frei	122,00
C 30/37 (56)	XC3/XW1/XD2/XF3/XA1T/XA1L (A)	BS1 B	bis F 45	CEM I 42,5 N C3A-frei	122,00
C 30/37 (56)	XC4/XW2/XD2/XF2/XF4/XA1T/XA1L (A)	BS1 C	bis F 45	CEM I 42,5 N C3A-frei	130,00
C 35/45	XC2 (A)	XC2	bis F 45	CEM II 42,5 N	91,00
C 35/45	XW1 (A)	XW1	bis F 45	CEM II 42,5 N	94,00
C 35/45	XW2 (A)	XW2	bis F 45	CEM II 42,5 N	101,00
C 35/45	XC3/XW1 (A)	B1	bis F 45	CEM II 42,5 N	94,00
C 35/45	XC4/XW1/XD2/XF1/XA1L (A)	B2	bis F 45	CEM II 42,5 N	97,00
C 35/45	XC4/XW1/XD2/XF3/XA1L (A)	B3	bis F 45	CEM II 42,5 N	99,00
C 35/45	XC4/XW2/XD2/XF1/XA1L (A)	B4	bis F 45	CEM II 42,5 N	101,00
C 35/45	XC4/XW2/XD2/XF2/XF3/XA1L (A)	B5	bis F 45	CEM II 42,5 N	103,00
C 40/50	XC2 (A)	XC2	bis F 45	CEM II 42,5 N	96,00
C 40/50	XW1 (A)	XW1	bis F 45	CEM II 42,5 N	99,00
C 40/50	XW2 (A)	XW2	bis F 45	CEM II 42,5 N	106,00
C 40/50	XC3/XW1(A)	B1	bis F 45	CEM II 42,5 N	99,00
C 40/50	XC4/XW1/XD2/XF1/XA1L (A)	B2	bis F 45	CEM II 42,5 N	102,00
C 40/50	XC4/XW1/XD2/XF3/XA1L (A)	B3	bis F 45	CEM II 42,5 N	104,00
C 40/50	XC4/XW2/XD2/XF1/XA1L (A)	B4	bis F 45	CEM II 42,5 N	106,00
C 40/50	XC4/XW2/XD2/XF2/XF3/XA1L (A)	B5	bis F 45	CEM II 42,5 N	108,00
C 45/55	XC2 (A)	XC2	bis F 45	CEM II 42,5 N	101,00
C 45/55	XW1 (A)	XW1	bis F 45	CEM II 42,5 N	104,00
C 45/55	XW2 (A)	XW2	bis F 45	CEM II 42,5 N	111,00
C 45/55	XC3/XW1 (A)	B1	bis F 45	CEM II 42,5 N	104,00
C 45/55	XC4/XW1/XD2/XF1/XA1L (A)	B2	bis F 45	CEM II 42,5 N	107,00
C 45/55	XC4/XW1/XD2/XF3/XA1L (A)	B3	bis F 45	CEM II 42,5 N	109,00
C 45/55	XC4/XW2/XD2/XF1/XA1L (A)	B4	bis F 45	CEM II 42,5 N	111,00

111,00 € Gross/m³

Seite 2 von 3

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Raiffeisenverband Salzburg IBAN: AT62 3500 0000 0005 2837 BIC (Swift): RVSAAT2S

PASST IMMER

Rebar Steel

GROSSCHÄDL
ESB-BETONSTAHL

Lagerpreisliste

Betonstahl BST 550
gemäß ÖNORM B 4200, Teil 7; Länge: 14 m

Durchmesser mm	Theoretisches Gewicht kg / m	Preis bis 99 kg EUR / to	Preis 100 – 399 kg EUR / to	Preis 400 – 999 kg EUR / to
8	0,40	1.429,00	1.250,00	1.027,00
10	0,62	1.329,00	1.163,00	955,00
12	0,89	1.262,00	1.105,00	907,00
14	1,21	1.262,00	1.105,00	907,00
16	1,58	1.262,00	1.105,00	907,00
20	2,47	1.279,00	1.119,00	919,00
26	4,17	1.279,00	1.119,00	919,00
30	5,55	1.279,00	1.119,00	919,00
Aufpreis für Schneiden und Biegen: € 200,- / to				

919,00 € Gross/t

A – AQ Baustahlgitter
nach ÖNORM B 4200 Teil 7 Lagermatten-Programm, Format 6,00 m x 2,40 m = 14,40 m²

	Stahlquerschnitt je 1 m Breite					
Type	längs cm²	quer cm²	Abstand der Längs-Querdrähte	Durchschnitts-gewicht / m²	Durchschnitts-gewicht / Matte	Preis EUR / 100 m²
A 60	2,83	0,65	100 300	2,73	39,31	465,92
A 70	3,85	0,79	100 300	3,64	52,42	601,82
A 82	5,28	1,11	100 300	5,02	72,29	829,98
AQ 42	1,38	1,38	100 100	2,18	31,39	372,06
AQ 50	1,96	1,96	100 100	3,08	44,35	513,34
AQ 55	2,38	2,38	100 100	3,74	53,86	608,37
AQ 60	2,83	2,83	100 100	4,44	63,94	722,24
AQ 65	3,32	3,32	100 100	5,20	74,88	838,04
AQ 70	3,85	3,85	100 100	6,04	86,98	958,35
AQ 76	4,54	4,54	100 100	7,12	102,53	1.120,22
AQ 82	5,28	5,28	100 100	8,30	119,52	1.305,87
AQ 90	6,36	6,36	100 100	9,98	143,71	1.636,72
AQ 100	7,85	7,85	100 100	12,34	177,70	2.023,76

ÖMAT-Schlaufenmatte
Nach ÖNORM B 4200, Teil 7 Lagermatten-Programm, Format 6,00 m x 2,40 m = 14,40 m²

Type	Abstand der Längs-Querdrähte	Durchschnitts-gewicht / m²	Durchschnitts-gewicht / Matte	Bundgröße	Preis EURO / 100 m²
CS 70	150 300	2,80	40,32	40	444,27
CS 80	150 300	3,30	47,52	40	517,00
CS 90	150 300	3,86	55,58	40	604,74
CS 100	150 300	4,92	70,85	20	770,80
AS 30	100 300	0,75	10,80	100	169,00
AS 90	100 300	5,74	82,66	25	918,40
AS 100	100 300	7,04	101,38	20	1.126,40
CQS 50	150 150	2,16	31,10	40	345,60
CQS 60	150 150	3,11	44,78	40	483,10
CQS 70	150 150	4,10	59,04	40	631,40
CQS 80	150 150	5,24	75,46	20	789,50
CQS 90	150 150	6,54	94,18	20	985,36
CQS 100	150 150	8,12	116,93	20	1.212,59
AQS 30	100 100	1,14	16,42	100	256,88
AQS 90	100 100	9,90	142,56	15	1.564,20
AQS 100	100 100	12,11	174,38	10	1.913,39

Frachtkosten Bewehrung pro Lieferung

Graz	EUR 220,00
Graz Umgebung (Bruck, Kapfenberg, Leoben, Leibnitz, Feldbach)	EUR 290,00
Weitere Entfernungen in der Steiermark	EUR 360,00
Aufpreis Kranentladung je Entladestelle	EUR 120,00

1

8.2 Tables

Table 3: Module measurements

Module	Part	Length	Width	Height	Area
A/B North, 14 - Stories	Exterior Wall, East/West	8,60 m	/	49,32 m	**424,15 m²**
A/B North, 14 - Stories	Exterior Wall, North/South	4,20 m	/	49,32 m	**207,14 m²**
B/C North, 14 - Stories	Interior Wall	8,60 m	/	49,32 m	**424,15 m²**
C North, 14 – Stories	Exterior Wall, North/South	5,30 m		49,32 m	**261,40 m²**
A/B South 13 - Stories	Exterior Wall, East/West	8,60 m	/	46,05 m	**396,03 m²**
A/B South 13 - Stories	Exterior Wall, North/South	4,20 m	/	46,05 m	**193,41 m²**
A/B	Slab/Roof	8,60 m	4,20 m	/	**36,12 m²**
C	Slab/Roof	8,60 m	5,30 m	/	**45,58 m²**
Circulation	Slab/Roof Lift cutout	22,10 m 5,50 m 2,52 m	2,70 m 5,30 m 2,00 m	/ / /	59,67 m² 29,15 m² -5,05 m² **83,75 m²**

Table 4: “Treet” module building-part summarization

Part	Area	Factor/story	Stories	Sum
Exterior Wall East/West	424,15 m² (A/B North) 396,93 m² (A/B South)	2 4	/ /	848,30 m² 1587,72 m²
Exterior Wall North/South	207,14 m² (A/B North) 261,40 m² (C) 193,41 m² (A/B South)	8 2 8	/ / /	1657,12 m² 522,80 m² 1547,28 m²

Exterior Wall, Total				**6163,22 m²**
Interior Wall	424,15 m²	2	/	848,30 m²
Interior Wall, Total				**848,30 m²**
Wet Area Slab, B, Ground Floor	36,12 m²	4	1	144,48 m²
Wet Area Slab (Ground Floor), Total				**144,48 m²**
Wet Area Slab, B, Upper Floors	36,12 m²	4 2	12 1	1806,00 m²
Wet Area Slab (Upper Floors), Total				**1806,00 m²**
Standard Slab, A, Ground Floor	36,12 m²	4	1	144,48 m²
Standard Slab, C, Ground Floor	45,58 m²	1	1	45,58 m²
Standard Slab, Circulation, All Floors	83,75 m²	1	14	1172,50 m²
Standard Slab (Ground Floor + Circulation), Total				**1362,56 m²**
Standard Slab, A, Upper Floors	36,12 m²	4 2	12 1	1806,00 m²
Standard Slab, C, Upper Floors	45,58 m²	1	13	592,54 m²
Standard Slab (Upper Floors), Total				**2398,54 m²**
Roof, A/B	36,12 m²	8	1	288,96 m²
Roof, C	45,58 m²	1	1	45,58 m²
Roof, Circulation	83,75 m²	1	1	83,75 m²
Roof, Total				**418,29 m²**

Table 5: Wooden frame elements, expansion

Component	**Area**	**Max. length/width/height**	**Theoretic perpendicular expansion**

Exterior Wall, Vertical Elements	6163,22 m^2	8,60 m	716,65 m
Exterior Wall, Horizontal Elements	6163,22 m^2	49,32 m	124,96 m
Interior Wall, Vertical Elements	848,30 m^2	8,60 m	98,64 m
Wet Area Slab, Ground Floor	144,48 m^2	8,60 m	16,80 m
Wet Area Slab, Upper Floors	1806,00 m^2	8,60 m	210,00 m
Standard Slab, Ground Floor/Circulation	1362,56 m^2	8,60 m	158,44 m
Standard Slab, Upper Floors	2398,54 m^2	8,60 m	278,90 m
Roof	418,28 m^2	8,60 m	48,64 m

Table 6: Wooden frame elements, running lengths

Component	**Frame Element**	**Element Count**	**Expansion**	**Running Length**
Exterior Wall, Vertical Elements	30 x 45 mm 45 x 170 mm	15 15	716,65 m 716,65 m	10749,75 m 10749,75 m
Exterior Wall, Horizontal Elements	45 x 45 mm	83	124,96 m	10371,68 m
Interior Wall, Vertical Elements	45 x 95 mm 45 x 95 mm	15	98,64 m	1479,60 m
Wet Area Slab, Ground Floor	I - Profile	29	16,80 m	487,20 m
Wet Area Slab, Upper Floors	I – Profile 45 x 90 mm 20 x 45 mm	29 29 29	210,00 m 210,00 m 210,00 m	6090,00 m 6090,00 m 6090,00 m

	45 x 100 mm 21 x 70 mm	29 29	210,00 m 210,00 m	6090,00 m 6090,00 m
Standard Slab, Ground Floor/Circulation	I – Profile	15	158,44 m	2376,60 m
Standard Slab, Upper Floors	I – Profile 45 x 90 mm 20 x 45 mm 45 x 100 mm 21 x 70 mm	15 15 15 15 15	278,90 m 278,90 m 278,90 m 278,90 m 278,90 m	4183,50 m 4183,50 m 4183,50 m 4183,50 m 4183,50 m
Roof	45 x 70 mm I – Profile 21 x 70 mm	15 15 15	48,64 m 48,64 m 48,64 m	729,60 m 729,60 m 729,60 m

Table 7: Frame element volumes

Frame Element	**Material**	**Cross-Section**	**Running Length**	**Volume**
20 x 45 mm	KVH	9,00 x 10^{-5} m^2	10273,50 m	0,92 m^3
30 x 45 mm	KVH	13,50 x 10^{-5} m^2	10749,75 m	1,45 m^3
21 x 70 mm	KVH	14,70 x 10^{-5} m^2	4913,10 m	0,72 m^3
45 x 45 mm	KVH	20,25 x 10^{-5} m^2	10371,68 m	2,10 m^3
45 x 70 mm	KVH	31,50 x 10^{-5} m^2	729,60 m	0,23 m^3
45 x 90 mm	KVH	40,50 x 10^{-5} m^2	10273,50 m	4,16 m^3
45 x 95 mm	KVH	42,75 x 10^{-5} m^2	2959,20 m	1,27 m^3
45 x 100 mm	KVH	45,00 x 10^{-5} m^2	10273,50 m	4,62 m^3
I - Profile	KVH	18,65 x 10^{-5} m^2	11490,30 m	2,14 m^3
Total	**KVH**			**16,61 m^3**
I - Profile	OSB	20,00 x 10^{-5} m^2	11490,30 m	2,30 m^3
Total	**OSB**			**2,30 m^3**

Table 8: Planar element volumes (gross)

Component	**Element**	**Material**	**Area**	**Thickness**	**Volume**

Exterior Wall	Wall Board	KVH	6163,22 m^2	0,19 x 10^{-1} m	117,10 m^3
	OSB – Board	OSB	6163,22 m^2	0,08 x 10^{-1} m	49,31 m^3
	Insulation	Rockwool	6163,22 m^2	2,45 x 10^{-1} m	1509,99 m^3
Interior Wall	OSB – Board	OSB	848,30 m^2	0,16 x 10^{-1} m	13,57 m^3
	Insulation	Rockwool	848,30 m^2	1,90 x 10^{-1} m	161,18 m^3
Wet Area Slab, Ground Floor	Insulation	Rockwool	144,48 m^2	3,13 x 10^{-1} m	45,22 m^3
Wet Area Slab, Upper Floors	OSB – Board	OSB	1806,00 m^2	0,12 x 10^{-1} m	21,67 m^3
	Insulation	Rockwool	1806,00 m^2	4,13 x 10^{-1} m	745,88 m^3
Standard Slab, Ground Floor/Circulation	OSB – Board	OSB	1362,56 m^2	0,22 x 10^{-1} m	6,79 m^3
	Insulation	Rockwool	1362,56 m^2	3,13 x 10^{-1} m	426,48 m^3
Standard Slab, Upper Floors	OSB – Board	OSB	2398,54 m^2	0,34 x 10^{-1} m	81,55 m^3
	Insulation	Rockwool	2398,54 m^2	4,13 x 10^{-1} m	990,60 m^3
Roof	OSB – Board	OSB	418,28 m^2	0,26 x 10^{-1} m	10,88 m^3
	Insulation	Rockwool	418,28 m^2	3,00 x 10^{-1} m	125,48 m^3
Total		**KVH**			**117,10 m^3**
		OSB			**183,77 m^3**
		Rockwool (gross)			**4004,83 m^3**

Table 14: Basic EPD summary, GWP*

Material	**Production Stage**			**Total (production only)**	**Reuse D**	**Total (with reuse)**
	A1	**A2**	**A3**			
KVH	-777,00	9,45	37,70	-729,85	-358,00	-1087,85
OSB	-760,00			-760,00	-649,00	-1409,00
Rockwool	82,64			82,64	-5,92	76,72
CLT	-731,00	7,23	122,00	-601,77	-360,00	-961,77
Glulam	-663,00			-663,00	-338,00	-1001,00
Concrete	252,00	0,82	0,05	252,87	-23,08	229,79
Rebar Steel	839,00			839,00	350,00	1189,00

*Rebar Steel: kg CO_2 equivalent for 1 t, all other values: kg CO_2 equivalent for 1 m^3

Table 15: Basic EPD summary, TNRPE*

Material	Production Stage			Total (production only)	Reuse	Total (with reuse)
	A1	A2	A3		D	
KVH	369,00	133,00	676,00	1178,00	-7090,00	-5912,00
OSB	4810,00			4810,00	-10500,00	-5690,00
Rockwool	1184,90			1184,90	-99,43	1085,47
CLT	1000,00	103,00	2290,00	2493,00	-7390,00	-4897,00
Glulam	1510,00			1510,00	-4410,00	-2900,00
Concrete	1520,00	10,80	0,49	1531,27	-319,00	1212,27
Rebar Steel	10700,00			10700,00	3130,00	13830,00

*Rebar Steel: MJ equivalent for 1 t, all other values: MJ equivalent for 1 m^3

Table 16: Basic EPD summary, AP*

Material	Production Stage			Total (production only)	Reuse	Total (with reuse)
	A1	A2	A3		D	
KVH	0,148	0,0412	0,208	0,3972	-0,369	0,0282
OSB	1,04			1,04	-0,386	0,654
Rockwool	0,624			0,624	-0,00583	0,61817
CLT	0,241	0,0312	0,40	0,6722	-0,37	0,3022
Glulam	0,743			0,743	-1,63	-0,887
Concrete	0,191	0,00453	0,000179	0,195709	-0,041	0,154709
Rebar Steel	3,46			3,46	1,34	4,80

*Rebar Steel: kg SO_2 equivalent for 1 t, all other values: kg SO_2 equivalent for 1 m^3

Table 17: Basic price summary, material costs*

Material	Price, gross
KVH	283,86
OSB	306,80
Rockwool	108,67
CLT	795,00
Glulam	367,83

Concrete	111,00
Rebar Steel	919,00

*Rebar Steel: costs in € for 1 t, all other values: costs in € for 1 m^3

Table 25: RC benchmark, wall area

Type	Floor	Factor	Height	Running Length	Area
Exterior Wall	1.-13.	13 x	2,44 m	93,80 m	2975,34 m^2
Exterior Wall	14.	1 x	2,44 m	81,00 m	197,64 m^2
Interior Wall	1-13.	13 x	2,44 m	66,02 m	2094,15 m^2
Interior Wall	14.	1 x	2,44 m	44,62 m	108,87 m^2
Total					**5376,00 m^2**

Table 26: RC benchmark, concrete volumes

Type	Factor	Area	Thickness	Volume
Slab-To-Ground	1 x	457,60 m^2	0,40 m	183,04 m^3
Interior Slabs	13 x	452,56 m^2	0,25 m	1470,82 m^3
Balconies North	13 x	26,34 m^2	0,25 m	85,61 m^3
Balconies South	12 x	11,96 m^2	0,25 m	35,88 m^3
Walls	1 x	5376,00 m^2	0,20 m	1075,20 m^3
Roof	1 x	303,86 m^2	0,25 m	75,97 m^3
Total				**2926,52 m^3**

Table 27: RC benchmark, insulation volumes

Type	Area	Running Length	Height	Thickness	Volume
Slab-To-Ground	457,60 m^2	/	/	0,24 m	109,82 m^3
Exterior Walls 1.-13.		93,80 m	35,00 m	0,24 m	787,92 m^3
Exterior Walls 14.		81,00 m	2,69 m	0,24 m	52,29 m^3
Entire Roof	401,08 m^2	/	/	0,24 m	96,26 m^3

Total	**1046,29 m^3**

Table 28: RC benchmark, rebar mass

Type	Concrete Volume	Rebar Quotient	Steel Mass
Slab-To-Ground	183,04 m^3	125 kg/m^3	22,88 t
Walls	1075,20 m^3	100 kg/m^3	107,52 t
Slabs / Balconies / Roof	1668,28 m^3	135 kg/m^3	225,22 t
Total			**355,62 t**

Table 37: Building mass, "Treet"

Material	Volume	Medium Density	Mass
KVH	133,71 m^3	492,71 kg/m^3	65,88 t
OSB	186,07 m^3	610 kg/m^3	113,46 t
Rockwool	3993,17 m^3	90 kg/m^3	359,39 t
CLT	336,00 m^3	491,65 kg/m^3	165,19 t
Glulam	562,88 m^3	470 kg/m^3	264,55 t
Concrete	444,51 m^3	2450 kg/m^3	1089,05 t
Rebar Steel	58,10 t	/	58,10 t
Total			**2115,62 t**

Table 38: Building mass, RC benchmark

Material	Volume	Medium Density	Mass
Rockwool	1046,29 m^3	90 kg/m^3	94,16 t
Concrete	2926,52 m^3	2450 kg/m^3	7169,97 t
Rebar Steel	355,62 t	/	355,62 t
Total			**7619,76 t**