Curso 2015-16

CARBON FOOTPRINT OF THE TALLEST TIMBER BUILDING.

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RESUMEN

Huella de Carbono del edificio más alto de estructura de madera.

Treet, cuyo significado en noruego es "árbol", es con 14 plantas el edificio más alto del mundo hecho con estructura de madera. Está situado a escasos minutos a pie del centro de Bergen, la segunda ciudad más grande de Noruega.

Con este proyecto vamos a tratar de identificar los motivos que justifican su construcción, responder a preguntas como, ¿por qué construir el edificio más alto madera del mundo? ¿Por qué su ubicación, y no otro lugar? ¿Por qué el uso de módulos prefabricados de madera? Entender el funcionamiento del mismo, los motivos detrás del diseño de su estructura. Vamos a analizar las ventajas de los elementos de construcción prefabricados de madera, teniendo en cuenta como una primera hipótesis, que a pesar de que a priori, puede resultar más costoso que el sistema tradicional de hormigón armado, sigue significando una reducción en los costes totales, mediante el ahorro de mano de obra y tiempo de ejecución.

Sin embargo, el objetivo principal de este proyecto es calcular la cantidad de emisiones de CO2 que emite este edificio, para luego realizar una comparación con un edificio de hormigón armado de dimensiones y características similares (realizado en paralelo por un compañero). También desglosar el alcance que las emisiones de CO2, si incluye el transporte de material hacia la construcción, la construcción o las emisiones durante la vida útil del edificio. Para ello nos valdremos de una herramienta que comienza a utilizarse cada vez con mayor frecuencia en el mundo de la construcción, la Declaración Ambiental de Producto (DAP), estudiaremos este certificado, qué es, cómo funciona y de dónde viene.

Utilizaremos información proporcionada tanto por la constructora, proveedores, el arquitecto y la Universidad Høgskolen i Bergen (HiB).

Con este estudio se espera hacer patente que el uso de madera en edificios tiene un impacto ambiental mucho menor que el uso de hormigón armado.

PALABRAS CLAVE: estructura madera, Treet, reducir emisión de CO2, DAP, declaración ambiental, madera laminada, construcción sostenible.

ABSTRACT

Carbon Footprint of the Tallest Timber Building.

Treet, which means 'tree' in norwegian, is the world's tallest (14-storey) timber- framed structured. Located in an urban and central area of Bergen, the second largest city in Norway.

With this project I will try to identify the reasons and the motives behind its construction, answer questions like, why build the biggest wood-build? Why it's location, and not somewhere else? Why the use of prefabricated wood-modules? Understand the functioning, the reasons behind the design of its structure. Will study the advantages of wood prefabricated construction elements, considering as a first hypothesis, that even though the construction of prefabricated wooden elements could be more expensive than the traditional system, it reduces construction time, saving on overhead costs.

However, the aim of this project is to calculate the amount of CO2 emission is saving using wood as a main material, in comparison with the traditional concrete/steel structure (performed in parallel by a fellow). Also identify what this CO2 emission saving means, if it includes the material transport to the construction place, the construction and the emission during its use. To do this will use a tool that starts becoming more frequently used in the world of construction, the Environmental Product Declaration (EPD) system. And explain what is and how it works.

To do this we will use information provided by the developer, the architect and the University Høgskolen i Bergen (HiB).

With this study it is expected to prove that wooden building is way more sustainable than concrete/Steel building.

KEYWORDS: wooden structure, Treet, reduce CO2 emission, EPD, environmental declaration, CLT, build sustainable.

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1. INTRODUCTION.

1. INTRODUCTION

In this first chapter we will expose the main contents of the project starting with an analysis of the current situation of the global environmental background and the tools we

In addiction I will expose the main contents of the project, starting with the analysis of the current situation of the global environmental background in terms of CO2 emissions, what the alternatives are to current materials when constructing a building and the methodology we use to quantify CO2 carbon footprint emission.

1.1. BACKGROUND

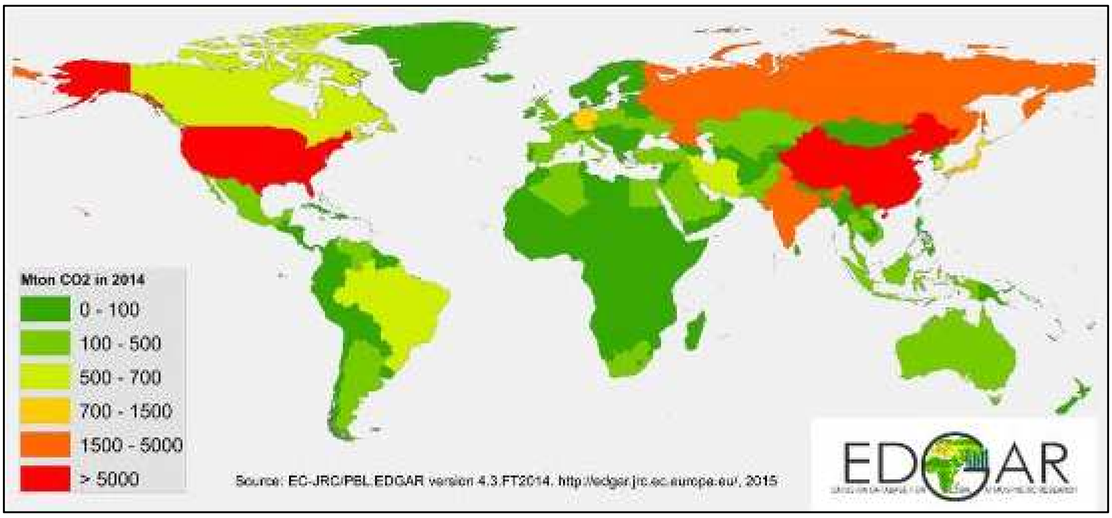
World's population exceeds 7.34 billion people, as of 2015 according to the latest report "The State of World Population 2015" by the United Nations Population Fund **(UNFPA [#1])**, moreover life expectancy is prolonged. In addition, the report lays down that population is expected to increase another billion in the forthcoming decade. Nevertheless, population growth is not directly linked to human development. Based in the "Human Development Report 2015" by United Nations Development Programme **(UNDP [#2])**, near 31% of the countries considered at the study are part of the Low Human Development Index Group.

Consequently, population growth has not agreed with improvement of well-being and poverty eradication in low developed countries. This trend is being modified by emerging countries, which resources and supplies demand increase as their economic growth and development maintains.

When it comes to consider future resource's consumptions, according to the "Decoupling Report 2011" by United Nations Environment Programme **(UNEP [#3])**, it is estimated that by 2050 humanity will consume 140 billion tonnes per year of minerals, ores, fossil fuels and biomass (three times the current amount).

Energy consumption and resource depletion are significant impacts which human activity is causing to the environment. Human activities such as industry, transportation or construction are the most pollutant ones and carbon dioxide among other pollutants are being emitted to the environment, plus great amounts of waste. The situation of the planet is becoming really concerning referring to greenhouse gas emissions, and of all pollutants generated, CO_2 emissions are the most important as being the main responsible of Global Warming.

Accordinng to the report "Trends in Global Emissions: 2015 Report" (#4) by PBL Netherlands Enviromental Assesment Agency and European Commission Join Research Centre Institute for Enviroment and Sustainability, after a decade of annual increases about 4% and being slowing down to about 1% during 2012 and 2013, the growth in global CO_2 emissions is almost stagnant in 2014 by only increasing a 0.5%.



1. Note that these time series report country-specific CO_2 emission totals of fossil fuel use and industrial processes (cement production, carbonate use of limestone and dolomite, non-energy use of fuels and other combustion). Excluded are: short-cycle biomass burning (such as agricultural waste burning) and large-scale biomass burning (such as forest fires)

1.2. RESEARCH

1.2.1. JUSTIFICATION

Construction industry, as one of the most relevant economic sectors, high raw materials claimant, energy consumer and pollutant-emitting activity of today's worldwide society; must increase its environment-friendliness if sustainable development wants to be a feasible objective. Moreover, nowadays practice by construction project designers and constructors' contractors is to overview environmental problems when taking decisions and alternatives, and focusing on different "more important" issues such as: durability, economic, performance, or even aesthetic criteria. As EPD is a tool that enables improvement of environmental issues by identifying highly pollutant products and services, its application and integration in the different phases of construction projects has to be reached by all the stakeholders included in the process.

1.2.2. OBJECT

This work aims to analyze and quantify CO_2 emissions in the construction industry. This paper wants to give a complete vision of EPD main strengths and, at the same time, offer a guide model for the application EPDs to concrete and timber structures.

1.2.3. OBJECTIVES

These are the recognizable objectives within the work at hand:

- Set the theoretical framework about EPD and timber/reinforced concrete structures in the construction environment.
- Expose a methodological guide to practitioners of EPD in the construction industry for assessing timber/reinforced concrete structures.
- Study wood as an environmental alternative material to use on high rise buildings.

But at the same time, it is also possible to point some other secondary objectives related to this work:

- Identify the actual framework about environment politics worldwide.
- Set the importance of construction industry, in relation to sustainability and environmental policies.
- Set the responsibility of energy consumption and environmental contamination by construction industry.
- Demonstrate the applicability and usefulness of EPD as a tool for assessing construction activities.
- Analyze pros related to the industrialization in the construction industry.
- Expose future lines of work for the topic.

2. METHODOLOGY AND DATA SOURCES.

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The methodology used to reach the document can be differentiated in these phases:

- COMPILATION
- REGISTRY AND STORING
- GUIDELINE
- DISSCUSSION
- SOFTWARE

Compilation.

The first part and move on this thesis, is the research of all the documentation needed to understand the environmental point of view of the construction area. Many documents, reports, publications and web pages were reviewed (the used ones are at the reference chapter).

The keywords used for this purpose were changing depending on the chapter, but mainly were: "Treet", "life cycle assessment", "LCA", "environmental product declaration", "EPD", "wood", "timber framework", "Wood Construction".

A secondary research was made during the investigation on every chapter, only to find information related to certain points and complete the chapters.

Registry, storing and analysis of the information.

The documents and the reports are organized and registered in the reference chapter database at the end of the thesis. This permit includes information as the author, title and data of the publication, web page etc. to make an easy consultation.

Also the information is shared on a Dropbox, the online storage space, for future consultations.

Guideline.

In order to understand a complementary study of the environmental issues and background is included, also a complete report of the EPD system. This additional information will help to familiarize with all the elements of the environmental issues.

The first step is to understand the Environmental Product Declaration system and the Life Cycle Assessment used in the documentation, for that purpose its necessary all the information compiled in the previous stages.

Then must decide the scope of the study, deciding whether a study will be conducted from the cradle-to-gate, or cradle-to-grave. In this case the study focuses on the cradle-to-gate stages. The next decision that has to be made is the boundary in those stages, the materials in the study. This thesis will assess only the structural elements, the unique elements, the façades and facilities can be the same in both kind of building (wood and concrete/steel).

After deciding the scope and defining the inventory, a study of the materials must be done. Calculating the amount of material in the building. With the amount, it is possible to calculate the Kg CO_2 equiv. using the data per stages in the EPD of each material.

For the transport phase, additional data must be searched, like the route used for some suppliers, and the CO_2 emission of the cargo ships or the rail.

The amount of wood inside the prefabricated modules, it will be done with the guidance of some sections and the data take from the planes.

With all the data will proceed to do the comparison and analysis of the results.

Discussion.

Based in the methodology used, some limitations on the assessment, the scope and the human error who can influence in the final result. This chapter aims to ease researches in the future (in any kind of life cycle assessment or comparison between different structures), using the experience obtained in this thesis.

Tools, software and databases.

The scope of building environmental assessment tools is vast and many different tools have already been launched around the world. But focusing on the EPD SYSTEM to quantify the CO_2 emissions and the LCA system of measure of materials.

To analyze the Treet building, the developers provided the model in an ArchiCAD file. ArchiCAD is a 3D architectural BIM software.

2.1. STRUCTURE

This project integrates an introduction, three body chapters, two final chapters and a final one for the references used, as it is shown as followed:

1. Introduction
2. Methodology and data sources
3. Theoretical framework
4. Analysis and results
5. Discussion
6. Conclusion
7. References

1. Introduction

Give a general view of the current environmental background, secondly and find the research performed where we talk about the object and objectives.

2. Methodology and data sources

In the second chapter it is included the methodology and data sources used to obtain the information for the later analysis and study.

3. Theoretical framework

In the third chapter it is included the theoretical framework compounded by six different epigraphs. First the sustainable development followed by the construction industry evolution related to the environment. After this an exposition of the timber construction in Norway including a subchapter talking about the Treet building.

To end with the chapter, we find two more epigraphs where we can find an explanation of Life Cycle Assessment (LCA) and the Environmental Product Declaration system (EPD).

4. Analysis and results

The fourth chapter, which is divided in two big epigraphs, is where we expose the main part of the project. We proceed to analyze two different hypotheses.

The first epigraph is based in the wooden hypothesis, which is the Treet building. The second epigraph and it includes all the calculations and steps needed in order to quantify the CO_2 emissions.

Thanks to Beatriz Canet Mahiques for her study and assess of a hypothetical concrete/steel model develop on her thesis "Study of Treet building Carbon footprint against a reinforced concrete building with similar characteristics", for share the information in order to do a proper comparison.

5. Discussion and conclusion

The fifth chapter includes a critical discussion on the results from the analysis studies.

6. Conclusion

In the sixth chapter is the conclusion of the project, with the personal opinion of the results.

7. References

The last chapter of the work is for the exposition of the references used at the work. It contains literature related such as: scientific articles, conference proceedings, books, web pages, etc. This part of the work is mainly important for latter consultation on behalf of future researchers and practitioners interested on EPD applicability to timber/concrete structures.

3. THEORETICAL FRAMEWORK.

3. THEORETICAL FRAMEWORK

3.1. SUSTAINABLE DEVELOPMENT

National Academy of Sciences from the United States of America is devastating on its declarations: "Climate change happening as a result of increases in CO_2, will persist for thousands of years even if emissions stop at any time". This is a symptom that we have to act, and the sooner the best. Governments are getting serious about this situation and after Kyoto agreement in 1997 (#5) where the main objective was to reduce a 5.2% the Greenhouse Gas (GHG) emissions from levels of 1990, during 2008-2012 term, a new international agreement has been approved recently. We are talking about The Paris Agreement (#6), where the main goal is to limitate the warming below to 2^0C but aspire to not to reach 1.5^0C respect preindustrial levels and expecting the 195 countries to sign the agreement where every country will have to communicate every 5 years (more ambitious than the previous one) new measures to contribute reducing the Greenhouse Gas (GHG) emissions. Also, one of the most important points is to level off GHG as soon as possible. When it comes to talk about the construction industry and sustainable development, it is not easy to find a solid solution since it depends on many factors that sometimes are not possible to mesure and control by humans.

According to European Comission, buildings are responsible for 36% of CO_2 emissions in Europe.

Currently, aproximately 35% of the buildings in Europe are over 50 years old. By improving the energy efficiency of buildings, we could lower CO_2 emissions by about 5%.

The 2010 Energy Performance of Buildings Directive [#10] and the 2012 Energy Efficiency Directive [#11] are the Europe's main legislation when it comes to reduce the energy consumption of buildings.

The Energy Performance of Buildings Directive states various measures in order to reach a near zero emissions construction industry. One of these measures recites that all new buildings must be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018)

On the other hand, the Energy Efficiency Directive states EU countries make energy efficient renovations to at least 3% of buildings owned and occupied by central government.

EU countries must draw-up long-term national building renovation strategies which can be included in their National Energy Efficiency Action Plans [#12]

A few years now, organizations such as ZEB, the Research Centre on Zero Emission Buildings located in Trondheim are taking seriously sustainable development trying to eliminate the Greenhouse Gas emissions caused by buildings and the mentioned directives are an important step to reach this goal.

3.2. CONSTRUCTION INDUSTRY

Throughout construction industry history, concrete has been the most extended way to build during the last century and the very first years of the new century, especially when we refer to high-rise buildings. The over production of CO_2 is the principal cause of the Greenhouse Effect and the concrete production is one of the human activities contributing to these CO_2 emissions. In fact, according to World Business Council for Sustainable Development "cement industry produces 5% of global man-made CO2 emissions, of which 50% is from the chemical process, and 40% from burning fuel. The remainder is split between electricity and transport uses" [#13]

2.2.1 PREFABRICATED INDUSTRALIZATION

Industrialization of a construction system regardless of the material used in principle provides a wider range of technically controlled products and therefore more quality in the production. It is a proven fact that industrial production systems or building components not necessarily entails a depersonalizing repetition of the buildings, but rather a rich and greater freedom in aesthetic forms that prevent overcrowding and monotony in the product, of course provided where they exist in their conception imaginative ideas, which is also not exempt craft solutions poorly designed. Industrial wood as building material compared with respect to their main competitors such as iron, steel and reinforced concrete, offers a set of advantages to consider:

• Wood is a renewable material

• Obtaining the material does not require any artificial energy as the tree is generated based on natural energies.

• Industrial production does not demand high energy costs and the process is quick, easy and relatively clean.

• The industrial material processing technology allows accurate and quality label product, since it is all fabricated under the same conditions and controlled.

• The technology used in the treatment for drying and protection of the material is essential for the proper performance of the components later.

• The types of construction systems can be based on solid, laminated and wooden boards.

• The effectiveness of industrial production is conditioned by the appropriate modular and dimensional coordination of structural systems, components and prefabricated elements finishes.

• The housing construction systems do not require too much skilled labor, or additional equipment for assembly.

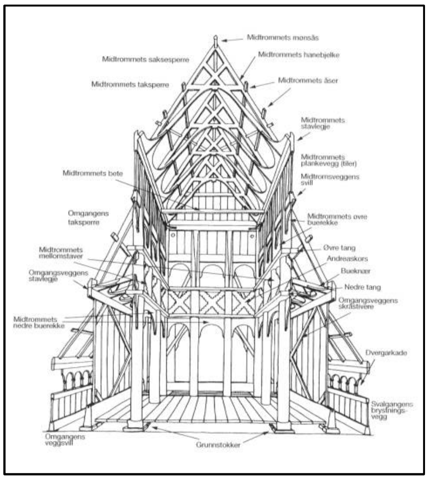
• The construction components allow a wider range of aesthetic and constructive solutions.

3.3. TIMBER CONSTRUCTION IN NORWAY

Norwegians know very well how to build with wood. As we know, many of the Norwegian treasures are wooden constructions and, as mentioned in the website visitnorway.com [#7] "thanks to the Vikings' interest in boat construction and home building, the technique and tradition of wood carving was further developed. The work culminated in the stave churches." Norwegian tradition in wood is wide and many of their precious treasures such as the Bryggen (UNESCO World Heritage Collection) in Bergen, boats and so on.

Stave churches are built all over northwest Europe but almost exclusively preserved in Norway. Heddal Stave Church, which is the largest one, was built in the 1200s and it is still in use. This is the evidence to prove that the durability of timber structures is wider than people think.

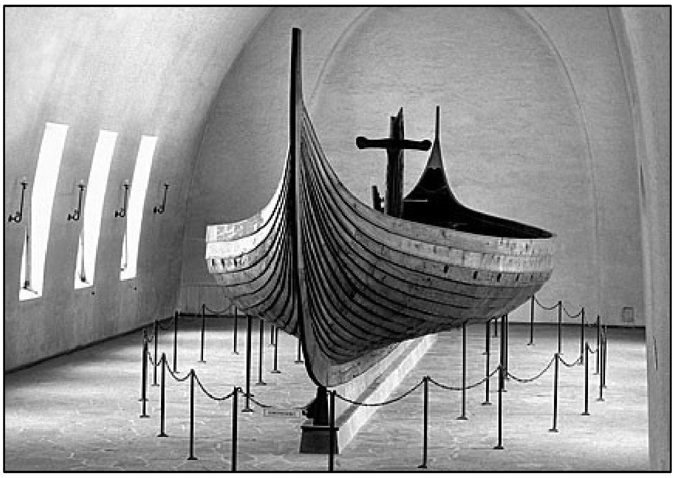
3. Heddal Stave Church in Telemark, Norway. Source: visittelemark.no



4. Stave Church. Source: unknown

Its structure is based in large pillers over a flat stone foundation, which function was to elevate the foundation from the ground level. This pillers "stave" in Norwegian, gave this type of churches its name. The walls were made from vertical planks topped with four more beams to support the roof.

Other of the greatest technical and artistic achievements of Norwegian wood tradition are Viking Ships. Vikings traded, explored and raided with this ships and its resistance gave these boats the popularity they deserve.



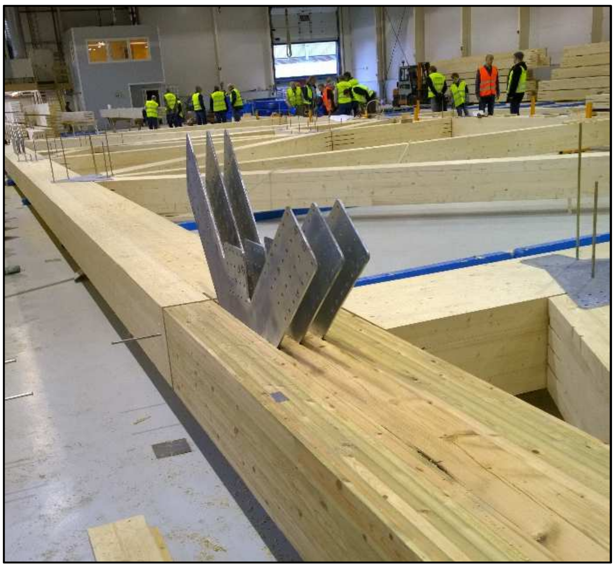
5. Rakkar ship in Oslo museum – source: unknown

6. Gokstaad ship in Oslo museum – source: https://byrdwords.wordpress.com/tag/ships/

But where we want to focus at this point is on Norwegian timber structure bridges. The first bridges ever built were made with timber structures and after all this time, timber is still a great solution when it comes to talk about resistance and durability but these are not the only reasons to use wood as a material to build bridges. Environmentally speaking, as we have mentioned in the previous chapter, wood consumes very low energy since it grows naturally itself, it is a renewable material and what keeps us focused on this project, it is a CO_2 bonding material which is more than interesting considering that we need to reduce as much as we can the Greenhouse Gas emissions in order to preserve the world we live at.

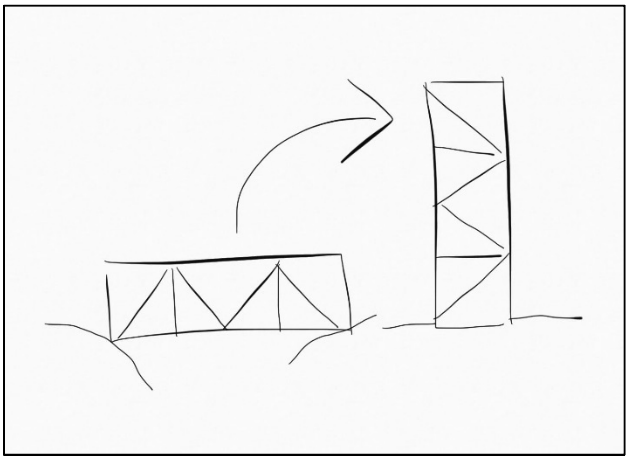
7. Flisa bridge 200 length – source: BROR.NO

But heading back to the structural characteristics of Norwegian timber bridges, durability, simplicity, robustness and aesthetics are the main keywords when talking about them. One of the ways to raise timber bridges is with the “slotted-in steel plates”, which consists in joint of several glulam members in a truss and inserted steel plates to acquire a solid structure as shown on the image below. It also gives the structure extra safety against a fire, delaying the collapsing time



8. Slotted-in steel plates structureof the Treet building – source: ARTEC

Since scandinavian know very well this technique, BOB BBL decided to enforce this solution of bridges construction but translated into high rise buildings. Basically, what we are talking about is to turn a bridge 90º. This way we provide the building with enough stiffness to support all the weight of the building.



9. Representation of the bridge- building structure – source: own elaboration.

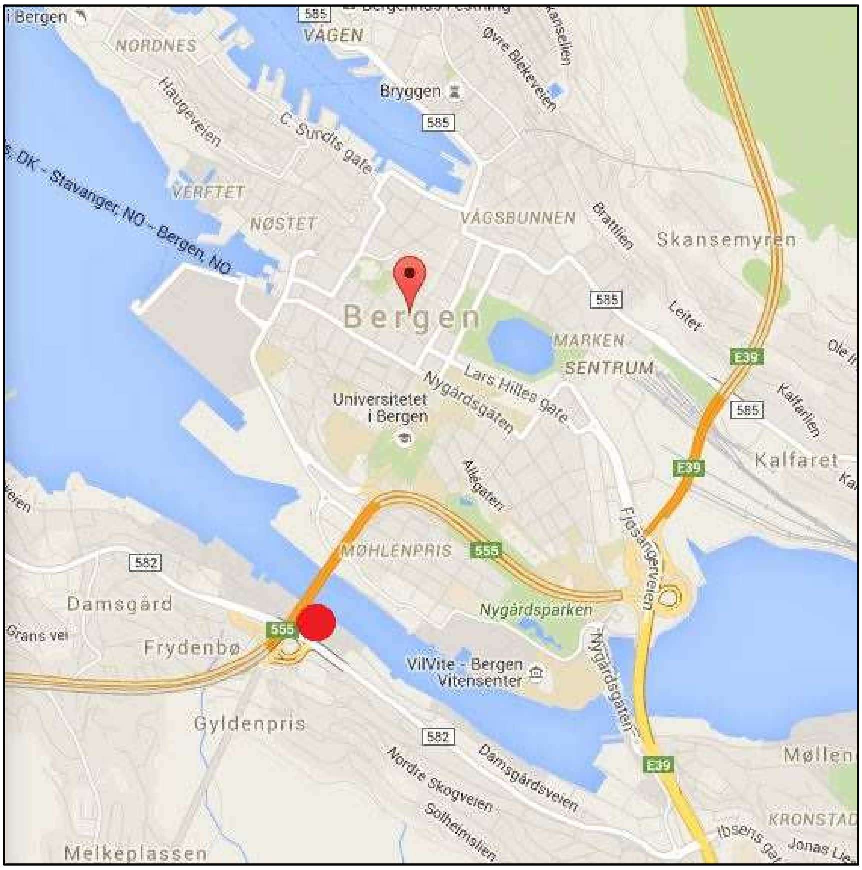
10. Timber structure of the Treet building. – source: ARTEC

3.3.1. TREET BUILDING

In 2010 starts in Bergen, Norway, the early phase of the world tallest timber structure building. It was not easy to raise a high rise building in a wooden structure so it was a hard task to develop a solution for such a big project. To do so, BOB BBL had in his team proffessionals from different specialities formed by:

- Sweco, as engineering group.
- Arctec, architecture.
- Moelven, glulam and cross laminated timber structures.
- Kodumaja, in charge of the prefabricated modules.

The building was finished by December 2015 and it reaches 52.8 meters high, known as "Treet" or “Treehus” by the locals. It is placed along the south shoreline of Puddefjord Bridge. Integrated into the Damsgård area of Bergen.



11. *Treethus placement (red dot) – source: Google maps*

Before the Treet was built, Melbourne's Forté (Australia) had the honor of being the tallest timber building, 32m tall of 10 storey block.

12.Forté build, Melbourne – source: http://www.victoriaharbour.com.au/live-here/forte-living

13.Picture of the Forté under construction source: http://www.thefifthestate.com.au/articles/clt-could-spark-local-manufacturing-industry/51883

Originally was an idea suggested by the architect Geir Brekke of Lund & Partnere in 2005, when the site was being zoned. But the project did not continue until 2010, when BOB BBL took care of the project. For this contract, the structure is a design of Arctect and Sweco. In addition, with the help of the Norwegian Institute of Wood Technology and the Norwegian University of Science and Technology (NTNU) which provided advice and additional support.

BOB thought of making the structure using solid cross-laminated timber, which has been used previously in Sweden (Väsjö), London (Murray Grove) and a variety of places in Austria.

14.*Murray Grove, London – Source: http://eoinc.weebly.com/uploads/3/0/5*

However, they concluded that the best solution for the development of the building, would be to combine prefabricated construction modules with a glulam structure. The structure is mainly a composite cross-laminated timber and glulam, built over a concrete foundation. Therefore, we can say that they have chosen materials that meet future requirement for sustainability and Greenhouse Gases, environmentally friendly.

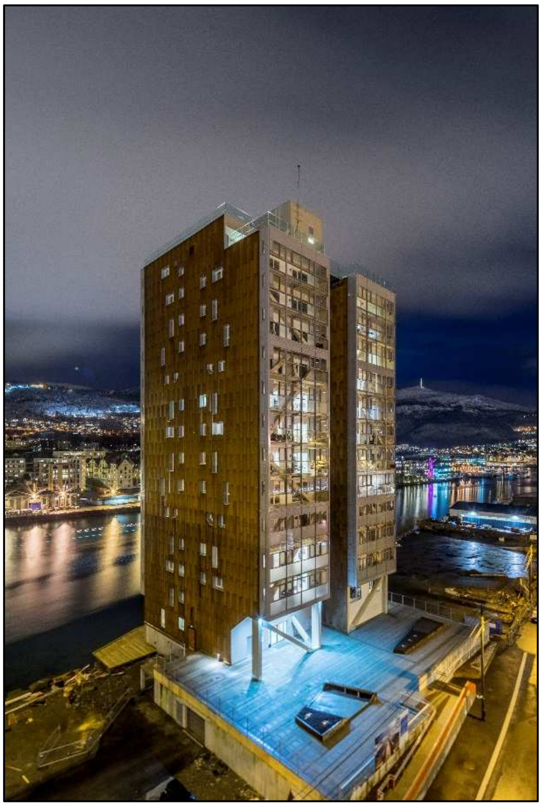
Department floors 5 and 10 must conform to the supporting structure with the beam across the interior. Most departments have their own balcony, and the building will have a terrace on the top floor (in the 13th and 14th floor). The building also has a gym and recreation areas.

In order to not exceed the maximum m^2 floor marked by the planning regulations, the architect had to

The architect was in the need to create "holes" inside the building (used in the gym), so as not to exhaust the maximum floor marked by the planning regulations, also like setback on the 14th floor, this way they manage to achieve the goal of the 14-storey building.

Developers and this project, want to demonstrate that there is possible to build with no harmful materials for nature. That meet emission standards gases into the atmosphere. It is expected that this type of construction is important for the future and serve as a pilot building for the next steps. In words of the architect, with the knowledge they achieve from this project, they could enhance the whole process, reducing the construction time and the economic waste.

16. *Treet building – source: Arctec*



15. *Treet building – source: Arctec*

The next quote was said during its construction:

"Kleppe estimates that the building will probably use about 9,500 cubic meters of lumber in its load-bearing structures thereby avoiding approximately 18,000 tonnes of CO_2 emissions. This is

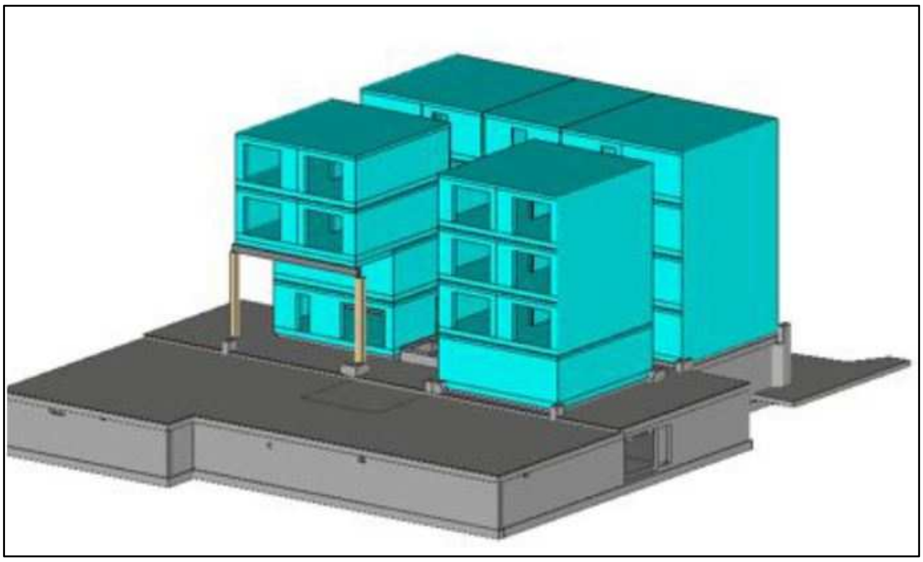
equivalent to avoiding driving a good 105 million kilometers in a petrol car that consumes 7.5 liters per kilometer or avoiding more than 210 million crossings of the Puddefjord bridge in Bergen. In addition, there is also the CO_2 stored in the wood in the prefabricated building modules. Overall the building will avoid more than 21,000 tonnes of CO2 emissions." [1]

3.3.2. STRUCTURE OF THE TREET BUILDING

The building rests on a concrete foundation, with an underground floor that serves as a parking place for cars. From this concrete foundation, the prefabricated modules begin to stack up until reach the floor number four.

The use of this prefabricated elements will reduce installation time on site, the erection time was significant faster than a concrete structure, and they were able to erect almost three levels in four days. Also there is an interest on work in this way of build, this is a pilot project for the future of the industrialization process in construction area. The modules are transported from Tartu, Estonia, by boat to the construction, were Vest Kran make the connections between the apartment modules and the glulam structure.

The building's apartment modules have been designed to comply with the Passive house sustainability standard and have been constructed in a factory in Estonia.



17. *First four levels of prefabricated modules – Source: ARTEC*

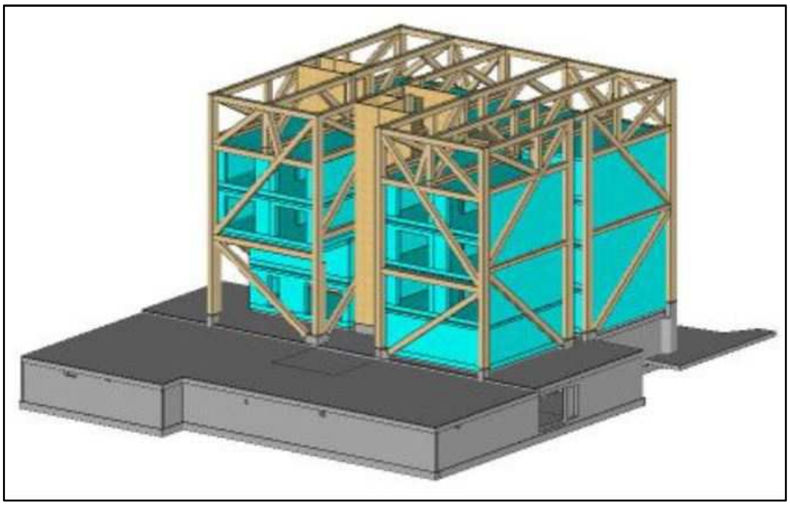
There is not much space available in the construction area for storage. So it is important not to store many materials, for that purpose, the prefabricated modules are perfect. They can be installed quite fast without waste space in the build zone. Likewise, with the use of these modules, the architect design a plant type, which is repeated throughout the different floors, making it easy to mount.

The timber-frame wrap the prefabricated modules. This structure is made with Glulam

The 5th and 10th floor are specially reinforced with four 3,00m high lattice beams of glulam, these four beams are fully visible from the inside the apartments. These plants are called "power plants" and they are responsible for supporting the following four levels intervals. With this disposition there is no need to use special reinforced modules on the lower floors.

The beams are anchored to the main resistance structure and connected to the construction modules.

The Cross-laminated Timber (CLT) is used in the staircases, elevator shaft, some inner walls and balconies, but is not structurally connected to the glulam frame. The decision behind this, is that the CLT has resistance problems, making less effective in comparison the glulam.

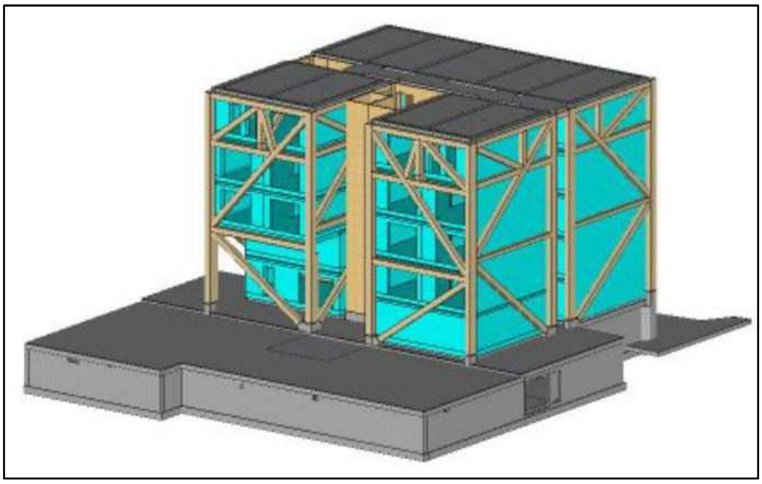


18. 5th floor "Power plant" and timber structure - source: ARTEC

To avoid that the building will sway in the wind the laminated construction is reinforced with diagonal laminated wooden beams. The modules will also be connected to the grid system to mitigate fluctuations in construction.

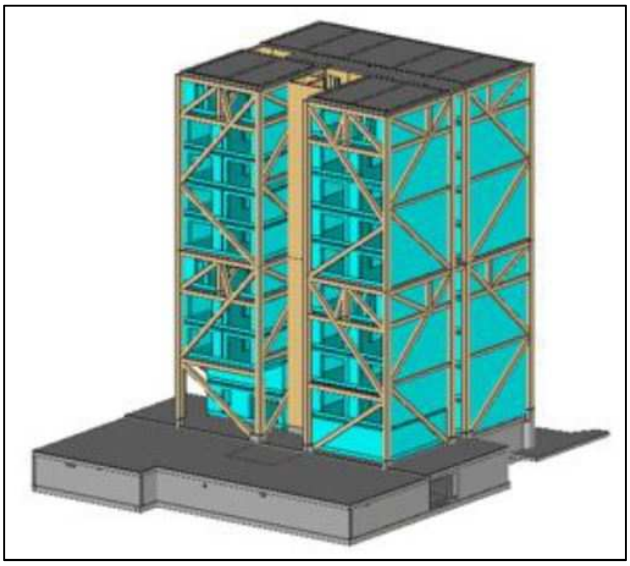
19. Picture *of the construction. The timber-frame and the modules after its installation – source: ARTEC*

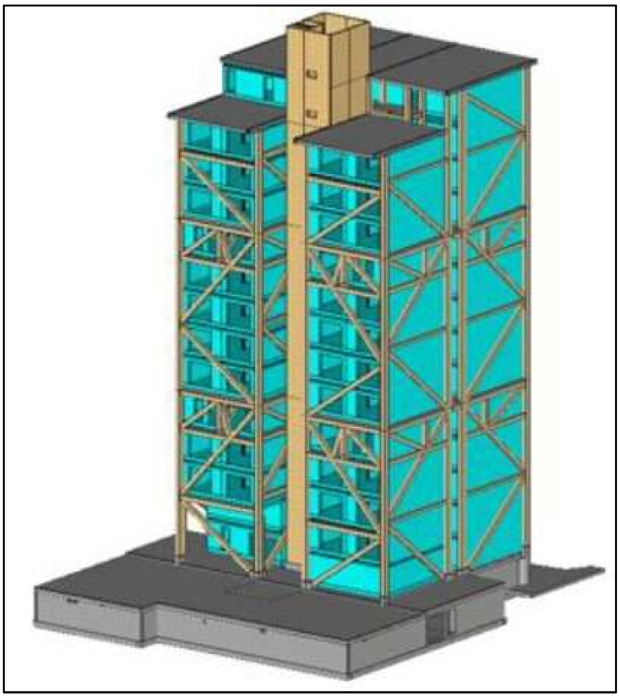
Although the whole structure is made of wood, a concrete slab on the “power plants” is placed. Its principal mission is to add more weight to the building, enhancing the dynamic behavior. Also serve as platforms for stacking the apartment modules.



20. *First four floors of the building. Structural concept and representation. With the power plant finished and the concrete slab above. – source: ARTEC*

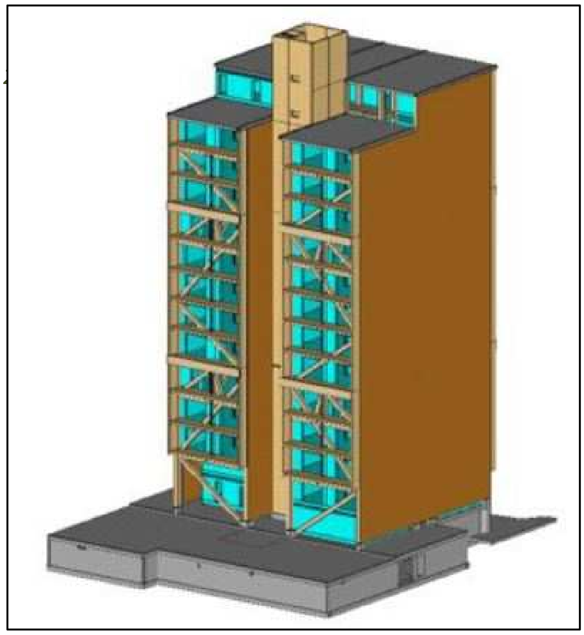
The process previously explained is repeated from the 6th floor until the 10th where there is another “power plant”. And then unto the roof (floor 14th).



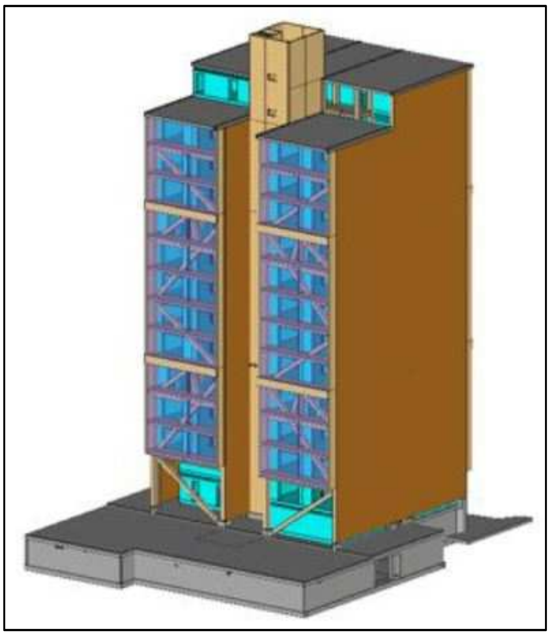


Façades.

There are two different types of façades in this building. The north-west and south-east are covered with a rusty steel plates, which protect the isolation against the damp weather. The other two façades cover the balconies with a steel-glass curtain wall. This reduce the maintenance required for the structure by protecting it from the local weather.



22. 3D model of the Treet building with steel cladding. – source: ARTEC

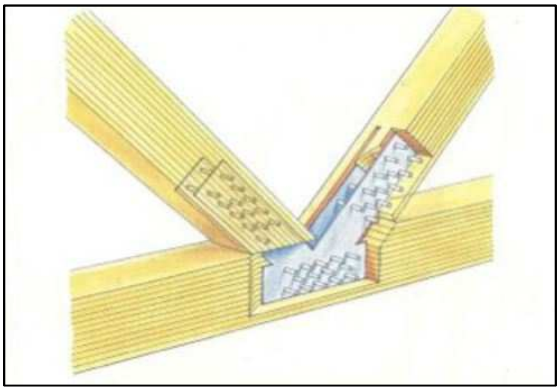


21. 3D model of the Treet building steel-glass façade – source: ARTEC

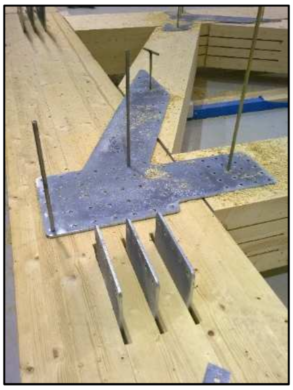
The main structure of the building, as explained previously in this project, has its inspiration in the structure of bridges.

One of the keys that allow this building are the beams connections. Taking this element from the Rena Bro.

With a core of steel bars and plates. Perfectly withstands the most demanding actions to which it is subjected the building. These steel connections are hidden inside the timber, as shown in the images below, providing them with protection from the fire effects.



24. *Drawing of the steel connections on the timber structure – source: ARTEC*



25. Steel connections on the timber structure – source: ARTEC

3.4. LIFE CYCLE ASSESSMENT (LCA)

All products, not just construction products, have an impact on the environment and this impact can occur at any time during the manufacture, use or end of life. All these stages are collectively called a life cycle. Construction products have impacts from the extraction of raw materials, processing and production, maintenance and renewal, for eventual end of life and disposal. The measurement of this impact is called life-cycle assessment (LCA). There are two types of stroke of construction products:

Generic assessments: Where the data is collected from various manufacturers of the same product type to create an industry average.

Property assessments: Using information from a specific manufacturer, doing a personalized scenario to your product.

International Organization for Standardization (ISO) defines LCA as "a method for summarizing and evaluating the total investment of a product (or service) system throughout the life cycle, and the impact or potential impact on the environment” ISO 14040 for their life cycle from cradle-to-grave, or cradle-to-gate. Depending on the scope of the LCA.

At a stroke the potential of each process and impact productive stage is evaluated by performing the following activities:

- Compile an inventory of inputs and outputs most important system of a product.
- Assess the potential environmental impacts associated with those inputs and outputs.
- Interpret the results of the inventory analysis and stages evaluated in accordance with the objectives of the study

Regulations: ISO 14040: 2006 (LCA): Environmental management. Life cycle assessment. Principles and structure.

Environmental Protection Agency (EPA) define four main stages for the life cycle:

- Obtaining the raw material. Includes he resources consumed, as well as the materials and energy spent for the extraction and transport of the materials.
- Production, includes the activities of raw materials transformation, product execution and its transport and conditioning to its destiny.
- Use, reuse and maintenance.
- Recycling and waste treatment.

Also is important to consider the “Embodied energy”, the energy using at the early phases of the life cycle, raw material extraction, production processes and transportation of raw materials to the factory and products to consumers.

A LCA study compounds of four phases according to the ISO standard.

1. Goal definition and scope assessment.
    - Expose relevant information: people in charge, team developing the study, company, case study, basic information of the study for achieve a correct presentation of the study.

- Description of the characteristics and peculiarities existing within the methodology.

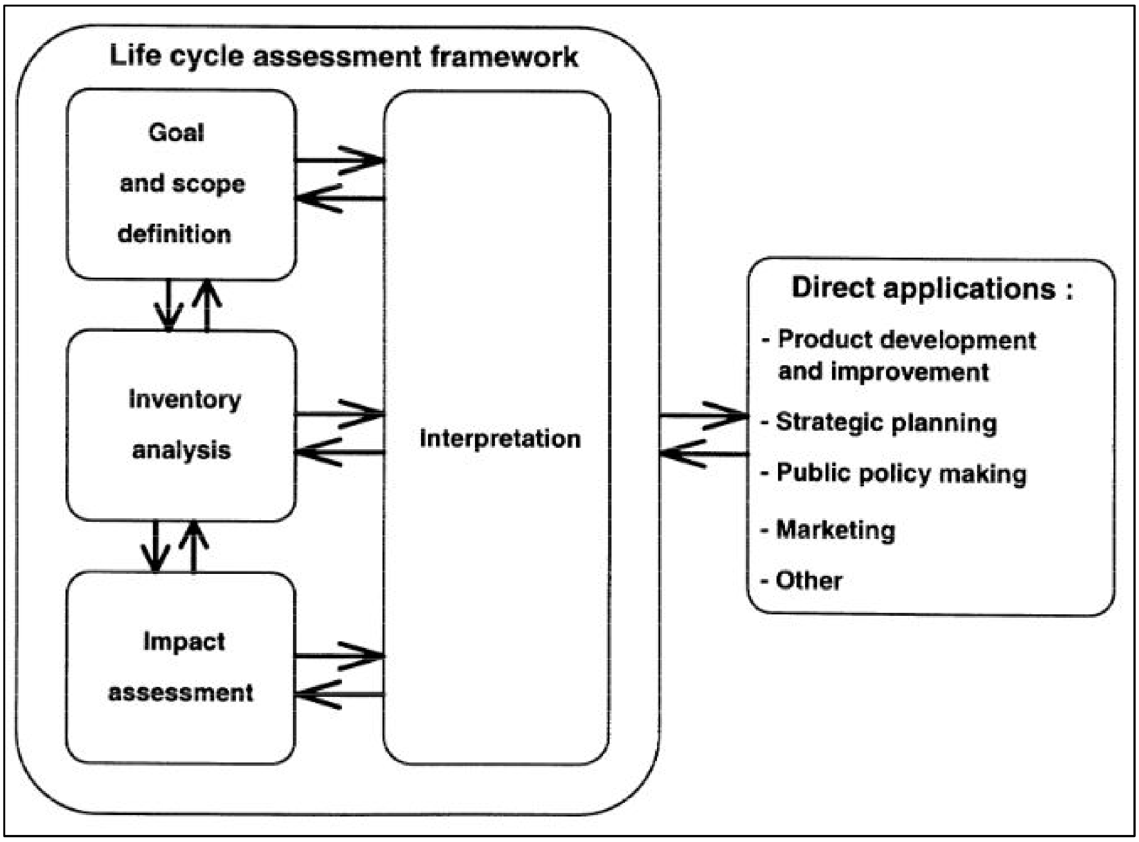
2. Inventory analysis. Life cycle inventory (LCI).

3. Impact assessment (life cycle impact assessment (LCIA), based on the LCI results. Associates inventory data with different environmental impact categories and characterized by each category indicators. According to the ISO standards, only the three first steps are obligatory.

   - Selection
   - Assignment of LCI results to the selected impact categories (classification.
   - Calculation of category indicator results (characterization).
   - Normalization
   - Grouping
   - Weighting
   - Data quality check

4. Interpretation

   This is the phase in which the results are discussed and reach relevant conclusions, set the final evaluation of the study.



26. Life cycle assessment framework – source: ISO 14040

Impact assessment identify mistakes or problems within the study

Second and the third phase are considered the active/dynamic phases of the assessment, where the data is captured and evaluated. The other two are the static phases.

After the study, a report must be made. There is an extra critical review, which is necessary when the study needs to be enhanced and be disclosed to the public.

LCA can be used and applied in many products and services, but it was developed for single products, not a whole build.

This make a new perspective of the studies, the different scales of the scopes, and too different kind of products, for this change in perspective from conventional to unconventional, LCA has defined two types of studies, Attributional and Consequential. Depending on the allocation method.

Attributional: describes the environmentally relevant physical flows of a product or process. It's the standard report. Use ordinary data.

Consequential: describes how relevant environmental flows will change in response to possible decisions. Also includes economical concepts (with dynamic models of supply and demand), making this kind of report more conceptually complex, using marginal data representing the effects of a small change in the output of the manufactured materials.

This difference on the study, is made in the first step of the LCA, the "goal and scope" phase.

Environmental impacts that can be seen in a LCA.

- Impacts on renewable resources.
- Impacts on non-renewable resources.
- Global warming potential (carbon footprint).
- Potential deterioration of the ozone layer.
- Acidification potential.
- Creation potential photo-chemical ozone.
- Energy use.
- Using water.
- Toxicity (human, terrestrial, aquatic)

General objetives of LCA.

- Getting key and specific information associated with the production of goods.
- Identification of critical points in production processes.
- long-term strategic planning.
- Login differential niche market.
- Provide consumers with a clear, relevant and usable information.

Advantages and benefits of LCA.

- Development and improvement of products.
- Strategic planning: process optimization and reduction of risks associated with competition with similar products.
- Marketing and advertising: improve brand image.
- Access to international markets and compliance with current environmental regulations
- Positioning in Retail Sector (TESCO, Metro Group, M & S, Wal-Mart, Pepsico, etc.).

- Income differentials niche market: the possibility of expanding the market.
- Selection of specific environmental performance indicators for each product.

Key features of a LCA study and comparisons.

• **Goal and Scope**: These must be considered and described for any study and are an explanation of the context of the study, its boundaries and methodology and how and to whom the results are to be communicated. The following will also be covered by the Scope of the study:

• **Transparency**: Information must be provided on the sources of data, what assumptions have been made during the study and what rules or methodology has been used.

• **Environmental Indicators**: The range of environmental indicators assessed must be listed and justified.

• **Life Cycle Phases**: Studies should look beyond the factory gate, to include the transport and installation of the product, its use and maintenance, and disposal at the end of life. Should there be significant differences in gate to grave processes for different products, these life cycle phases must be evaluated when product comparisons are made.

• **Impact Measurement**: Impacts must be measured for both upstream and downstream impacts. This means assessing the impacts of the inputs and energy required for the process (upstream), as well as those resulting from disposal of any wastes (downstream impacts).

• **Functionality Issues**: Studies can take into account the additional functionality of some processes or products, for example those that produce co-products or which provide more insulation than other products.

• **Comparisons**: Any comparisons between LCAs must be on the basis of common functionality, scope and methodology.

• **Compliance with standards**: All LCA standards which are made public should be critically reviewed to ISO 14044 if they make comparative.

3.4.1. LIFE CYCLE IMPACT ASSESSMENT INDICATORS

The Life cycle assessment studies several Areas which are:

27. Environmental Impact Areas – source: Embodied impacts brochure small V9

Each one is studied with a specific measure that is involved on it. Those areas have the next impacts categories:

- Embodied carbon.
- Acidification.
- Eutrophication.
- Stratospheric ozone depletion.
- Photochemical ozone creation.
- Abiotic depletion: elements and energy.
- Raw material use/ mineral extraction.
- Toxicity.
- Land use.
- Embodied water.

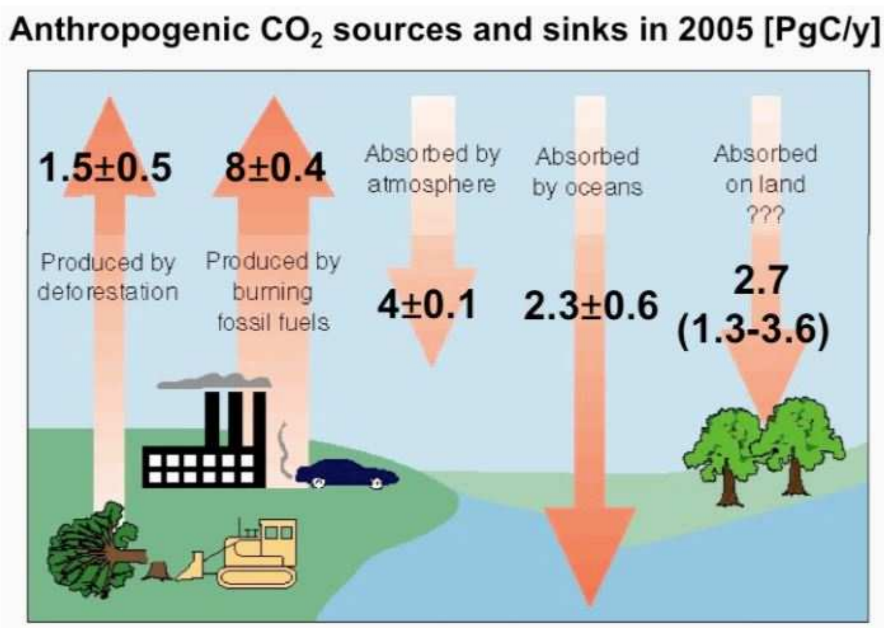
With this project we will focus on the Global warming potential, in order to calculate carbon footprint and the emission of CO_2 (Kg). Which is also called Greenhouse Gas (GHG).

Embodied Carbon.

"Carbon Footprint, global warming/global warming potential, climate change, embedded carbon."

It's the carbon dioxide emission emit with the manufacture and/or use of a service or product. In the construction area this include the material raw extraction, transport to the factory, manufacturing, transport to the construction, installation, use life emission and end of life (recycle or place at a landfill).

The extraction phase and the manufacturing are the ones with more emission of carbon dioxide.



28. *Carbon dioxide cycle – ideo.columbia.edu*

There is an interesting fact to emphasize, and it's the difference between the "embodied carbon" of the product, which is the emission during its construction (10-25% of the emission). And the "operational carbon" which is the emission during the everyday use of the building (75-90%).

Global warming potential (climate change).

Global warming is the result of the effect of different gases, which are measure with the amount of CO_2 which would need to be released to have the same radiative strength effect as a release of 1 g of the Greenhouse gas, in a certain time period, (20, 100, 500 years).

Sources of embodied carbon

As we have said before, the daily use of the building produces greater emission of carbon dioxide, but is in a range of approximately 100 years, which makes it significant emissions in the early stages of the life cycle.

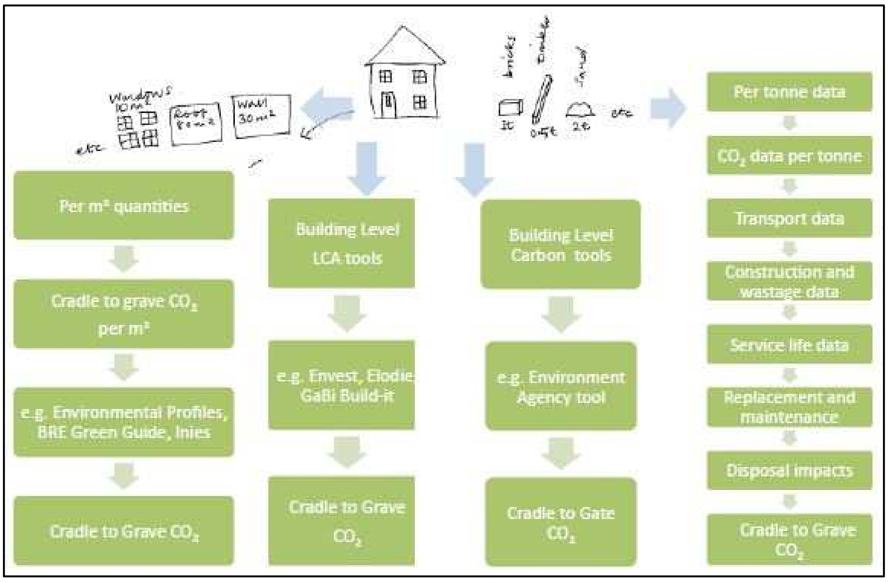
In the construction industry the critical emissions are from the use of energy, as mentioned before, the extraction and the manufacturing of the materials are the most contaminant phases.

The disposal process, recycling, landfill, have a considerable impact on nature but not usually cause for in-depth studies (transport or reprocessing). There is a point with the biomass disposal like timber, which is a subject of ongoing research, there are studies suggesting most timber will stay intact, other things that timber emits a mix of CO_2 and methane, with different degrees of collection for flaring or energy recovery. There are other that says the biomass while its growing, take the carbon from the atmosphere, as a consequence the carbon emission is considered negative, which have benefits to the ozone.

Assessing the impact of materials at the building level.

Use of EPDs for Building assessment schemes

Operational impacts (primary heating, cooling, ventilation and lighting of buildings) decreased by regulating new construction, and the technologies of each system, then the impact of the materials used for the construction of buildings becomes more important, and of course to calculate the environmental impact. There are different ways to do such study, as it can be seen in the next diagram.



29. "a guide to understanding the embodied impacts of construction products" – source: Construction products association

The diagram shows several approaches to measure the environmental impact associated with the materials at building level. Some only measures carbon dioxide (or greenhouse gases "GHG"), while others include a wider range of indicators (always included in official databases). This is for an EPD report, so the boundaries are the same than the ISO standards (Cradle-to-gate or the cradle-to-grave). Even the simplest approach combines measures of different specifications of the elements areas, and their impact data on the carbon impact can be obtained from a variety of sources such as the Green Guide BRE (which provides support to serious emissions embodied greenhouse gases of data per square meter for each element), manual fixing Hutchins price as UK Blackbook (cradle to gate data embedded carbon) or other relevant bodies such as EPD INIES (FR) that provide the impact m² sources. This approach means that the base of the door or the cradle to the grave impact can be calculated for embodied CO_2.

An alternative approach is to consider the mass of individual materials, and environmental data provided on this basis. The measurement of the individual materials on a mass basis can be carried out by converting quantitative data lists tonnages, and this may be linked to data per ton of product. There are a huge variety of official databases that can be used, of course it is advisable to use the fonts created by the country in which the study was conducted

<u>Why are EPDs suitable for building assessment schemes?</u>

EPDs are suitable for building assessment schemes since they are:

- Based on international standards.
- Include the life cycle perspective (cradle-to-gate or cradle-to-grave, depending on the product).
- Cover multiple environmental impact categories.
- Are independently verified and aim for comparability within the same product category.
- It's a neutral study which only measure the amount of CO_2 (and other environmental issues).

- Do not label a building as a "good" or "bad" environmental performance, just for evaluation assessment scheme.

Inventory analysis structure of a building:

1. Develop a flow diagram of the process being evaluated. (Construction techniques, assumptions of the practitioner, location and project constraints….) exhaustive calculation process of materials used at the construction for the structure. While more detailed this diagram, the more detailed the diagram, more complete will the report be.

2. Develop a data collection plan.

First part of the LCI is done by data recollection. When collecting data of LCI, it is advisable to establish a plan taking into account this aspects:

Data normally used in LCIs,

- Environmental data of the own investigated processes.
- System data on the flow of raw materials, energy and products through the investigated process.
- Performance data related to the definition of the functional unit used to compare different product systems.
    - Correct source of the data: transparency and reliability
    - Data according each country
    - Use software databases from outside origin country of the materials, needs special attention

3. Collect and distribution of the data

   All data in the inventory, should be described well and thoroughly referenced

4. Evaluate and report the results.

   Verification of data collected using benchmarks. Aggregate or no some parts of the life cycle of the elements.

Advantages: the method can be applied in many kind of products. The studies are neutral. LCA are open to everyone. It's intended to be objective method. Has its own international standard.

Disadvantages: production processes in construction are very complicated and different. It could be bad praxis. Risk of committing mistakes increases with the degree of complexity of the functional unit and system boundaries considered in the study. The result may vary depending on the investigator selection of the scope and objectives. There is no standardization for every product/system. Interpretation of the result depends on the investigator. Not consider social factors only economic and environmental.

3.5. ENVIRONMENTAL PRODUCT DECLARATION (EPD) INTERNATIONAL SYSTEM

Sustainability concern in the construction industry has increased in the recent years. Global warming it's a fact, and the many treaties signed force the construction industry in reducing the environmental impact of its products, making construction developers to find eco-friendlier forms of building and construction, as the use of alternative materials.

As an initiative for which there was a certain etiquette that is created for this reason, as the program of European eco- label, the acquisition of European green products, and ISO 14020, which definitely all three series:

- Type I, according with the ISO 14024
- Type II, according with the ISO 14021
- Type III, according with the ISO 14025.

The type III could be the most practical and useful for the studies of this project and the environmental impact of construction material. This environmental labeling provides information on Life Cycle Assessment (LCA) of the product/services, which can be used for the EPD report.

So, the EPD is the particular type of life-cycle assessment (LCA) has been developed to provide environmental information LCA studies in a common format, based on common standards known as PCR (PCR).

Life Cycle Assessment + Product Category Rules = Environmental Product Declaration

EPD have been used for construction products since the early environmental assessment schemes were developed in the 1990s and EPD ISO standard, ISO 14025: 2006 establishes international standards to be met.

EPD can only be compared when the rules of PCR used are the same and all stages of the life cycle in question were included (like PCR, to ensure the scope, methodology, quality of data and indicators should be thereof), in amounts, you should eat the same EPD program. For example, an EPD for 1 m^2 of concrete cannot be compared with EPD for 1 kg of structural steel profile. In addition, products cannot be compared unless its functionality and its use are considered at the building level within a system. The comparison should also take into account other materials that may be necessary, for example, for fire protection and bases to support the weight of the different solutions and any difference in service life, maintenance and disposal of the two structural systems are compared.

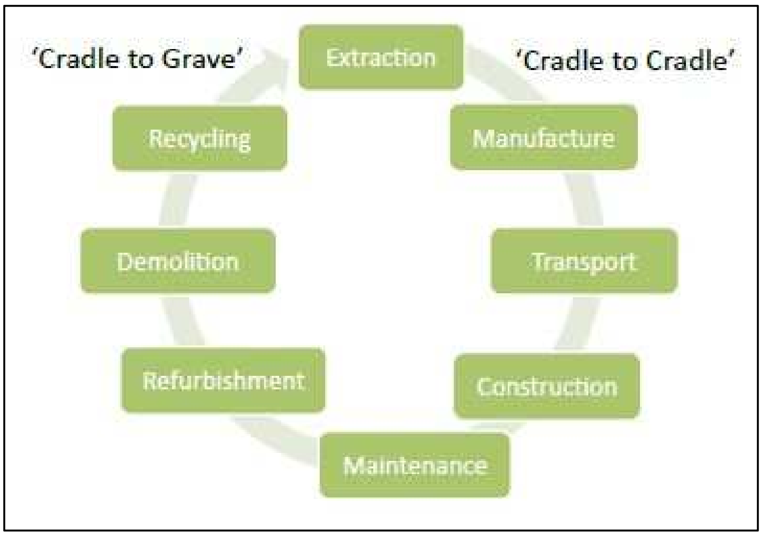
Construction EPD should be in concordance with the ISO 14040, ISO 14044 and ISO 14025:2006.

The EPD System has as main objective help and support organizations to communicate the environmental performance of their products and services in a transparency, credible and understandable way by:

- Offering a complete program for any interested organization in any country to develop and communicate environmental declarations according to ISO 14025 and EN 15804, additional information on certain environmental issues such as the carbon footprint of products in accordance with ISO / TS 14067 as "a single theme EPD".

- Support for other programs (national, sectoral, etc.) environmental statements in seeking cooperation and harmonization and helping organizations to expand the use of environmental claims in an international market

Also offers a program around the world which serve to disseminate verified information related to the product, created EPD's, and more information related with the environmental materials.

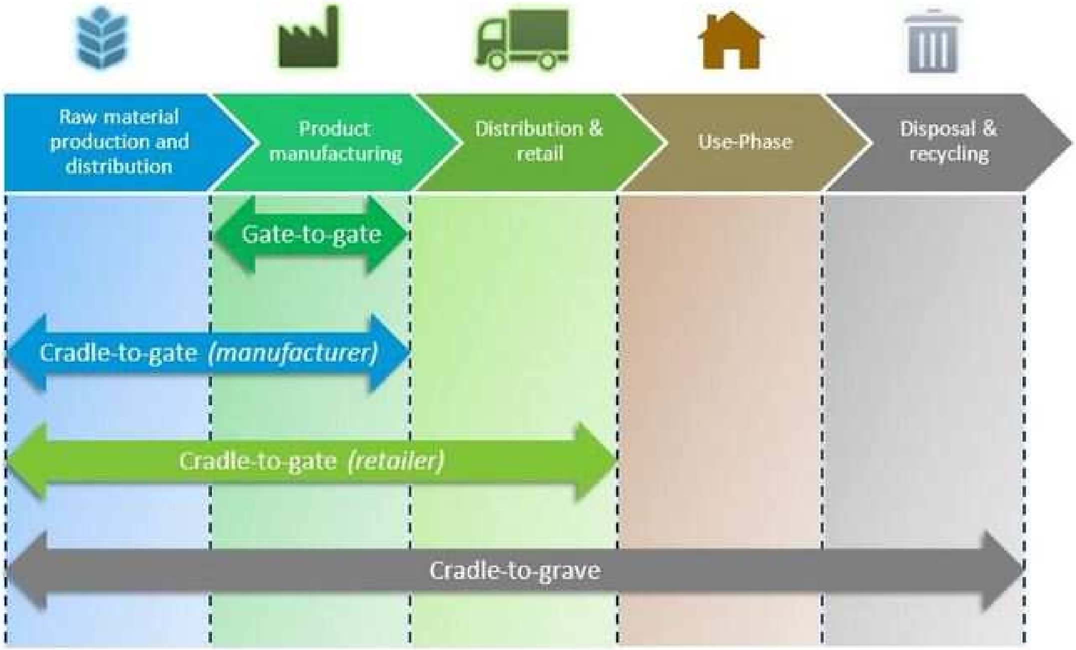


30. "A guide to understanding the embodied impacts of construction products" – source: Construction products association

According to ISO 15804 there are three kinds of EPD depending on the functional unit boundary.

EPD Type	Life cycle stages included	Units	Use for comparison
Cradle to gate	Covering product stage information A1 to A3 (raw material supply, transport, manufacturing of products, and all upstream processes from cradle to gate). This comprises the minimum of processes that shall be required in a declaration for compliance with EN 15804:2012	Declared unit	Shall not be used for comparison
Cradle to gate with options	Covering product stage information as a minimum, plus any other information modules from both the use stage and the end-of-life stage (B1 through to C4). Benefits and loads beyond the system boundary (Module D) may be included	Declared unit or functional unit	Shall not be used for comparison
Cradle to grave	Covering all of the life cycle stages as a minimum, including end-of-life at or beyond the study period. Benefits and loads beyond the system boundary (Module D) may be included	Functional unit	Can be used for comparison if the functional unit is equivalent

31. Source: ISO regulation 15804



32. A guide to understanding the emboiled impacts of construction products - source: Construction Products Association

Depending on the functional system we are, there are the next system boundaries.

Product			Construction		Use stage							End-of-life				Benefits and loads beyond the system boundary
					Related to the building fabric					Related to the building operation						
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Demolition	Transport	Waste processing	Disposal	Reuse / Recovery / Recycling potential

33. Stages in an EPD – source: ISO 125804

Product stages, modules A1-A3

A1: Raw material extraction and processing, and the processing of secondary material.

A2: Transport of raw material to the manufacturer.

A3: Manufacturing materials and products.

Includes energy used in factories, factory support offices. Provision of all material, products and energy. Also includes any other output leaving the system that has a value associated with it (but must be identified).

Excludes: Head offices and sales offices, contribution of capital equipment and infrastructure it’s not usual to be included.

Construction Process stage, modules A4-A5

A4: Transport of construction product from the manufacturer gate/ to the building site.

A5: Installation into the building.

Here ends the cradle-to-gate EPD, and include all the materials and energies used in the transport and installation of the manufactured elements. In construction products, ancillary and water should be included, if it’s included in the process.

Usage stage (building fabric), modules B1-B5

B1: Use or application of the installed product.

B2: Maintenance.

B3: Repair.

B4: Replacement.

B5: Refurbishment.

As the modules A4-A5, includes the elements used on it, water, ancillary and any material used on it (production, transportation, energy, water…).

Usage stage (related to the operation of the building), modules B6-B7

B6: Operational energy use.

B7: Operational water use.

Include the energy and water using during the operation of the product (heating, ventilation, cooling, lighting, domestic water, services, communication, IT, internal transport, fire and security).

End of life stage, modules C1-C4

C1: De-construction, demolition.

C2: Transport to waste processing.

C3: Waste processing for reuse, recycling, and energy recovery.

C4: Disposal and the associated processes.

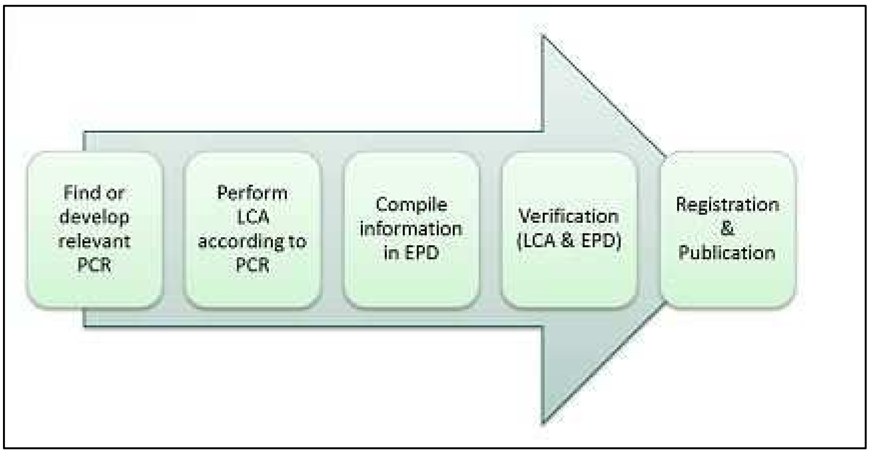
Net impact, module D

Covers the net benefits and loads arising from the outputs of the reusable products, recyclable materials and fuel from the previous stages.

Is applied only to materials which substitute other materials or fuels in another system and reached the last stage of the life cycle. Double counting of those materials and products have to be avoided.

3.5.1. CREATING AN EPD

An EPD is created in accordance with ISO 14025, a standard developed by the International Organization for Standardization (ISO). Often times, a Program Operator is hired by the manufacturer or industry association to manage the EPD creation process. The process typically requires the following three key steps:



34. Environdec – web page.

Step 1: Identify/Create a PCR

Product Category Rules (or PCRs) describe how a Life Cycle Assessment (LCA) for a particular product is to be conducted. The first step is to determine if a PCR exists for the particular product category. If a relevant PCR does not exist (or has expired) for a product category, it shall be created. In the case of expired PCR, can be reactivated and updated for a prolonged period of time. The creation of a PCR entails an open, consultative, transparent and participatory process, which typically features substantial input from several interested parties including product manufacturers, consultants and others.

PCRs include a variety of pertinent information including the unit of measure to be assessed as well as the boundaries of the LCA. For example, it will indicate whether the LCA should assess the products environmental impact from cradle-to-gate, cradle-to-job or cradle-to-grave.

They are considered complementary to the general requirements of EPD programs. Rules Product Category documents (PCR) define the requirements for the EPD of a particular product category. They are vital to the concept of environmental claims because they allow transparency and comparability between different EPD based on the PCR itself.

Step 2: Perform a Life Cycle Assessment (LCA) according to PCR

An LCA is prepared according to the rules outlined in the PCR. It features a compilation of inputs, outputs and potential environmental impacts of a products described from a life cycle perspective.

Sometimes there is a lack of information, and a specific LCA data do not exits. In that case, it's allowed to use a defined proportion of selected generic data in their report, which is described in the PCR.

Step 3: Compile information in EPD format

Once the LCA is completed, the LCA data for a particular product is entered into an EPD format, which makes it easy for users to compare the environmental impact results of one product to another.

- Cover page (voluntary)
- Programme-related information
- Product-related information
- Content declaration
- Environmental performance-related information
- Additional information
- Mandatory statements
- Executive summary in English (in case of EPD only published in another language)

When evaluating products whose EPDs were created using the same PCR, this enables more of an "apples to apples" comparison. Other variables to consider when comparing EPDs for similar products may be the years in which LCA data for each product was collected, the software programs used and perhaps which version of the TRACI database (if applicable) was used to develop environmental impact figures.

The LCA data within an EPD is 3rd-party verified to ensure a high degree of accuracy. Once the EPD is complete, it is registered by the Program Operator and posted online for the public to view.

Step 4: Verification (LCA & EPD)

The standard ISO 14025 states that the rules for verification shall be set up in accordance with the standards ISO 14040 and ISO 14020. The justification of independent verification of LCA data is explained in ISO standard 14040: Life Cycle Assessments - General Principles and Framework indicating that the results of any LCA study shall be critically reviewed before the information can be used for comparative purposes.

Underlying data and the EPD® reporting format shall be independently verified externally within the framework of the international EPD® system either as:

- EPD Verification (most common alternative): verification of LCA-based data, additional environmental information and the EPD®, conducted by a recognized individual verifier or an accredited certification body, or as:
- EPD Process Certification: verification of an internal organization process aimed at developing EPD®s according to the General Programme Instructions. Only accredited certification bodies are allowed to certify an EPD Process.

All types of information and data shall be independently verified. This means that the independent verifiers, whether internal or external to the organization, shall not have been involved in the execution of the LCA or the development of the declaration, and shall not have conflicts of interest resulting from their position in the organization.

The verification procedure shall be transparent and result in a verification report in English by the verifier. The report shall document the verification process, while adhering to the rules of data confidentiality. This report shall be included in the EPD registration request and available to any person upon request.

The verification report shall state if the verification is the first to be done by the verifier in the scope of the International EPD® System, as this verification may be subject for an additional check by the Technical Committee.

Step 5: Registration & publication

Every EPD must be register and published into a proper platform, where the free access is guarantee for all the interested.

4. ANALISYS AND RESULTS.

4. ANALISYS AND RESULTS

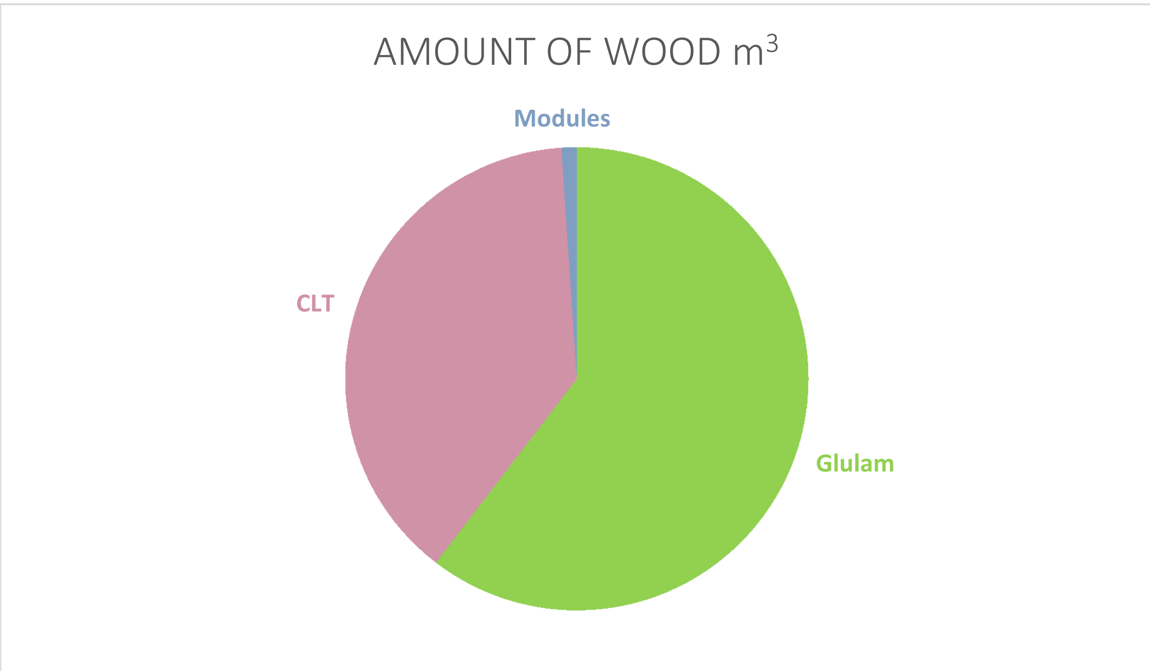
In this part of the project will study the Treet building which is already built and the other one will be a non-built reinforced concrete hypothesis with the same characteristics such as height and plant size developed and given by Beatriz Canet Mahiques on her thesis “Study of Treet building Carbon footprint against a reinforced concrete building with similar characteristics”. It is important to clarify that we are only discussing structural elements of the buildings since it is considered and proved the part where the CO_2 emissions are focused and, consequently where the difference would be major.

4.1. WOODEN STRUCTURE HYPOTHESIS (TREET BUILDING)

4.1.1. MATERIALS INVOLVED

The complete building includes many materials. But most of them wood.

The materials involved we can distinguish in the wooden hypothesis are the glulam, Cross Laminated Timber (CLT) and the prefabricated modules. These last ones will be deeply analyzed due to its constructive complexity as there are no wooden materials included and several wooden materials. To reach this review, we studied the sections of the prefabricated modules which providers provided us. To understand better which materials are included and not we will have a look to the actual drawings shown below. The next graph we can observe the relation of the amount of wood used in the building. It’s surprising the small amount of wood into the modules, but that’s why their function is “structural” in the module, the modules are mainly made of isolations and gypsum panels.



Modules composition analysis:

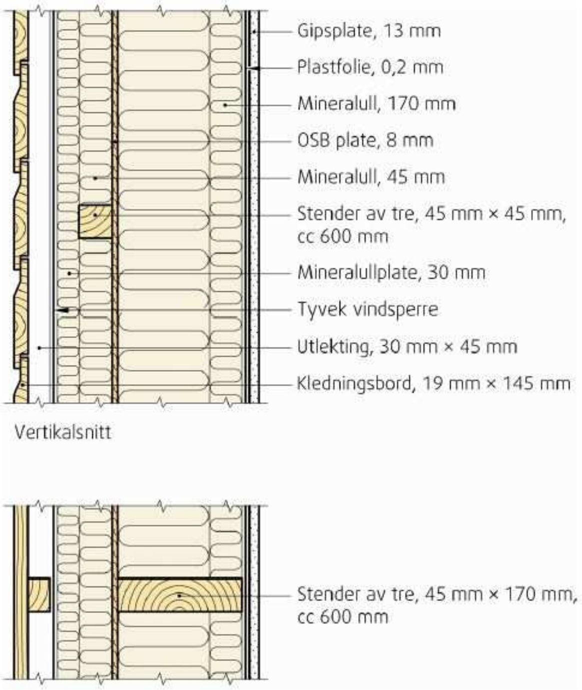
Kodumaja is the supplier of the construction modules.

The figure 1 is a diagram of the modules used in the Treet.

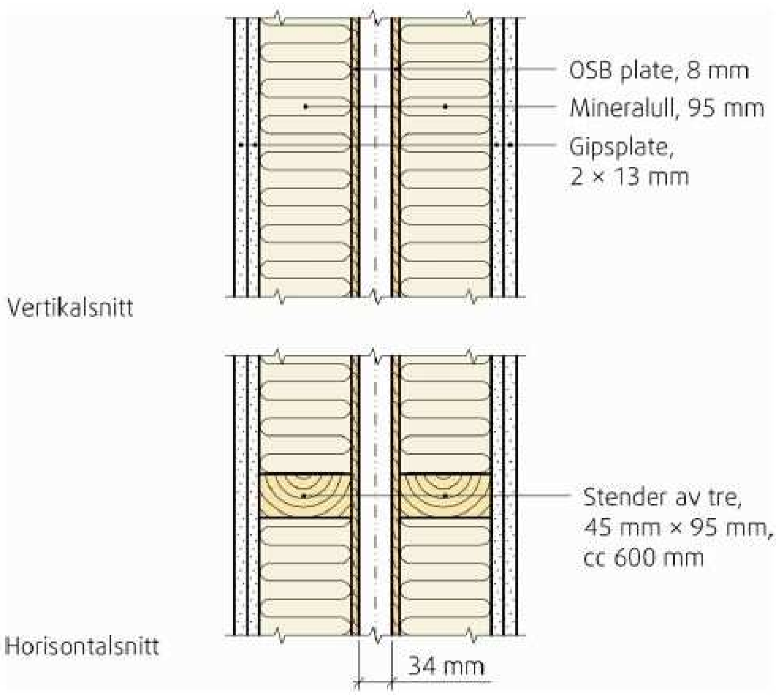
35. figure 1. Construction modules

The composition and sections of these modules are exposed next.

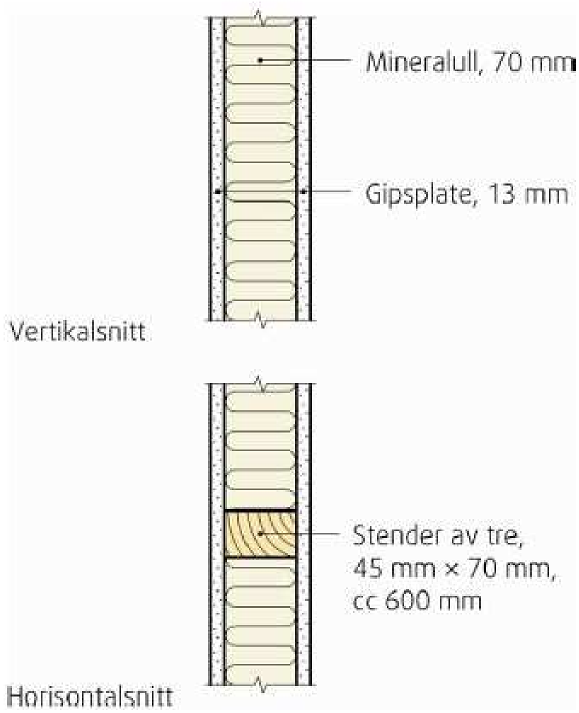
VERTICAL ENCLOSURE SECTIONS:



36. Vertical enclosure of a Kodumaja prefabricated module, texts in Norwegian. Section 1

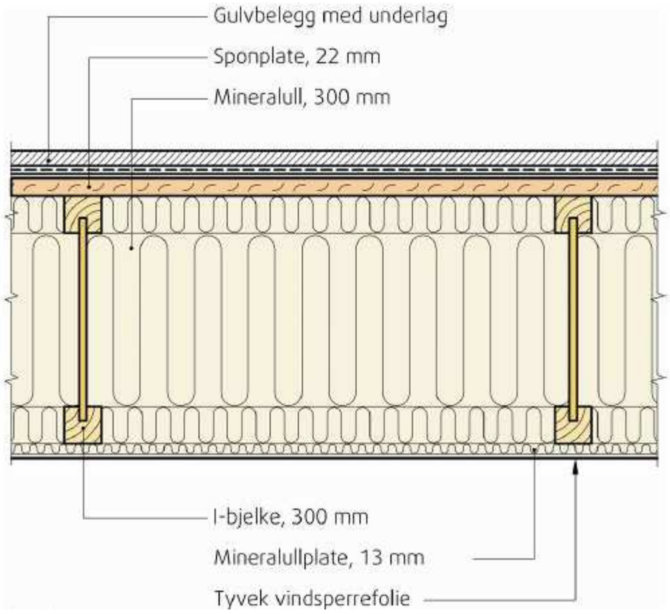


37. Module-module partition of a Kodumaja prefabricated module. Texts in Norwegian. Section 2.

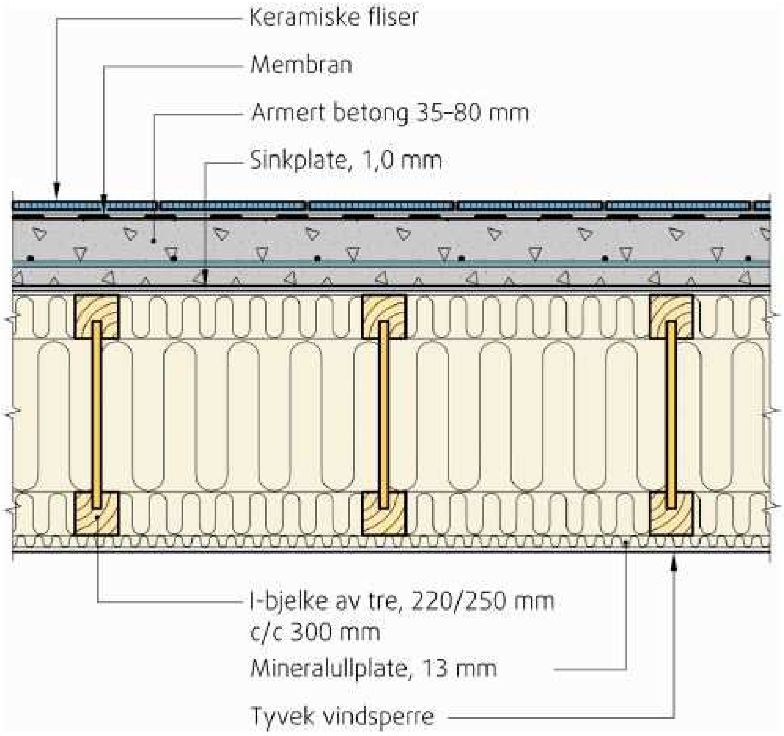


38. Standard partition of a Kodumaja prefabricated module. Texts in Norwegian. Section 3

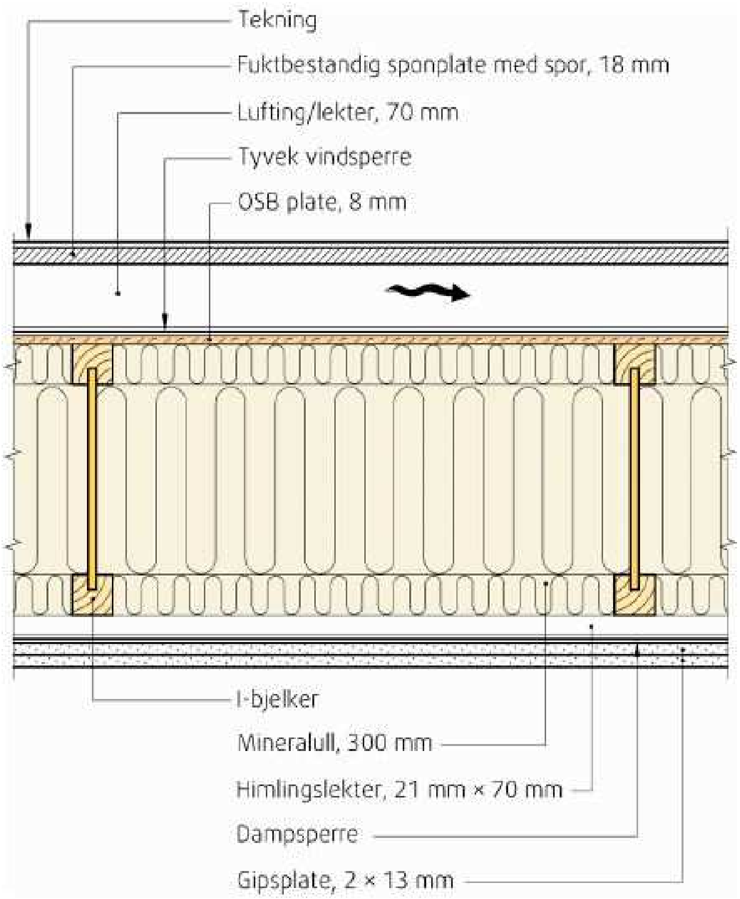
HORIZONTAL ENCLOSURE SECTIONS:



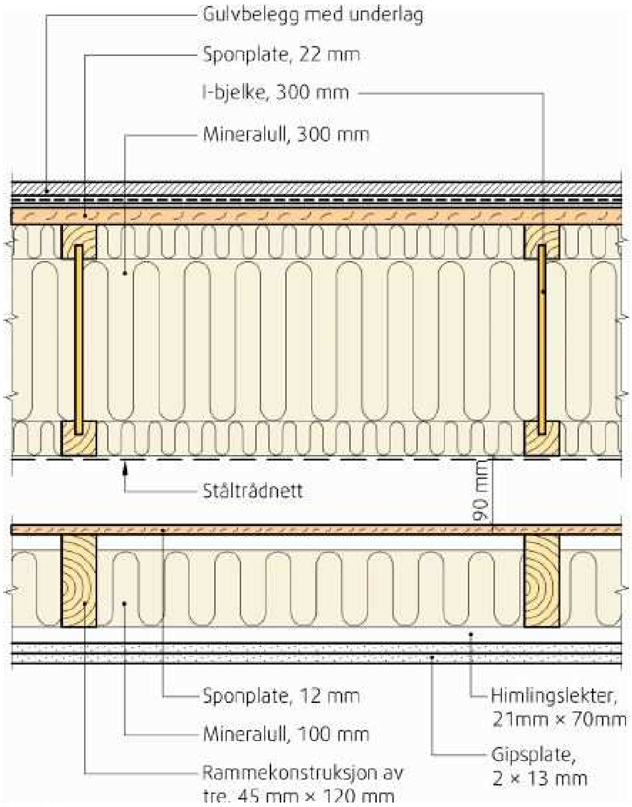
39. Standard flooring over foundations of a Kodumaja prefabricated module. Texts in Norwegian. Section 1



40. Standard flooring over foundations (humid areas) of a Kodumaja prefabricated module. Texts in Norwegian. Section 2



41. Standard roof flooring of a Kodumaja prefabricated module. Texts in Norwegian. Section 3.



42. Standard flooring of a Kodumaja prefabricated module. Texts in Norwegian. Section 4.

After analyzing all the different types of sections, we can summarize with the following different types of wooden materials with structural purposes:

- Vertical enclosure materials
    - Kledningsbord/cladding boards (thickness 19 mm)
    - Stender/stands (each 600mm)
        - 45x45 mm
        - 45x30 mm
        - 45x170 mm
        - 45x95 mm
        - 45x70 mm
    - OSB plate (thickness 8 mm)

- Horizontal enclosure materials
    - Sponplate/particleboard
        - Thickness 12 mm
        - Thickness 22 mm
    - I-bjelke/ I-beams
        - 300 mm each 600 mm
        - 220/250 mm each 300 mm (in humid areas)
    - Rammekonstruksjon/constructive frame 45x120 mm

- OSB plate (thickness 8 mm)

Amount of wood per section in m^3.

Vertical	Kledningsbord	Stender
Section 1 (external walls)	0,002755	0,02530
Section 2	-	0,01655
Section 3	-	0,00315
Horizontal		
Section 1	-	0,05480
Section 2 (humid areas)	-	0,01620
Section 3	-	0,04080
Section 4	-	0,05020
Average horizontal section		0,04126

It is important to distinguish all the materials included in every single section to work with accurate figures and obtain better results when analyzing the CO_2 emissions.

1.2.3. CALCULATIONS

For this project the use stage of the life cycle assessment will not be included, there are too many factors that are unpredictable, like the users maintenance. Also the demolition and reuse of the elements will not be included. For that reason the aim of this study will focus on the production stage.

Estimate of the amount of wood inside the modules (according to the previous drawings and sections):

Modules:

	Module element	Element area		m3 wood per m2 element	
				Kledningsbord	Stender
Humid modules	External walls	66,00m^2		0,0028	0,0253
	Floor	39,15 m^2		0,0000	0,0162
	Internal walls	16,01 m^2		0,0000	0,0166
				0,0028	0,0581
			total 65	**0,1791**	**3,7749**

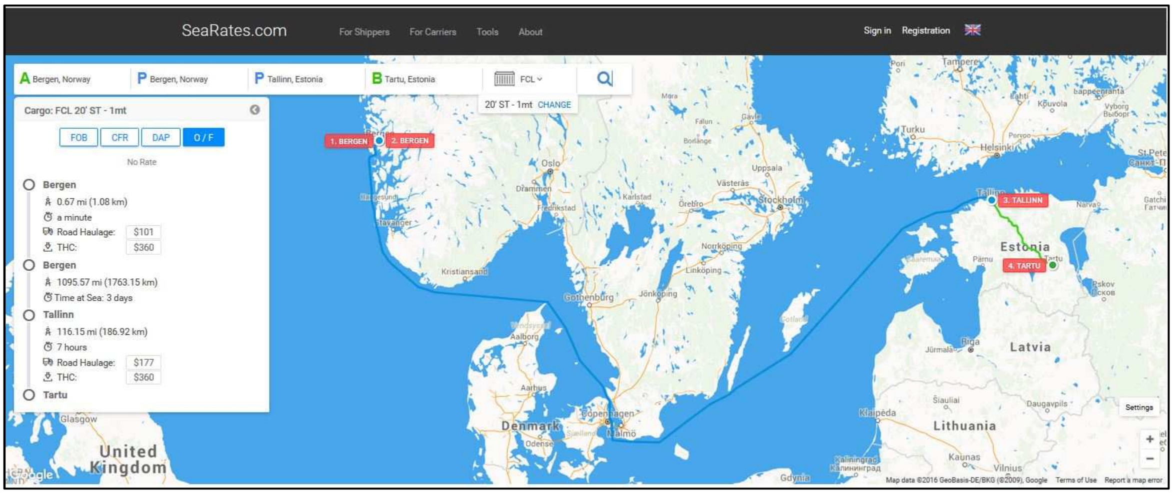
Normal moduels	External walls	66,00 m^2		0,0028	0,0253
	Floor	39,15 m^2		0,0000	0,0413
	Internal walls	16,01 m^2		0,0000	0,0166
				0,0028	0,0831
			total 70	**0,1960**	**5,8195**

According to the developer there are 135 modules in total (65 humid and70 normal modules).

The modules are transported to Bergen from Tartu, Estonia. Made by the company Kodumaja.

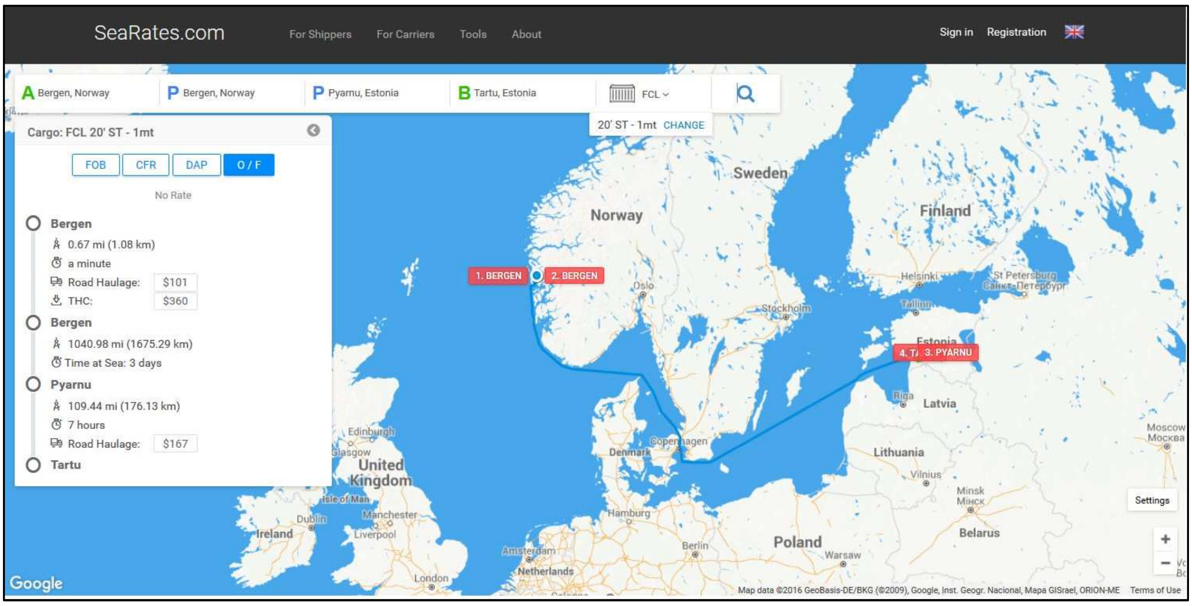
There are two possible hypothesis of transport.

One is the route from Tartu-Tallin-Bergen. [Figure 1]



43. Maritime route Tallin to Bergen – SeaRates.com

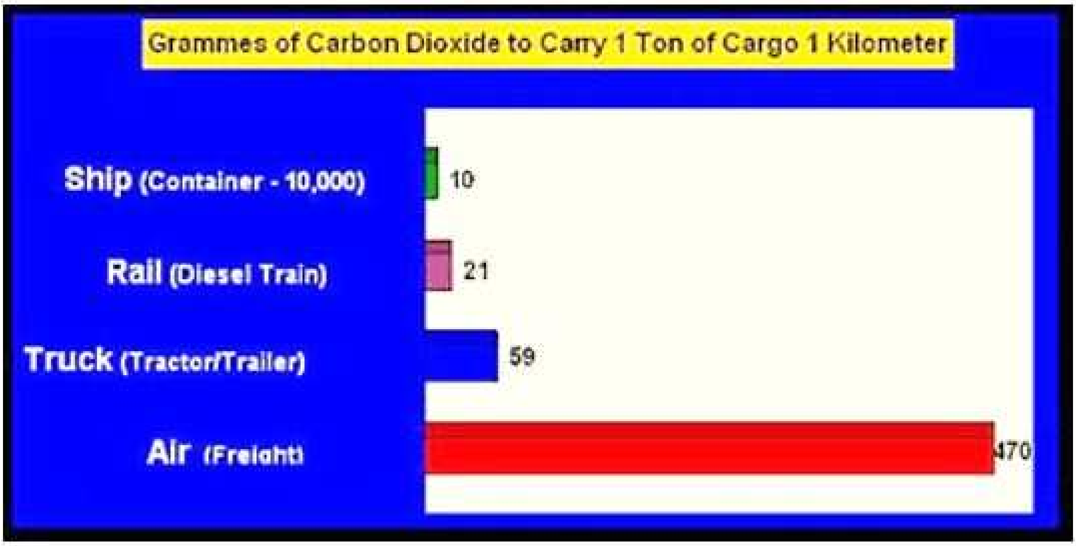
And the second route is the one from Tartu – Pyarnu – Bergen. [Figure 2].



44. Maritime route Pyarnu to Bergen – SeaRates.com

In order to do a proper analysis, we will consider the longest journey, the first option, which is 1.763,15 Km maritime route, and 186.92km truck transport.

The ship used for the delivery was the "Wilson Fedje", with a deadweight capacity of 4.300Tn, and a Gross tonnage of 3.561Tn (more specifications at the attached document). According to the Network for Transport and the Environment, one cargo ship container has the next $CO_{2.}$ Emission relation. In addiction appears a comparison with another transports. [Figure 3].



45. Data provided by Network for Transport and the Environment.

With the previous data for the CO_2 emission of the transport. We procced to calculate the Kg CO_2. By the number of modules and the ship capacity, we estimate the total weight of the 135 modules of the building. With an average weight of 12 tons per modules, that's a total of 1350 tons.

Using the previous data, we are able to estimate the total of Kg Co_2 of the transport from Tartu to Bergen:

	Km	**Kg CO_2**
Road route	186,92	5.299,18
Maritime route	1763,15	23.802,52
Total	**1950,07**	**29.101,70**

Life cycle assessment of the wood modules. There is a problem here, the modules has not an EPD for the entire element. But there are EPD for the elements of each module, which were explained before:

*	Production stage		Building construction		
	A1	A2	A3	A4	A5
Kledningsbord	1,600	0,580	0,034	0,580	-
Stender	1.920				

* Units used for Global warming Potential: Kg CO_2 equiv.

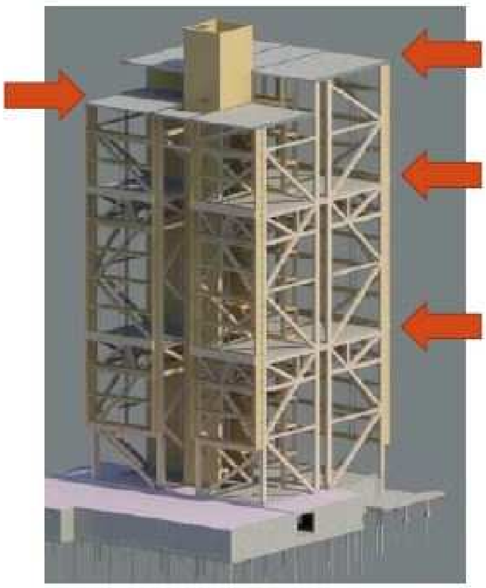
The total Kg CO_2 emission of the department modules is:

TOTAL	total EPD	Humid modules	Normal modules
Kledningsbord	2,794	0,500	0,548
Stender	1,920	7,248	11,173
		TOTAL	19,469 Kg CO_2

Concrete Slabs

The building has three concrete slabs, at the 5th, 10th and the last floor. These elements have 20cm thickness, and the current area of every storey is 464,45m^2, discounting the holes.

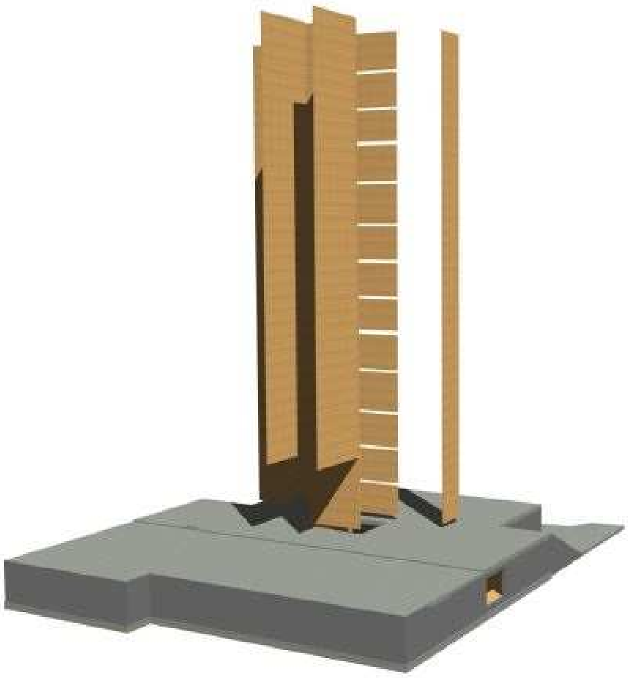
	Production stage			Building construction		
	A1	A2	A3	A4	Total LCA	CO2 Concrete
Concrete	252,8687			10,6000	263,4700	**73.421,1849**



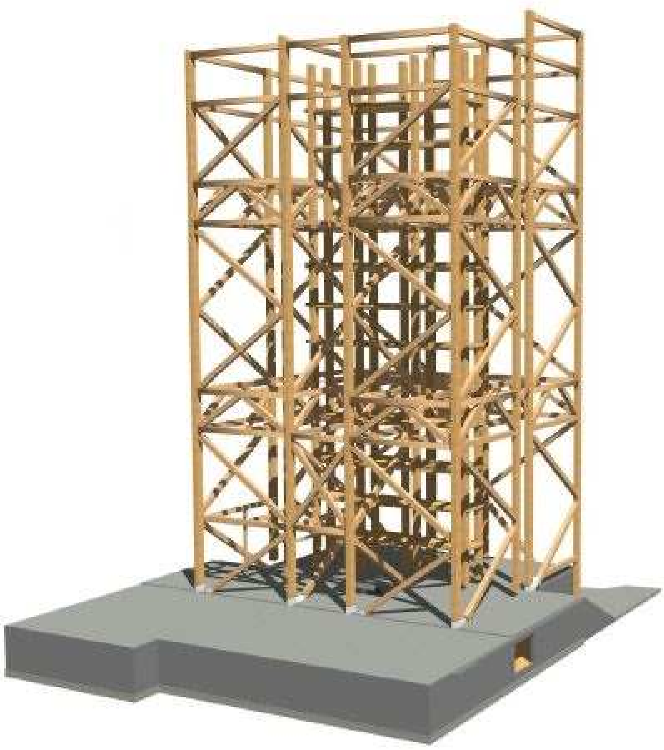
46. Concrete Slabs

CLT and Glulam

The next drawings show the elements of study. First in the figure 6 appears only the Cross-laminated timber. In the figure 7 there is only the glulam structure.



47. Treet: CLT elements – source: ARTEC



48. Treet: GLULAM elements. – source: ARTEC

Cross-Laminated Timber and Glulam construction elements relation. Amount m^3 of materials (according to the developer).

Construction Elements	Glulam (m3)	Cross-Laminated Timber (m3) (CLT)
Timber-frame	531,74	
Secondary structure	31,14	
Walls		143,77
Roof		39,12
Stairs		22,99
Balcony walls		42,08
Balcony roof		111,03
TOTAL	**562,88**	**358,99**

According to the building company, the distance of the factory, the number of trips made are the following:

For the $KgCO_2$ of the transport we used the data showed in the figure 4. Supposing a rail transport.

Transport	Material	Nº trips	M3 transport per trip	Km per trip	TOTAL km	kg CO_2
Moelv – Bergen	Glulam	23	24,47	450	10.350	57.500,72
Airchach - Bergen	CLT	11	32,64	1.879	20.669	76.599,31

The two main structural timber element of the building has EPD, and was given by the developers.

The EPD of both material contains the following data:

*	Production stage		Building construction		Total EPD per 1 m³
	A1	A2	A3	A4	
CLT	-731,000	7,230	122,000	**	-601,770
Glulam	-663,000			**	-663,000

* Units used for Global warming Potential: Kg CO_2 equiv.

** Transport was calculated previously, and will be included in the next table.

*** The Kg CO_2 equiv. is give per m^3, using the data of the total material, we can obtain the result of the next table.

The final and complete assessment, which includes the three wood elements of the Treet, multiplying the Kg CO_2 with the amount of wood.

Kg CO_2 equiv	**CO2 TREET**	**transport included**
CLT	-216.029,41	-139.430,10
Glulam	-373.189,44	-315.688,72
Modules	19,47	29.121,17
Concrete		73.421,18
Total	-589.199,38	**-352.576,47**

The boundary of the first column does not include the transport of the elements to the site. The second column does it.

The yellow square contains the final result of the assessment.

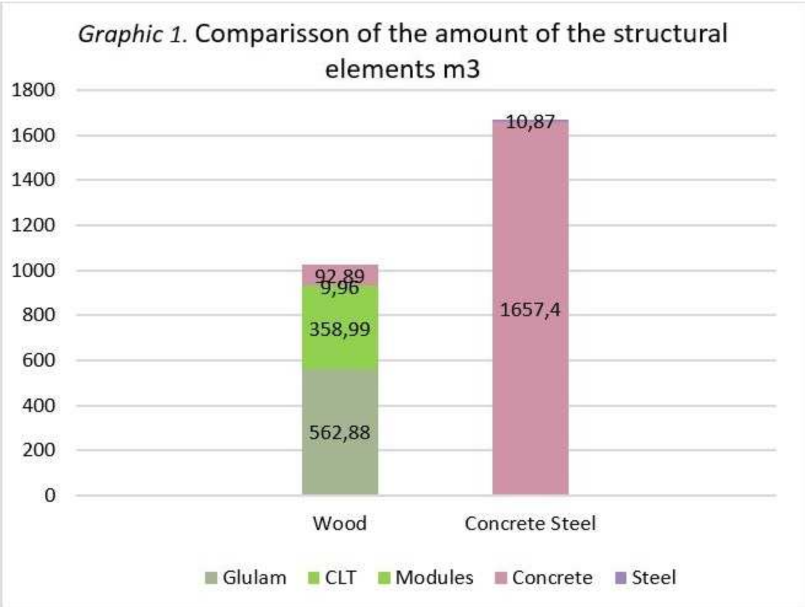
49. Treet: Complete with all elements. – source: ARTEC

5. DISCUSSION.

5. DISCUSSION

The results clearly show that a wooden structure building has lower CO_2 emissions than a concrete steel building. However, this result could be possible, there are many factors that can influence in the final result. Some elements and issues can be improved for future studies and assessments.

The traditional concrete steel needs a big amount of material to build the "same" building [Graphic 1], the reason behind this is the highest level of prefabrication of the Treet, the wood is used on the beams and some walls at the stair case. The modules take up the full space, and they are made with isolation, gypsum, ceramic and concrete, the wood is only for "structural" use. In opposition the concrete must have a full reinforced slab per storey and a "forest" of pillars supporting the structure.



The first problem begins with the scope of the study, which will determinate the stages to be included in the calculation. Should include the full life cycle? Until the construction stage? Those are decisions that the investigator have to make before start the assessment and of course will determinate all the study. Whatever the investigator decide, must be the same boundary in both elements (the wood case, and the concrete/steel), in order to do a proper comparison.

Even with only a cradle-to-gate study there are many factors that can change the result. For example, the transport of the elements from the factory to the construction, what kind of vehicle the supplier used, what was the route? Those are questions for the transport, but, what if the boundary is the end of life of the element, there are only hypothesis of how will be the end of the materials, especially in new buildings like these, which still has many years of use life. The hypothetical concrete/steel building made for the comparison also has these problem, in fact, the concrete EPD does not include the end of life, only

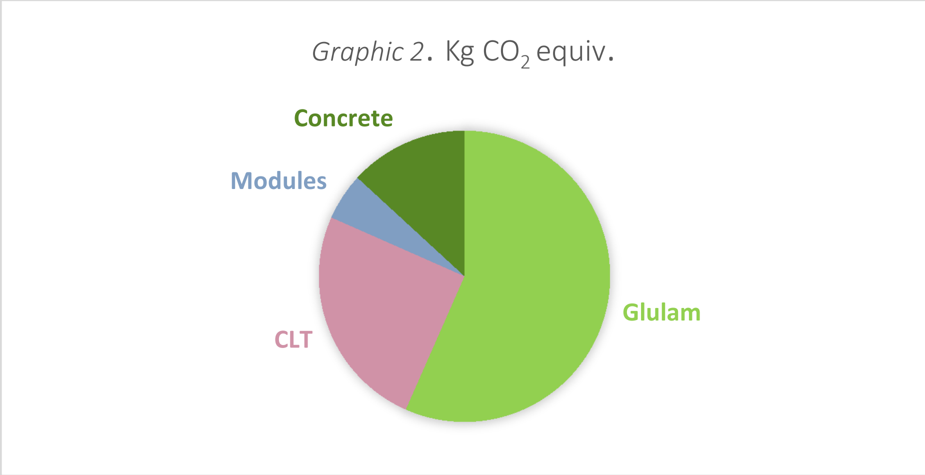
Even after deciding the stage of study, there are troubles with the scope of each phase. What elements of the building should study? It's quite difficult to study all the materials used in this building, when most of them do not have an EPD, or their EPD are not completed at all, like the steel, which only includes until the transport to the building, omitting al the rest of phases. The EPD's are limited to the transparency and reliability of the producer. All these data influence the results. The lack of information provided from the suppliers, force the researcher to find alternative reports. For those reasons, in this thesis decide to make a cradle-to-gate study, trying to make a proper use of the information.

This thesis focuses only in the structural elements, the Cross-laminated timber, the Glulam and the wooden elements in the prefabricated modules, which is the structural part of them. The foundations were not included; it is not a significant change in the final result. The CO_2 emission of the concrete/steel building barely vary with or without the foundations. Also we do not consider any of the other elements, as the façades, made of steel and glass, or any of the components like the electrical, plumbing and others. These elements could be almost the same in both kind of structure (wood and concrete/steel).

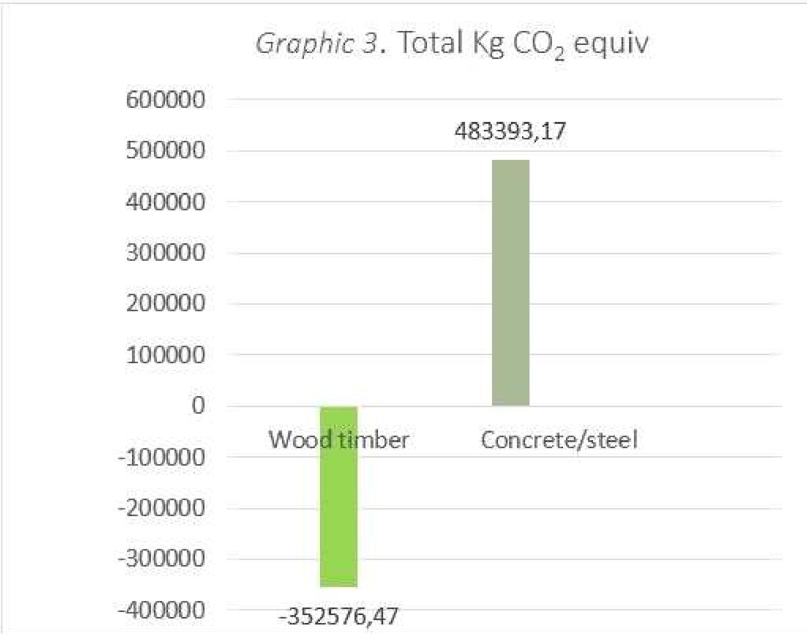
For all the previous reasons, it's quite difficult to achieve an accurate result in the study.

According to the CLT EPD, the first stage, the carbon ultimately stored in the product is withdrawn again from the system during recycling in the form of waste wood, producing a negative emission. Because wood it's a biomass and it can be almost fully reused o recycled. While the concrete did not study, we can assume the high emission of CO_2 of this element, with the handicap of their properties, which require a highest energy consumption needed for the recycling.

The graphic 2 shows the relation between the different elements which compose the building and the CO_2 emission. We can observe that the glulam is the one which emits the highest quantity but in a negative result, that's because it's a biomass and most of the material can be reused and recycling at almost its totality. As well the CLT, the next most used material, and the second one with the highest emission, it's the same case than the glulam, and the negative emission. Despite the modules are the most used element, we are only counting the wood inside them, which in comparison the remainder of the materials, is a really low part of them. As we explain in a previous paragraph, the wood inside the modules does not represent an important quantity. The concrete also has an influential mention, although its amount is not representative, the CO_2 emission is the most contaminant element in the building, and we can observe on the traditional build hypothesis the high valor of the carbon footprint (graphic 3).



The results are environmental positive to the wood case, with a very low CO_2 emission. The concrete structure hypothesis emits a high emission of gas. [Graphic 3.]



Although the environmental area is getting more and more popularity, with all those treaty and protocol (like the Kyoto protocol, or the Paris, and all the international regulations). Is still a new area for research, there is a need for more and new information. Investigate the use stage of the buildings, and the end-of-life of them, and the development of proper information for the future. This will require the collaboration of the supplier companies and other participants in the construction, if they could prepare the EPD of their own products and material, which will help the reliability and the accurate of the studies. Instead of searching for similar EPD's from equivalent materials.

6. CONCLUSION.

6. CONCLUSION

All the researches and results in this thesis conclude in one view, and it's: The wood has been proved as an environmental material.

With a very low CO_2 gas emission, and a proved structural resistance, the wood can be used as an alternative material for high-rise buildings, in this case, 14 storeys buildings.

Although the environmental concern is increasing and becoming an international issue, the needs in looks for new sustainable materials for the construction industry, instead of the use of the traditional materials, concrete/steel. Thanks to the new protocols like the Kyoto, or the Paris, the construction industry tends to be more sustainable, and the developers are reintroducing the wood as a main structural material.

The use of environmental tools as the EPD declarations, only proves the sustainability of this (of course it's not a label of sustainability, but the results on it makes us think on It. with the pass of the years the buildings will tend to reach the zero emission and the passive house quality.

The only weak argument against the wood could be the deforestation of the forest, or the expensive the wood could be, but hope the research of a controlled raw material extraction could help on this issue, making the wood as the best alternative in all points of view, over the concrete/steel.

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8. TABLE OF FIGURES.

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9. APPENDIX.

APPENDIX: ASSESS OF THE CARBON FOOTPRINT OF THE HYPOTHETICAL CONCRETE/STEEL MODEL.

Abstract from Beatriz Canet Mahiques work in her thesis : Study of Treet building carbon footprint against a reinforced concrete building with similar characteristics.

CONVENTIONAL HYPOTHESIS (REINFORCED CONCRETE)

When talking about conventional ways to raise high rise buildings (10-20 storeys approximately) the most extended way to build is using reinforced concrete structures. Usually, this kind of constructions do not follow environmental regulations. Like we have mentioned before in this document, concrete is not environmental friendly at all. In fact, it is one of the most contaminant materials when talking about construction industry.

MATERIALS INVOLVED

After setting a reinforced concrete structure as the second hypothesis to analyze we need to list the materials part of the structure itself. Concrete and steel (steel bars) are the main materials we can differentiate in a conventional reinforced concrete structure.

CALCULATIONS

To proceed with the Environmental Product Declaration (EPD) calculations, we need first the total amount of concrete (m^3) and steel bars (kg) needed in the structure and to reach this results we will use CYPE software version 2015 (student license).

CONSIDERATIONS AND ASSUMPTIONS

In order to proceed with the calculations of the reinforced concrete structure we need to set some considerations and assumptions such as measurements of the structural parts, safety coefficients. One of our main goals was to reach a very similar structure to reach as close as possible the timber structure characteristics. To do so, we have considered the following points

- Building with pillars 40x40 cm, in the central spans of building and pillars of 40x80 cm on the facades, to continue with the current aesthetics of it. When working with concrete is normal to use screen elements that absorb efforts wind and earthquake, as core, this has involved the central staircase with concrete screen walls whom we generate a tough core.

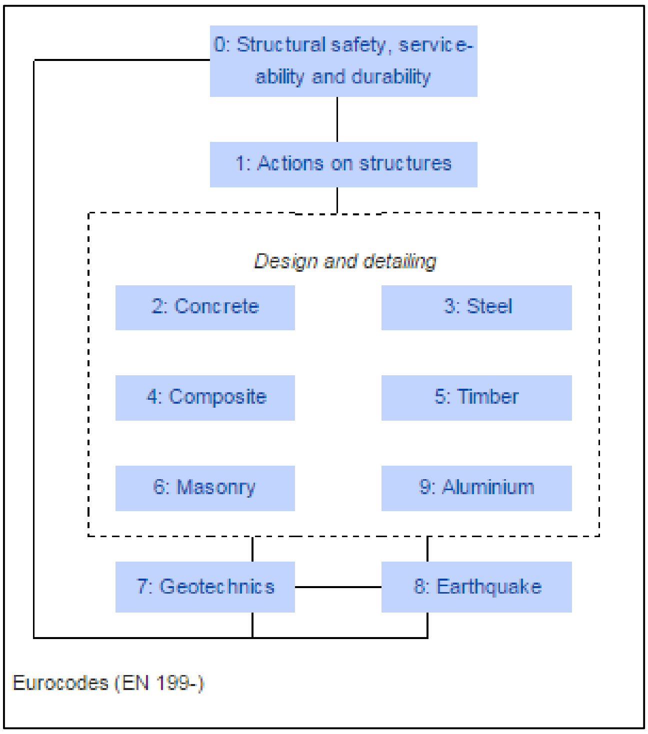
- The basement is covered with reticular wrought with abacuses in the area of the supports, as a surface charge of use of 1 KN / m^2 is added, to consider moving vehicles.

- The remaining plants are made with forged unidirectional prestressed beams, ridge beams.

- At plants 4, 9 and 12, which are considered initial draft technical plants, also called power plants at the wooden hypothesis, it is added an overload of 0.5 KN / m^2, to consider the facilities.

- Finally, the hard core of the staircase is covered with a concrete solid slab.

It is also important to follow regulations to do with different actions such as snow, wind or fire. In order to set these different coefficients, we need to check on standard regulations. In this case we are focusing on Eurocodes. Eurocodes are the ten European standards (EN; harmonized technical rules) specifying how design should be conducted within the European Union (EU).



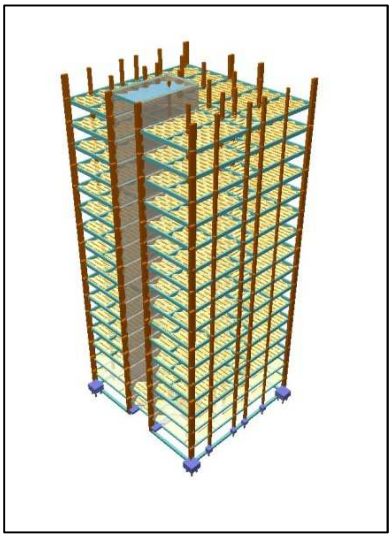
1. Eurocodes – source: wikipedia

The calculations are based on the following Eurocodes:

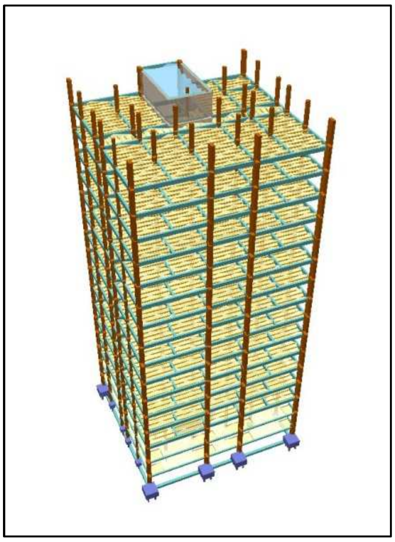
- Eurocode 1: wind
- Eurocode 2: concrete elements
- Eurocode 3: steel elements
- Eurocode 4: steel elements
- Eurocode 8: seisms

At last, we are considering EN1992-1-2:2004 refering to fire and the usage will be RESIDENTIAL.

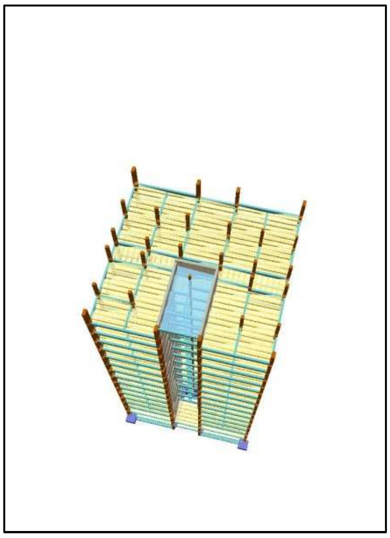
After considering all the points mentioned before, as we can see in the images below, the structure is very similar to the first hypothesis made with timber. We can find a summary of all the calculations in the appendix and all the files in the digital version of this project.



2. Reinforced Concrete Structure - source: CYPE V15



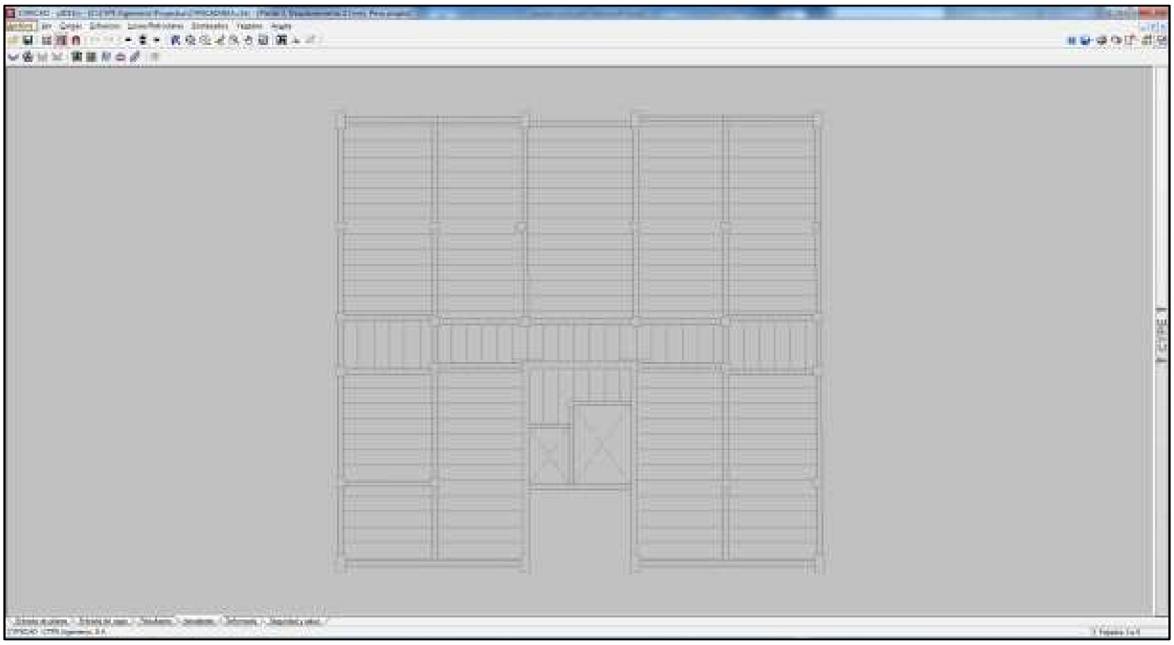
4. Reinforced Concrete Structure - source: CYPE V15



3. Reinforced Concrete Structure - source: CYPE V15

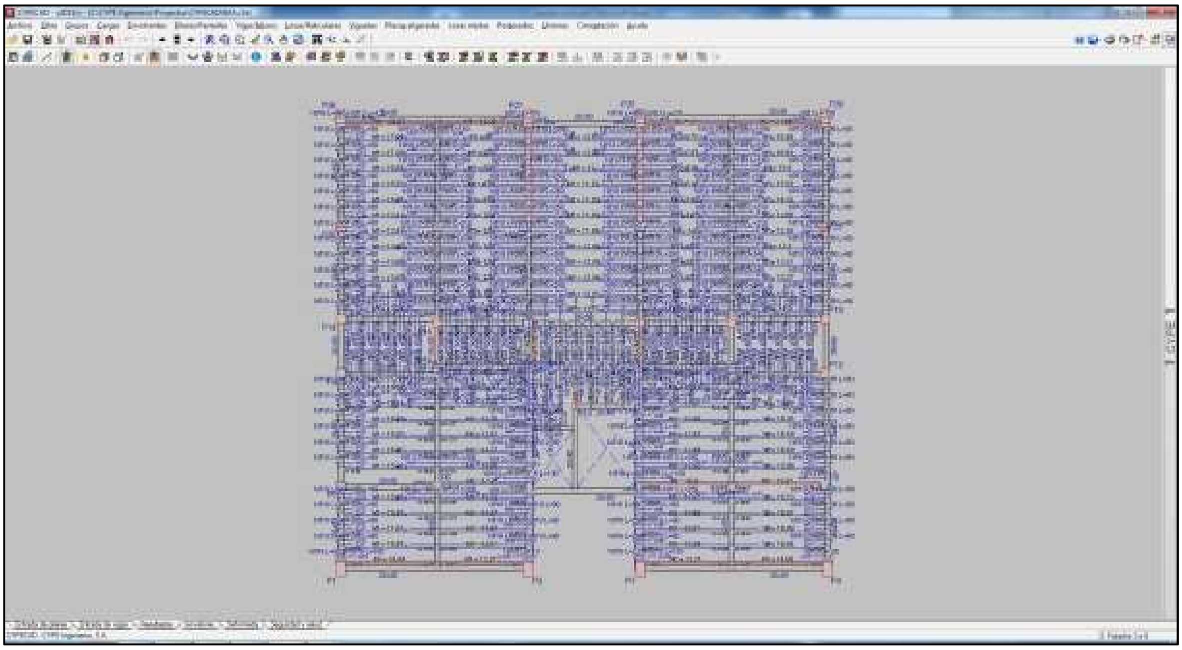
SCHEME OF THE STRUCTURE

On the image below we can see an example of the structural elements composing a plant, in this case the plants from 2 to 5.



5. Structural elements on plants from 2 to 5 - source: CYPE V15

It is also interesting to have a look at the position of reinforcement bars on the calculation plans to see the direction of the slab.



6. Structural elements on plants from 2 to 5 - source: CYPE V15

We can find the other plants at the appendix where all the calculations are attached.

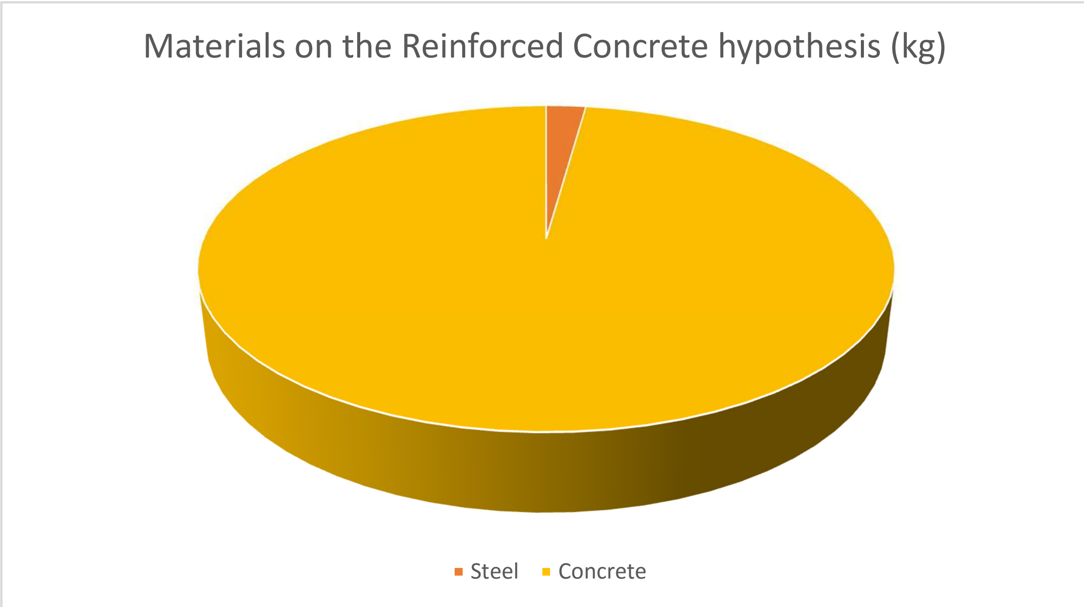
RESULTS

After all the calculations, we expose in this part a table with the total amount of concrete and steel bars needed to build the structure of the hypothetical reinforced concrete case. Is is differentiated among all the structural elements, such as slabs, pillars, beams, etc.

WHOLE BUILDING STRUCTURE: 7227.35 m^2

Element	Area (m^2)	Concrete Volume (m^3)	SteelBars (Kg)
Solid slab	42.59	6.39	458
Unidirectional	5397.58	509.92	9487
Reticulated	816.20	139.82	2293
*reinf. base reticulated	-	-	3140
*reinf. base abacus	-	-	1642
beams	872.72	368.54	27492
Lateral formwork	1741.39		
walls	2542.72	381.42	14224
Pillars (Area formwork)	2261.58	251.31	26660
Total	13674.78	1657.40	85396
m^2	1.892	0.229	11.82

To try to visualize how important concrete is in a conventional way to build we took the total amount of concrete in m^3 of the hypothesis we are calculating in this case. To do so, we need to setting the average weight of $1m^3$ of this material which is 2300 kg approximately.



TOTAL CO^2 EMISSIONS

In order to keep the calculations as equitable as possible, the use stage of the life cycle assessment will not be included, there are too many unpredictable factors which could not be included such as users' maintenance or the END OF LIFE stage, where demolition and reuse of the elements will not be included. For that reason, this study will focus on the production stage, which includes A1, A2, A3 and A4.

Kg CO2 Equiv/ 1 m3 of material.

	Production stage			Building construction		Diposal stage			Reuse			
	A1	**A2**	**A3**	**A4**	**A5**	**C2**	**C3**	**C4**	**D**	**Total LCA**	**CO2 TREET**	**transport included**
Concrete	252,8687			10,6000						263,47	**436.673,02**	436.673,02
Steel	0,5190			0,0281						0,55	**46.720,15**	46.720,15
										TOTAL	**483.393,17**	**483.393,17**

ENVIRONMENTAL PRODUCT DECLARATION

epd-norge.no
The Norwegian EPD Foundation

in accordance with ISO 14025, ISO 21930 and EN 15804

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

Generell informasjon

Produkt:
Standard limtrebjelke

Eier av deklarasjonen:
Moelven Limtre AS
Kontakt person: Kato Sveen
Tlf: +47 908 59 468
e-post: kato.sveen@moelven.no

Program operatør:
Næringslivets Stiftelse for Miljødeklarasjoner
Postboks 5250 Majorstuen, 0303 Oslo
Tlf: +47 23 08 82 92
e-post: post@epd-norge.no

Produsenter:

Moelven Limtre AS, Moelv	Moelven Limtre AS, Avd. Agder
Lundemovegen 1	Stasjonsveien 4
2391 Moelv	4730 Vatnestrøm
Norge	Norge

Deklarasjon nummer:
NEPD-336-222-NO

Produksjonssted:
Moelv, Norge
Vatnestrøm, Norge

ECO Platform registreringsnummer:

Kvalitet/Miljøsystem:
ISO 9001:2008, ISO 14001:2004, PEFC ST 2002:2013

Deklarasjonen er basert på PCR:
CEN Standard EN 15804 tjener som kjerne PCR
NPCR015 Wood and wood-based products for use in construction (08/2013)

Org. no.:
913 711 300

Erklæringen om ansvar:
Eieren av deklarasjonen skal være ansvarlig for den underliggende informasjon og bevis. EPD Norge skal ikke være ansvarlig med hensyn til produsent informasjon, livsløpsvurdering data og bevis.

Godkjent dato:
01.07.2015

Gyldig til:
01.07.2020

Deklarert enhet:
Produksjon av 1 m^3 standard limtrebjelke av gran eller furu

Årstall for studien:
2014-2015

Deklarert enhet med opsjon:

Sammenlignbarhet:
EPD av byggevarer er nødvendigvis ikke sammenlignbare hvis de ikke samsvarer med NS-EN 15804 og ses i en bygningskontekst.

Funksjonell enhet:
1 m^3 standard limtrebjelke av gran eller furu fra vugge-til-grav med en referanselevetid på 60 år.

Miljødeklarasjonen er utarbeidet av:
Lars G. F. Tellnes
Norsk Treteknisk Institutt

Treteknisk

Verifikasjon:
Uavhengig verifikasjon av deklarasjonen og data, i henhold til ISO 14025:2010

internt ☐ eksternt ☑

Tredjeparts verifikator:

Helene Sedal, seniorrådgiver
(Uavhengig verifikator godkjent av EPD Norge)

Godkjent

Dagfinn Malnes
Daglig leder av EPD-Norge

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.

Markedsområde:
Norge og Sverige

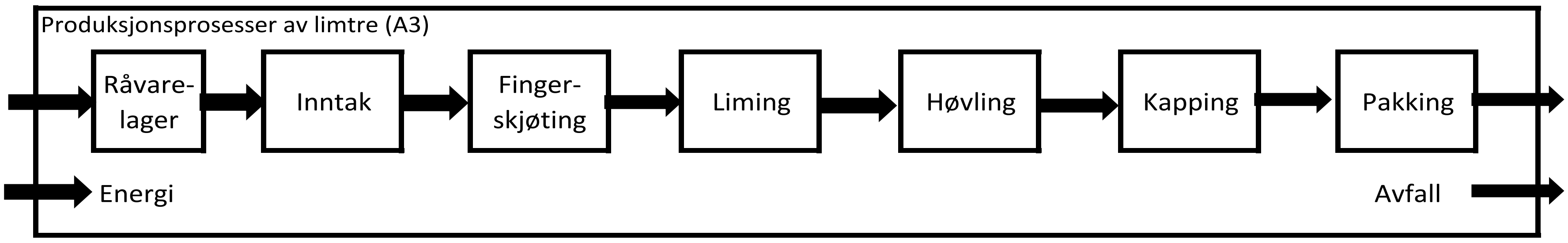
Levetid:
Referanselevetid er den samme som for byggverket, som regel settes denne til 60 år.

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	

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: Scenarier og annen teknisk informasjon

Følgende informasjon beskriver scenariene for modulene i EPDen.

Det er forutsatt en transport til byggeplass på 200 km, hvor 100 km skjer på stor lastebil og 100 km på en middels stor lastebil.

Transport fra produksjonssted til bruker (A4)

Type	Kapasitetsutnyttelse inkl. retur (%)	Kjøretøytype	Distanse km	Brennstoff/ Energiforbruk		Verdi (l/t)
Bil	53	EURO4, >32 tonn	100	0,02	l/tkm	2
Bil	26	EURO4, 16-32 tonn	100	0,045	l/tkm	4,5

I byggefasen er det antatt et behov for 1 MJ elektrisitet og at det blir 5 % svinn av produktet.

Byggefase (A5)

	Enhet	Verdi
Hjelpematerialer	kg	
Vannforbruk	m^3	
Elektrisitetsforbruk	MJ	1
Andre energikilder	MJ	
Materialtap	kg	23,5
Materialer fra avfallsbehandling	kg	
Støv i luften	kg	

Produktet har emisjoner til innemiljø deklarert under inneklima, men ingen LCA-relatert miljøpåvirkning i bruk.

Montert produkter i bruk (B1)

	Enhet	Verdi
Ingen LCA-relatert miljøpåvirkning i bruk		

Produktet krever normalt ingen vedlikehold eller reparasjon.

Vedlikehold (B2)/Reparasjon (B3)

	Enhet	Verdi
Vedlikeholdsfrekvens	År	
Hjelpematerialer	kg	
Andre ressurser	kg	
Vannforbruk	m^3	
Elektrisitetsforbruk	kWh	
Andre energikilder	MJ	
Materialtap	kg	

Produktet krever normalt ingen utskiftning i byggets levetid.

Utskifting (B4)/Renovering (B5)

	Enhet	Verdi
Utskiftingsfrekvens	År	60
Elektrisitetsforbruk	kWh	
Utskifting av slitte deler	0	

Produktet har ingen drifts energi og vannbruk

Drifts energi (B6) og vannbruk (B7)

	Enhet	Verdi
Vannforbruk	m^3	
Elektrisitetsforbruk	kWh	
Andre energikilder	MJ	
Utstyrets varmeeffekt	kW	

Limtre skal sorteres som blandet treavfall på byggeplass og behandles med energigjenvinning.

Sluttfase (C1, C3, C4)

	Enhet	Verdi
Farlig avfall	kg	
Blandet avfall	kg	
Gjenbruk	kg	
Resirkulering	kg	
Energigjenvinning	kg	470
Til deponi	kg	

Transporten av treavfall er basert på gjennomsnittsavstand for 2007 i Norge og utgjør 85 km (Raadal et al. (2009). Det er videre estimert at 36% av dette blir videre transportert til Sverige for behandling der. Det er estimert at 67% går på bil, 9% går på tog og 24% blir transportert på båt, mens transportavstandene er anslått.

Transport avfallsbehandling (C2)

Type	Kapasitetsutnyttelse inkl. retur (%)	Kjøretøytype	Distanse km	Brennstoff/ Energiforbruk		Verdi (l/t)
Bil		Uspesifisert	85	0,045	l/tkm	3,8
Bil	53	EURO4, >32t	200	0,019	l/tkm	3,8
Tog		Frakttog	400	-	l/tkm	-
Båt		Pram	800	0,011	l/tkm	8,8

Gevinsten av eksportert energi fra energigjenvinning er beregnet med erstatning av norsk el-miks, norsk fjernvarmemiks, ulike former for industrielt brensel og eksport til Sverige. Data for el-miks er samme som brukt i A1-A3, fjernvarmemiks er basert på produksjonen i 2013, industrielt brensel er fra spesifikke produksjonssteder, mens generiske data fra ELCD er brukt for andelen som er eksportert til Sverige.

Gevinst og belastninger etter endt levetid (D)

	Enhet	Verdi
Erstatning av elektrisk energi	MJ	626
Erstatning av termisk energi	MJ	4643

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

Livsløpets slutt - Avfall

Parameter	Unit	A1-A3	A4	A5	C1	C2	C3	B1-B7, C4	D
HW	kg	1,36E+00	4,95E-02	1,82E-01	1,83E-04	4,55E-02	2,19E+00	0	-6,21E-01
NHW	kg	3,33E+01	1,13E+01	2,90E+00	6,41E-03	7,89E+00	5,29E+00	0	-5,34E+00
RW	kg	4,01E-03	1,25E-03	3,19E-04	7,20E-07	9,39E-04	1,74E-04	0	-1,40E-02

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

Livsløpets slutt - Utgangsfaktorer

Parameter	Unit	A1-A3	A4	A5	C1	C2	C3	B1-B7, C4	D
CR	kg	INA	INA	INA	INA	INA	INA	0	INA
MR	kg	1,74E+00	INA	1,09E+00	INA	INA	INA	0	INA
MER	kg	8,00E-02	INA	4,00E-03	INA	INA	INA	0	INA
EEE	MJ	INA	INA	2,84E+01	INA	INA	5,68E+02	0	-6,26E+02
ETE	MJ	INA	INA	2,11E+02	INA	INA	4,21E+03	0	-4,64E+03

INA = Indikator er ikke vurdert

CR-komponenter for gjenbruk, MR Materialer for resirkulering, MER Materialer for energigjenvinning, EEE Eksportert elektrisk energi; ETE Eksportert termisk energi

Lese eksempel: 9,0 E-03 = $9{,}0 \cdot 10^{-3}$ = 0,009

Norske tilleggskrav

Klimagassutslipp fra bruk av elektrisitet i produksjonsfasen

Nasjonal produksjonsmiks fra import, medium spenning (produksjon av overføringslinjer, i tillegg til direkte emissions tap i nettet) av anvendt elektrisitet for produksjonprosessen (A3).

Data kilde	Mengde	Enhet
Econinvent v3.1 (june 2014)	22,8	gram CO_2-ekv/kWh

Farlige stoffer

- ☐ Produktet inneholder ingen stoffer fra REACH Kandidatliste eller den norske prioritetslisten
- ☑ Produktet inneholde stoffer som er under 0,1 vekt% på REACH Kandidatliste
- ☐ Produktet inneholde stoffer fra REACH Kandidatliste eller den norske prioritetslisten, se tabell under Spesifikke norske krav.
- ☐ Produktet inneholder ingen stoffer på REACH Kandidatliste eller den norske prioritetslisten. Produktet kan karakteriseres som farlig avfall (etter Avfallsforskiften, Vedlegg III), se tabell under Spesifikke norske krav.

Transport

Transport fra produksjonssted til byggeplass i Norge i henhold til scenario i A4: 200 km

Inneklima

Limtrebjelk av gran har blitt testet for emisjoner av totalt flykte oragniske forbindelser (TVOC), formaldehyd og ammoniakk. Resultatene etter 28 dager viser en emisjonshastighet på 0.04 mg/m^{2}h for TVOC, <0.033 mg/m^{2}h for formaldehyd og <0.005 mg/m^{2}h. I følge den finske innklimaklassifiseringen av byggematerialer fra Rakennustieto, så vil dette ligge i klassen M1. Resultatene har også blitt vurdert til å oppfylle kravene til E1 i NS-EN 717-1:2004 med en beregnet formaldehydemisjon på <0.009 mg/m^3. Dokumentasjon av testresultater kan fås på forespørsel til Moelven limtre AS.

Klimadeklarasjon

Det er ikke utarbeidet klimadeklarasjon for produktet.

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Statistisk sentralbyrå	*Tabell 09469: Nettoproduksjon av fjernvarme*
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Treteknisk	**Forfatter av Livssyklusrapporten** Lars G. F. Tellnes Norsk Treteknisk Institutt Postboks 113 Blindern, 0314 Oslo, Norge	Tlf: Fax e-post: web	+47 98 85 33 33 firmapost@treteknisk.no www.treteknisk.no

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.

www.bau-umwelt.com

1 General information

Studiengemeinschaft Holzleimbau e.V.	Cross-laminated timber (X-Lam)
Programme holder IBU - Institut Bauen und Umwelt e.V. Panoramastr. 1 D-10178 Berlin	**Holder of the Declaration** Studiengemeinschaft Holzleimbau e.V. Elfriede-Stremmel-Straße 69 D-42369 Wuppertal
Declaration number EPD-SHL-2012211-EN	**Declared product/unit** 1m³ cross-laminated timber
This Declaration is based on the Product Category Rules: PCR Part B Solid Wood, 2011-06 (PCR examined and approved by the independent Expert Committee, SVA)	**Area of applicability:** In Germany, approx. 50,000 m³ of cross-laminated timber were manufactured in 2009, of which 100% was accounted for by members of Studiengemeinschaft Holzleimbau e.V. The contents of this Declaration are based on information from 90% of the members, whereby the technology presented here is representative for all members.
Issue date 20.09.2014	**Verification** The CEN DIN EN 15804 standard serves as the core PCR.
Valid to 19.09.2015	Verification of the EPD by an independent third party in accordance with ISO 14025 ☐ internal ☒ external
Prof. Dr.-Ing. Horst J. Bossenmayer (President of Institut Bauen und Umwelt e.V.)	
Prof. Dr.-Ing. Hans-Wolf Reinhardt (Chairman of the Expert Committee (SVA))	Dr. Frank Werner (Independent auditor appointed by the SVA)

2 Product

2.1 Product description

Cross-laminated timber (X-Lam) is an industrially-manufactured plane timber product for load-bearing purposes. It is used as plate or panel elements. Cross-laminated timber generally displays a symmetrical layup and comprises at least three layers of coniferous timber glued at right angles. Please refer to the manufacturer-specific approvals for further details on cross-sectional layups.

Owing to their crosswise structure, cross-laminated timber elements are very dimensionally stable on the one hand and can also transfer loads both lengthwise and transverse to the main load-bearing direction.

2.2 Application

X-Lam is used as load-bearing components in structural engineering and bridge construction.

2.3 Technical data

X-Lam is manufactured from spruce, fir, pine, larch or Douglas fir. Other coniferous woods are permissible, albeit not typical.

Adhesives in accordance with 2.6 are used for gluing.

X-Lam is manufactured with a maximum moisture content of 15%.

X-Lam is manufactured in sizes as per 2.5 and manufacturer-specific dimensional tolerances.

The building component's mechanical resistance at normal temperature and resistance to fire are dependent on the properties of the layers, cross-sectional layup, static system and load distribution. Mechanical resistance and resistance to fire must be established for the respective building in accordance with the applicable design rules.

X-Lam is supplied in various manufacturer-specific surface qualities.

X-Lam can be used in service classes 1 or 2 in accordance with DIN 1052: 2008, *Design of timber structures - General rules and rules for buildings*, or DIN EN 1995-1-1: 2010, *Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings.*

The use of a preservative treatment in accordance with DIN 68800-3:2012-02, *Wood preservation - Part 3: Preventive protection of wood with wood preservatives* is not typical as in most cases, preventive constructural measures in accordance with DIN 68800-2:2012-02, *Wood preservation - Part 2: Preventive constructional measures in buildings* are sufficient.

2.4 Placing on the market / Application rules

The products are subject to the manufacturer-specific technical approvals (abZ) of the Deutsches

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/m^3). 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

- The toxicity of combustion gases complies with that of natural wood.

Water

No ingredients are washed out which could be hazardous to water.

Mechanical destruction

X-Lam breakage features display an appearance which is typical for solid wood.

2.15 Re-use phase

In the event of selective rebuilding after the end of the usage phase, X-Lam can be easily re-used.

If X-Lam can not be recycled, it is directed towards thermal recycling for generating process heat and electricity on account of its high calorific value of approx. 19 MJ/kg.

In the case of energetic recycling, the requirements outlined in the German Pollution Act must be observed. In accordance with Annex III of the directive governing requirements on recycling and disposing of waste wood (Waste Wood Act) dated 15.08.2002, untreated X-Lam is allocated to waste key 17 02 01 (depending on the type of wood protection agent used, treated X-Lam is allocated to waste key 17 02 04).

2.16 Disposal

Waste wood may not be used for landfilling in accordance with §9 of the Waste Wood Act (AltholzV).

2.17 Further information

More detailed information can be found at www.brettsperrholz.org.

3 LCA: Calculation rules

3.1 Declared unit

The declared unit under ecological review is one cubic metre of cross-laminated timber taking consideration of the mix of adhesives used as outlined in 2.6 and a mass of 491.65 kg/m³ with wood moisture of 12% which in turn complies with a water content of approx. 10.5%. Adhesives account for 2%.

3.2 System limit

The Declaration type conforms with an EPD "from cradle to factory gate with options". Contents include the stage of production, i.e. from the provision of raw materials to the production gate (cradle to gate, Modules A1 to A3), as well as parts of the end-of-life stage (Modules C2 to C4). Furthermore, the credits and encumbrances are considered over and beyond the product life cycle (Module D).

Module A1 analyses the provision of wood from forestry, the provision of additional modified wood products as well as the provision of adhesives. Transport of these materials is considered in Module A2. Module A3 comprises the provision of fuels, operating resources and electricity as well as the manufacturing processes on site. These essentially involve debarking, cutting, drying, planing and profiling processes, as well as gluing and packing the products.

Module C2 takes consideration of transport to the disposal company; Module C3 deals with preparing and sorting the waste wood; Module D analyses thermal recycling as well as the ensuing credits in the form of a system extension.

3.3 Estimates and assumptions

As a general rule, all material and energy flows for the processes required for production are established specifically on site. The emissions from combustion and other processes arising on site could only however be estimated on the basis of literary references. All other data is based on average values. Detailed information on all estimates and assumptions made can be referenced in (S. Rüter, S. Diederichs: 2012).

3.4 Cut-off criteria

The choice of material and energy flows considered depends on their use of renewable and non-renewable primary energy per unit process. A decision on the flows to be observed is the result of existing studies for analysing wood products. At least those material and energy flows were assessed which account for 1% of the use of renewable or non-renewable primary energy, whereby the total sum of flows not considered is not greater than 5% of the indicators referred to. No material or energy flows already detected have been ignored which fell below the 1% limit.

The inputs and outputs arising from information provided by the company were examined for plausibility.

The expenses associated with providing the infrastructure (i.e. machinery, buildings etc.) for the entire primary system were not taken into consideration. This is based on the assumption that the total expenses associated with building and maintaining the infrastructure do not exceed the 1% of overall expenses referred to above. The energetic expenses in the form of heat and electricity required for operating the infrastructure were taken into consideration. Detailed information on the cut-off criteria can be found in (S. Rüter, S. Diederichs: 2012).

3.5 Background data

All background data has been taken from the GaBi Professional data base.

3.6 Data quality

With the exception of forest wood, the background data used for wooden raw materials for material and energetic use originates from the years 2008 to 2010. The power mix originates from 2009; the provision of forest wood was taken from a publication dated 2008 which is essentially based on information from the years 1994 to 1997. All other information was taken from the GaBi Professional data base which does not permit any exact containment of quality. As the essential information originates from highly-representative primary data surveys, the data quality can be rated as being very good.

3.7 Period under review

The data survey was performed over a period from 2009 to 2011, whereby data was established for the respective full calendar year. The data is therefore based on the years 2008 to 2010. Hence, all information is based on the data for 12 consecutive months.

3.8 Allocation

The allocations performed comply with the requirements outlined in EN 15804:2012 and are explained in detail in (S. Rüter, S. Diederichs: 2012). Essentially, the following system area extensions and allocations were performed.

General information

All properties inherent to materials were allocated in accordance with physical causalities; all other allocations were performed on an economic basis. An exception is presented by the allocation of heat required in heat and power combinations which were allocated on the basis of exergy of electricity and process heat products.

Module A1

- Forestry: Forestry expenses were allocated to logs and industrial wood on the basis of their prices.
- The provision of waste wood does not take consideration of any expenses from the previous life cycle.

Module A3

- Wood-processing industry: Expenses were allocated to the primary products and residuals on the basis of their prices.
- With the exception of wood-based materials, the waste incurred by disposal in production is based on a system extension. The heat and electricity generated are credited to the system via substitution processes. The credits achieved here are significantly less than 1% of the overall expenses.
- In the case of combined generation of heat and electricity, all firing expenses were allocated to these two products after exergy.
- The provision of waste wood does not take consideration of any expenses from the previous life cycle (analogue to Module A1).

Module D

The system area extension performed in Module D complies with an energetic recycling scenario for waste wood.

3.9 Comparability

As a general rule, EPD data can only be compared or evaluated when all of the data records to be compared have been drawn up in accordance with EN 15804:2012 and the building context or product-specific performance features are taken into consideration.

4 LCA: Scenarios and further technical information

End of life (C2-C4)

For energy recovery	Waste wood 491.65 kg

In the form of waste wood, the product is recycled at the end of the life cycle in the same composition as the declared unit described. 23% thermal recycling is assumed in a biomass power plant with a total supply level of 35% and combined heat and power efficiency of 35%, whereby one tonne of wood (atro) (with approx. 18% moisture), approx. 1231 kWh electricity and 2313 MJ useful heat are generated during incineration.

Reuse, recovery and recycling potential (D)

The exported energy substitutes fossil fuels, whereby it is alleged that the thermal energy was generated from natural gas, and the substituted electricity complies with the German power mix for 2009.

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

Parameter	Unit	Production A1	Production A2	Production A3	Disposal C2	Disposal C3	Disposal C4	Credit 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

Parameter	Unit	Production A1	Production A2	Production A3	Disposal C2	Disposal C3	Disposal C4	Credit 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

Parameter	Unit	Production A1	Production A2	Production A3	Disposal C2	Disposal C3	Disposal C4	Credit 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

6 LCA: Interpretation

6.1 General information

The results are essentially interpreted for the production phase, i.e. Modules A1 to A3, as they are based on specific company data. To this aim, the results established in Modules A1 to A3 are summarised and put in the context of national emissions, i.e. standardised. The relevance of the global warming potential (GWP) for globally effective emissions and that of the acidification potential (AP) and the potential formation of summer smog (POCP) becomes apparent for the emissions with local effects (Fig. 1).

(*) Standardisation of the greenhouse gas potential performed here exclusively relates to the emissions from fossil sources. The three essential indicators referred to here are outlined in more detail below.

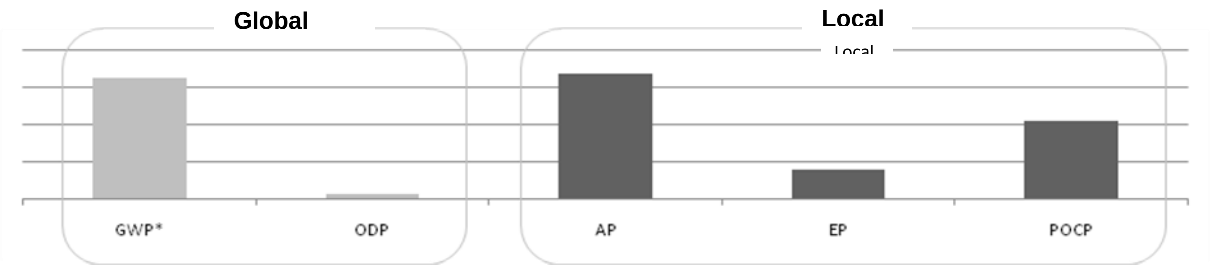

Fig. 1: Relative extent of impact indicators after standardisation to overall German emissions

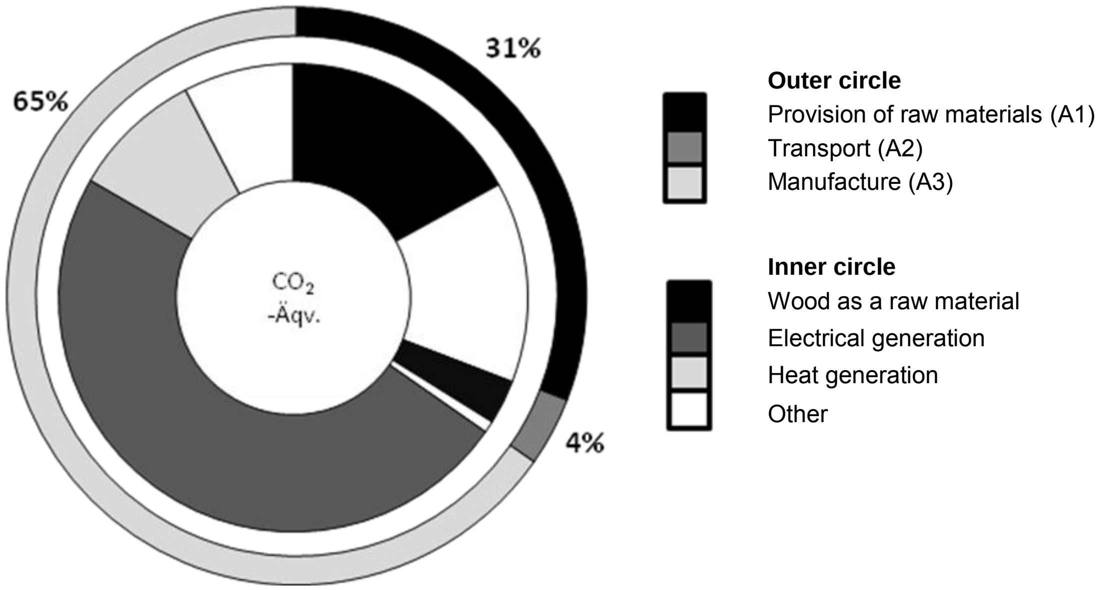

Fig. 2: Sources of fossil greenhouse gas emissions by module

Of the fossil greenhouse gases analysed in Modules A1 to A3, 31% is attributed to the provision of raw materials, 4% is accounted for by transport and 65% by manufacture, whereby the provision of wooden raw materials also includes extensive areas of the finishing chain as the corresponding finished products are bought in for production. Electricity consumption in the plant is an essential influential factor (49%). The contribution made by transporting the raw materials, generating heat and other emissions essentially comprising the combustion of diesel fuel on the plant site account for a total of 17% of cradle-to-gate emissions (Fig. 2).

Fig. 3 depicts an analysis of carbon from biomass. In total, approx. 1016 kg CO_2 enter the system in the form of carbon stored in biomass, of which 77 kg CO_2 are emitted along the preliminary chains and 150 kg CO_2 are emitted within the framework of heat generation on site. The carbon ultimately stored in the product is withdrawn again from the system during recycling in the form of waste wood.

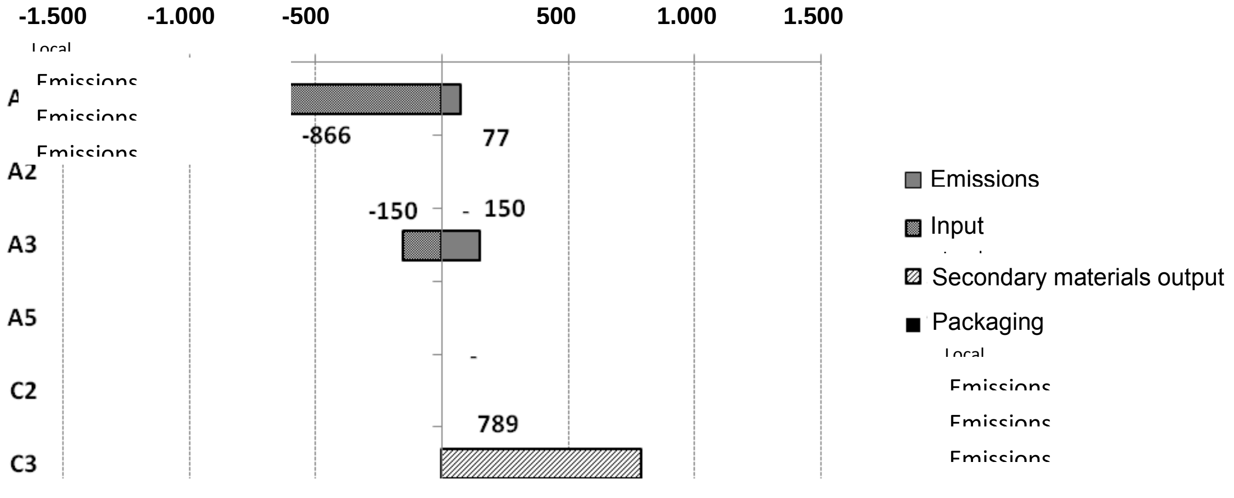

Fig. 3: Analysis of carbon flows from wooden raw materials and products

6.2 Acidification potential

The combustion of wood and diesel are essentially the relevant sources for emissions making a potential contribution towards the acidification potential. Drying bought-in products as well as the provision of heat required for this process and the use of fuels in forestry ensure a relatively high contribution by Module A1 (30%) (wood products) although emissions from the provision of adhesives are not insignificant (6%). Accounting for 4%, the transport of raw materials only makes up for a low percentage of overall cradle-to-gate emissions. Within the framework of manufacturing on site (A3), the provision of heat (26%), electricity consumption (22%) and combustion of diesel play an essential role.

6.3 Summer smog formation potential

Emissions contributing towards the formation of near-ground ozone are primarily incurred during the wood drying process. All in all, 35% is emitted during provision in Module A1, 3% during transport and 59% within the framework of Module A3.

6.4 Use of primary energy

Renewable fuels are primarily used in the form of wood for generating process heat. Of a total of 2583 MJ, 68 MJ is attributable to the combustion of waste wood.

Non-renewable energy is primarily used for generating electricity and in the form of fuels for the transport processes. Smaller quantities are also required for the manufacture of adhesives.

6.5 Range of results

The individual results of the participating companies are distinguished from the average results in the Environmental Product Declaration. In total, deviations of +2%/-17%, +12%/-1% and +16%/-2% were measured in relation to the results described here for the three indicators GWP, AP and POCP, respectively. These deviations are primarily attributable to differences in the fuels used and specific electricity consumption levels incurred by the various processes.

7 Requisite evidence

7.1 Formaldehyde

The formaldehyde emissions are established in accordance with the European standard draft prEN 16351: 2011, Timber structures – *Cross-laminated timber – Requirements*, with reference to DIN EN 717-1, *Wood-based panels - Determination of formaldehyde release - Part 1: Formaldehyde emission by the chamber method.*.

Emission values from X-Lam glued with adhesives containing formaldehyde account for less than 60% of the limit value in accordance with the Chemical Restriction Regulation (0.1 ml HCHO/m^3 indoor air).

Emission values from X-Lam glued with adhesives which do not contain formaldehyde result in area-specific emission rates in the area of unglued wood (approx. one-twentieth of the limit value in accordance with the Chemical Restriction Regulation (0.1 ml HCHO/m^3 indoor air).

7.2 MDI

During the X-Lam gluing process, the MDI contained in the moisture-binding single-component polyurethane adhesives used is cured in full. MDI emissions from the cured X-Lam are therefore not possible; there is no test standard in place.

In tests based on the measuring method for determining formaldehyde emissions from DIN EN 717-2, *Wood-based panels - Determination of formaldehyde release - Part 2: Formaldehyde release by the gas analysis method*, MDI emissions can not be detected (detection limit: 0.05 µg/m³).

7.3 VOC

Evidence of VOC is optional when the EPD is valid for a shorter period of time (1 year).

8 References

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DIN EN 1

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DIN EN 717-1:2005-01, Wood-based panels - Determination of formaldehyde release - Part 1: Formaldehyde emission by the chamber method; German version EN 717-1:2004

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Waste Wood Act: Directive governing the requirements on utilisation and disposal of waste wood (Waste Wood Act - AltholzV) dated 15.08.2002, last amended by Art. 5, § 26 G dated 24.2.2012 I 212

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BOB VHT

Mengdeoppsett (cantidad de) for CO2-regnskap (contabilidad)

Konstruksjon	**Limtre (glulam** Gran/Furu	**Massivtre(solido** Gran
Hovedkonstruksjon (estructura principal	531,74	
Sekundærkonstruksjon gavler	31,14	
Vegger (paredes		143,77
Dekker (cubierta		39,12
Trappeløp (escalera		22,99
Balkongvegger (paredes balcón		42,08
Balkongdekker (techo balcón		111,03
Sum (suma	**562,88**	**358,99**

Transport	Turer (viajes Antall (nº	m3/tur	km pr. tur en vei(un camino	km pr. tur tur/retur(Retorno)
Moelv (suecia) - Bergen	23	24,47	450	900
Aichach (alemania(Tyskland) - Bergen	11	32,64	1879	3758

ENVIRONMENTAL PRODUCT DECLARATION

ISO 14025 ISO 21930 EN 15804

epd-norge.no
The Norwegian EPD Foundation

Eier av deklarasjonen	Velde Betong AS
Programoperatør	NÞ ringslivets Stiftelse for Miljßdeklarasjoner
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

Generell informasjon

Produkt:
1 M3. B45 SV40 <200mm

Programoperatør:
Næringslivets stiftelse for Miljødeklarasjoner
Pb. 5250 Majorstuen
0303 Oslo
Phone: +47 23 08 82 92
e-post: post@epd-norge.no

Deklarasjonsnummer: NEPD-334-218-NO

Deklarasjon er basert på PCR:
EN 15804:2012+A1:2013 tjener som kjerne-PCR.
PCR for Precast Concrete Products, NPCR 20.2011

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

Deklarert enhet med opsjon:
A1,A2,A3,A4

Funksjonell enhet:

Miljødeklarasjonen er utarbeidet av:
Deklarasjonen er utviklet ved bruk av EPDGen-version 1.0, Godkjenning: NEPDT03
Bedriftsspesifikke data er samlet og registret av:
Kåre Morten Eriksen
Bedriftsspesifikke data er kontrollert av:
Hernan Mujica

Verifikasjon:
Uavhengig verifikasjon av data, annen miljøinformasjon og EPD er foretatt etter ISO 14025:2010, kapittel 8.1.3 og 8.1.4

ekstern

Seniorforsker Anne Rønning
(Uavhengig verifikator godkjent av EPD Norway)

Eier av deklarasjon:
Velde Betong AS
Kontakt person: Reidar Velde
Telefon: 900 73 007
e-post: post@veldeas.no

Produsent:
Velde Betong AS

Produksjonssted:
Velde Betong AS. Noredalsveien 294, 4308 Sandnes. Norge

Kvalitet/Miljøsystem:

Org. No:
988 328 731

Godkjent dato:
08.06.2015

Gyldig til:
08.06.2020

Sammenlignbarhet:
EPD av byggevarer er ikke nødvendigvis sammenlignbare hvis de ikke samsvarer med NS-EN-15804 og sees i en bygningskontekst.

Årstall for studien:
2015

Godkjent:

Dagfinn Malnes
Daglig leder av EPD-Norge

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

Nøkkelindikatorer	Enhet	Vugge til port A1 - A3	Transport A4
Global oppvarming	kg CO2 eqv	252,8687	10,6
Energi bruk	MJ	2150,6000	142,187
Farlige stoffer		*	*

*Produktet inneholder ingen stoffer fra REACH kandidatlisten eller den norske prioritetslisten

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: Scenarier og annen teknisk informasjon

Følgende informasjonen beskriver scenariene for modulene i EPDen.

Transport fra produksjonssted til bruker (A4)

Type	Kapasitetsutnyttelse inkl retur %	Kjøretøytype	Distanse km	Brennstoff/Energi forbruk	Enhet	Verdi (l/t)
Bil	50 %	Concrete truck	25	0,029441	l/tkm	0,74
Jernbane	.	.	.	.	.	.
Båt	.	.	.	.	.	.
Annet	.	.	.	.	.	.

Byggefase (A5)

.	Enhet	Verdi
Hjelpematerialer	kg	0
Vannforbruk	m3	0
Elektrisitetsforbruk	kWh	0
Andre energikilder	MJ	0
Materialtap	kg	0
Materialer fra avfallsbehandling	kg	0
Støv i luften	kg	0

Label

Monterte produkter i bruk (B1):

.	Enhet	Verdi
Ingen påvirkning	0	0

Sluttfase (C1,C3,C4)

.	Enhet	Verdi
Farlig avfall	kg	0
Blandet avfall	kg	0
Gjenbruk	kg	0
Resirkulering	kg	0
Energigjenvinning	kg	0
Til deponi	kg	0

Vedlikehold (B2)/Reparasjon (B3)

.	Enhet	Verdi
Vedlikeholdsfrekvens	.	0
Hjelpematerialer	kg	0
Andre ressurser	kg	0
Vannforbruk	M3	0
Elektrisitetsforbruk	kWh	0
Andre energikilder	MJ	0
Materialtap	kg	0

Transport avfallsbehandling (C2)

Type	Kapasitetsutnyttelse inkl retur %	Kjøretøytype	Distanse km	Brennstoff/Energi forbruk	Enhet	Verdi (l/t)
Bil	0 %	-	0	0	l/tkm	0
Jernbane	.	.	.	.	.	.
Båt	.	.	.	.	.	.
Annet	.	.	.	.	.	.

Gevinst og belastninger etter endt levetid (D)

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

Norske tilleggskrav

Elektrisitet
Følgende datasett fra databasen ecoinvent v3 (juni 2012) for norsk produksjonsmiks inkludert import, på lavspenning er benyttet; Energy/Electricity country mix/Low voltage/Market: Electricity, low voltage {NO}| market for | Alloc Def, U. Produksjon av overføringsnett, i tillegg til direkte utslipp og tap ved overføring, er inkludert. Karakteriseringsfaktorer fra EN15804:2012+A1:2013 er benyttet. Dette gir et klimagassutslipp på: 24 g CO2-ekv/kWh

Farlige stoffer
Produktet er ikke tilført stoffer fra REACH kandidatliste (sjekket 04.06.2015) over stoffer av svært stor bekymring, stoffer på den norske Prioritetslisten (sjekket 04.06.2015) og stoffer som fører til at produktet blir klassifisert som farlig avfall. Det kjemiske innholdet i produktet er i samsvar med den norske produktforskriften.

Inneklima

Bibliografi

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NS-EN 15804:2012+A1:2013 Bærekraftig byggverk - Miljødeklarasjoner - Grunnleggende produktkategoriregler for byggevarer
ISO 21930:2007 Sustainability in building construction - Environmental declaration of building products

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