MASTER

"How much does your building weigh, Ms. van den Hurk?" towards designing an inexhaustible building environment

van den Hurk, S.

Award date:
2013

“HOW MUCH DOES YOUR BUILDING WEIGH, MS. VAN DEN HURK?”

- Towards designing an inexhaustible building environment -

Graduation report - Smart Living
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August 2013 - Eindhoven University of Technology

PROJECT: Graduation project
Smart Living

TITLE: "What does your building weigh,
Ms. van den Hurk?"
- Towards designing an inexhaustible building environment -

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PREFACE

This is my graduation report regarding a search towards designing an inexhaustible building environment. The report describes the final project within the master track Architecture, Building and Planning at Eindhoven University of Technology.

Sustainability already got my attention for a few years now, so I am grateful to put my energy into this subject and hopefully help to spread the word about what sustainability includes.

I would like to thank my graduation committee, which consists of prof. dr. ir. Bauke de Vries, ir. Maarten Willems and ir. Hajo Schilperoort. I want to thank Michiel Ritzen as well, co-developer of the tool that I used.

They all assisted me with their specific knowledge and remarks, which resulted in this final report.

Stephanie van den Hurk

Eindhoven, August 2013

SUMMARY

Smart Living, is how the graduation studio is called, but what does it mean? To me it means: "The use of ICT on behalf of sustainability, careful use of energy and water, care and health, safety, education and mobility." This definition forms an important starting paint of my graduation project.

Sustainability and energy consumption is getting more and more attention nowadays, which is quite necessary: the worldwide energy consumption has been increased extremely last 30 years. An important factor in this is the building industry: at the moment we use 20-40% of the total energy consumption in the building industry. This means that depletion of energy and material sources can become a large problem in the near future. So this creates a challenge for all engineers that are involved in the building environment: how to improve this situation?

We are already going to 0-energy buildings in the operational phase, but the energy use that comes along with materials is often ignored: the embodied energy that is stored in the materials and the energy that has been used during production processes and transport is mostly not taken in account.

The idea of paying more attention to the embodied energy, helped me to define the goal of the graduation project: a research towards the difference in embodied energy of building materials. Therefore I designed three different houses: one with biobased materials (biobased means that it can regrow naturally) and one with recycled materials. The last one consists out of conventional materials, in order to compare the other two with the average situation, it forms a baseline measurement.

With the Maxergy tool their exergetic performance will be compared: the impact of the building on the final land use, expressed in Embodied Land. With Embodied Land (in hectare-year) is meant: the land needed for the extraction of raw materials, the growth of materials, the generation of power etc., in order to restore the original stage. The input for the Maxergy calculation is the amount (in kilogram) of new and recycled materials that will be used for a product or building. This makes also the title of the report clear: for all houses the amount of materials have been calculated.

In order to compare the houses, the operational energy is kept as much as possible on the same level. This resulted in a general concept for all of them: a passive house with approximately the same dimensions. Subsequent, each house got its own individual design and detailing.

What can be concluded from this research?
First of all, the embodied energy of the materials is responsible for a substantial larger part in the total Embodied Land than the operational energy is. Furthermore, the biobased house performances by far as best result: the Embodied Land is almost six times lower than the recycled house and conventional house, which are almost of the same level. It turned out that steel is responsible for a large part in the calculation. Although recycled, the effect can not been calculated really well, since the technical cycle is such an unclear process. So this means that the recycling of steel does not by definition gives a persuasive positive result on the environmental impact.

SAMENVATTING

Smart Living is de naam van het afstudeeratelier, maar wat betekent het eigenlijk? Voor mij betekent het: "Het gebruik van ICT ten behoeve van duurzaamheid, zorgvuldig gebruik van energie en water, zorg- en welzijn, veiligheid, onderwijs en mobiliteit." Deze definitie vormt een belangrijk uitgangspunt binnen mijn afstudeerproject.

Duurzaamheid en energiegebruik krijgen vandaag de dag steeds meer aandacht, wat ook zeker noodzakelijk is: het energieverbuik wereldwijd is enorm toegenomen de laatste 30 jaar. Een belangrijke factor hierin is de bouwsector: op het moment gebruiken we 20-40% van het totale energieverbruik in de bouw. Dit betekent dat de uitputting van energiebronnen en materialen een groot probleem kan worden in de nabije toekomst. Dit levert alle ingenieurs in de bouwsector dus een uitdaging op: hoe kan deze situatie verbeterd worden?

We gaan al richting 0-energie gebouwen in de operationele fase, maar de energie die materialen met zich meebrengen wordt vaak genegeerd: de embodied energy die opgeslagen zit in materialen en de energie die gebruikt wordt tijdens het productieproces en het transport worden vaak niet mee geteld.

Het idee om meer aandacht te schenken aan de embodied energy, zorgde voor een formulering van het afstudeerproject: een onderzoek naar het verschil in embodied energy van bouwmaterialen. Hiertoe heb ik drie verschillende huizen ontworpen: een met biobased materialen (biobased wil zeggen dat het opnieuw kan groeien in de natuur) en een met gerecyclede materialen. Het derde huis bestaat uit conventionele materialen, om op deze manier de andere twee te vergelijken met een gemiddelde situatie, het vormt een soort ijkpunt/nulmeting.

Met de Maxergy tool zullen de exergetische prestaties vergeleken worden: wat is de impact op het uiteindelijke landgebruik, uitgedrukt in Embodied Land. Met Embodied Land (in hectare-jaar) wordt bedoeld: land dat nodig is voor de extractie van grondstoffen, de groei van materialen, de opwekking van energie, etc., zodat de oorspronkelijk staat hersteld kan worden. De input voor de Maxergy berekening is de hoeveelheid nieuwe en gerecyclede materialen (in kilogram) die gebruikt wordt voor een product of gebouw. Dit verklaart tevens de titel van het rapport: voor alle huizen is de hoeveelheid aan materiaal uitgerekend.

Om de huizen te kunnen vergelijken, is geprobeerd de operationele energie zoveel mogelijk op een gelijk niveau te houden. Dit resulteerde in een algemeen concept voor de drie huizen: een passief huis met ongeveer dezelfde afmetingen. Daaropvolgend heeft elke huis haar individueel ontwerp en detaillering gekregen.

Wat kan er uit het onderzoek geconcludeerd worden?
Allereerst is de embodied energy van de materialen verantwoordelijk voor een aanzienlijk groter deel dan de operationele energie. Ten tweede presteert het biobased huis verruit het beste: de Embodied Land is bijna zes keer zo laag als die van het gerecyclede en het conventionele huis, die ongeveer op een gelijk niveau zitten. Verder bleek dat staal verantwoordelijk is voor een groot aandeel in de berekening. Alhoewel het gerecycled kan worden, kan het effect niet goed gemeten worden, zolang de technische kringloop een vaag gebied blijft. Dit betekent dus dat de recycling van staal niet per definitie een overtuigend positief effect op het milieu heeft.

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0. PRELEGOMENON

"How much does your building weigh, Ms. Van den Hurk?" is the title of this graduation report called. Originally derived from the movie title "How much does your building weigh Mr. Foster?", but now asked at me by a fellow student when I was doing my calculations.

"This question seems to haunt every project Lord Norman Foster designs. Challenged by Buckminster Fuller in the '70s, Foster began to seriously investigate weight, energy and performance to answer this difficult question. And his architecture shows it."

"When you ask Foster to define his modus operandi, he isn't able to break down the synthesis of all of the elements in his design process. When you ask him to choose form or function, he says the two are inseparable. Foster doesn't play the architect's favourite ideological game of simplifying the design process down to a golden rule. To him, a great building is based on plural consideration—structure, aesthetics, materials, daylighting, ecology, function and many more—and never the imposition of one at the detriment of another." (Lynn Wang, SOMA Magazine)

His passion for aesthetics and functionality is clearly visible in his buildings. The projects together with Buckminster Fuller seemed to be a catalyst in the development of a more sustainable way of designing.

This is exactly why both architects are great sources of inspiration to me. This interest started already in my first year at the university up till now, so it is really satisfying to carry it out in my graduation project.

In an interview (by Martin C. Pedersen, Archdaily) Norman Foster explains his connection with Buckminster Fuller as following:

"It was his philosophy, his optimism, his belief in friendly clean technology that would enable the species to survive if they used their intelligence. There were other influences during that time. But I never dreamed that a few years later I'd end up being approached by Bucky to collaborate with him on projects and for it to become such a close relationship."

Foster also talked about Bucky to younger audiences, and when he is asked if Buckminsters ideas connect with this audience he says:

"I think they really resonate. He empowered a generation. It's not too much of an exaggeration to say that he triggered the green movement. Whether anything has made enough of an impact can be debated, but certainly the environmental movement is rooted in Bucky. He has tremendous appeal and relevance to younger generation architects and environmentalists today and in a way, I feel that he's not recognized the way that he should be. He's been much more widely understood in Europe. I don't know how you feel, but I don't think he's ever been truly understood in America."

During my graduation process I experienced that there can also arise some tension between aesthetics and functionality, or to speak in terms of fields: between architecture and building technology. On the one hand men could argue that these are different directions, or specializations, but on the other hand should these expertise interweave with each other all along the process. So although I have to fight sometimes against myself interfering both specializations, I will continue doing so.

HOW TO READ THIS REPORT?
In chapter 1 you can read some background information about the subject of the graduation studio Smart Living, how I interpret the subject, the social and scientific relevance of it and a formulation of the problem together with my research goal.
Chapter 2 gives information about sustainability, emphasizing on the difference between operational and embodied energy.
Chapter 3 explains how the calculation works with Maxergy; the tool that will be used to express sustainability.
In chapter 4 the research question is clearly formulated, which comes along with some secondary questions and a research model.
In chapter 5 the overall concept will be explained; a general passive design model.
In chapter 6 the program of requirements is listed, and in the sub chapters the three designs are fully explained: each containing a more specific concept, calculations and technical drawings.
Chapter 7 interprets the results of the three designs and in chapter 8 the conclusion on this will be drawn, also the research question will be answered here.
Chapter 9 provides scope for discussion and recommendations and chapter 10 gives an evaluation on the graduation project.

1. SMART LIVING

Almost everything around us gets smart: cell phones, computers, cars, and also in the health care we apply smart technologies. But will this also be the case for the housing industry? How do we feel about smart homes and what will be the future for the housing industry?

To set the borders of this report there are a few definitions that need to be discussed. The first one is 'smart home'. What is this exactly? Like almost every term there is not just one definition, most of the time there are more explanations. According to the Smart Homes Association, smart home technology is: "The integration of technology and services through home networking for a better quality of living." This definition is quite clear, except for what can be understood from the quality of living. According to Jacqueline Vischer (2007), the overall quality of life can be explained with three levels of environmental comfort: physical, functional and psychological comfort. Optimal environmental comfort can be reached when all three levels of comfort are properly represented, see figure [01]: the diagram of Vischer (2007). The physical comfort level includes basic human needs such as safety, temperature, lighting and accessibility. Without these aspects, a house would be uninhabitable. The level of functional comfort responds to the specific needs and preferences of the user, the environment should support the tasks and activities of people. The psychological comfort level is related to people's lifestyle, it results from feelings of belonging, ownership and control. (Allameh, Mohammadali, de Vries, Timmermans & Beetz, 2010) and (Vischer, 2007).

So while designing a smart home, one should aim for an optimal balance between the three comfort levels, which improves the quality of life.

According to the Strategic Research Agenda (2011) of the Dutch ICT Innovation Platform 'Home Automation and Smart Living' (IIP DSL), a more recent term would be smart living. This would refer to "The use of ICT on behalf of sustainability, careful use of energy and water, care and health, safety, education and mobility." "This approach marks a shift from the attention for the use of ICT in the physical house to ICT for living and for the living environment." Integrating sustainable issues in the definition and looking at the complete living environment gives a more holistic approach than only reviewing one single smart home.
This need for integrating sustainability is obvious: the

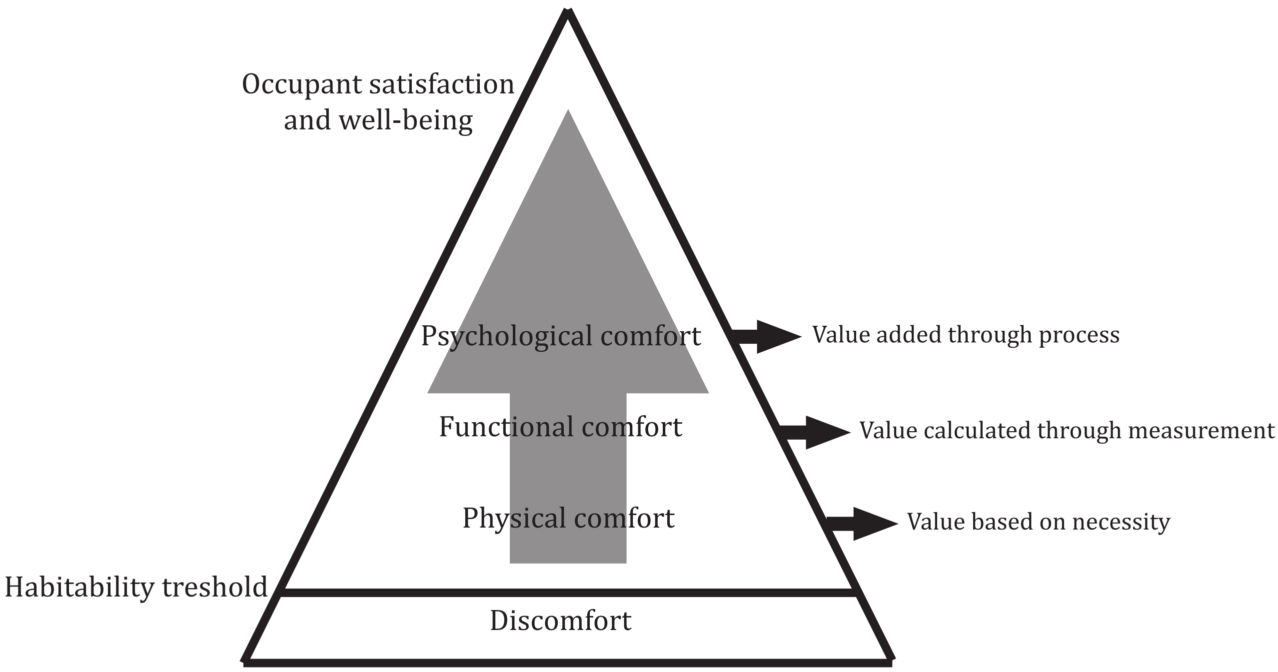


Fig. 01: The 'Habitability' pyramid

worldwide energy consumption has been increased extremely last 30 years, see the figure [02] (U.S. Energy Information Administration, 2013). The building environment is on the moment responsible for 20-40% of the total energy consumption (Pérez-Lombard, Ortiz & Pout, 2007).

SCIENTIFIC AND SOCIAL RELEVANCE

The facts mentioned above will mark the scientific relevance of the report: contributing knowledge to the environmental impact of the housing industry. Architects will have to take the environment more in account in the near future, innovative ideas and concepts are becoming absolutely necessary. Moreover, it will become an integral challenge for all engineers involved in the process.

Sustainability is also important to the social relevance of this report, since awareness and implementation by the average user are stumbling blocks nowadays (de Volkskrant, February 15, 2013). So here are problems to overcome as well: sustainability should also be socially desirable.
On the other hand there is a large interest from private commissioners to buy building sites, with the intention to build their own special house (de Volkskrant, June 6, 2013). This provides chances to make them enthusiastic for interesting, innovative possibilities and solutions.

PROBLEM FORMULATION AND GOAL

This scientific and social relevance leads to the problem formulation and objective of the report:
The main problem is that if we (as architects) continue the way designing houses as been done in the past and users consume these houses as they did in the past, our energy and material sources will get depleted really soon. So the goal of this research is to aim for an optimized design attitude for sustainable housing on the one hand and uncover it to the public on the other hand.

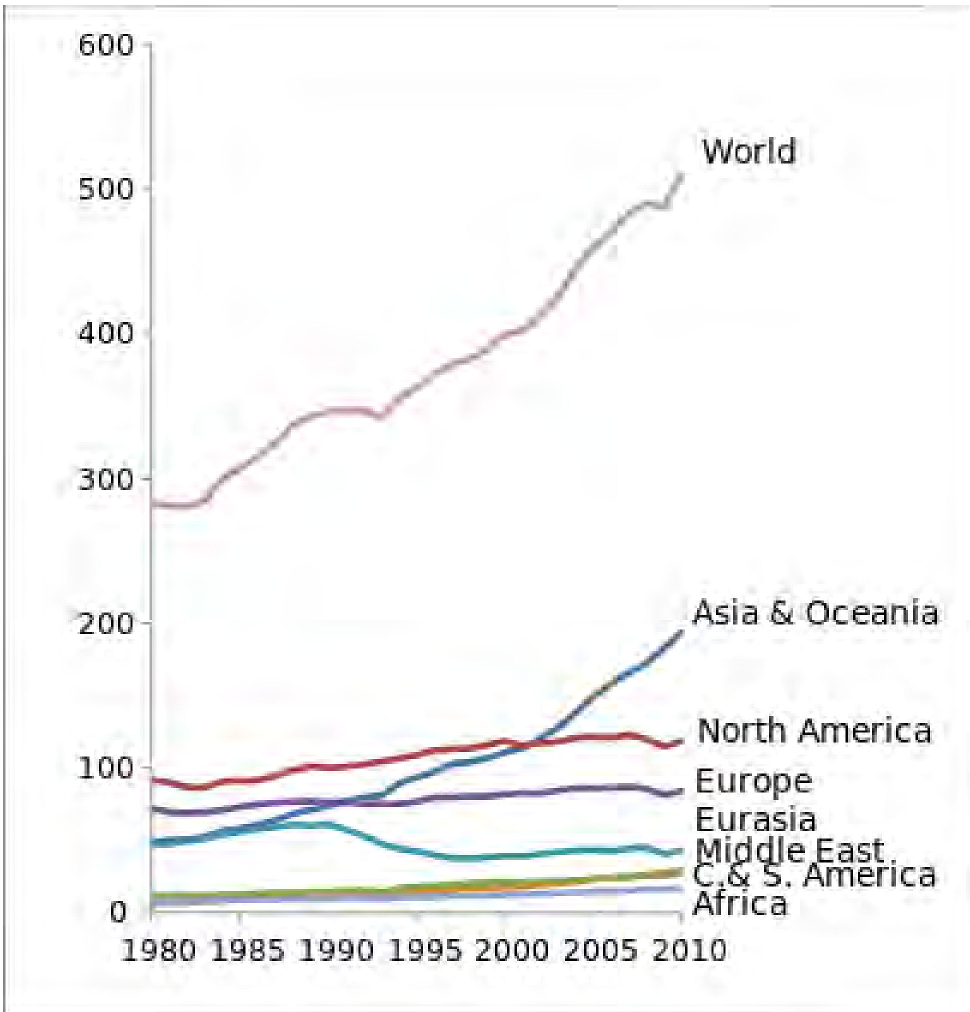


Fig. 02: World primary energy consumption, in quadrillion Btu (1 Btu is about 1055 joules)

According to the pervious chapter, it becomes clear that sustainability will become a very important aspect in our building environment. So 'sustainability' is another term that needs to be clarified, a challenge that has already been attempted by a large number of scientists. The definition of sustainability can often be explained and interpret in many different ways, which mostly depends on the specific field where it is used. Sustainability is a very wide term, but the most common definition, given in the report 'Our Common Future' (or 'Brundtland Report') of the World Commission on Environment and Development (1987), is: "Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs". The Brundtland Report can be seen as a starting point of sustainable awareness (Kramer, 2012). Nowadays, sustainability becomes more and more important and it gets a lot more attention. This brings us new insights, definitions, methods and tools for measurement.

OPERATIONAL AND EMBODIED ENERGY

Although, with this general definition of sustainability, it does not directly become clear what it means for the building environment. Defined like this, its scope is very wide. The term is used whether appropriate or not and tends to incorporate human desires that are not measurable.

When talking about sustainability in the building industry most policies and assessment tools focus only on the space heating and cooling demands of buildings, the energy used for lighting and appliances, this is also called the operational energy. It accounts for about one-fifth of the total delivered energy in the world (Hernandez & Kenny, 2011). Consequently, there is a focus on saving this operational energy and using it more efficient. There is a growing consciousness for the fact that energy sources will get depleted and for the effect of global warming. The building industry responds on this, for example, with the development of passive houses, zero energy houses and active houses. The European Energy Performance of Building Directive (EPDB) have even set the goal that EU member states have to ensure that all new buildings are 'nearly zero energy' by the end of 2020 (Hernandez & Kenny, 2011). The Dutch Ministry for example, responds on this with their energy neutral building program: they provide information on things such as the application of 'Trias Energetica'. This strategy consists out of three steps that incorporate energy saving actions: restrict the energy demand, use energy from renewable/surplus sources and use fossil energy sources efficiently (Agentschap NL, 2012). Insufficiently, this strategy and also zero energy buildings (although a standard definition does not exist according to Hernandez & Kenny) focus only on the operational phase and do not consider the energy use in other phases of the total life cycle. However, buildings are also responsible for a large part of energy use in other sectors. This can be defined as embodied energy: the energy that is needed for the

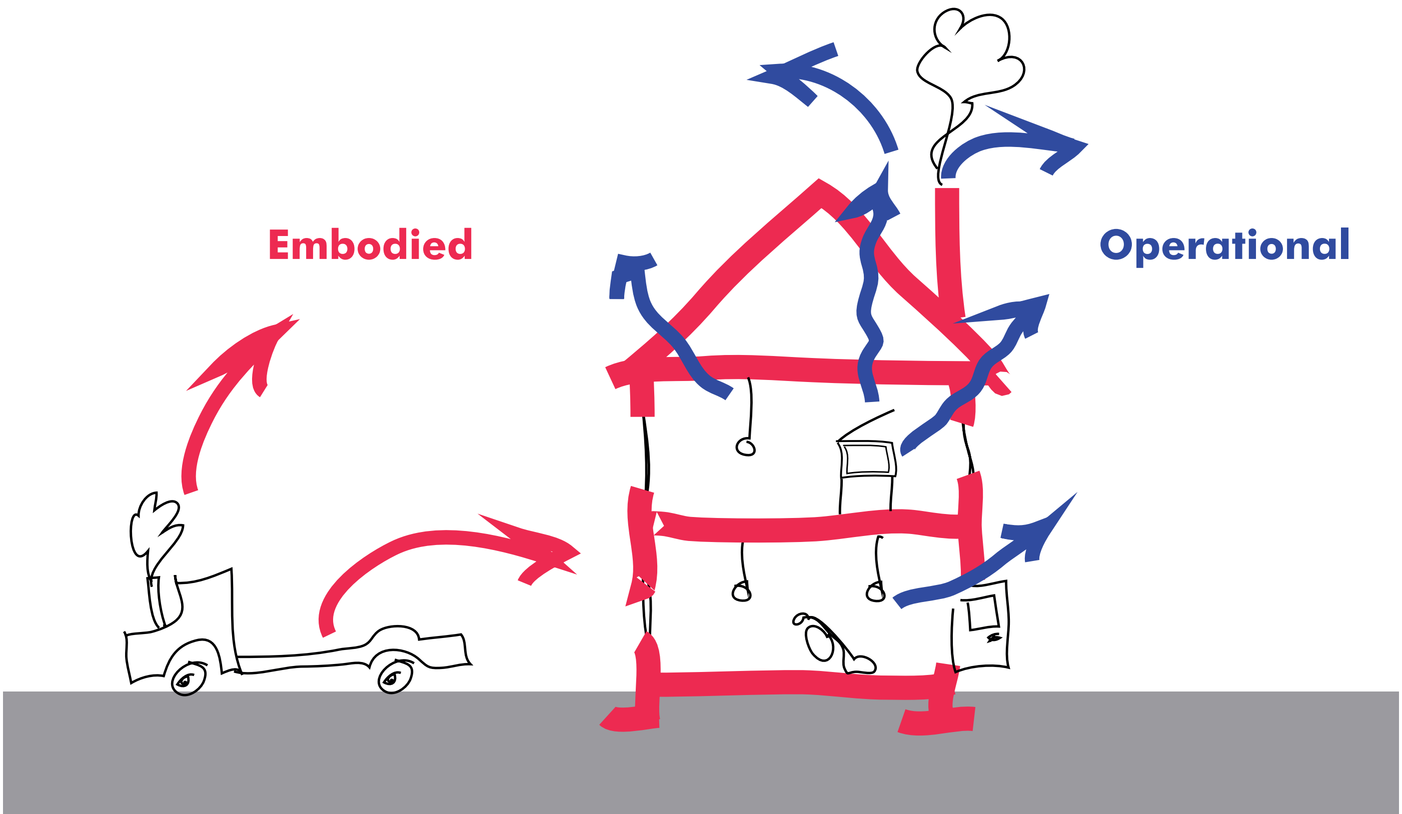


Fig. 03: Operational and embodied energy

processes of production, transport, construction and demolition, which is most of the time neglected. Figure [03] illustrates this difference between operational and embodied energy. So often only a small part of the total life cycle energy will be assessed with current tools, which gives us a disproportional image of measuring sustainability (Ritzen, Rovers, Gommans, Geurts, Vroon & Sighwart, 2013).

Several studies are pointing out that space-heating energy only represents a small proportion of the life cycle energy consumption of a household, at most 23%. Even when the remaining operational energies (lighting, appliances, etc.) are taken into account as well this number increases to at most 47% (Stephan, Crawford & de Myttenaere, 2011).

The embodied energy of buildings (including transport energy etc.) is responsible for the biggest part of the life cycle energy. This might cause that subsidies promoting the energy performance of buildings go towards the incorrect target. This means inaccurate situations can occur, for example: people living in subsidized low-energy houses in the suburbs consume more energy in total than an urban version where people live in a less efficient dwelling (Stephan, Crawford & de Myttenaere, 2011).

In order to come to a more legitimate definition of what can be understand by sustainability in the building industry, the embodied energy should be taken into account as well. There are many methods, tools and certificates available nowadays, since the importance of instruments that help to implement regulations and codes for analysing sustainability in the building environment is growing. Nevertheless, they rarely measure real improvements on the impact of resources and climate. Often these methods contain subjective parts, use forced weighting factors, refer a new situation to an old reference, or compare items on different levels. Tools can fast become inaccurate when different indicators are added to one final score. Moreover, the calculations are sometimes so complicated that they are not transparent anymore (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011).

RiBuilT, an international research institute for sustainable development and transition in the building environment, recently (2013) developed a new tool called Maxergy. Their approach is to develop a tool that not just looks at the absolute use of sources, but verifies if the use of sources can be continued for an indefinite time within a certain space. A closed cycle performance is much more interesting than the optimisation of a life cycle (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011). This closed cycle approach is related to the well-known cradle-to-cradle principle of McDonough and Braungart: no loss of energy and no deposited products. Cradle-to-cradle has its focus on materials, while Maxergy goes a step further than this because the calculation is based on the reach of a system.

The use of materials and energy can be described with the same physical unit by means of the exergetic performance; the time and space that is needed for the energy demand of materials, serving a specific function in a specific surroundings. Figure [04] shows a scheme of the exergetic demand of a building. Exergy is the amount of 'energy' that maximum can be obtained out of a energy- or material flow. Techniques are used to convert energy into useful formats, however with a certain efficiency. Hereby will always occur some loss of exergy. This will be replenished with solar energy that moves into the system (a building, city or region). This energy moving in needs to be at least be as much as the loss of exergy, in order to speak of a continuous situation: a maintainable quality.

Maxergy, which stands for taking out and maintaining the maximum quality (exergy) in a system, aims to create a closed cycle and tries to avoid the loss of exergy. This means that sources we use need to be recovered in their original state, which guarantees the continuity of those sources for materials and energy. The Maxergy tool is based on a time-space calculation and expresses itself in Embodied Land (EL). The Embodied Land of a product (in hectare-year) means: the land needed for the extraction of raw materials, the growth of materials, the generation of power etc., in order to restore the original stage (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011).

The total Embodied Land of a product is calculated out of different databases with as input the amount of new and recycled materials, this will be treated in the next chapter. One first distinction is made between the primary and secondary impact. The primary impact is the impact of the product itself. The secondary impact is de Embodied Land of the techniques and installations that are needed to produce the materials where the product is made of (in a later version of the tool also the water that is needed). The tertiary impact and further is not taken into account. Within the primary impact, a distinction can be made between direct and indirect Embodied Land of materials. Each material has a certain Embodied Land, Embodied Energy and Embodied Water in itself. For the Embodied Land of materials, the data about the yield of the harvest and the winning per hectare can directly be translated to the Embodied Land of the product. Embodied Energy and Water however, need to be translated in ha-year by a step in between and will be determined by the efficiency of the technique. Last, some products also need energy and/or water while using them; this belongs to the operational part (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011). Figure [..] gives a schematic overview how the Maxergy calculation works. The yellow blocks are showing the input that is needed and the red blocks are giving the output information. Explanations of the most important terms that are used in this scheme are given below.

> Embodied Land Direct
The Embodied land of a material indicates how much land and time it needed to arise.

>Embodied Land Indirect (mainly Embodied Energy)
The energy that is needed to produce, transport and recover the materials (the Embodied Energy). This energy can be generated with techniques that require a certain surface and time span, so that de Embodied Energy can be expressed in Embodied Land as well.

> Embodied Land Technique
Next to the primary impact of the materials themselves,

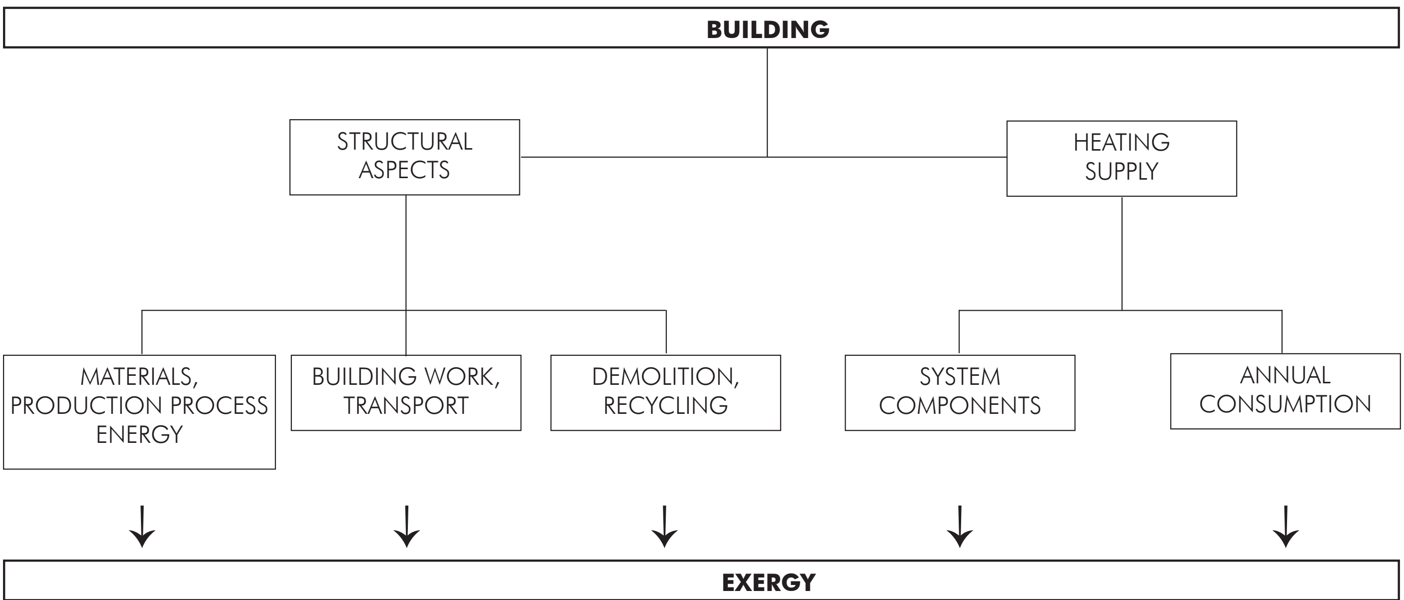


Fig. 04: Scheme with the exergetic demand of a building

the production of the energy techniques that transforms the Embodied Energy in Embodied Land requires materials and energy as well. This secondary impact needs to be taken into account for the calculations as well.

> Embodied Land Operational

For some products the operational phase needs energy input as well, like electric appliances and buildings. This energy will also be taken into account for the total Embodied Land. When sustainable sources such as wind or sun are being used, then also a part of the energy needs to be stored in order to compensate for fluctuations (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011).

EXAMPLE CALCULATION OF A BEAM

In order to illustrate the method and calculation a simple comparison between two beams can be made: one existing out of wood and the other out of steel. Both beams are taken from a comparable floor part, and only the materials will be reviewed, not the operational energy. Figure [06] shows the three components of the Maxergy calculation: direct land use for the raw material (EL-harvest), land use for generating the embodied energy (EL-emb) and the land use to realise the compensation (EL-Return energy). For these last two components the direct needed energy (PV) surface has been calculated, together with the impact of the production of the panels for this. It becomes clear that there is a big difference in embodied land between the wooden beam and the beam made of steel. 19 Million versus 57 m2-jaar.

Since a lot of different tools have been developed last years, some parts of the calculation might be recognizable or are even derived from other tools. The basic framework for Maxergy is most closely related to two other methods: LCA and Ecological Footprint. What are the differences and what are the similarities with Maxergy? This will be pointed out in the next paragraphs.

MAXERGY VS LCA

LCA is a recent and commonly used method, which

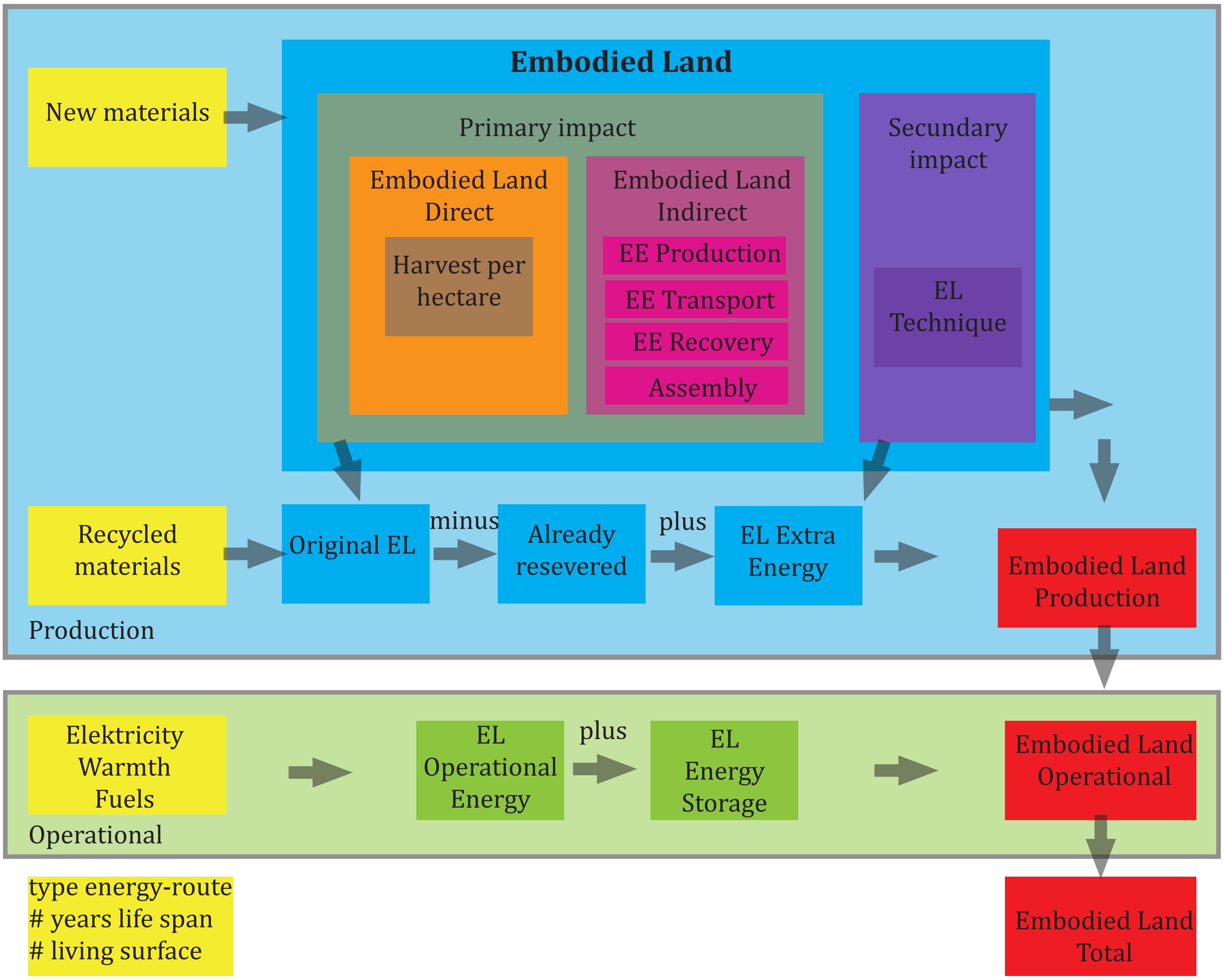


Fig. 05: Schematic overview of the structure of the Maxergy calculation.

met versie 1.0							
steel and wood beam adapted for comparable load (carry floor section)							
						without return	
m2 (-year)		Emb Land, Ren. Energy based				or prim. harvest EL	Embodied energy
	kg	EL-harvest	EL -emb.energy	EL-return energy	TOTAL EL-RE	is only EL from EE	in MJ
steel beam	18	0,002	255	19130681,00	19130936,0	255	630
wood beam	11,3	23,8	33,4	0	57,2	33,4	83,25

Fig. 06: Example calculation comparing a steel and wooden beam

stands for Life Cycle Assessment (also known as life cycle analysis or cradle to grave analysis). A cradle to grave approach begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. With a LCA tool the environmental impact of products during their entire life cycle will be systematically analysed. The life cycle of a product basically consists of raw material acquisition, manufacturing, usage and waste management (SAIC, 2006). However, the environmental impacts are evaluated throughout, so it also includes the up- and downstream processes that are coming along with all life cycle phases. These impacts refer to all relevant extractions from the environment, as well as emissions into the environment. There are several impact categories to identify this; global warming, ozone depletion and resource depletion are global impacts measured by a lot of chemical gasses in the air and the quantity of minerals and fuels that are used. Photochemical smog and acidification are regional impacts measured by chemicals as well. Local impacts are: human health, terrestrial toxicity, aquatic toxicity, eutrophication, land use and water use. This will be measured by chemicals, releases and usage (SAIC, 2006).

Figure [07] illustrates the typical input, the life cycle stages and the output of an LCA tool (SAIC, 2006). The environmental impacts are bundled with a weighting factor to one score for the total impact of a product. A disadvantage of the use of the LCA method is that these weighting factors are a subjective and forced way to reach one distinct score. Another disadvantage is that every phase of the life cycle contains a certain error margin, which accumulates itself further during the process. On the other hand, some of the environmental impacts that are part of the LCA calculation are not directly taken into account in the Maxergy calculation (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011). But the fact that the LCA method has its focus on materials makes it less suitable for evaluating sustainability in the housing industry.

EMBODIED LAND VS ECOLOGICAL FOOTPRINT

What is the difference between Embodied Land and Ecological Footprint? Also 'Carbon Footprint' is a term that is often used in this context nowadays, but

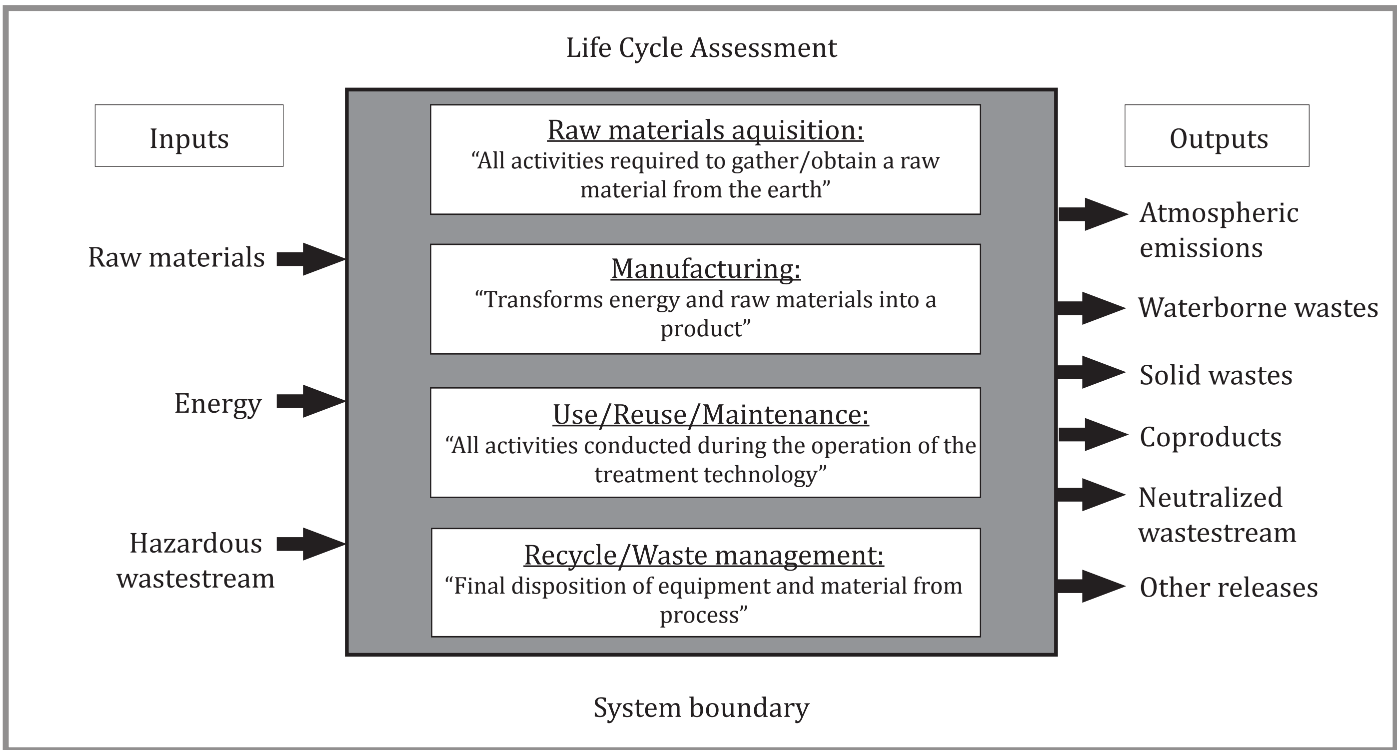


Fig. 07: Life Cycle Stages

what do these indicators actually incorporate?
According to the document 'Calculating Methodology for the National Footprint Accounts (Ewing, Reed, Galli, Kitzes & Wackernagel, 2010) the Ecological Footprint is defined as following:
"…it measures human appropriation of ecosystem products and services in terms of the amount of bio-productive land and sea area needed to supply these products and services. The area of land or sea available to serve a particular use is called biological capacity (bio capacity), and represents the biosphere's ability to meet human demand for material consumption and waste disposal". Figure [8] displays the fields that are taken into consideration and it shows that Carbon Footprint is actually a specialised type within the Ecological Footprint.

Maxergy calculations, which are based on embodied land, and calculations based on the Ecological Footprint have a lot in common. Both methods give a final number in needed hectare for a product/service (Maxergy) or a person/land/city/region (Footprint, including food). Both methods decompose the unit that will be researched in primary materials and use the terms Embodied Energy and Embodied Footprint/Land (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011).

One of differences is that Footprint puts the consumption in hectares against the ground that is available in the world, whereby it will be clear if we use more than there is or not. Hereby, also the productivity of the ground is taken into account. Furthermore, Footprint looks next to the production and consumption to the production of waste as well and the capability of eco systems to use that waste again so that no accumulation of waste arises (also greenhouse gasses). This means that Footprint looks at 'end-of-pipe' effects (i.e. cradle-to-grave). Embodied Land looks at closed cycles and therefore, to primary loads whereby CO2 emissions are not relevant (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011).

Another difference is that Footprint does not consider renewable sources: only regrowable sources that can regenerate themselves within a human time scale are taken in consideration. Further, Footprint is often presented by a spatial system (not a single product) whereby the result can be distorted through import and export (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011).

The final number of Footprint is not in absolute hectares, but in global hectares, which represents the average production of a hectare in the world. So Footprint is based on norms, not on actual numbers. Hectare-year as a unit for determining the sustainability of a product/service/building as is used in Maxergy is thoroughly different than the Ecological Footprint method, although the base is quite the same and there are a lot of common principles. All in all, calculations based on Embodied Land give new, interesting insights with different application possibilities (Rovers, Rovers, de Flander, Broers, Houben, Gommans, et al., 2011) and (Ewing, Reed, Galli, Kitzes & Wackernagel, 2010).

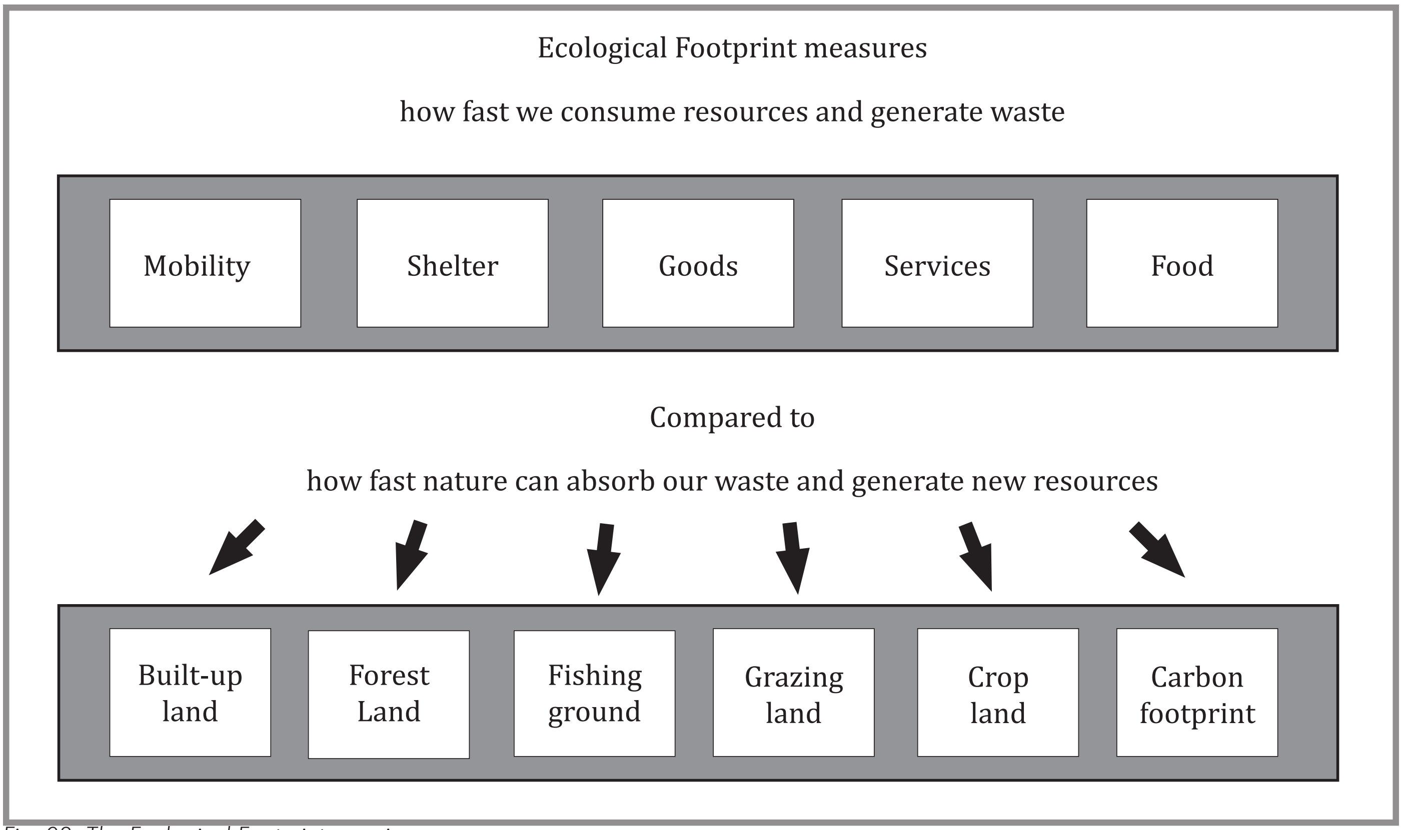


Fig. 08: The Ecological Footprint overview

4. RESEARCH QUESTION: BIOBASED VS RECYCLED

RESEARCH QUESTION

The pre-research phase towards sustainability aspects in the building industry brought some interesting questions along, with as main topic what the difference in environmental impact would be between biobased and recycled materials. This will be expressed in the exergetic performance: the impact of a building on the final land use, expressed in embodied land.

This comes down the following research question:

>What is the difference in exergetic performance between a house with mainly new, biobased materials and a house with mainly recycled materials?

With a biobased material is meant: a material that (re) grows in a natural way: the materials have a built-in reproduction mechanism in nature. Wood is an example of a biobased material.
A recycled material is a material that is used again, after human intervention. Steel is an example of a material that can be recycled.

In order to compare these two designs with an average situation, a third design will be added that consists out of conventional materials. This house will function as a baseline measurement within the research, this makes the conclusion more valuable.

The input for the Maxergy calculation is the amount of new and recycled materials that will be used for the final product. Recycled materials are being calculated apart from new materials since the energy costs can be different. For recycled materials, it is possible to indicate a part of already been compensated land use, if there is information about it available.

So what will come out as most sustainable according to Maxergy: biobased materials or recycled materials? Or an even more relevant question: how will our future building environment look like with this elaborated knowledge about how we should measure sustainability in the housing industry? Is it possible to head towards an inexhaustible building environment?

SECONDARY QUESTIONS:

1. What are the requirements in order to compare the houses?
2. What are the requirements for a passive house?
3. What biobased materials can be used?
4. What recycled materials can be used?
5. What are conventional materials?
6. How to add materials to the Maxergy tool?

The first 5 questions will be answered in the next chapters. The last question is necessary to answer as well, but will not include a separate chapter in this report since this does not belong to the main focus of the project.

ADDING MATERIALS TO THE MAXERGY TOOL

Since a lot of different materials will be used in the designs and Maxergy does not contain them all yet, question number five is added. In order to answer this question more background information about Maxergy is essential. The embodied energy value of materials are expressed in Megajoule per kg. There are databases with the embodied energy values of materials. Maxergy makes for a large part use of the ICE database van Hammond and Jones (Hammond et al, 2011); an up to date and often used database.

Two important materials I would use in the biobased house are not included in the tool: foam concrete and coconut coir. For foam concrete the ICE database provides some information to make a calculation on the embodied energy of the material, but there is unfortunately no information on coconut. This means that there was some extra research needed: other databases or journals gave a definite answer on the embodied energy of coconut coir.

RESEARCH MODEL

In order to give a complete overview of the research, all important aspects are organized in a scheme. See the figure [09] on the next page.

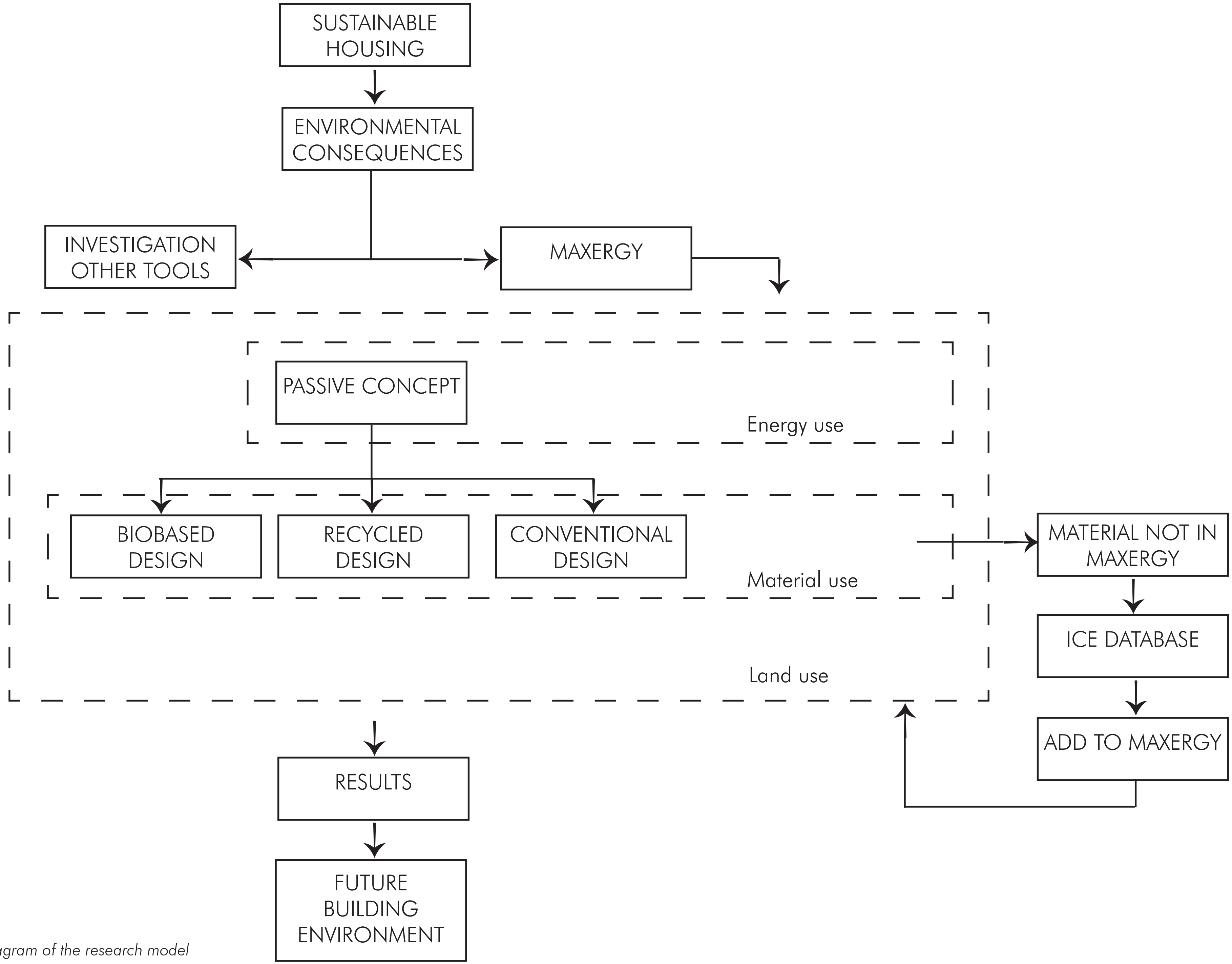


Fig. 09: Diagram of the research model

5. GENERAL CONCEPT: A PASSIVE HOUSE

We are already going towards standard zero energy houses in the operational phase, so it makes more sense to research the embodied energy. As already described in the research question the focus will be on materials. This resulted in designing three houses with different materials but one general concept for the operational energy: a passive house.

"The heat losses of the building are reduced so much that it hardly needs any heating at all. Passive heat sources like the sun, human occupants, household appliances and the heat from the extract air cover a large part of the heating demand. The remaining heat can be provided by the supply air if the maximum heating load is less than 10 W per square metre of living space. If such supply-air heating suffices as the only heat source, we call the building a Passive House." - Univ. Prof. Dr. Wolfgang Feist, director of the Passive House Institute -

This is the official definition of a passive house, but there basically five aspects with specific requirements, see also figure [10]:

1. Exceptionally high level of thermal insulation
All components of the building shell are insulated with a Rc-value >6,5 m2K/W and U ≤0,15 W/m2K.
U-value glazed frame ≤0,8 W/m2K
Linear heat transmission coefficient ≤0,01 W/mK

2. Well-insulated window frames with triple low-e glazing
Solar gain factor glazing ≥ 50%

3. Airtight building envelope
Airtightness n50-value ≤ 0,6 h-1
The airtightness value of buildings/dwellings (n50-value) will be measured by a BlowerDoor test.

4. Comfort ventilation with highly efficient heat recovery
Energy use ventilation ≤0,45 Wh/m3
Efficiency heat recovery ≥75%

5. Thermal-bridge-free construction
Avoid a complex building: corners and staggered levels are giving more connections and pay extra attention to the detailing.

6. Optional: use of renewable energy like solar panels, collectors and boilers.

Other design principles that need to be taken in account:
- Shape of the building: a sphere is ideal, but practically the base will be a cube.
- Compact building: max. volume, min. façade surface.
- Orientation on the south (max. deviation: 20 degrees

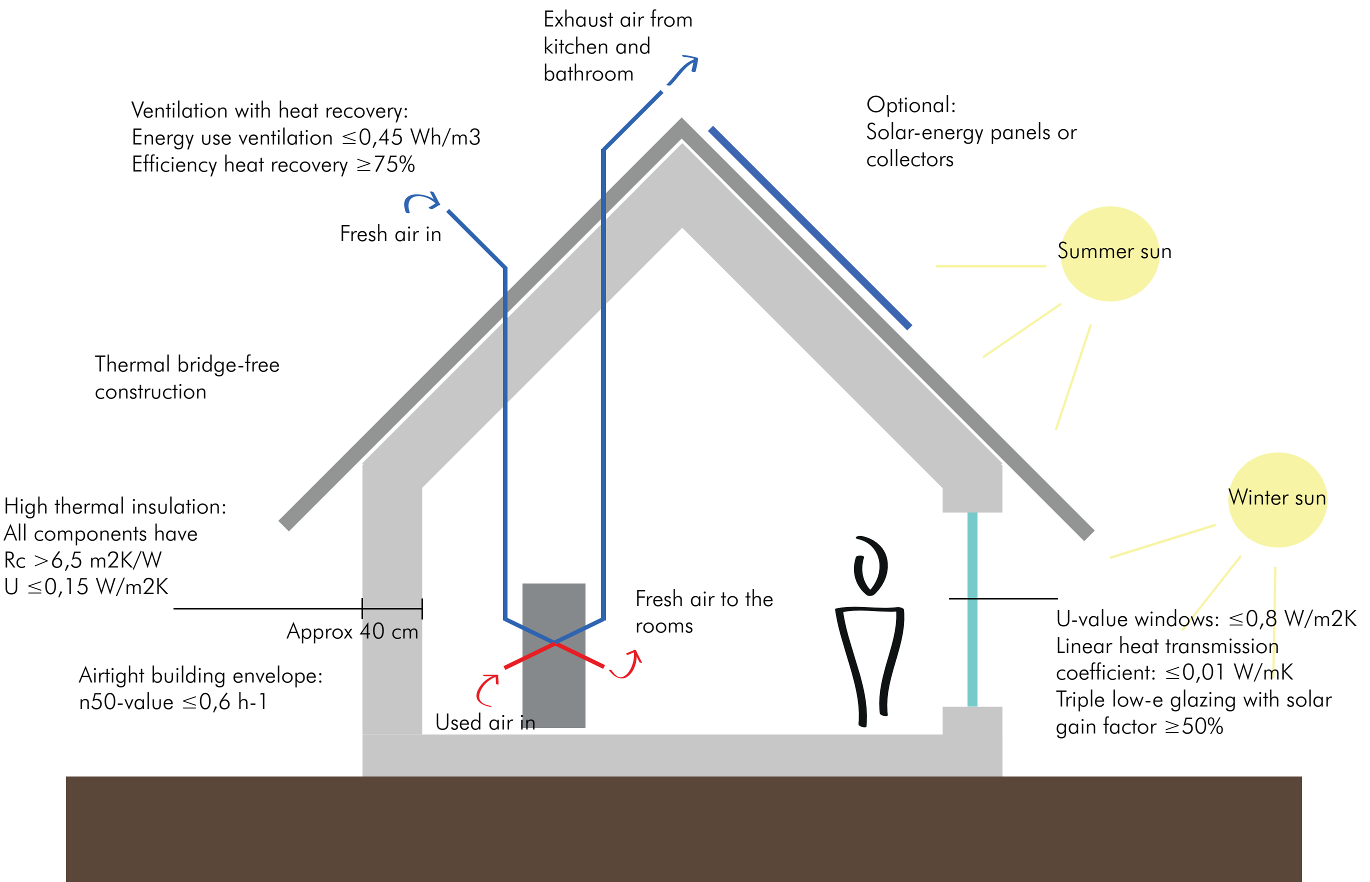


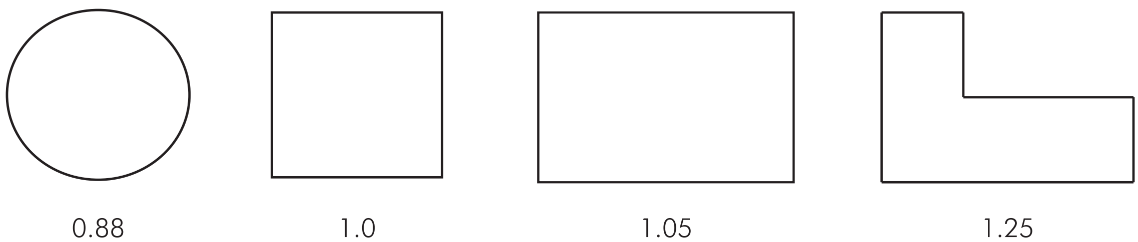
Fig. 10: Scheme of a passive house

west or 20 degrees east), with 30-50% of glass.
- Small windows on west and east, as less as possible on the north.
- Max. vertical obstruction corner: 16 degrees (urban planning).
- No shadow in the winter through balconies or big cantilevers.
- Sun screens on the south above the windows (on the west vertical sun screen): blinds or louvers.
- Sanitary above/next to each other (short pipes).
- Space for ventilation tunnels and installations.

Based on all these aspects, a general design concept followed. An airtight building envelope and large windows on the south facade, resulted in some sort of 'jacket' covering the north facade and the roof, but opening up on the south. The roof and the north facade can be literally one by extending the cladding material.

The most optimal biomimetic shape is a sphere. But regarding livability as well, a cube would be the second best. Making it a bit more rectangular, does have an impact on it, but this is almost zero. Going even further, towards an L-shape makes the impact significantly bigger, see figure [11].

However, the focus points of this research are materials and embodied energy, not the operational energy. So in stead of the really extensive PHPP-calculation, (PHPP stands for Passive House Planning Package), an EPC-calculation (which stands for Energy performance coefficient) will be made in order to make sure that all designs are energetically on the same level. The coefficient is changing really fast, the government already adjusted it from 1,4 in 1996 to 0,6 at the moment (conform the Dutch norm for new housing, NEN 7120). The calculations in this report are made with software based on the NPR 5129. This is actually an older version, nevertheless the adjusted EPC-norm of 0,6 has been taken in account.
This software program consists out of several components like the energy system and the dimensions of the building. Floor square meters and facade surfaces need to be filled out, accompanying their thermal resistance (Rc-values). For all houses a Rc-calculation is made of the ground floor, the exterior walls and the roof. With these results, the first aspect of a passive house (see previous page) could be checked as well. The other five aspects with the specific requirements of a passive house are also integrated in the EPC-calculation.



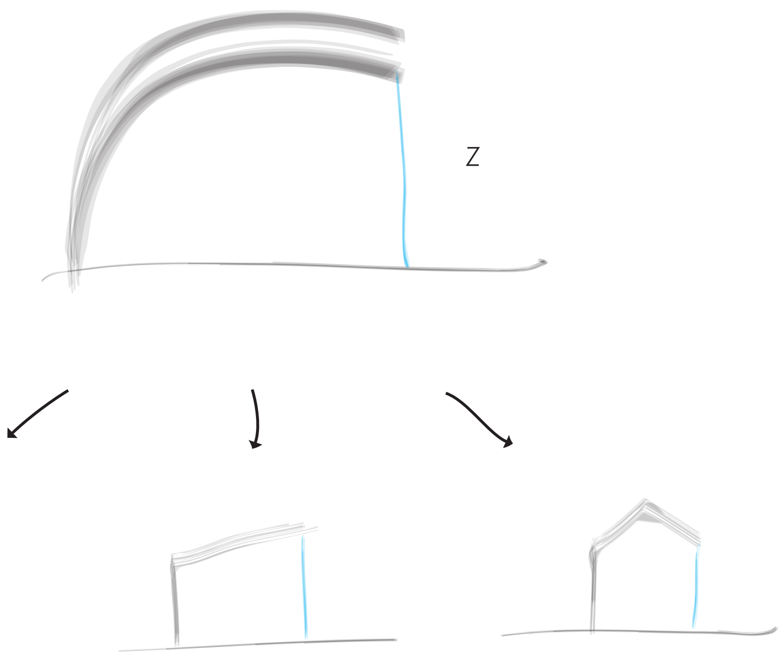


Fig. 11: General design concept

6. HOUSING DESIGNS

According to the research question, three houses will be designed and compared. Therefore they will have some common parameters, only the materials will be the variable aspect in this research.
One house is made of biobased materials, one house of recycled materials and one house consists of conventional materials. Explanations of what this entails and how it expresses itself in an individual design, are given later on, in each paragraph of the concerning housing design.

The information in chapter about people that are very interested in building their own house, or better said the group of private commissioners, will function as the this target group of the 'model' house. Assuming that they have a modal income, a basic assumption for the program of requirements has been defined. This will be the same for all three houses:

Affordable, detached home for a single family: one living room, one kitchen, three bedrooms, one bathroom, two toilets and one storage/installation room.

Other parameters that are fixed, in oder to compare the houses on the same level:
- The volume of the house: around 550m3
- The floor space: around 175m2
- Amount of stories: two
- The bruto facade surface: around 275m2
- The window percentage on specific orientation:
> East 10-15%
> South 30-40%
> West 10-15%

The aim of the research is to design houses without a specific location, in order that they can be applied as a 'model' dwelling. But due to climate and soil differences it is necessary to set at least a specific region. For this research Brabant (The Netherlands) will be the 'model' location. Figure [12] gives a complete overview of the fixed parameters and program of requirements.

Since the houses will be compared on their embodied energy, they will all have the same heating system in order to keep the operational energy as much as possible on the same level.
The system that will be applied consists out of a ground source heat pump, serving the air heating/cooling system and warm tap water. This is combined with a heat recovery system, see figures [13] and [14].

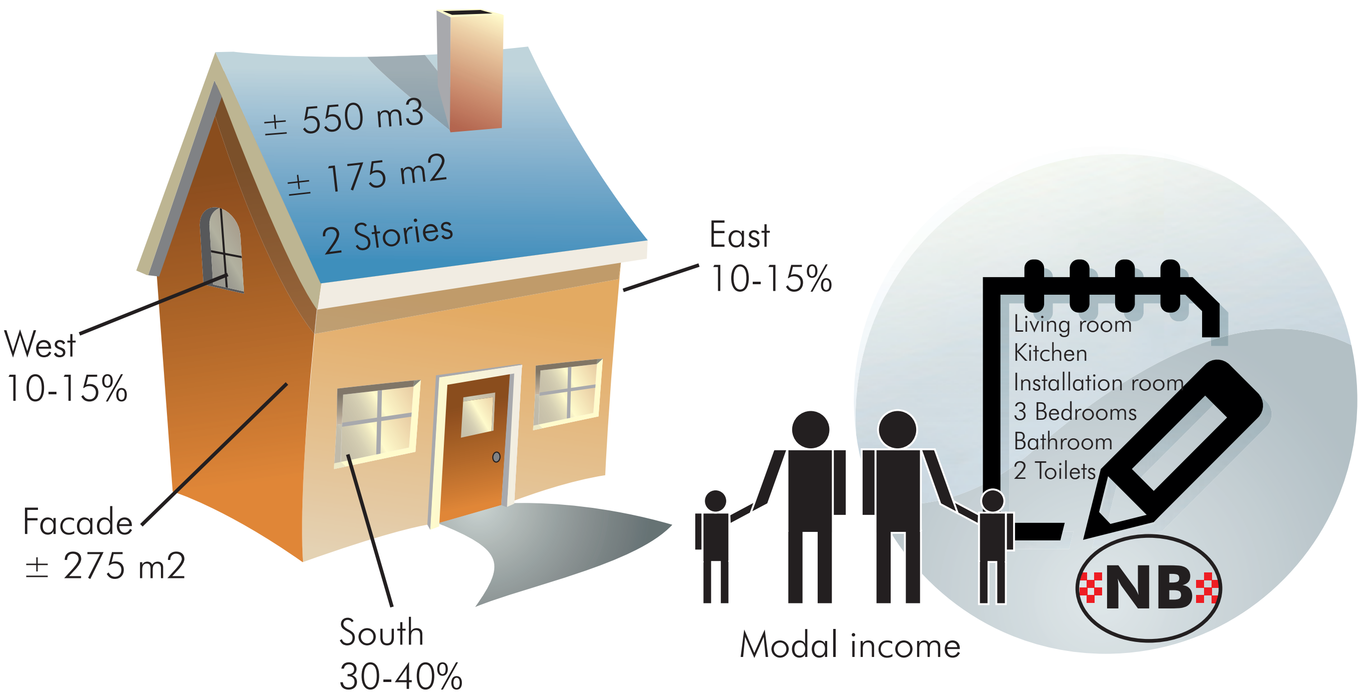


Fig. 12: Fixed parameters and program of requirements

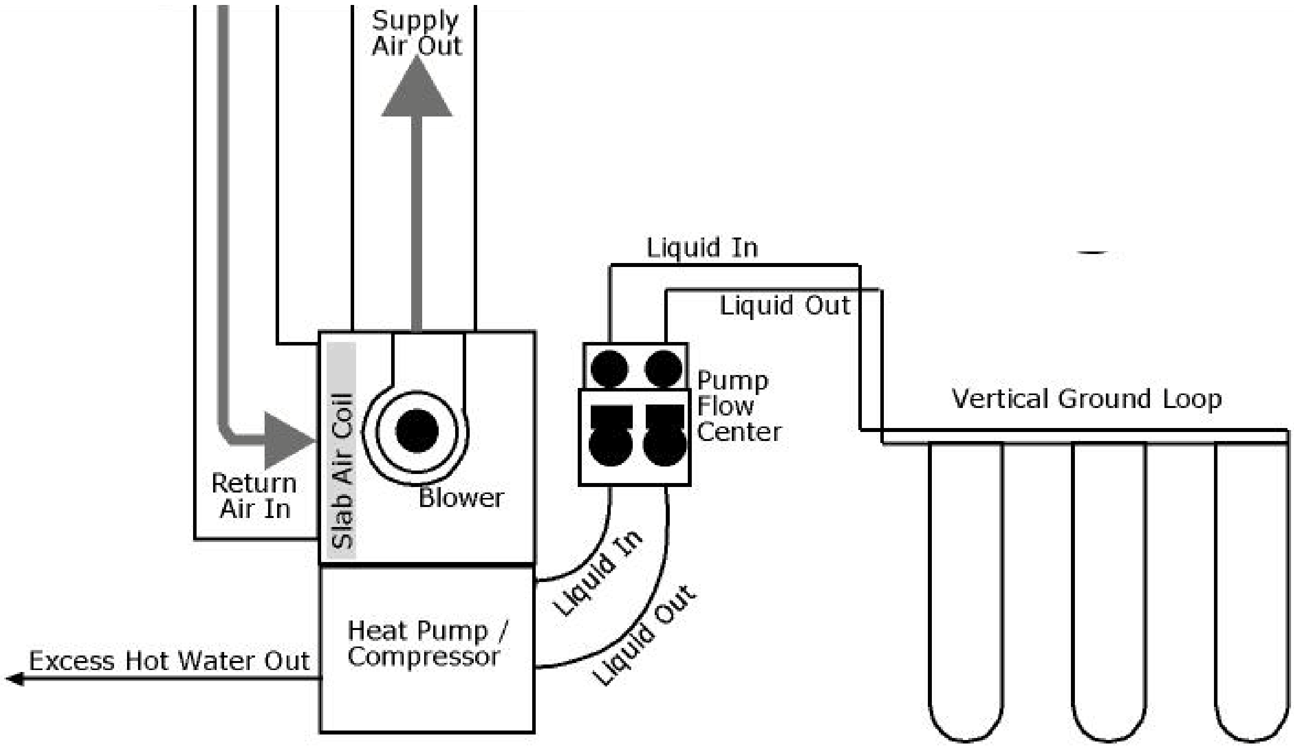


Fig. 13: Geothermal system diagram

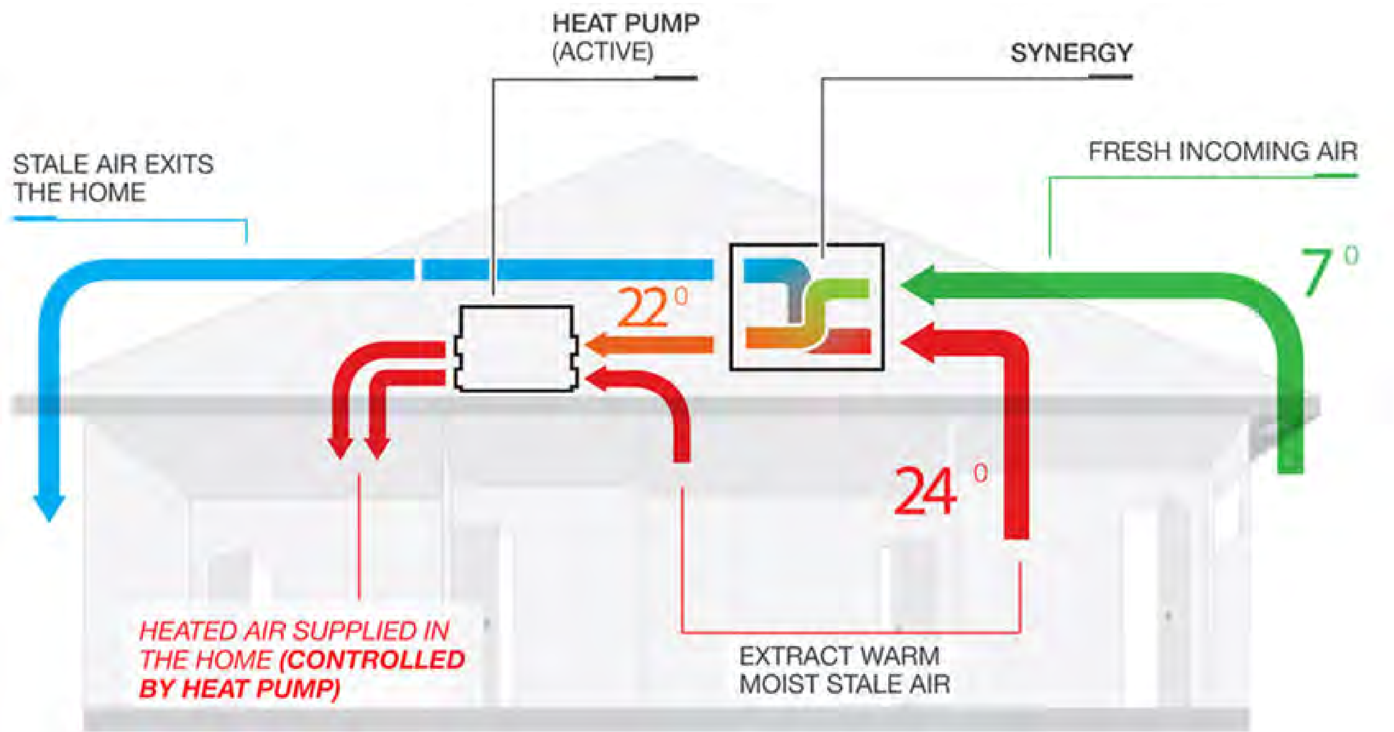


Fig. 14: Air heating and cooling system with heat recovery

BIOBASED HOUSE

CONCEPT

The biobased house consists for the main part out of biobased materials. Biobased means that the materials have a built-in reproduction mechanism in nature, the materials can naturally regrow in nature.

For the housing design this means that the body will consist of wood. Other biobased materials that will be used for an important part in the design are thatch and flax. From such raw materials a lot of different final products can be made.

Having this idea of the natural cycle in mind, it would be interesting to project this to the appearance of the design. Staying close to nature, surrounded by plants or even literally living in the forest, became the main focus of this concept. 'All along the watchtower' will translate itself into an open living space with an amazing view on the first floor and all the sleeping rooms on the more closed ground floor.

Some of the biobased materials brought specific requirements along: thatch for example, can only be applied on a roof with a slope >25 degrees.
So taking these requirements and the idea of the natural cycle in consideration, it resulted in a shape that is optimized for its function: the house overlooking the natural landscape.

This architectural concept expresses itself mostly in the wooden facade cladding: dark horizontal planks on the ground floor facade and lighter stained, vertical planks on the first floor facade. All windows are placed in the same way as the planks. Also the cantilevered first floor emphasises (literally) the difference between the two floors. This resulted in a house that is readable from the outside: you can even see in the facade where the transport zone is placed.

Designing the house according to this concept also brought some compromises along.

Fig. 15: Concept sketch biobased house

- Not all the materials can be biobased: the foundation is made of foam concrete and the windows are made of regular glass, since alternatives are not fully in the market yet.

- The window that is set back can cause some energy loss, since it increases the surface and chance on energy loss.

The main structure consists of laminated columns and beams, with a center to center distance of 5000 mm, this means 3 portal frames in total. The walls, the floor and the roof consist of wooden frames with Finnjoist I-shaped columns and beams.

On the next pages you will find the list of materials, the Rc-values and the EPC-calculation (the result of this software is unfortunately in Dutch). After that follows the Maxergy result and all technical drawings.

Volume	573 m3
Floor space	175 m2
Bruto facade	304 m2
Windows east	11%
Windows south	33%
Windows west	14%

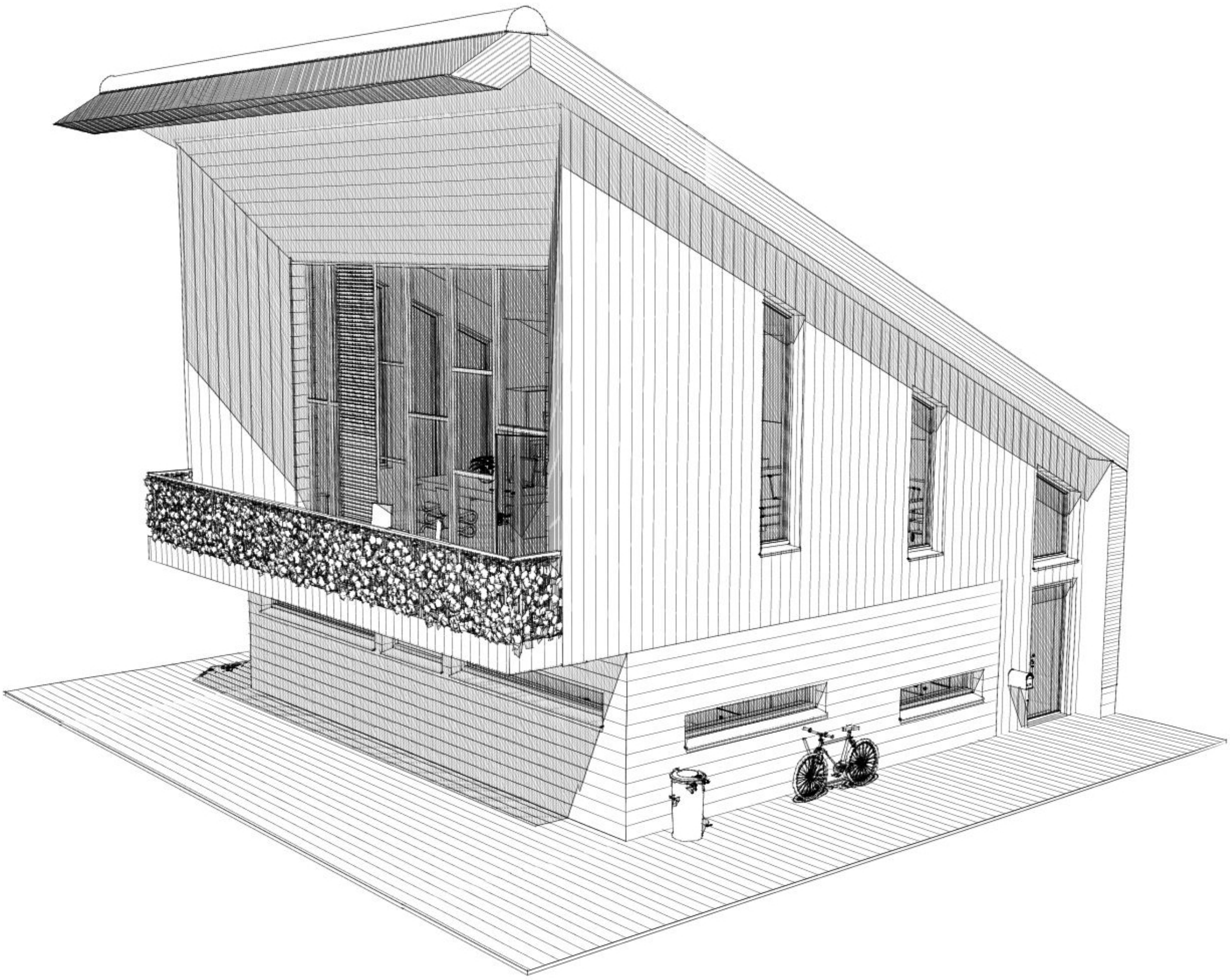


Fig. 16: 3D sketch biobased house

LIST OF MATERIALS

Building component	**Material**	**Color**	**Thickness** (m)	**Surface** (m2)	**Specific weight** (kg/m3)	**Total weight** (kg)
Foundation						
PE membrane	Polyethylene		0,0002	136,5	0,94	0,03
Reinforced concrete	Concrete		0,1	136,5	2400	32.760,00
	Steel			136,5	5,175 kg/m2	583,12
Foam concrete	Foam concrete		0,525	136,5	500	35.831,25
Ground floor						
Coconut coir	Coconut coir	Brown	0,045	93,97	200	845,73
Foam concrete	Foam concrete		0,395	93,97	500	18.559,08
Exterior wall // Ground floor // North						
Thatched facade covering	Thatch	Dark brown	0,3	29,01	130	1.131,39
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	29,01	800	417,74
Flax insulation	Flax		0,2	29,01	50	290,10
Finnjoist (FJI 89x200) hoh 600	Deal wood			17 columns 2,600 m	4,42 kg/m	195,36
Airtightness membrane	Polypropylene		0,0002	29,01	0,91	0,01
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	29,01	560	259,93
Exterior wall // Ground floor // East						
Shiplap board modified wood	Pinewood	Dark stained	0,021	23,19	400	194,80
Battens (22x50) hoh 600	Deal wood			12 laths 2,600 m	460	15,79
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	23,19	800	333,94
Flax insulation	Flax		0,34	23,19	50	394,23
Finnjoist (FJI 58x360) hoh 600	Deal wood			12 columns 2,600 m	4,19 kg/m	130,73
Airtightness membrane	Polypropylene		0,0002	23,19	0,91	0,00
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	23,19	560	207,78
Hardwood framed triple glazing	Glass		0,012	3,3	2500	99,00
	Bamboo wood		0,114	1,28198	700	102,30
Window sill	Pinewood		0,016	0,8016	400	5,13
Weathering	Aluminium		0,002	1,1856	2755	6,53
Exterior wall // Ground floor // South						
Shiplap board modified wood	Pinewood	Dark stained	0,021	24,61	400	206,72
Battens (22x50) hoh 600	Deal wood			15 laths 2,600 m	460	19,73
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	24,61	800	354,38
Flax insulation	Flax		0,34	24,61	50	418,37
Finnjoist (FJI 58x360) hoh 600	Deal wood			15 columns 2,600 m	4,19 kg/m	163,41
Airtightness membrane	Polypropylene		0,0002	24,61	0,91	0,00
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	24,61	560	220,51
Hardwood framed triple glazing	Glass		0,012	2,3	2500	69,00
	Bamboo wood		0,114	1,371	700	109,41
Window sill	Pinewood		0,016	3,417	400	21,87
Weathering	Aluminium		0,002	5,054	2755	27,85
Exterior wall // Ground floor // West						
Shiplap board modified wood	Pinewood	Dark stained	0,021	23,19	400	194,80
Battens (22x50) hoh 600	Deal wood			12 laths 2,600	460	15,79
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	23,19	800	333,94
Flax insulation	Flax		0,34	23,19	50	394,23
Finnjoist (FJI 58x360) hoh 600	Deal wood			12 columns 2,600 m	4,19 kg/m	130,73
Airtightness membrane	Polypropylene		0,0002	23,19	0,91	0,00
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	23,19	560	207,78
Hardwood framed triple glazing	Glass		0,012	3,3	2500	99,00
	Bamboo wood		0,114	1,28198	700	102,30
Window sill	Pinewood		0,016	0,8016	400	5,13
Weathering	Aluminium		0,002	1,1856	2755	6,53
Interior wall // Ground floor						
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	88,62	560	794,04
Flax insulation	Flax		0,2	88,62	50	886,20
Finnjoist (FJI 58x200) hoh 600	Deal wood			55 columns 2,600 m	3,16 kg/m	451,88
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	88,62	560	794,04
Upper floor						
Coconut coir	Coconut coir	Brown	0,045	81,02	200	729,18
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	81,02	800	1.166,69
Flax insulation	Flax		0,34	81,02	50	1.377,34
Finnjoist (FJI 89x300) hoh 400	Deal wood			26 columns 4,117 m	5,06 kg/m	541,63
				16 columns 10,269 m	5,06 kg/m	831,38
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	81,02	350	453,71
Exterior wall // First floor // North						
Thatched facade covering	Thatch	Dark brown	0,3	20,34	130	793,26
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	20,34	800	292,90
Flax insulation	Flax		0,2	20,34	50	203,40
Finnjoist (FJI 89x200) hoh 600	Deal wood			17 columns 1,425m	4,42 kg/m	107,07
Airtightness membrane	Polypropylene		0,0002	20,34	0,91	0,00
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	20,34	560	182,25
Exterior wall // First floor // East						
Shiplap board modified wood	Pinewood	Clear stained	0,021	45,35	400	380,94
Battens (22x50) hoh 600	Deal wood			12 laths 3,721 m	460	22,59
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	45,35	800	653,04
Flax insulation	Flax		0,34	45,35	50	770,95
Finnjoist (FJI 58x360) hoh 600	Deal wood			12 columns 3,721 m	4,19 kg/m	187,09
Airtightness membrane	Polypropylene		0,0002	45,35	0,91	0,01
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	45,35	560	406,34
Hardwood framed triple glazing	Glass		0,012	4,91	2500	147,30

	Bamboo wood		0,114	1,37149	700	109,44
Window sill	Pinewood		0,016	0,4676	400	2,99
Weathering	Aluminium		0,002	0,6916	2755	3,81
Exterior wall // First floor // South						
Shiplap board modified wood	Pinewood	Clear stained	0,021	42,62	400	358,01
Battens (22x50) hoh 600	Deal wood			6 laths 5,585 m	460	16,96
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	42,62	800	613,73
Flax insulation	Flax		0,34	42,62	50	724,54
Finnjoist (FJI 58x360) hoh 600	Deal wood			6 columns 5,585m	4,19 kg/m	140,41
Airtightness membrane	Polypropylene		0,0002	42,62	0,91	0,01
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	42,62	560	381,88
Hardwood framed triple glazing	Glass		0,012	31,04	2500	931,20
	Bamboo wood		0,114	3,177	700	253,52
Exterior wall // First floor // West						
Shiplap board modified wood	Pinewood	Clear stained	0,021	42,56	400	357,50
Battens (22x50) hoh 600	Deal wood			12 laths 3,721 m	460	22,59
Wood fibre board Pavatex Isolair L	Wood fibre		0,018	42,56	800	612,86
Flax insulation	Flax		0,34	42,56	50	723,52
Finnjoist (FJI 58x360) hoh 600	Deal wood			12 columns 3,721m	4,19 kg/m	187,09
Airtightness membrane	Polypropylene		0,0002	42,56	0,91	0,01
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	42,56	560	381,34
Hardwood framed triple glazing	Glass		0,012	7,7	2500	231,00
	Bamboo wood		0,114	2,06762	700	165,00
Window sill	Pinewood		0,016	0,6012	400	3,85
Weathering	Aluminium		0,002	0,8892	2755	4,90
Interior wall First floor						
None						
Structure						
Laminated beam 120x680	Deal wood		0,0816	3 beams 9,900 m	460	1.114,82
Laminated column 120x400	Deal wood		0,048	2 columns 8,928 m	460	394,26
				2 columns 6,620 m		292,34
				2 columns 4,275 m		188,78
Stair	Bamboo wood		0,06	2,8	650	109,20
Roof						
Thatched roof covering	Thatch	Dark brown	0,3	130,24	130	5.079,36
Wood fibre board Pavatex Isolair L	Flax fibre		0,018	130,24	800	1.875,46
Flax insulation	Flax		0,2	130,24	50	1.302,40
Finnjoist (FJI 89x200) hoh 600	Deal wood			19 columns 13,009m	4,42 kg/m	1.092,50
Airtightness membrane	Polypropylene		0,0002	130,24	0,91	0,02
Flax fibre board Linex Pro-Grass	Flax fibre	Brown	0,016	130,24	560	1.166,95
Fascia board treated Kerto-Q	Deal wood	Brown	0,027	20,48	510	282,01

Total materials	**Weight (kg)**
Foam concrete	54.390,33
Concrete	32.760,00
Steel	583,12
Polyethylene	0,03
Coconut coir	1.574,91
Wood fibre	6.654,67
Deal wood	6.063,82
Flax fibre	5.716,46
Flax	7.485,28
Pinewood	1.726,61
Polypropylene	0,07
Glass	1.576,50
Bamboo	841,98
Aluminium	49,62
Thatch	7.004,01
	126.427,40

RC-VALUE GROUND FLOOR

Ti = 20 °C
Te = -10 °C

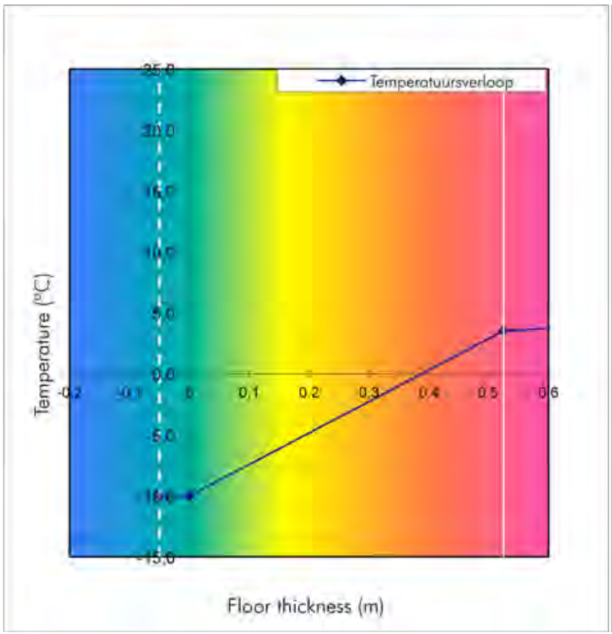
φi = 60 %
φe = 50 %

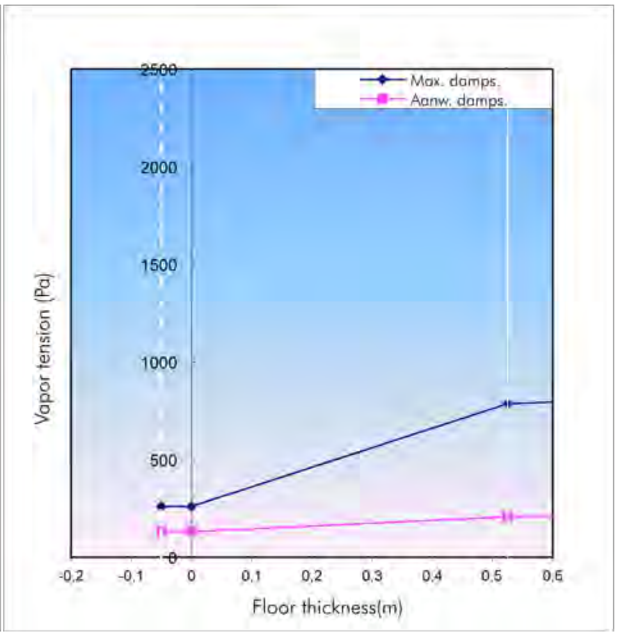
Ri en Re = Vloer in contact met gro
Element = α -
Gebruiksfunctie Woonfunctie

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,00	0,0						
					-10,0	260				130
Foam concrete	0,525	0,2	2,63	13,5			1	0,525	77	
					3,5	786				207
Reinforced concrete	0,1	2	0,05	0,3			0,51	0,051	7	
					3,8	796				214
PE membrane	0,0002	0,2	0,00	0,0			1000	0	29	
					3,8	796				244
Foam concrete	0,395	0,2	1,98	10,2			20	7,9	1158	
					14,0	1589				1401
Coconut coir	0,045	0,045	1,00	5,2			0,38	0,0171	3	
					19,1	2212				1404
	0	1	0,00	0,0			0	0	0	
					19,1	2212				1404
	0	1	0,00	0,0			0	0	0	
					19,1	2212				1404
Ri			0,17	0,9						
Inside air					20,0	2340				1404
Totaal:	1,07	Rl =	5,82	30,00			μ =	8,69	1274	

Vapor pressure difference	Temperature factor thermal bridge
Dampsp. = 1404 Pa	(F) Eis = 0,65
Dampsp. = 130 Pa	F = (Tio-Te) / (Ti-Te) = 0,97 Sufficient
Δ Dampsp = 1274 Pa	

Rc = 5,7 m²K/W	Rl = 5,82 m²K/W	U = 0,17 W/m²K



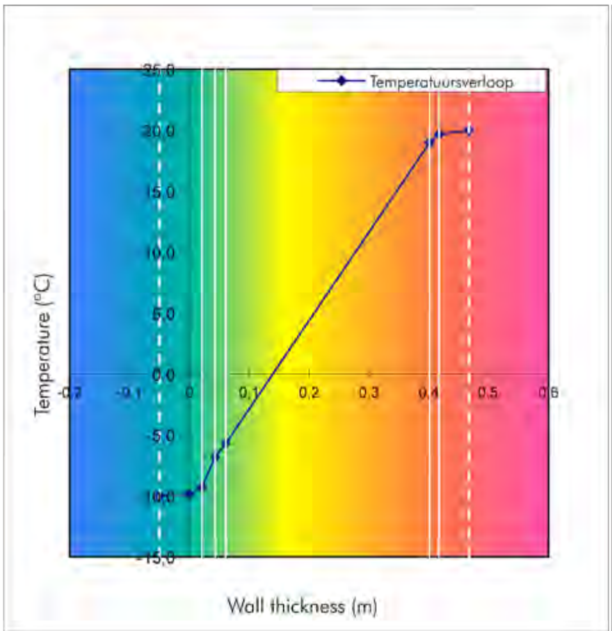


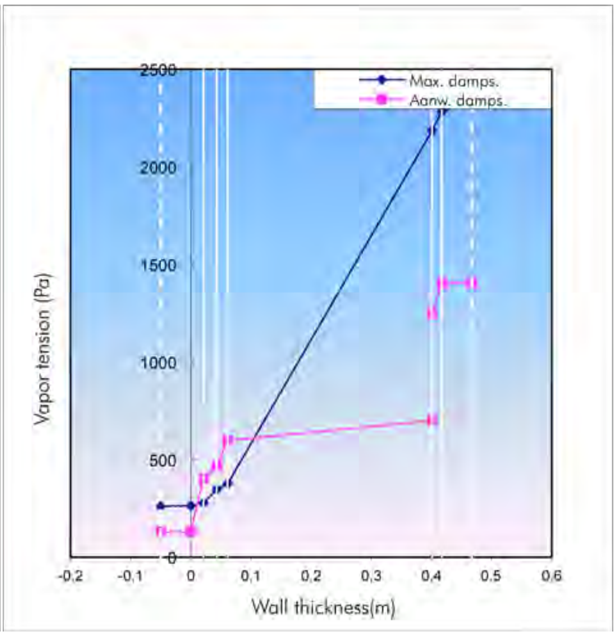
RC-VALUE EXTERIOR WALLS

φi = 60 %	Ri en Re = Buitenmuur Bi»Bu	Element = α -
φe = 50 %	Gebruiksfunctie Woonfunctie	

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,04	0,1						
					-9,9	264				130
Shiplap board modified wood	0,021	0,099	0,21	0,6			4,76	0,09996	273	
					-9,3	276				403
Air cavity	0,022	0,024	0,92	2,5			1,09	0,02398	66	
					-6,8	347				469
Wood fibe board	0,018	0,047	0,38	1,1			2,63	0	129	
					-5,7	377				598
Flax insulation	0,34	0,038	8,95	24,7			0,11	0,0374	102	
					19,0	2184				701
PP membrane	0,0002	0,2	0,00	0,0			1000	0,2	547	
					19,0	2184				1248
Flax fibre board	0,016	0,065	0,25	0,7			3,57	0,05712	156	
					19,6	2281				1404
	0	1	0,00	0,0			0	0	0	
					19,6	2281				1404
Ri			0,13	0,4						
Inside air					20,0	2340				1404
Totaal:	0,42	Rl =	10,88	30,00			μ =	0,47	1274	

Vapor pressure difference	Temperature factor thermal bridge	
	(F) Eis = 0,65	
Dampsp. = 1404 Pa		
Dampsp. = 130 Pa	F = (Tio-Te) / (Ti-Te) = 0,99	Sufficient
Δ Dampsp = 1274 Pa		
Rc = 10,7 m²K/W	Rl = 10,88 m²K/W	U = 0,09 W/m²K





RC-VALUE ROOF

Ti = 20 °C
Te = -10 °C

φi = 60 %
φe = 50 %

Ri en Re = Hellend dak ≤ 75° Bi»Bu

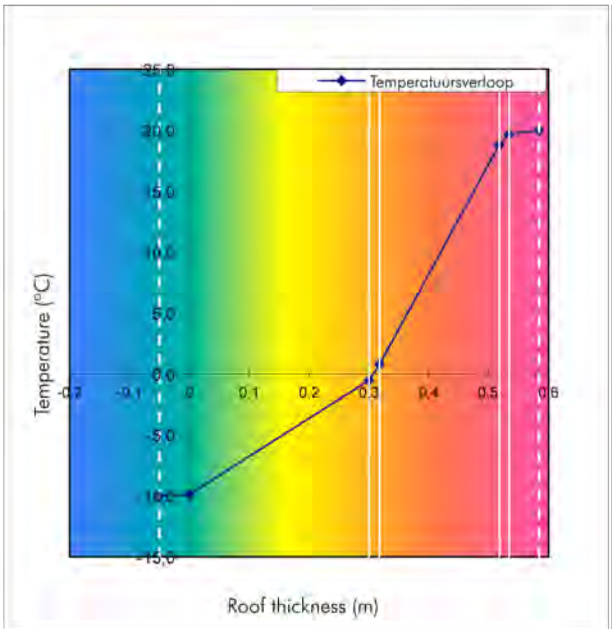
Element = α -

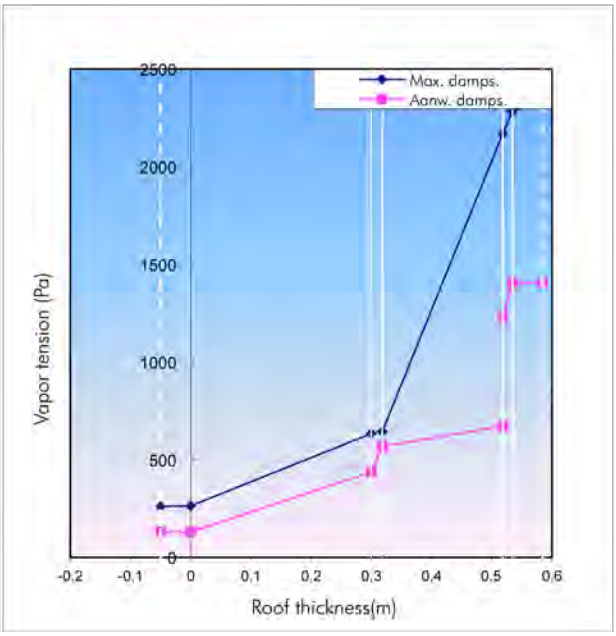
Gebruiksfunctie Woonfunctie

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,04	0,1						
					-9,9	264				130
Thatch	0,3	0,11	2,73	9,3			0,37	0,111	307	
					-0,5	633				437
Wood fibre board	0,018	0,047	0,38	1,3			2,63	0,04734	131	
					0,8	643				568
Flax insulation	0,2	0,038	5,26	18,0			0,19	0	105	
					18,8	2170				673
PP membrane	0,0002	0,2	0,00	0,0			1000	0,2	554	
					18,8	2170				1227
Flax fibre board	0,016	0,065	0,25	0,8			4	0,064	177	
					19,7	2281				1404
	0	1	0,00	0,0			0	0	0	
					19,7	2281				1404
	0	1	0,00	0,0			0	0	0	
					19,7	2281				1404
Ri			0,10	0,3						
Inside air					20,0	2340				1404
Totaal:	0,53	Rl =	8,76	30,00			μ =	0,46	1274	

Vapor pressure difference			Temperature factor thermal bridge		
Dampsp. =	1404	Pa	(F) Eis =	0,65	
Dampsp. =	130	Pa	F = (Tio-Te) / (Ti-Te) =	0,99	Sufficient
Δ Dampsp =	1274	Pa			

Rc = 8,6 m²K/W	Rl = 8,76 m²K/W	U = 0,11 W/m²K





EPC-CALCULATION

ALGEMENE GEGEVENS

Projectomschrijving	:	Biobased
Bestandsnaam	:	L:\EPW v2.0\Biobased.epw
Omschrijving bouwwerk	:	
Adres	:	
Soort bouwwerk	:	Woonfunctie
EPC-eis	:	0,6

INDELING GEBOUW

Type	*Omschrijving zone*	*Ag [m²]*
Verwarmd	Begane grond	93,97
Verwarmd	1e Verdieping	81,02
		------------- +
totaal		174,99

BOUWKUNDIGE GEGEVENS - TRANSMISSIE

Definitie scheidingsconstructies zone: Begane grond

constructie	*begrenzing*	*constructiedeel*	*A*	*Hkr*	*Rc*	*U*	*ZTA*	*helling*	*zon-*	*beschaduwing*
			[m²]	*[m]*	*[m²K/W]*	*[W/m²K]*	*[-]*	*[°]*	*wering*	
Vloer	grond	Schuimbeton	94,0		5,70	0,09				
Gevel noord	buiten, N	HSB pakket riet	29,0		8,60	0,11				
Gevel oost	buiten, O	HSB pakket hout	23,2		10,70	0,09				
		Ramen	3,3			0,80	0,50	90	nee	maximale belemmering
Gevel zuid	buiten, Z	HSB pakket hout	24,6		10,70	0,09				
		Ramen	2,3			0,80	0,50	90	nee	constante overstek
Gevel west	buiten, W	HSB pakket hout	23,2		10,70	0,09				
		Ramen	3,3			0,80	0,50	90	nee	maximale belemmering
			---------- +							
Totaal			202,9							

Definitie scheidingsconstructies zone: 1e Verdieping

constructie	*begrenzing*	*constructiedeel*	*A*	*Hkr*	*Rc*	*U*	*ZTA*	*helling*	*zon-*	*beschaduwing*
			[m²]	*[m]*	*[m²K/W]*	*[W/m²K]*	*[-]*	*[°]*	*wering*	
Gevel noord	buiten, N	HSB pakket riet	20,3		8,60	0,11				
Gevel oost	buiten, O	HSB pakket hout	45,4		10,70	0,09				
		Ramen	4,9			0,80	0,50	90	nee	maximale belemmering
Gevel zuid	buiten, Z	HSB pakket hout	42,6		10,70	0,09				
		Ramen	31,0			0,80	0,50	90	ja	minimale belemmering
Gevel west	buiten, W	HSB pakket hout	42,6		10,70	0,09				
		Ramen	7,7			0,80	0,50	90	nee	maximale belemmering
Dak	buiten, boven	HSB pakket riet	130,2		8,60	0,11				
			---------- +							
Totaal			324,8							

BOUWKUNDIGE GEGEVENS - BELEMMERINGEN EN OVERSTEKKEN

Definitie beschaduwing zone: Begane grond

constructie	*constr.deel*	*beschaduwing*	*belemmeringen*				*overstekken*				*besch.factor*
			1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	
Gevel zuid	Ramen	constante overstek	20	20	20	20	20	90	90	20	0,90

BOUWKUNDIGE GEGEVENS - LINEAIRE KOUDEBRUGGEN

Er is gerekend volgens de forfaitaire methode m.b.t. de koudebruggen.

Bij de forfaitaire methode wordt een correctie op de U-waarde toegepast.

Definitie lineaire koudebruggen zone: Begane grond

constructie	*begrenzing*	*koudebrug*	*P*
			[m]
Vloer	grond	Perimeter	38,64

Definitie lineaire koudebruggen zone: 1e Verdieping

Voor deze zone zijn geen gegevens voor lineaire koudebruggen ingevoerd

BOUWKUNDIGE GEGEVENS - INFILTRATIE

qv10;kar/m² van de woonfunctie: 0,150 [dm³/sm²]

BOUWKUNDIGE GEGEVENS - THERMISCHE CAPACITEIT

bouwtype van de woonfunctie: volledig houtskeletbouw

INSTALLATIE W - VERWARMING EN HULPENERGIE

Verwarmingssysteem 1 - Verwarming 1

verwarmingstoestel	type toestel	:	individuele electrische warmtepomp, voldoet aan tabel B2
	bron warmtepomp	:	bodem
	aanvoertemperatuur	:	35°C < T <= 45°C
installatiekenmerken	individuele bemetering	:	ja
	installatie voorzien van buffervat	:	nee
	type verwarmingslichaam	:	overig (bijv. radiatoren)
	opwekkingsrendement (Nopw;verw)	:	1,950 [-]
	systeemrendement (Nsys;verw)	:	0,950 [-]
hulpenergie	aantal ketels-cv/luchtverwarmers met waakvlam	:	0
	gasketels-cv	:	niet voorzien van ventilator
		:	niet voorzien van elektronica
		:	geen circulatiepomp aanwezig
	warmtepomp	:	geen circulatiepomp aanwezig
	individuele warmtepomp	:	geen parallel buffervat aanwezig
	gebouwgebonden warmte-kracht	:	lengte circulatieleiding 0,00 km
aangewezen zones:	Begane grond		
	1e Verdieping		

INSTALLATIE W - WARMTAPWATER

nr.	*opwekkingstoestel*	*klasse*	*Nopw;tap*	*qv;wp*	*aantal*	*aantal*	*Lbadr*	*Laanr*	*Lcirc*	*d;inw*
			[-]	*[dm³/s]*	*badr*	*aanr*	*[m]*	*[m]*	*[m]*	*[mm]*
1	warmtepomp, retourlucht als bron (Bijlage C)	1	0,850	0,00	1	1	6-8	8-10	0,0	<= 10

INSTALLATIE W - VENTILATIE

Ventilatie verwarmde zone: Begane grond

ventilatievoorziening	:	mechanische luchttoe- en afvoer
type warmteterugwinning	:	tegenstroom-warmtewisselaar
Nwtw	:	0,75
regelbaar door bewoners	:	ja
toevoer in zomer	:	toevoer uitschakelbaar
bypass aanwezig	:	luchttoevoerventilator uitschakelbaar of 100% bypass
type voorverwarming	:	voorverwarming door warmteterugwinning

Ventilatie verwarmde zone: 1e Verdieping

ventilatievoorziening	:	mechanische luchttoe- en afvoer
type warmteterugwinning	:	tegenstroom-warmtewisselaar
Nwtw	:	0,75
regelbaar door bewoners	:	ja
toevoer in zomer	:	toevoer uitschakelbaar
bypass aanwezig	:	luchttoevoerventilator uitschakelbaar of 100% bypass
type voorverwarming	:	voorverwarming door warmteterugwinning

INSTALLATIE W - VENTILATOREN

omschrijving zone	*type ventilator*
Begane grond	gebalanceerde ventilatie, wisselstroom
1e Verdieping	gebalanceerde ventilatie, wisselstroom

INSTALLATIE W - KOELING

koelsysteem:	type toestel	:	geen koelmachine aanwezig
	vrije koeling	:	nee
	opwekkingsrendement voor koeling (Nopw;koel)	:	0,000 [-]
	systeemrendement voor koeling (Nsys;koel)	:	0,000 [-]

INSTALLATIE E - VERLICHTING

omschrijving zone	*Ag [m²]*		*Qprim;vl [MJ]*	
Begane grond	94,0		5301	
1e Verdieping	81,0		4570	
	------------	+	------------	+
totaal	175,0		9871	

RESULTATEN - ENERGIEPRESTATIEGEGEVENS

verwarming	Qprim;verw	12062 MJ
hulpenergie	Qprim;hulp;verw	0 MJ
warmtapwater	Qprim;tap	18856 MJ
ventilatoren	Qprim;vent	8561 MJ
verlichting	Qprim;vl	9871 MJ
zomercomfort	Qzom;comf	9176 MJ
koeling	Qprim;koel	0 MJ
bevochtiging	Qprim;bev	0 MJ
comp. PV-cellen	Qprim;pv	0 MJ
comp. WK	Qprim;comp;WK	0 MJ
		----------------- +
totaal	Qpres;tot	58526 MJ
	Qpres;toel	101035 MJ

Qpres;totaal /	((330 *	Ag;verw	+ 65 *	Averlies	) *	Cepc	) =	EPC	
58526		175,0		499,4		1,12		0,58	Epc voldoet

RESULTATEN - INFORMATIEF

CO2-emissie	3425 kg

Risico te hoge temperaturen [TOjuli]

Omschrijving zone	*TOjuli*	
Begane grond	0,70	(laag - matig risico)
1e Verdieping	3,76	(matig - groot risico)

RESULTATEN - AANDACHTSPUNTEN

Verwarmingssysteem '1 - Verwarming 1': er is geen hulpenergie gespecificeerd.

Er is nog geen waarde voor de luchtvolumestroom qv;wp ingevuld.

Indien geen gemeten waarde beschikbaar is geldt qv;wp=0.44*Ag;verwz met een minimum van 44 dm3/s.

MAXERGY RESULTS

One of the first results that came out of the Maxergy calculation are the two graphs below, see figure [17] and [18] regarding the Embodied land of the operational energy and the Embodied Land of the materials. Comparing these two makes obviously clear that there is an really big difference between them. This determines the assumption made in the beginning of the project: the embodied energy of materials should get more attention when reviewing sustainability.

Scrutinizing the building materials of the house more, resulted in the figures [19] and [20]. In these graphs the weight and the Embodied Land of all individual materials are visible. Comparing these figures makes clear that weight is not in proportion with Embodied Land.

Furthermore can be noticed that steel and aluminium are responsible for a large part of the Embodied Land in the calculation.

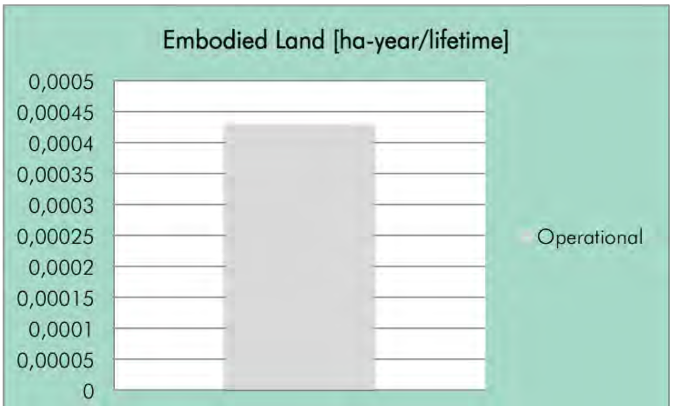


Fig. 17: Embodied Land operational energy

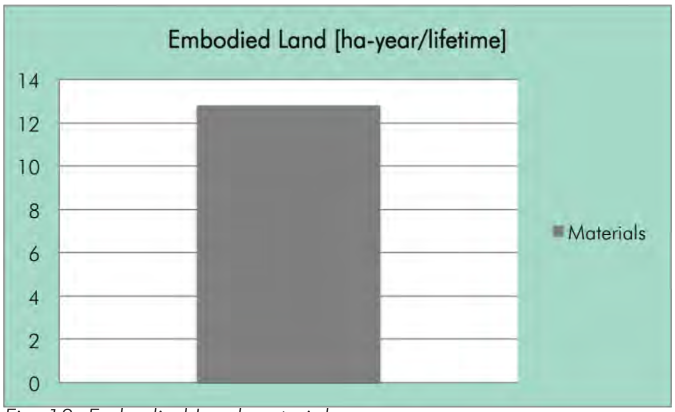


Fig. 18: Embodied Land materials

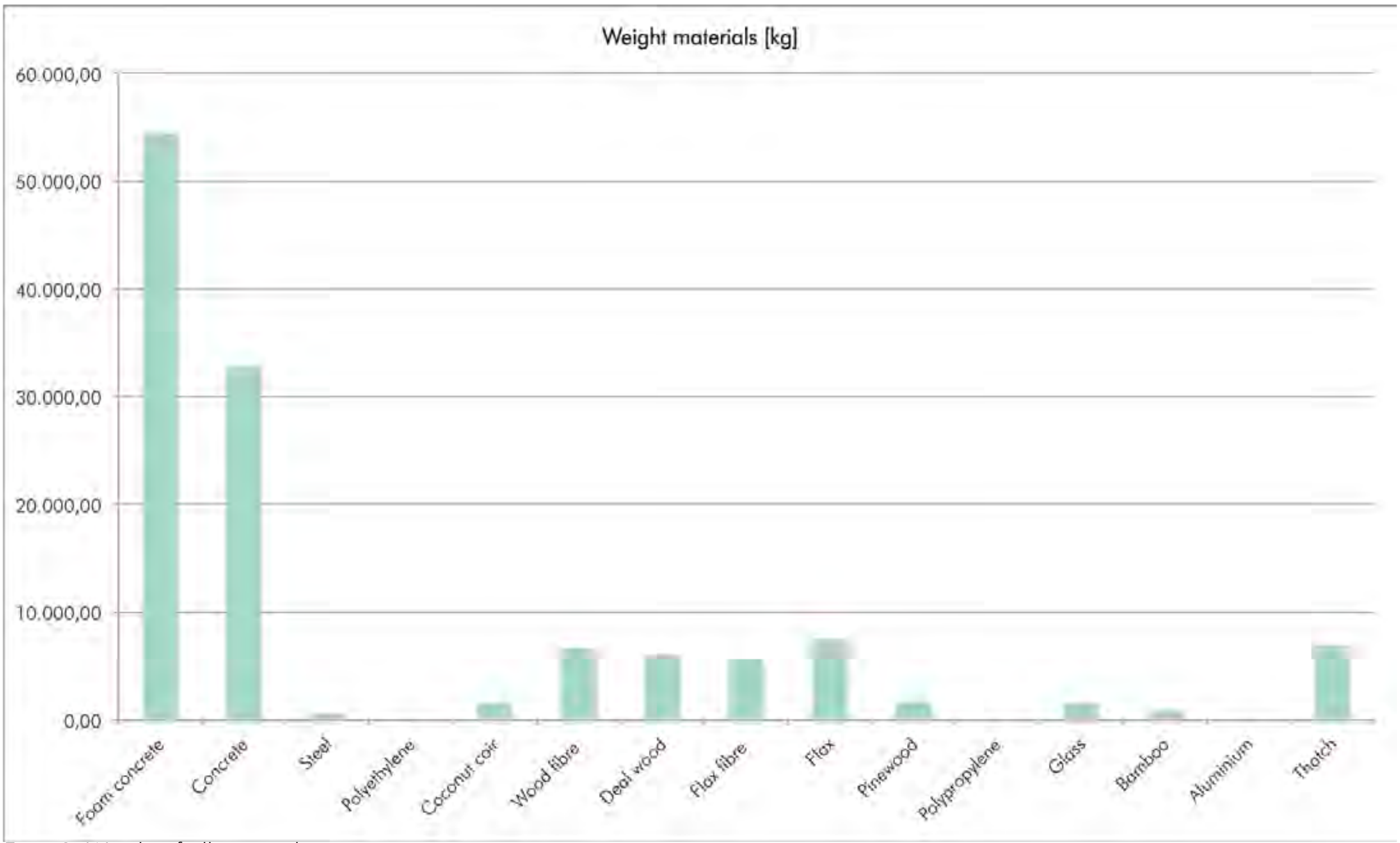


Fig. 19: Weight of all materials

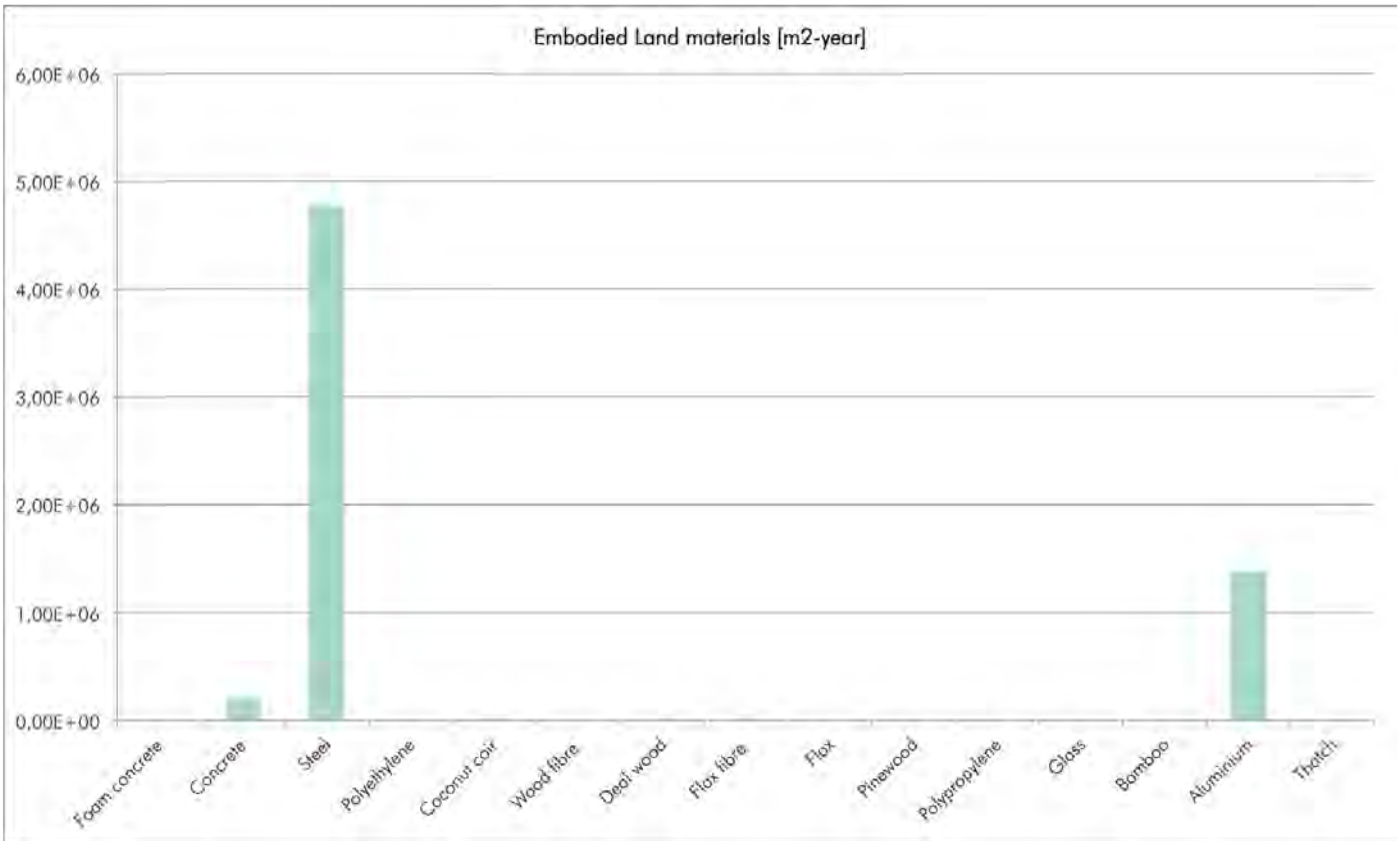


Fig. 20: Embodied Land of all materials

DRAWINGS

> PLANS
Ground floor, 1st floor

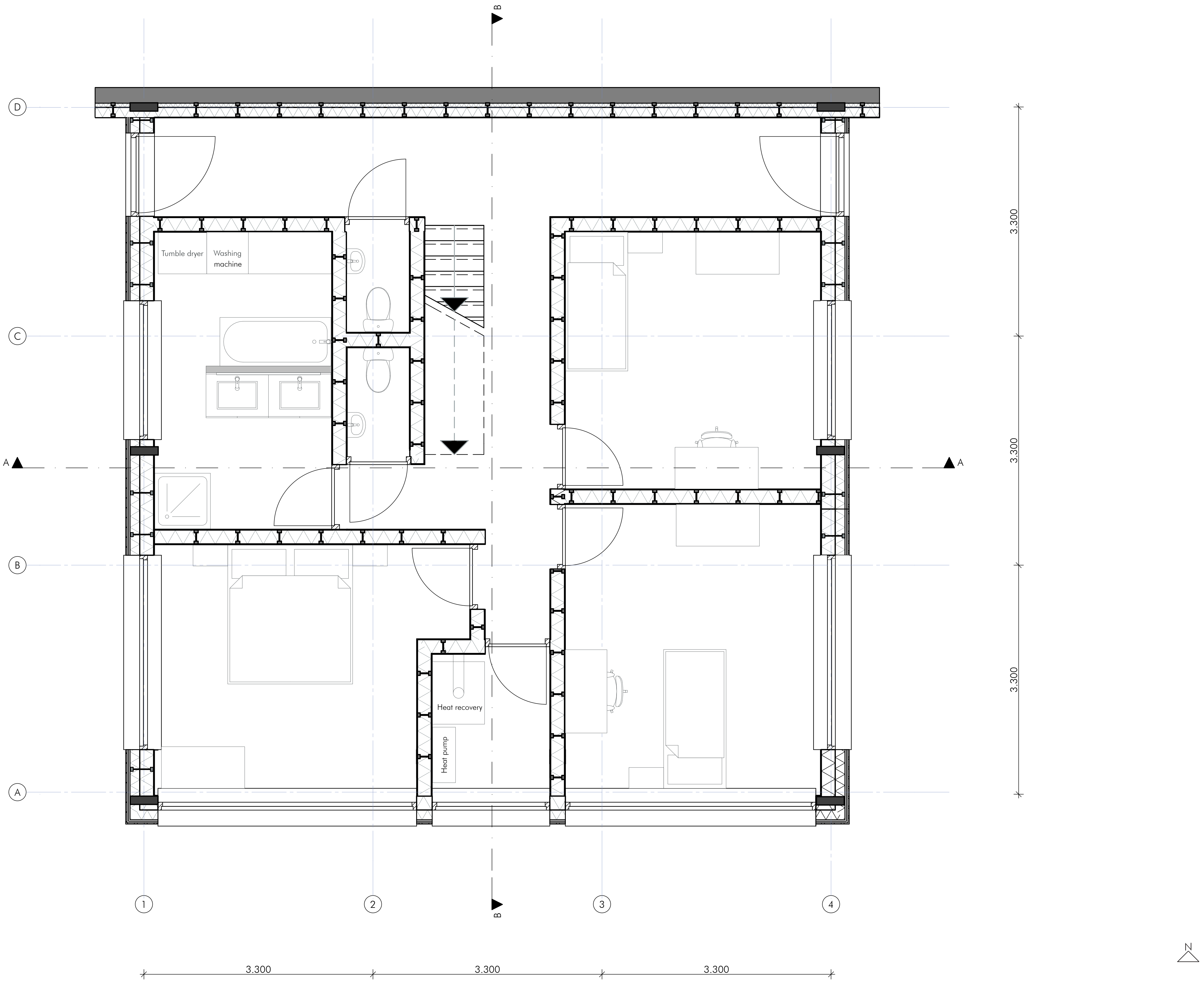
> SECTIONS
AA, BB

> ELEVATIONS
North, East, South, West

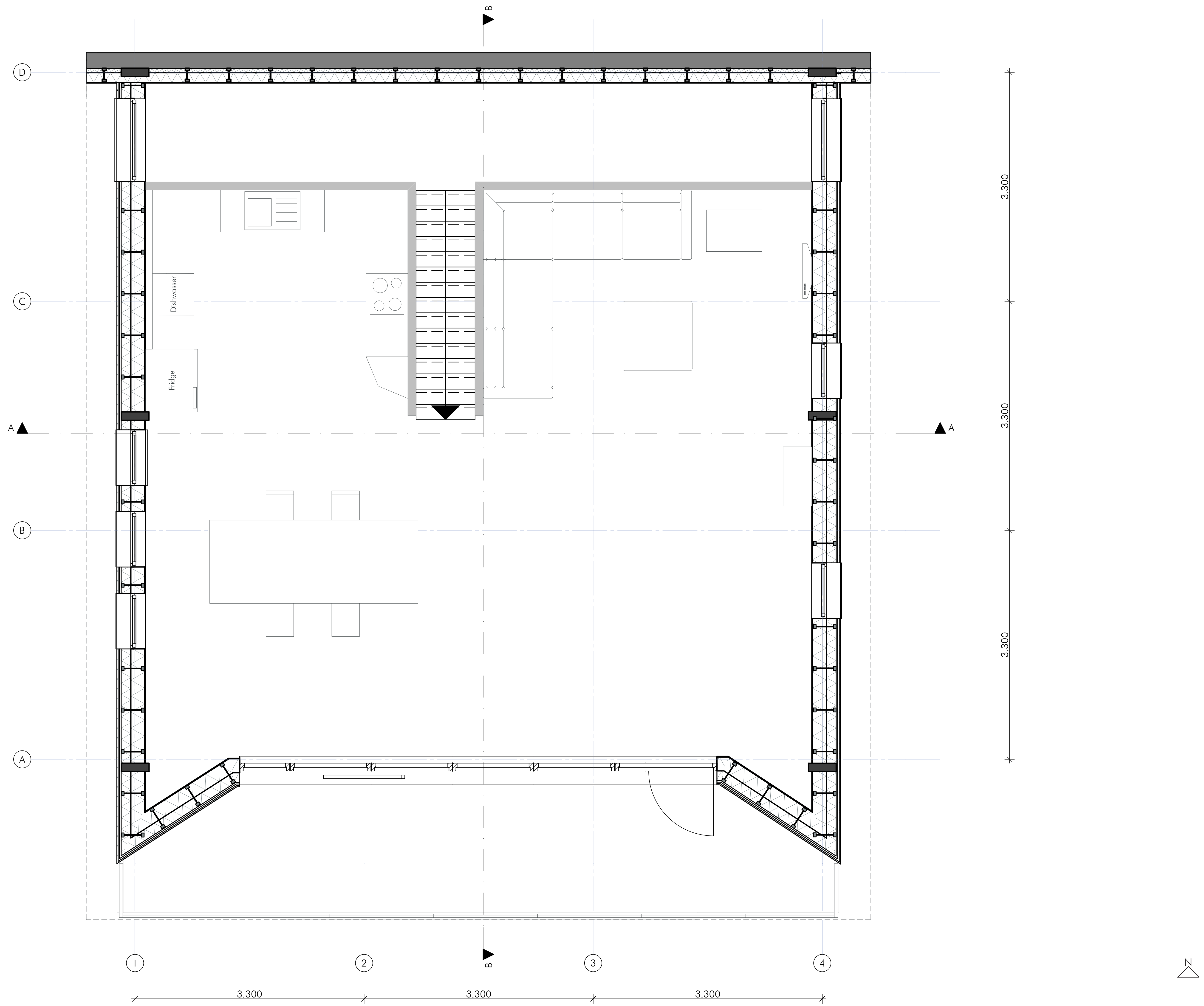
> DETAILS
A.01 t/m A.05, B.01 t/m B.06

> 3D
Exterior, interior

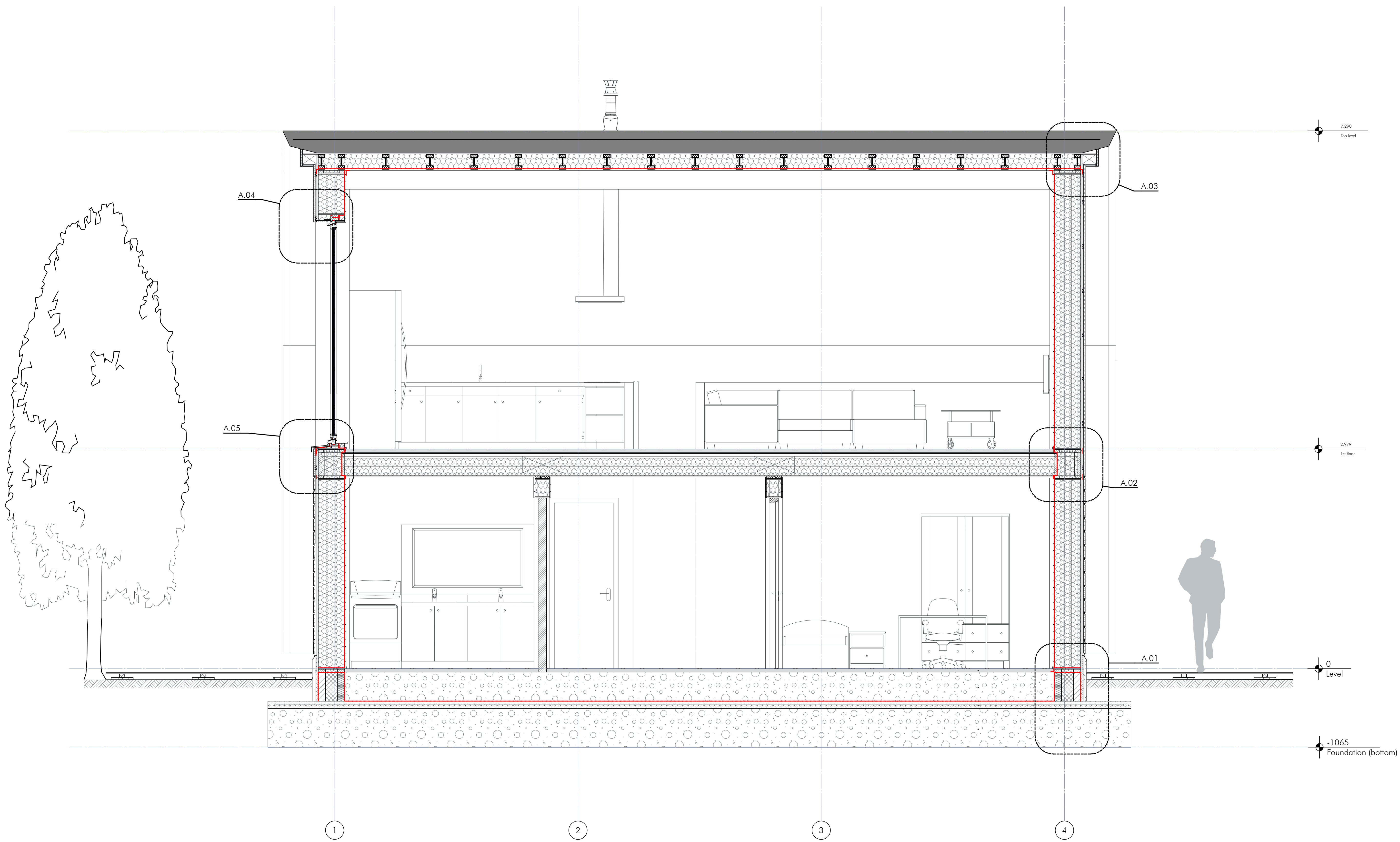
PLAN GROUND FLOOR 1:50



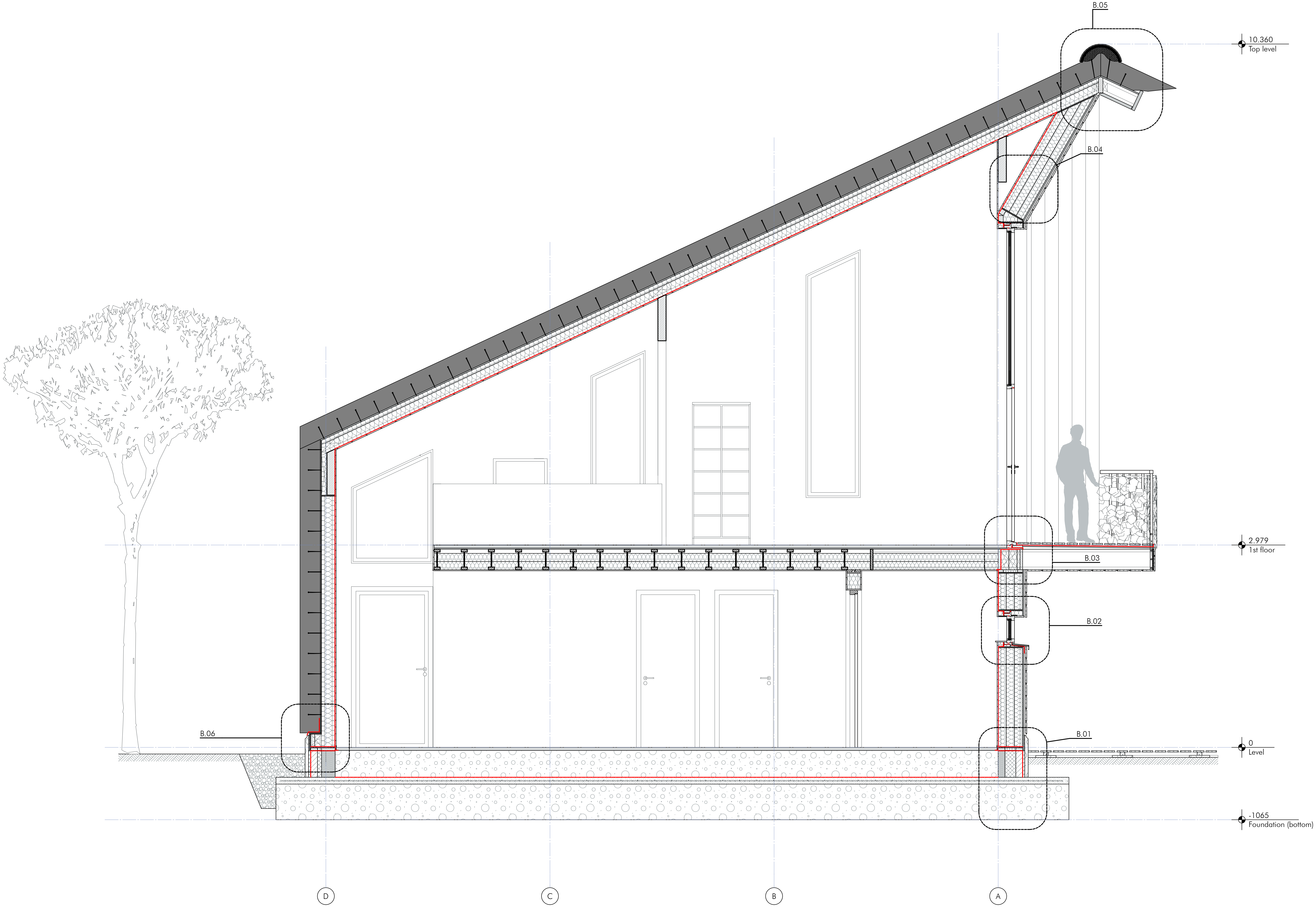
PLAN FIRST FLOOR 1:50



SECTION A-A 1:50



SECTION B-B 1:50



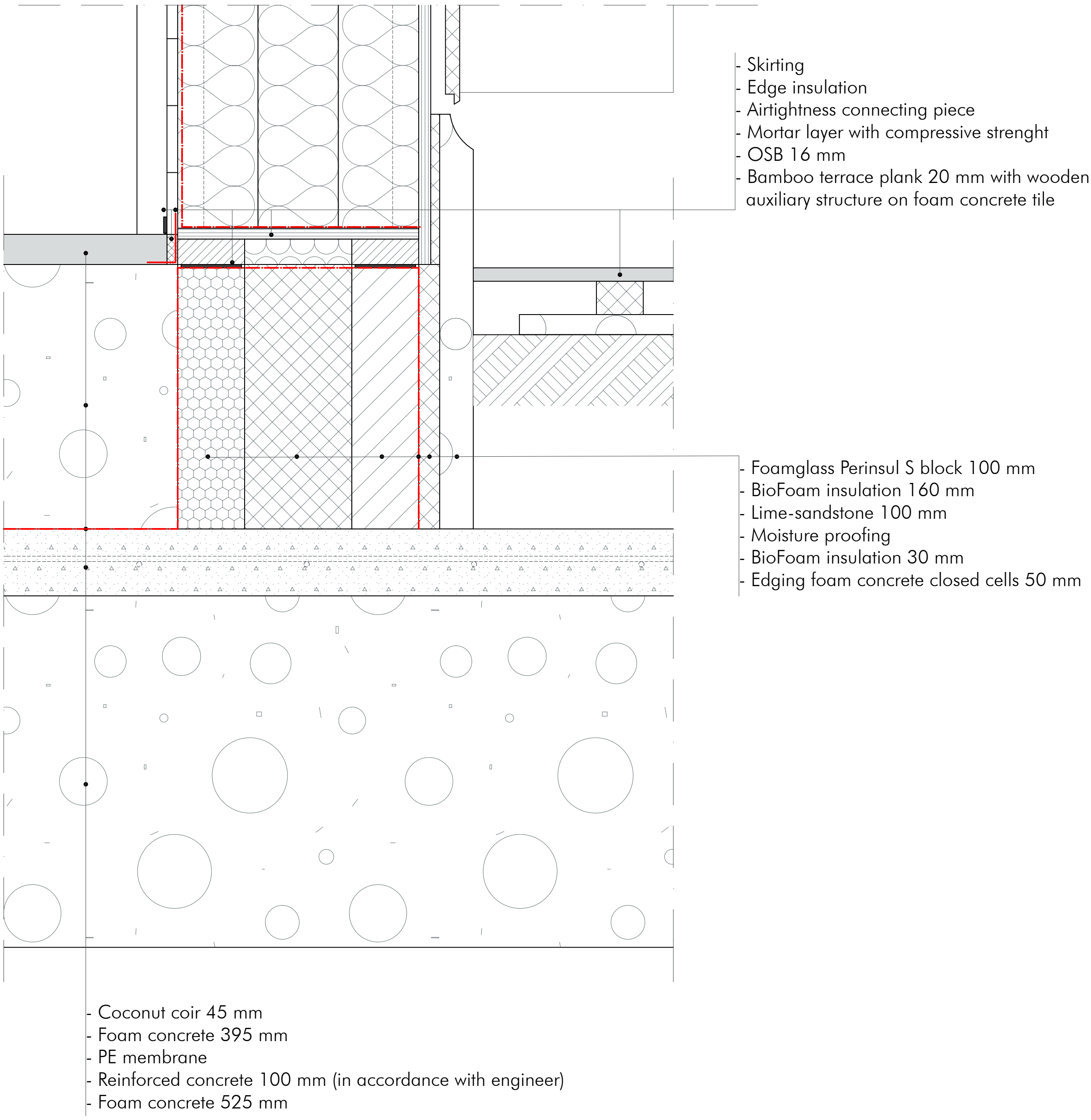
ELEVATION NORTH 1:50

ELEVATION EAST 1:50

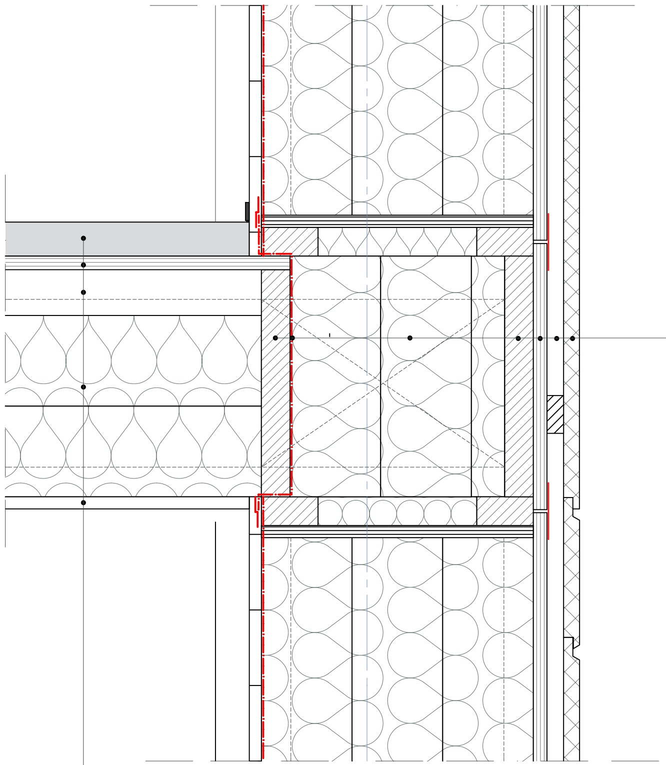
ELEVATION SOUTH 1:50

ELEVATION WEST 1:50

DETAIL A.01 1:10

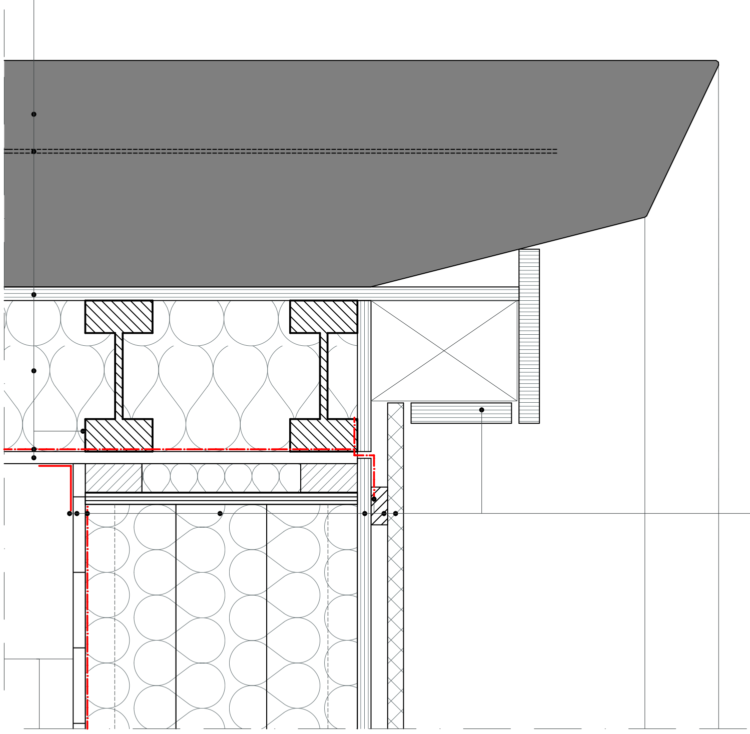


DETAIL A.02 1:10



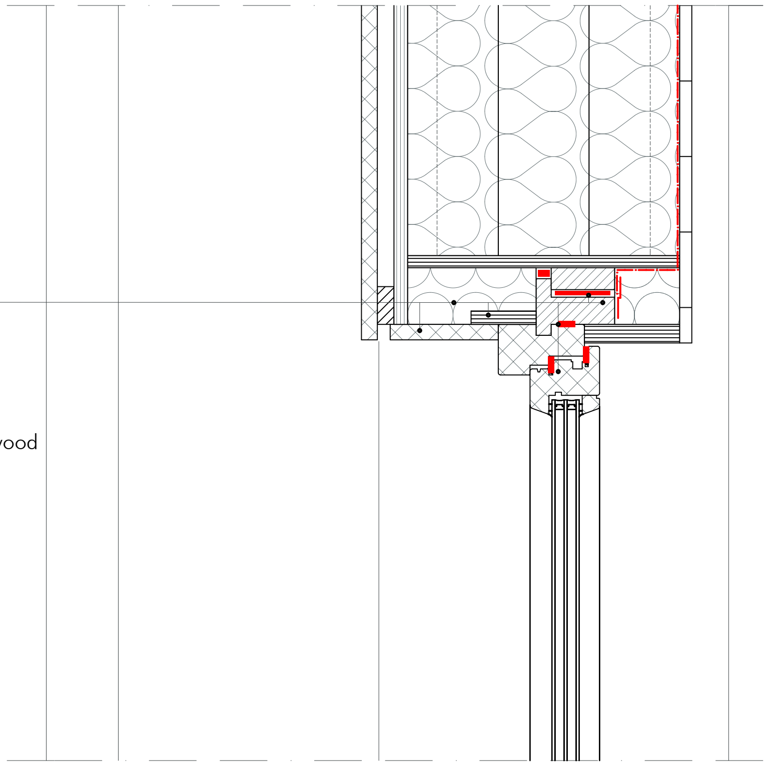
DETAIL A.03 1:10

- Thatched roof covering 300 mm
- Crook
- Wood fibre board Pavatex Isolair L 18 mm
- Flax insulation 200 mm
- FJI 89x200 mm hoh 600 (Finnjoist)
- Airtightness membrane
- Flax fibre board Linex Pro-Grass 16 mm



- Airtightness connecting piece
- Flax fibre board Linex Pro-Grass 16 mm
- Airtightness membrane
- FJI 58x360 mm hoh 600 (Finnjoist)
- Flax insulation 120-120-120 mm
- Wood fibre board Pavatex Isolair L 18 mm
- Vapor-open, water-repellent membrane
- Air cavity with battens 22x50 mm
- Shiplap board vertical, modified pinewood 21x 200 mm, light stained
- Fascia board treated Kerto-Q 27 mm

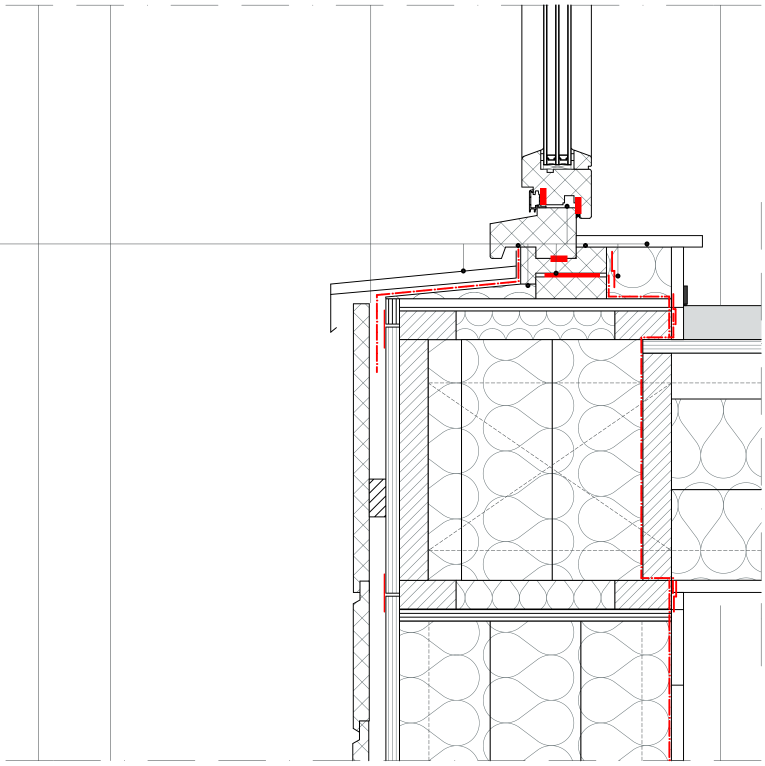
DETAIL A.04 1:10



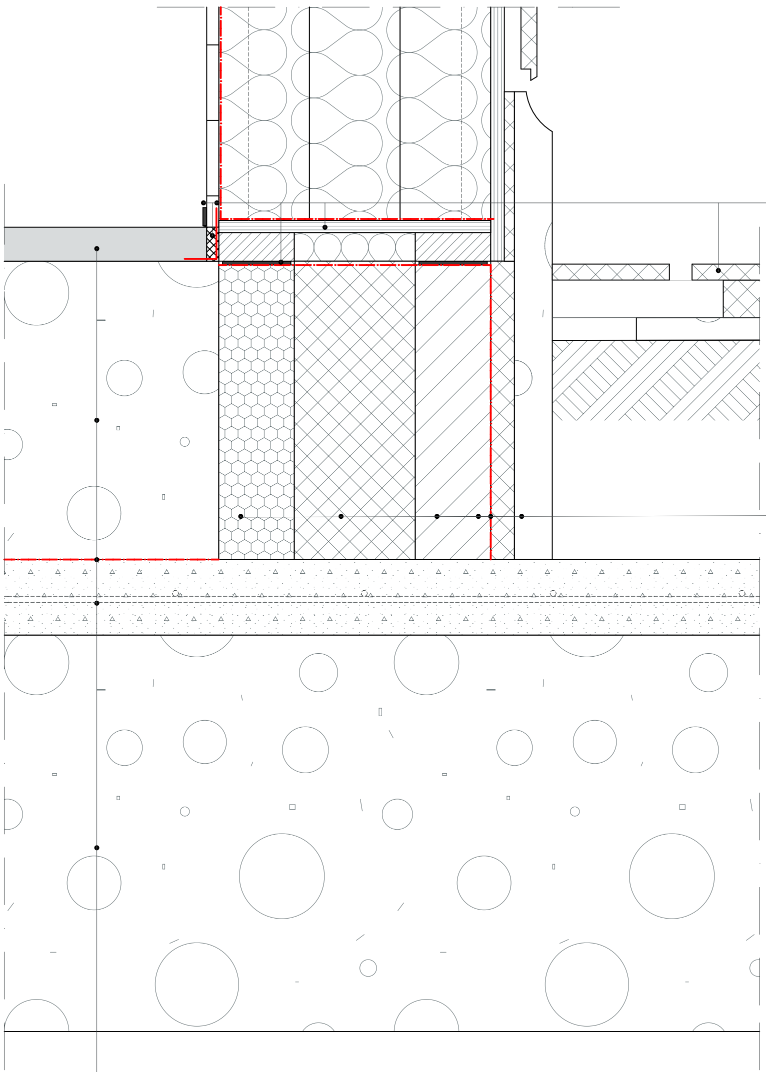
- Wooden buck
- Sealing red areas
- Bamboo wood frame with triple glazing
- OSB 16 mm
- Flax insulation 75 mm
- Shiplap board horizontal, modified pinewood 21x 200 mm, light stained

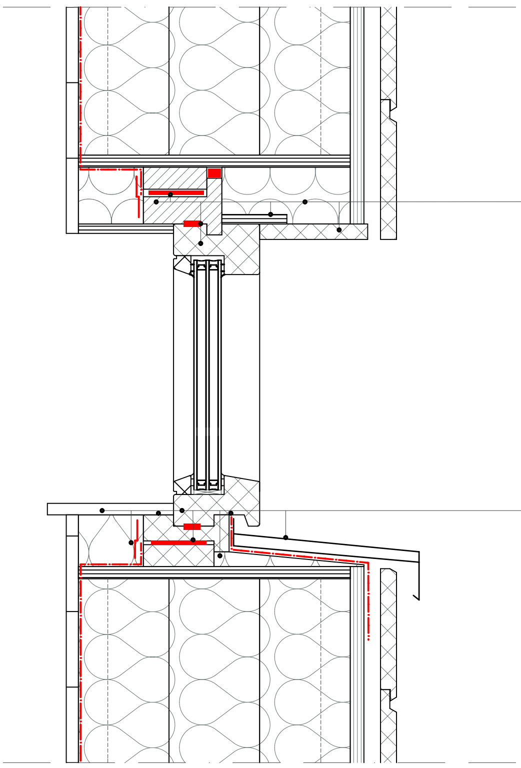
DETAIL A.05 1:10

- Pinewood window sill
- Airtightness membrane with connecting piece
- Wooden buck
- Bamboo wood frame with triple glazing
- Sealing red ares
- Flax insulation
- Vapor-open, water-repelling membrane
- Aluminium weathering

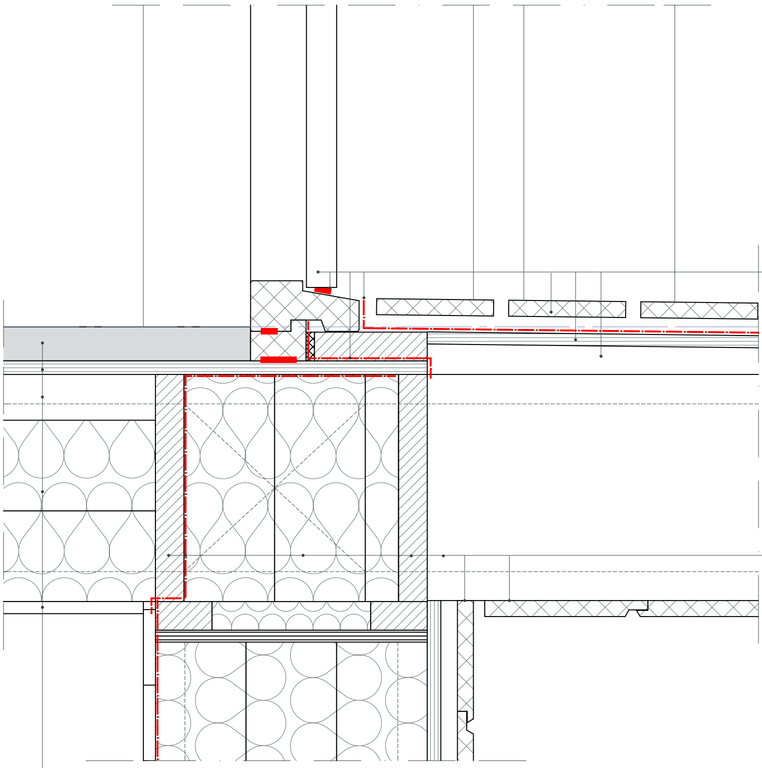


DETAIL B.01 1:10




- Wooden buck
- Sealing red areas
- Bamboo wood frame with triple glazing
- OSB 16 mm
- Flax insulation 75 mm
- Shiplap board horizontal, modified pinewood
21x 200 mm, light stained
- Pinewood window sill
- Airtightness membrane with connecting piece
- Wooden buck
- Bamboo wood frame with triple glazing
- Sealing red ares
- Flax insulation
- Vapor-open, water-repelling membrane
- Aluminium weathering

DETAIL B.03 1:10

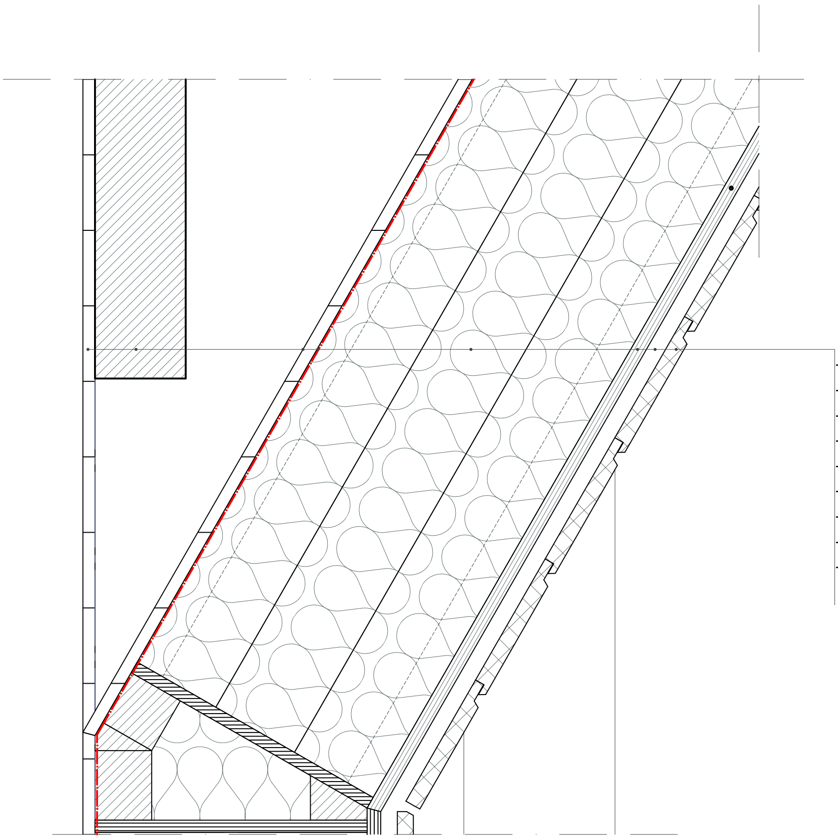


- Fall protection
- Sealing red areas
- Vapor-open, water-repellent membrane
- Bituminous layer, water discharge by internal gutter and open pipe
- Bamboo terrace plank 20 mm
- Wood fibre board Pavatex Isolair L 18 mm
- Tapered beam hoh 400

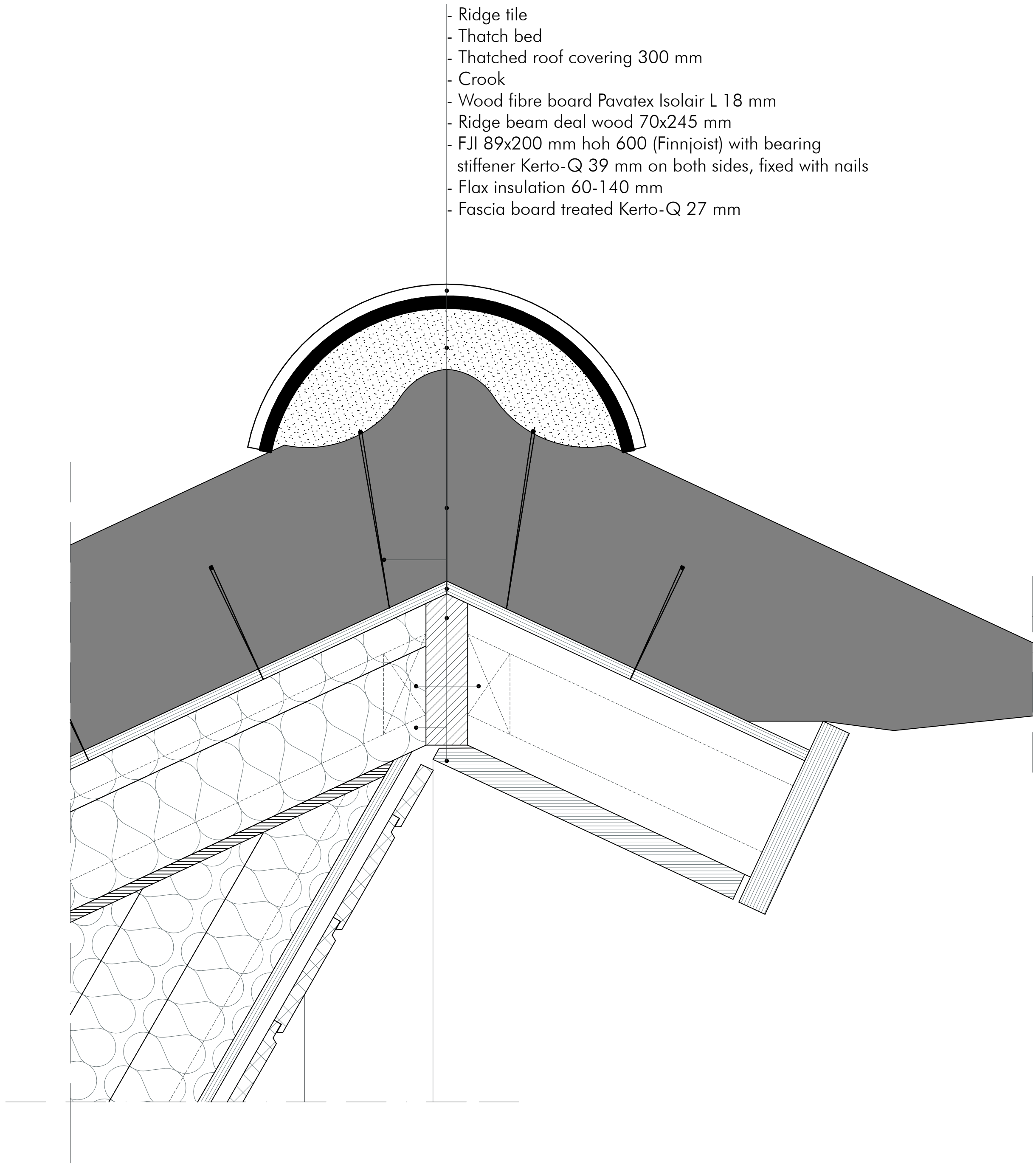
- Bearing stiffener Kerto-Q 39 mm, fixed with CNA nails
- Airtightness membrane
- Flax insulation 120-120-40 mm
- Bearing stiffener Kerto-Q 39 mm, fixed with CNA nails
- FJI 89x300 mm hoh 400 (Finnjoist)
- Shiplap board horizontal, modified pinewood 21x 200 mm, dark stained
- Shiplap board horizontal, modified deal pinewood 21x 200 mm, light stained

- Coconut coir 45 mm
- Wood fibre board Pavatex Isolair L 18 mm
- FJI 89x300 mm hoh 400 (Finnjoist)
- Flax insulation 2x120 mm
- Flax fibre board Linex Pro-Grass 16 mm

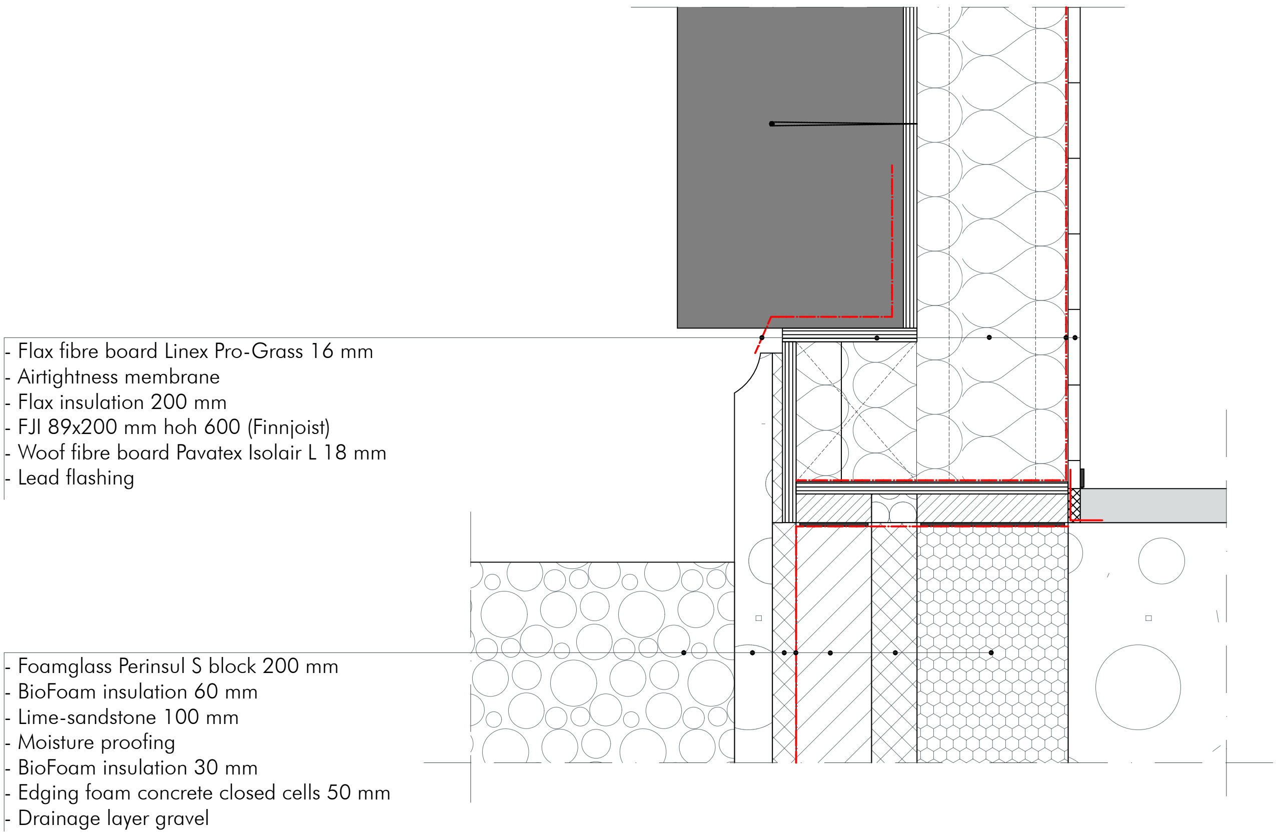
DETAIL B.04 1:10



- Flax fibre board Linex Pro-Grass 16 mm
- Laminated beam dealwood 120x680 mm
- Flax fibre board Linex Pro-Grass 16 mm
- Airtightness membrane
- FJI 58x360 mm hoh 600 (Finnjoist)
- Flax insulation 120-120-120 mm
- Wood fibre boardPavatex Isolair L 18 mm
- Air cavity with battens 22x50 mm
- Shiplap board horizontal, modified deal pinewood 21x 200 mm, light stained


- Ridge tile
- Thatch bed
- Thatched roof covering 300 mm
- Crook
- Wood fibre board Pavatex Isolair L 18 mm
- Ridge beam deal wood 70x245 mm
- FJI 89x200 mm hoh 600 (Finnjoist) with bearing stiffener Kerto-Q 39 mm on both sides, fixed with nails
- Flax insulation 60-140 mm
- Fascia board treated Kerto-Q 27 mm

DETAIL B.06 1:10



RECYCLED HOUSE

CONCEPT

The recycled house consists for the main part out of materials that are recycled. Recycled means that the materials are used again, after human intervention.

For the housing design this means that the body will consist of steel. Other recycled materials that will be used for an important part in the design are rubber, cotton, plaster, glass and ceramic tiles. These materials will get a second life after adjustment.

Having this idea of the technical cycle in mind, it would be interesting to project this to the appearance of the design. Showing the process of degradation, or literally the process of waste, translate itself into a rough, edgy architectural concept.

Executing this idea, puts attention to the spatial dimensions because it easily can look tangled or overdone. The living room therefore is two stories high, which gives extra air in this main room. In order to reduce the amount of lost space, an outside space has been created on the first floor. These effects, these shapes are nicely visible on the inside. Feeling the roughness of the materials, can also be achieved this way because on this outside space you can literally touch the facade.

This, together with the specific aspects of the recycled materials such as the irregularity in size, resulted in a shape that is optimized for its function: the house enjoying waste.

Designing the house according to this concept also brought some compromises along.

- Not all materials are recycled or fully recycled: most materials have a certain maximal percentage for the recycling process.

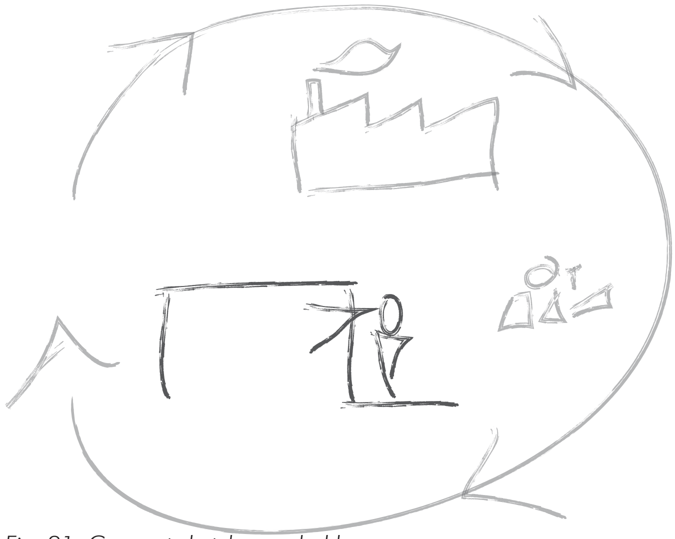


Fig. 21: Concept sketch recycled house

- Only materials that can be literally recycled are taken in consideration. Reusing materials is something different, therefore it will not be part of this design.

- The outside space on the first floor creates a more complex shape and therefore more change on energy loss and thermal bridges.

The whole skeleton (walls, floor and roof) consists of a steel frame with cold rolled C-profiles. Only two HEA-beams together with HEA-columns were needed to support the balcony, which 'hangs' free in space.

On the next pages you will find the list of materials, the Rc-values and the EPC-calculation (the result of this software is unfortunately in Dutch). After that follows the Maxergy result and all technical drawings.

Volume	525 m3
Floor space	174 m2
Bruto facade	286 m2
Windows east	11%
Windows south	31%
Windows west	12%

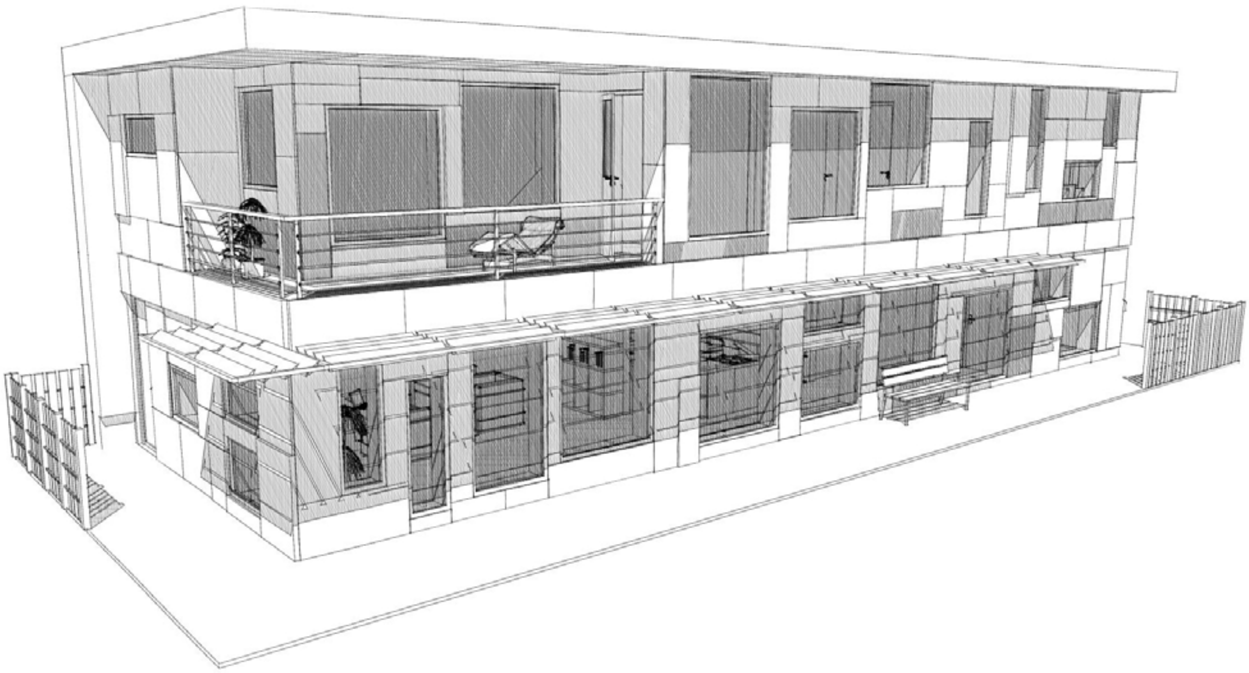


Fig. 22: 3D sketch recycled house

LIST OF MATERIALS

Building component	Material	Color	Thickness (m)	Surface (m2)	Specific weight (kg/m3)	Total weight (kg)
Foundation						
Reinforced concrete strip footing 50,35 m	Recycled concrete			0,47	2400	56.794,80
	Recycled steel 51%				70 kg/m3	1.656,52
Ground floor						
Rubber granulate	Recycled rubber 56%	Grey	0,02	100,89	900	1.816,02
Reinforced cement screed	Cement		0,03	100,89	2100	6.356,07
	Recycled steel 51%			100,89	5,175 kg/m2	522,11
PE membrane (3x)	Recycled polyethylene 100%		0,0002	100,89	0,94	0,06
Compressive XPS insulation	Extruded polystyrene		0,22	100,89	28	621,48
Cement layer	Cement		0,04	100,89	2100	8.474,76
Reinforced concrete floor	Recycled concrete		0,2	100,89	2400	48.427,20
	Recycled steel 51% (2x)			100,89	5,175 kg/m2	522,11
Exterior wall // Ground floor // North						
Bituminous facade cladding Icopal	Recycled bitumen 15%	Black	0,0045	58,05	1050	274,29
OSB	Recycled oriented strand board		0,018	58,05	600	626,94
Wood fibre insulation	Recycled wood fibre		0,24	58,05	150	2.089,80
OSB	Recycled Oriented strand board		0,018	58,05	600	626,94
Airtightness membrane	Recycled polypropylene 100%		0,0002	58,05	0,91	0,01
Cotton insulation Metisse	Recycled cotton 85%		0,14	58,05	18	146,29
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		30 profiles 2,600 m		4,63 kg/m	361,14
Grey' plasterbord	Recycled plaster 100%	White	0,012	58,05	1150	801,09
Exterior wall // Ground floor // East						
Corrugated metal sheet cladding 1/3	Recycled metal sheet 70%	Brown, grey, turquoise	0,002	3,77	7800	58,81
Ceramic tile cladding 1/3	Recycled ceramic	Grey, blue	0,02	3,77	2000	150,80
Glass tile cladding Structuran 1/3	Recycled toughened glass 100%	Green	0,02	3,77	2400	180,96
Auxiliary structure	Recycled stainless steel		0,002	10,725	7930	170,10
Vapor open, water-repellent membrane	Recycled High Density Polyethylene 100%		0,0002	11,31	0,96	0,00
OSB	Recycled Oriented strand board		0,018	11,31	600	122,15
Wood fibre insulation	Recycled wood fibre		0,24	11,31	150	407,16
OSB	Recycled oriented strand board		0,018	11,31	600	122,15
Cotton insulation Metisse	Recycled cotton 85%		0,14	11,31	18	28,50
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		10 profiles 2,600 m		4,63 kg/m	120,38
Airtightness membrane	Recycled polypropylene 100%		0,0002	11,31	0,91	0,00
Grey' plasterbord	Recycled plaster 100%	White	0,012	11,31	1150	156,08
Aluminium framed triple glazing	Recycled glass		0,012	3,13	2500	93,90
	Recycled aluminium 47%	Black	0,002	5,24667	2755	28,91
Window sill	Recycled ceramic	Grey, blue	0,02	0,426184	2000	17,05
Weathering (2x)	Recycled aluminium 47%		0,002	1,260688	2755	6,95
Exterior wall // Ground floor // South						
Corrugated metal sheet cladding 1/3	Recycled metal sheet 70%	Brown, grey, turquoise	0,002	9,81	7800	153,04
Ceramic tile cladding 1/3	Recycled ceramic	Grey, blue	0,02	9,81	2000	392,40
Glass tile cladding Structuran 1/3	Recycled toughened glass 100%	Green	0,02	9,81	2400	470,88
Auxiliary structure	Recycled stainless steel		0,002	33,2475	7930	527,31
Vapor open, water-repellent membrane	Recycled High Density Polyethylene 100%		0,0002	9,81	0,96	0,00
OSB	Recycled Oriented strand board		0,018	9,81	600	105,95
Wood fibre insulation	Recycled wood fibre		0,24	9,81	150	353,16
OSB	Recycled oriented strand board		0,018	9,81	600	105,95
Cotton insulation Metisse	Recycled cotton 85%		0,14	9,81	18	24,72
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		30 profiles 2,600 m		4,63 kg/m	361,14
Airtightness membrane	Recycled polypropylene 100%		0,0002	9,81	0,91	0,00
Grey' plasterbord	Recycled plaster 100%	White	0,012	9,81	1150	135,38
Aluminium framed triple glazing	Recycled glass		0,012	14,95	2500	448,50
	Recycled aluminium 47%	Black	0,002	21,312005	2755	117,43
Window sill	Recycled ceramic	Grey, blue	0,02	2,479616	2000	99,18
Weathering (2x)	Recycled aluminium 47%		0,002	6,607744	2755	36,41
Exterior wall // Ground floor // West						
Corrugated metal sheet cladding 1/3	Recycled metal sheet 70%	Brown, grey, turquoise	0,002	3,49	7800	54,44
Ceramic tile cladding 1/3	Recycled ceramic	Grey, blue	0,02	3,49	2000	139,60
Glass tile cladding Structuran 1/3	Recycled toughened glass 100%	Green	0,02	3,49	2400	167,52
Auxiliary structure	Recycled stainless steel		0,002	10,725	7930	170,10
Vapor open, water-repellent membrane	Recycled High Density Polyethylene 100%		0,0002	10,47	0,96	0,00
OSB	Recycled Oriented strand board		0,018	10,47	600	113,08
Wood fibre insulation	Recycled wood fibre		0,24	10,47	150	376,92
OSB	Recycled oriented strand board		0,018	10,47	600	113,08
Cotton insulation Metisse	Recycled cotton 85%		0,14	10,47	18	26,38
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		10 profiles 2,600 m		4,63 kg/m	120,38
Airtightness membrane	Recycled polypropylene 100%		0,0002	10,47	0,91	0,00
Grey' plasterbord	Recycled plaster 100%	White	0,012	10,47	1150	144,49
Aluminium framed triple glazing	Recycled glass		0,012	3,97	2500	119,10
	Recycled aluminium 47%	Black	0,002	4,53596	2755	24,99
Window sill	Recycled ceramic	Grey, blue	0,02	0,58116	2000	23,25
Weathering (2x)	Recycled aluminium 47%		0,002	1,71912	2755	9,47
Interior wall // Ground floor						
Grey' plasterbord	Recycled plaster 100%	White	0,012	56,77	1150	783,43
Cotton insulation Metisse	Recycled cotton 85%		0,14	56,77	18	143,06
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		35 profiles 2,600 m		4,63 kg/m	421,33
Grey' plasterbord	Recycled plaster 100%	White	0,012	56,77	1150	783,43
Upper floor						
Rubber granulate	Recycled rubber 56%	Grey	0,02	72,8	900	1.310,40
OSB	Recycled oriented strand board		0,018	72,8	600	786,24
C-profie 240 Star Frame hoh 600	Recycled steel 87%		23 profiles 6,000 m		6,20 kg/m	855,60
Cotton insulation Metisse	Recycled cotton 85%		0,24	72,8	18	314,50
Grey' plasterboard	Recycled plaster 100%	White	0,012	72,8	1150	1.004,64
Exterior wall // First floor // North						
Bituminous facade cladding Icopal	Recycled bitumen 15%	Black	0,0045	58,48	1050	276,32
OSB	Recycled oriented strand board		0,018	58,48	600	631,58
Wood fibre insulation	Recycled wood fibre		0,24	58,48	150	2.105,28
OSB	Recycled Oriented strand board		0,018	58,48	600	631,58
Airtightness membrane	Recycled polypropylene 100%		0,0002	58,48	0,91	0,01
Cotton insulation Metisse	Recycled cotton 85%		0,14	58,48	18	147,37
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		30 profiles 2,600 m		4,63 kg/m	361,14
Grey' plasterbord	Recycled plaster 100%	White	0,012	58,48	1150	807,02
Exterior wall // First floor // East						
Corrugated metal sheet cladding 0,28	Recycled metal sheet 70%	Brown, grey, turquoise	0,002	4,7358	7800	73,88
Ceramic tile cladding 0,28	Recycled ceramic	Grey, blue	0,02	4,7358	2000	189,43
Glass tile cladding Structuran 0,28	Recycled toughened glass 100%	Green	0,02	4,7358	2400	227,32

Aluminium sheet cladding 0,19	Recycled aluminium 47%		0,002	3,2129	2755	17,70
Auxiliary structure	Recycled stainless steel		0,002	10,725	7930	170,10
Vapor open, water-repellent membrane	Recycled High Density Polyethylene 100%		0,0002	16,91	0,96	0,00
OSB	Recycled Oriented strand board		0,018	16,91	600	182,63
Wood fibre insulation	Recycled wood fibre		0,24	16,91	150	608,76
OSB	Recycled oriented strand board		0,018	16,91	600	182,63
Cotton insulation Metisse	Recycled cotton 85%		0,14	16,91	18	42,61
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		10 profiles 2,600 m		4,63 kg/m	120,38
Airtightness membrane	Recycled polypropylene 100%		0,0002	16,91	0,91	0,00
Grey' plasterbord	Recycled plaster 100%	White	0,012	16,91	1150	233,36
Aluminium framed triple glazing	Recycled glass		0,012	2,28	2500	68,40
	Recycled aluminium 47%	Black	0,002	5,1909	2755	28,60
Window sill	Recycled ceramic	Grey, blue	0,02	0,617232	2000	24,69
Weathering (2x)	Recycled aluminium 47%		0,002	1,825824	2755	10,06
Exterior wall // First floor // South						
Corrugated metal sheet cladding 0,28	Recycled metal sheet 70%	Brown, grey, turquoise	0,002	11,6816	7800	182,23
Ceramic tile cladding 0,28	Recycled ceramic	Grey, blue	0,02	11,6816	2000	467,26
Glass tile cladding Structuran 0,28	Recycled toughened glass 100%	Green	0,02	11,6816	2400	560,72
Aluminium sheet cladding 0,19	Recycled aluminium 47%		0,002	7,9268	2755	43,68
Auxiliary structure	Recycled stainless steel		0,002	33,2475	7930	527,31
Vapor open, water-repellent membrane	Recycled High Density Polyethylene 100%		0,0002	41,72	0,96	0,01
OSB	Recycled Oriented strand board		0,018	41,72	600	450,58
Wood fibre insulation	Recycled wood fibre		0,24	41,72	150	1.501,92
OSB	Recycled oriented strand board		0,018	41,72	600	450,58
Cotton insulation Metisse	Recycled cotton 85%		0,14	41,72	18	105,13
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		30 profiles 2,600 m		4,63 kg/m	361,14
Airtightness membrane	Recycled polypropylene 100%		0,0002	41,72	0,91	0,01
Grey' plasterbord	Recycled plaster 100%	White	0,012	41,72	1150	575,74
Aluminium framed triple glazing	Recycled glass		0,012	16,45	2500	493,50
	Recycled aluminium 47%	Black	0,002	18,85026	2755	103,86
Window sill	Recycled ceramic	Grey, blue	0,02	1,910981	2000	76,44
Weathering (2x)	Recycled aluminium 47%		0,002	5,652842	2755	31,15
Exterior wall // First floor // West						
Corrugated metal sheet cladding 0,28	Recycled metal sheet 70%	Brown, grey, turquoise	0,002	4,27	7800	66,61
Ceramic tile cladding 0,28	Recycled ceramic	Grey, blue	0,02	4,27	2000	170,80
Glass tile cladding Structuran 0,28	Recycled toughened glass 100%	Green	0,02	4,27	2400	204,96
Aluminium sheet cladding 0,19	Recycled aluminium 47%		0,002	2,8975	2755	15,97
Auxiliary structure	Recycled stainless steel		0,002	10,725	7930	170,10
Vapor open, water-repellent membrane	Recycled High Density Polyethylene 100%		0,0002	15,25	0,96	0,00
OSB	Recycled Oriented strand board		0,018	15,25	600	164,70
Wood fibre insulation	Recycled wood fibre		0,24	15,25	150	549,00
OSB	Recycled oriented strand board		0,018	15,25	600	164,70
Cotton insulation Metisse	Recycled cotton 85%		0,14	15,25	18	38,43
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		10 profiles 2,600 m		4,63 kg/m	120,38
Airtightness membrane	Recycled polypropylene 100%		0,0002	15,25	0,91	0,00
Grey' plasterbord	Recycled plaster 100%	White	0,012	15,25	1150	210,45
Aluminium framed triple glazing	Recycled glass		0,012	3,94	2500	118,20
	Recycled aluminium 47%	Black	0,002	5,574855	2755	30,72
Window sill	Recycled ceramic	Grey, blue	0,02	0,426184	2000	17,05
Weathering (2x)	Recycled aluminium 47%		0,002	1,260688	2755	6,95
Interior wall First floor						
Grey' plasterbord	Recycled plaster 100%	White	0,012	81,42	1150	1.123,60
Cotton insulation Metisse	Recycled cotton 85%		0,14	81,42	18	205,18
C-Profile 140 Star Frame hoh 600	Recycled steel 87%		50 profiles 2,600 m		4,63 kg/m	601,9
Grey' plasterbord	Recycled plaster 100%	White	0,012	81,42	1150	1.123,60
Structure						
HEA 240 beam	Recycled steel 51%			2 beams 6,000 m	61,5 kg/m	738,00
HEA 140 column	Recycled steel 51%			4 columns 2,600 m	25,1 kg/m	261,04
Wooden beam 60x240 mm	Deal wood			40 beams 1,570 m	460	415,99
	Deal wood			10 beams 2,885 m	460	191,10
Stair	Recycled steel 51%		0,005	5,1	7800	198,90
Roof						
Bituminous roof Icopal	Recycled bitumen 15%	Black	0,0045	58,48	1050	5.591,30
Wood fibre insulation	Recycled wood fibre		0,2	58,48	150	109,30
OSB	Recycled Oriented strand board		0,018	58,48	600	207,66
Airtightness membrane	Recycled polypropylene 100%		0,0002	58,48	0,91	0,01
Cotton insulation Metisse	Recycled cotton 85%		0,24	58,48	18	252,63
C-Profile 240 Star Frame hoh 600	Recycled steel 87%		30 profiles 2,600 m		4,63 kg/m	361,14
Grey' plasterbord	Recycled plaster 100%	White	0,012	58,48	1150	807,02
Cover profile Roval	Recycled aluminium 47%		0,002	20,68528	510	21,10
Internal gutter	Recycled polyvinyl chloride 100%		0,003	8,296	7200	179,19

Total materials	**Weight (kg)**
Recycled concrete	105.222,00
Recycled steel 51%	3.898,67
Recycled rubber 56%	3.126,42
Cement	14.830,83
Recycled polyethylene 100%	0,06
Extruded polystyrene	621,48
Recycled oriented strand board	5.789,10
Recycled steel 87%	4.166,05
Recycled cotton 85%	1.474,81
Recycled plaster 100%	8.689,31
Recycled metal sheet 70%	589,02
Recycled ceramic tiles and window sills	1.832,51
Recycled toughened glass 100%	1.812,36
Recycled stainless steel	1.735,00
Recycled High Density Polyethylene 100%	0,02
Recycled wood fibre	8.101,30
Recycled glass	1.341,60
Recycled aluminium 47%	533,94
Recycled bitumen 15%	6.141,90
Recycled polypropylene 100%	0,05
Deal wood	607,09
Recycled polyvinyl chloride 100%	179,19
	170.692,71

RC-VALUE GROUND FLOOR

Ti = 20 °C
Te = -10 °C

φi = 60 %
φe = 50 %

Ri en Re = Vloer in contact met gro[nd]

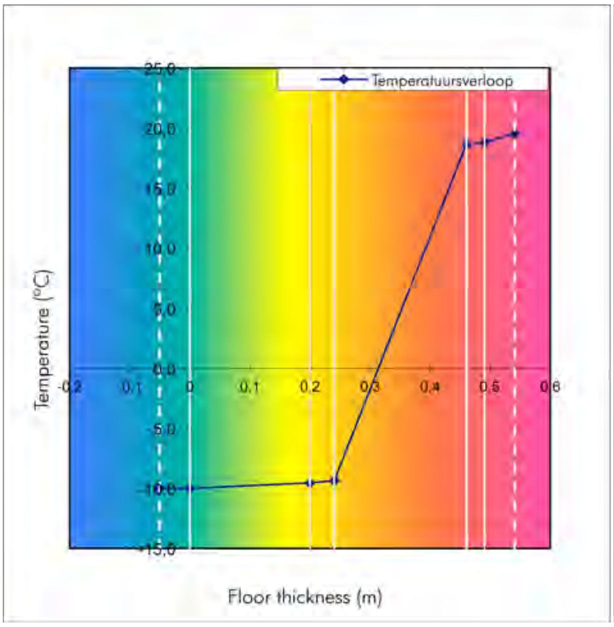
Element = α -

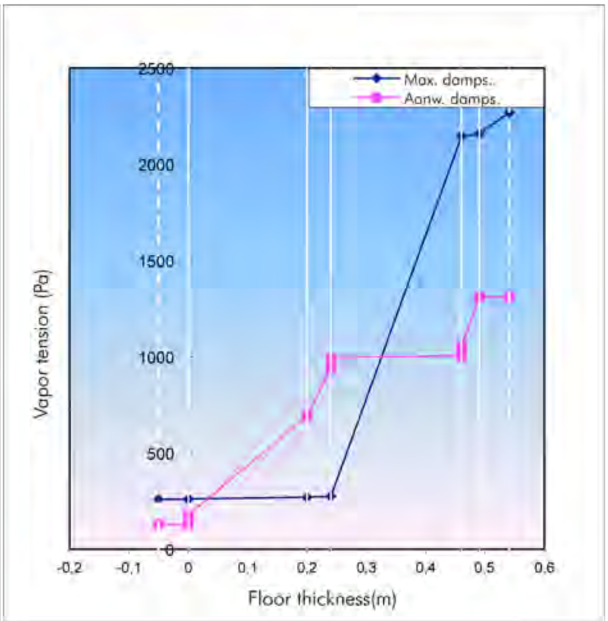
Gebruiksfunctie Woonfunctie

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,00	0,0						
					-10,0	260				130
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	51	
					-10,0	261				181
Reinforced concrete	0,2	2	0,10	0,4			10	2	509	
					-9,6	271				690
Cement layer	0,04	0,9	0,04	0,2			25	1	255	
					-9,4	276				945
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	51	
					-9,3	276				996
XPS insulation	0,22	0,035	6,29	28,0			0,159	0,03498	9	
					18,6	2144				1005
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	51	
					18,6	2144				1056
Reinforced cement screed	0,03	0,9	0,03	0,1			33,3	0,999	254	
					18,8	2157				1310
Rubber granulate	0,02	0,2	0,10	0,4			10	0,2	51	
Ri			0,17	0,8						
Inside air					19,6	2268				1310
Totaal:	0,51	Rl =	6,74	30,00			μ =	4,83	1231	

Vapor pressure difference			Temperature factor thermal bridge
			(F) Eis = 0,65
Dampsp. =	1360,8	Pa	
Dampsp. =	130	Pa	F = (Tio-Te) / (Ti-Te) = 0,96 Sufficient
Δ Dampsp =	1230,8	Pa	

Rc = 6,6 m²K/W	Rl = 6,74 m²K/W	U = 0,15 W/m²K





RC-VALUE EXTERIOR WALLS

Ti = 20 °C
Te = -10 °C

φi = 60 %
φe = 50 %

Ri en Re = Buitenmuur Bi»Bu

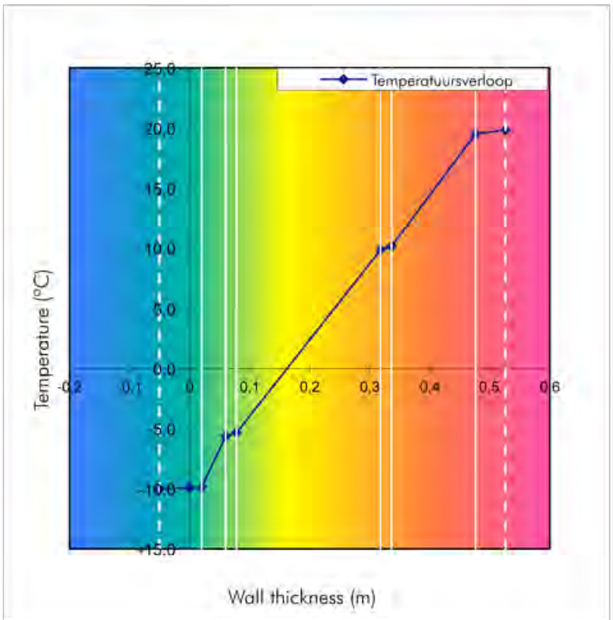
Element = α -

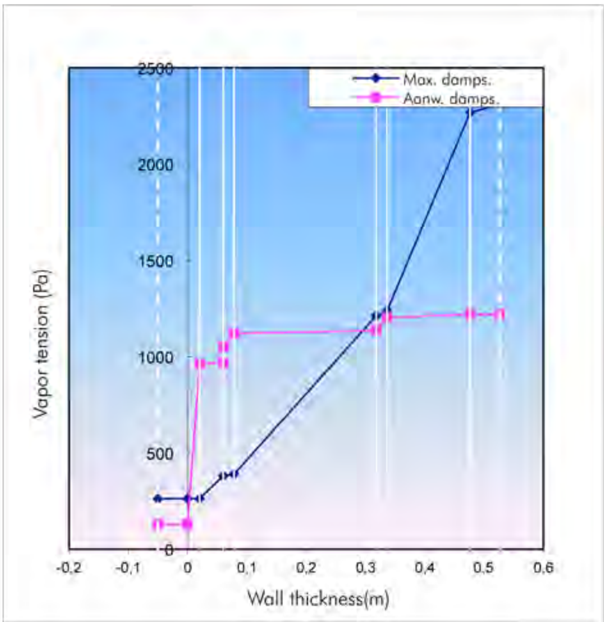
Gebruiksfunctie Woonfunctie

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,04	0,1						
					-9,9	264				130
Cladding	0,02	1,5	0,01	0,0			100	2	829	
					-9,9	264				959
Air cavity	0,04	0,024	1,67	4,2			0,599	0,02396	10	
					-5,6	381				969
HDPE-membrane	0,0002	0,2	0,00	0,0			1000	0	83	
					-5,6	381				1052
OSB	0,018	0,17	0,11	0,3			9,09	0,16362	68	
					-5,4	391				1120
Wood fibre insulation	0,24	0,04	6,00	15,2			0,167	0,04008	17	
					9,9	1212				1137
OSB	0,018	0,17	0,11	0,3			9,09	0,16362	68	
					10,2	1237				1204
Cotton insulation	0,14	0,038	3,68	9,4			0,272	0,03808	16	
					19,5	2268				1220
PP-membrane	0,0002	0,2	0,00	0,0			1000	0,2	83	
					19,5	2268				1303
Grey plasterboard	0,012	0,21	0,06	0,1			16,67	0,20004	83	
Ri			0,13	0,3						
Inside air					19,9	2310				1220
Totaal:	0,49	Rl =	11,81	30,00			μ =	3,03	1256	

Vapor pressure difference	Temperature factor thermal bridge
Dampsp. = 1386 Pa	(F) Eis = 0,65
Dampsp. = 130 Pa	
Δ Dampsp = 1256 Pa	F = (Tio-Te) / (Ti-Te) = 0,98 Sufficient

Rc = 11,6 m²K/W	Rl = 11,81 m²K/W	U = 0,08 W/m²K





RC-VALUE ROOF

Ti = 20 °C
Te = -10 °C

φi = 60 %
φe = 50 %

Ri en Re = Vloer in contact met gror

Element = α -

Gebruiksfunctie Woonfunctie

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,00	0,0						
					-10,0	260				130
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	51	
					-10,0	261				181
Reinforced concrete	0,2	2	0,10	0,4			10	2	509	
					-9,6	271				690
Cement layer	0,04	0,9	0,04	0,2			25	1	255	
					-9,4	276				945
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	51	
					-9,3	276				996
XPS insulation	0,22	0,035	6,29	28,0			0,159	0,03498	9	
					18,6	2144				1005
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	51	
					18,6	2144				1056
Reinforced cement screed	0,03	0,9	0,03	0,1			33,3	0,999	254	
					18,8	2157				1310
Rubber granulate	0,02	0,2	0,10	0,4			10	0,2	51	
Ri			0,17	0,8						
Inside air					19,6	2268				1310
Totaal:	0,51	Rl =	6,74	30,00			μ =	4,83	1231	

Vapor pressure difference

Dampsp. = 1360,8 Pa
Dampsp. = 130 Pa
Δ Dampsp = 1230,8 Pa

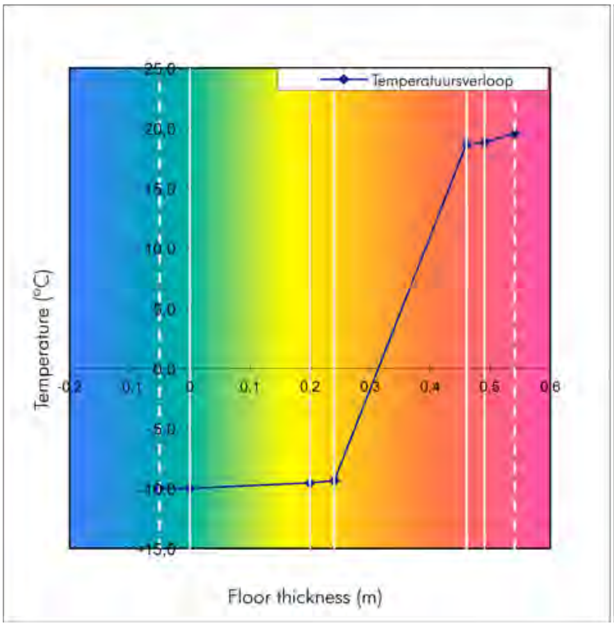
Temperature factor thermal bridge
(F) Eis = 0,65

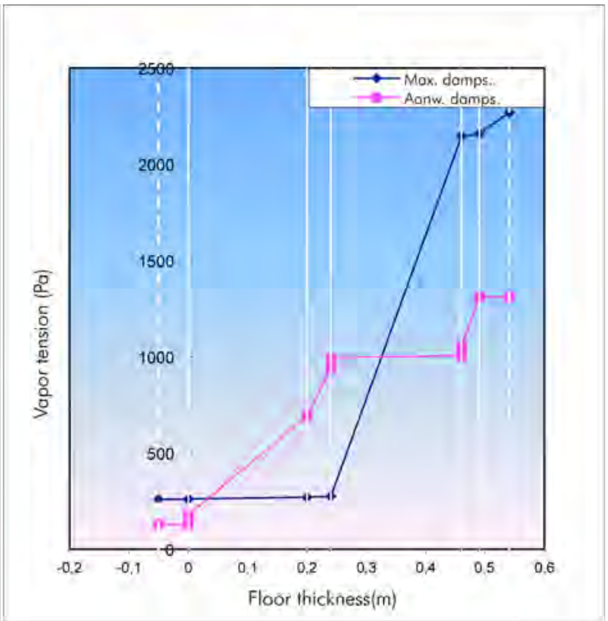
F = (Tio-Te) / (Ti-Te) = 0,96 Sufficient

Rc = 6,6 m²K/W

Rl = 6,74 m²K/W

U = 0,15 W/m²K





EPC-CALCULATION

ALGEMENE GEGEVENS

Projectomschrijving	:	Recycled House
Bestandsnaam	:	L:\EPW v2.0\Recycled.epw
Omschrijving bouwwerk	:	
Adres	:	
Soort bouwwerk	:	Woonfunctie
EPC-eis	:	0,6

INDELING GEBOUW

Type	*Omschrijving zone*	*Ag [m²]*	
Verwarmd	Begane grond	100,89	
Verwarmd	1e Verdieping	72,80	
		-------------	+
totaal		173,69	

BOUWKUNDIGE GEGEVENS - TRANSMISSIE

Definitie scheidingsconstructies zone: Begane grond

constructie	*begrenzing*	*constructiedeel*	*A*		*Hkr*	*Rc*	*U*	*ZTA*	*helling*	*zon-*	*beschaduwing*
			[m²]		*[m]*	*[m²K/W]*	*[W/m²K]*	*[-]*	*[°]*	*wering*	
Vloer	grond	Beton	100,9			6,60	0,09				
Gevel noord	buiten, N	Staalframe, bitumen	58,0			11,50	0,09				
Gevel oost	buiten, O	Staalframe, tegels	11,3			11,60	0,08				
		Ramen	3,1				0,80	0,50	90	nee	maximale belemmering
Gevel zuid	buiten, Z	Staalframe, tegels	29,4			11,60	0,08				
		Ramen	14,9				0,80	0,50	90	ja	minimale belemmering
Gevel west	buiten, W	Staalframe, tegels	10,5			11,60	0,08				
		Ramen	4,0				0,80	0,50	90	nee	maximale belemmering
			----------	+							
Totaal			232,2								

Definitie scheidingsconstructies zone: 1e Verdieping

constructie	*begrenzing*	*constructiedeel*	*A*		*Hkr*	*Rc*	*U*	*ZTA*	*helling*	*zon-*	*beschaduwing*
			[m²]		*[m]*	*[m²K/W]*	*[W/m²K]*	*[-]*	*[°]*	*wering*	
Gevel noord	buiten, N	Staalframe, bitumen	58,5			11,50	0,09				
Gevel oost	buiten, O	Staalframe, tegels	16,9			11,60	0,08				
		Ramen	2,3				0,80	0,50	90	nee	maximale belemmering
Gevel zuid	buiten, Z	Staalframe, tegels	41,7			11,60	0,08				
		Ramen	16,4				0,80	0,50	90	nee	minimale belemmering
Gevel west	buiten, W	Staalframe, tegels	15,3			11,60	0,08				
		Ramen	3,9				0,80	0,50	90	nee	maximale belemmering
Dak	buiten, boven	Staalframe, bitumen	136,9			11,50	0,09				
			----------	+							
Totaal			291,9								

BOUWKUNDIGE GEGEVENS - LINEAIRE KOUDEBRUGGEN

Er is gerekend volgens de forfaitaire methode m.b.t. de koudebruggen.

Bij de forfaitaire methode wordt een correctie op de U-waarde toegepast.

Definitie lineaire koudebruggen zone: Begane grond

constructie	*begrenzing*	*koudebrug*	*P*
			[m]
Vloer	grond	Perimeter	46,80

Definitie lineaire koudebruggen zone: 1e Verdieping

Voor deze zone zijn geen gegevens voor lineaire koudebruggen ingevoerd

BOUWKUNDIGE GEGEVENS - INFILTRATIE

qv10;kar/m² van de woonfunctie:	0,150	[dm³/sm²]

BOUWKUNDIGE GEGEVENS - THERMISCHE CAPACITEIT

bouwtype van de woonfunctie:	gemengd licht

INSTALLATIE W - VERWARMING EN HULPENERGIE

Verwarmingssysteem 1 - Verwarming 1

verwarmingstoestel	type toestel	:	individuele electrische warmtepomp, voldoet aan tabel B2
	bron warmtepomp	:	bodem
	aanvoertemperatuur	:	35°C < T <= 45°C
installatiekenmerken	individuele bemetering	:	ja
	installatie voorzien van buffervat	:	nee
	type verwarmingslichaam	:	overig (bijv. radiatoren)
	opwekkingsrendement (Nopw;verw)	:	1,950 [-]
	systeemrendement (Nsys;verw)	:	0,950 [-]
hulpenergie	aantal ketels-cv/luchtverwarmers met waakvlam	:	0
	gasketels-cv	:	niet voorzien van ventilator
		:	niet voorzien van elektronica
		:	geen circulatiepomp aanwezig
	warmtepomp	:	geen circulatiepomp aanwezig
	individuele warmtepomp	:	geen parallel buffervat aanwezig
	gebouwgebonden warmte-kracht	:	lengte circulatieleiding 0,00 km
aangewezen zones:	Begane grond		
	1e Verdieping		

INSTALLATIE W - WARMTAPWATER

nr.	*opwekkingstoestel*	*klasse*	*Nopw;tap*	*qv;wp*	*aantal*	*aantal*	*Lbadr*	*Laanr*	*Lcirc*	*d;inw*
			[-]	*[dm³/s]*	*badr*	*aanr*	*[m]*	*[m]*	*[m]*	*[mm]*
1	warmtepomp, retourlucht als bron (Bijlage C)	1	0,850	0,00	1	1	6-8	8-10	0,0	<= 10

INSTALLATIE W - VENTILATIE

Ventilatie verwarmde zone: Begane grond

ventilatievoorziening	:	mechanische luchttoe- en afvoer
type warmteterugwinning	:	tegenstroom-warmtewisselaar
Nwtw	:	0,75
regelbaar door bewoners	:	ja
toevoer in zomer	:	toevoer uitschakelbaar
bypass aanwezig	:	luchttoevoerventilator uitschakelbaar of 100% bypass
type voorverwarming	:	voorverwarming door warmteterugwinning

Ventilatie verwarmde zone: 1e Verdieping

ventilatievoorziening	:	mechanische luchttoe- en afvoer
type warmteterugwinning	:	tegenstroom-warmtewisselaar
Nwtw	:	0,75
regelbaar door bewoners	:	ja
toevoer in zomer	:	toevoer uitschakelbaar
bypass aanwezig	:	luchttoevoerventilator uitschakelbaar of 100% bypass
type voorverwarming	:	voorverwarming door warmteterugwinning

INSTALLATIE W - VENTILATOREN

omschrijving zone	*type ventilator*
Begane grond	gebalanceerde ventilatie, wisselstroom
1e Verdieping	gebalanceerde ventilatie, wisselstroom

INSTALLATIE W - KOELING

koelsysteem:	type toestel	:	geen koelmachine aanwezig
	vrije koeling	:	nee
	opwekkingsrendement voor koeling (Nopw;koel)	:	0,000 [-]
	systeemrendement voor koeling (Nsys;koel)	:	0,000 [-]

INSTALLATIE E - VERLICHTING

omschrijving zone	*Ag [m²]*		*Qprim;vl [MJ]*	
Begane grond	100,9		5691	
1e Verdieping	72,8		4107	
	------------	+	------------	+
totaal	173,7		9798	

RESULTATEN - ENERGIEPRESTATIEGEGEVENS

verwarming	Qprim;verw	11490 MJ
hulpenergie	Qprim;hulp;verw	0 MJ
warmtapwater	Qprim;tap	18715 MJ
ventilatoren	Qprim;vent	8498 MJ
verlichting	Qprim;vl	9798 MJ
zomercomfort	Qzom;comf	4402 MJ
koeling	Qprim;koel	0 MJ
bevochtiging	Qprim;bev	0 MJ
comp. PV-cellen	Qprim;pv	0 MJ
comp. WK	Qprim;comp;WK	0 MJ
		----------------- +
totaal	Qpres;tot	52903 MJ
	Qpres;toel	100147 MJ

Qpres;totaal /	((330 *	Ag;verw	+ 65 *	Averlies	) *	Cepc	) =	EPC	
52903		173,7		493,8		1,12		0,53	Epc voldoet

RESULTATEN - INFORMATIEF

CO2-emissie	3366 kg

Risico te hoge temperaturen [TOjuli]

Omschrijving zone	*TOjuli*	
Begane grond	0,47	(laag - matig risico)
1e Verdieping	3,07	(matig - groot risico)

RESULTATEN - AANDACHTSPUNTEN

Verwarmingssysteem '1 - Verwarming 1': er is geen hulpenergie gespecificeerd.

Er is nog geen waarde voor de luchtvolumestroom qv;wp ingevuld.

Indien geen gemeten waarde beschikbaar is geldt qv;wp=0.44*Ag;verwz met een minimum van 44 dm3/s.

MAXERGY RESULTS

The same story as for the biobased house is valid here: the two graphs below, figure [23] and [24] are showing that there is a big difference between the Embodied Land of the operational energy and the Embodied Land of the materials. The same result on the operational energy was likely to be expected. A really tiny difference can be remarked, this could be caused by a small variation in dimensions, surfaces and windows.

Another thing that becomes already clear here: the Embodied Land of the recycled materials is much higher compared to the biobased materials.

Scrutinizing the recycled materials more, shows that steel remains to have a large impact, although it is recycled for a certain part. This becomes visible in the figures [25] and [26].

Furthermore can be noticed that when a material, for example polyethylene, is completely recycled (for 100%) its Embodied Land approaches the result of zero m2-year.

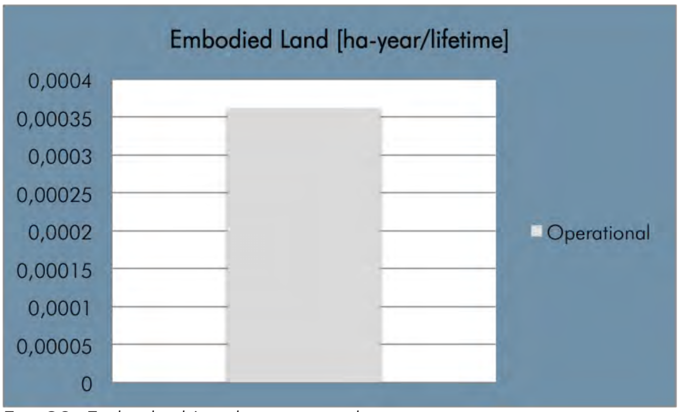


Fig. 23: Embodied Land operational energy

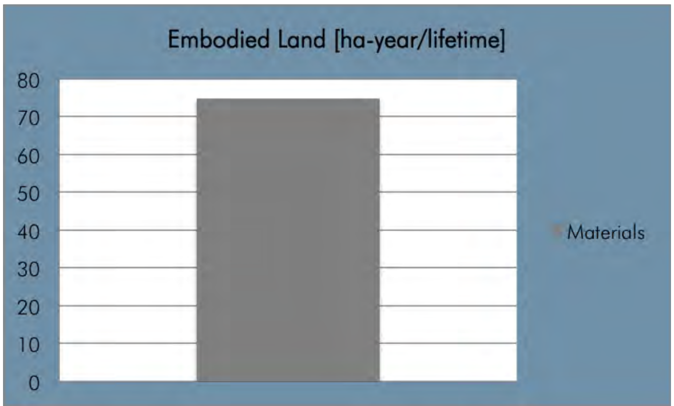


Fig. 24: Embodied Land materials

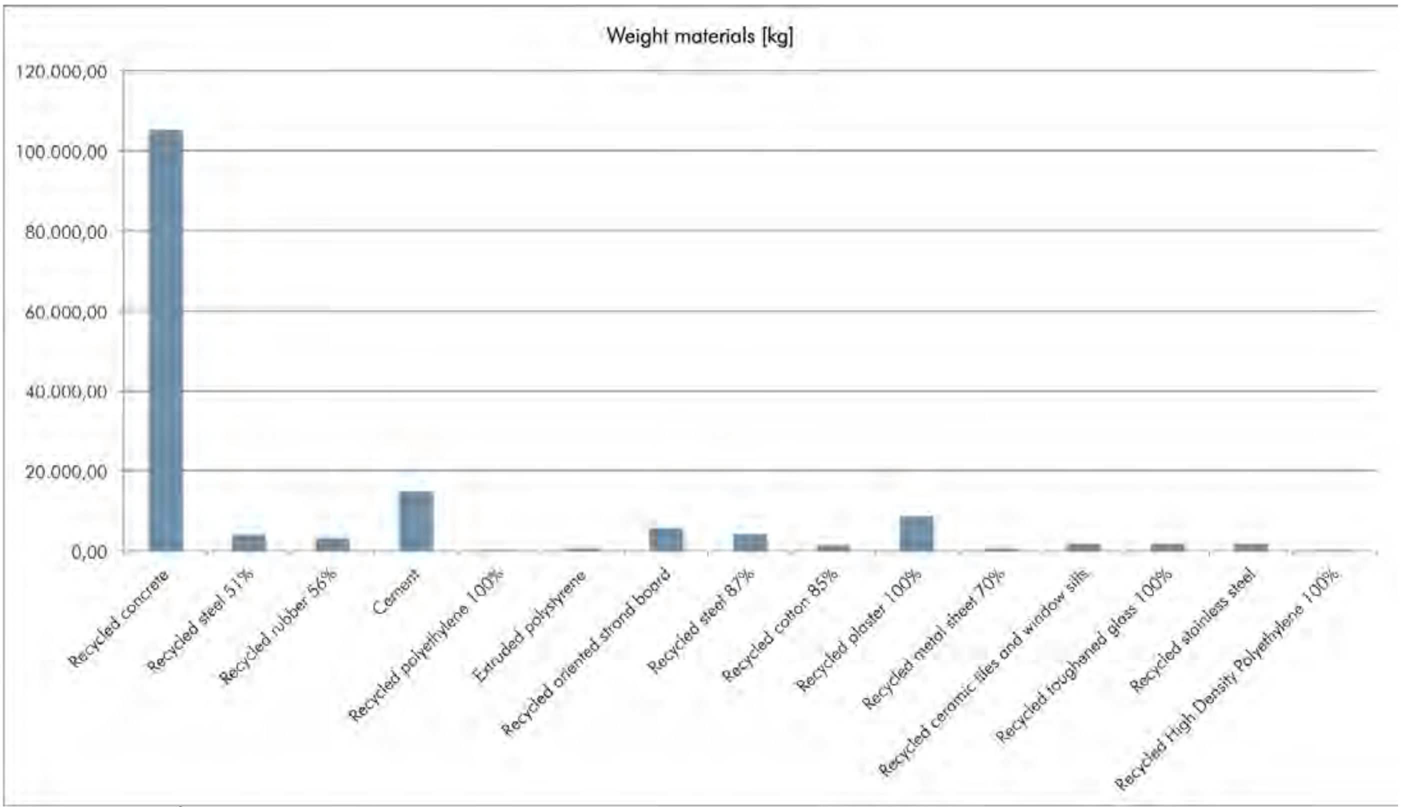


Fig. 25: Weight of all materials

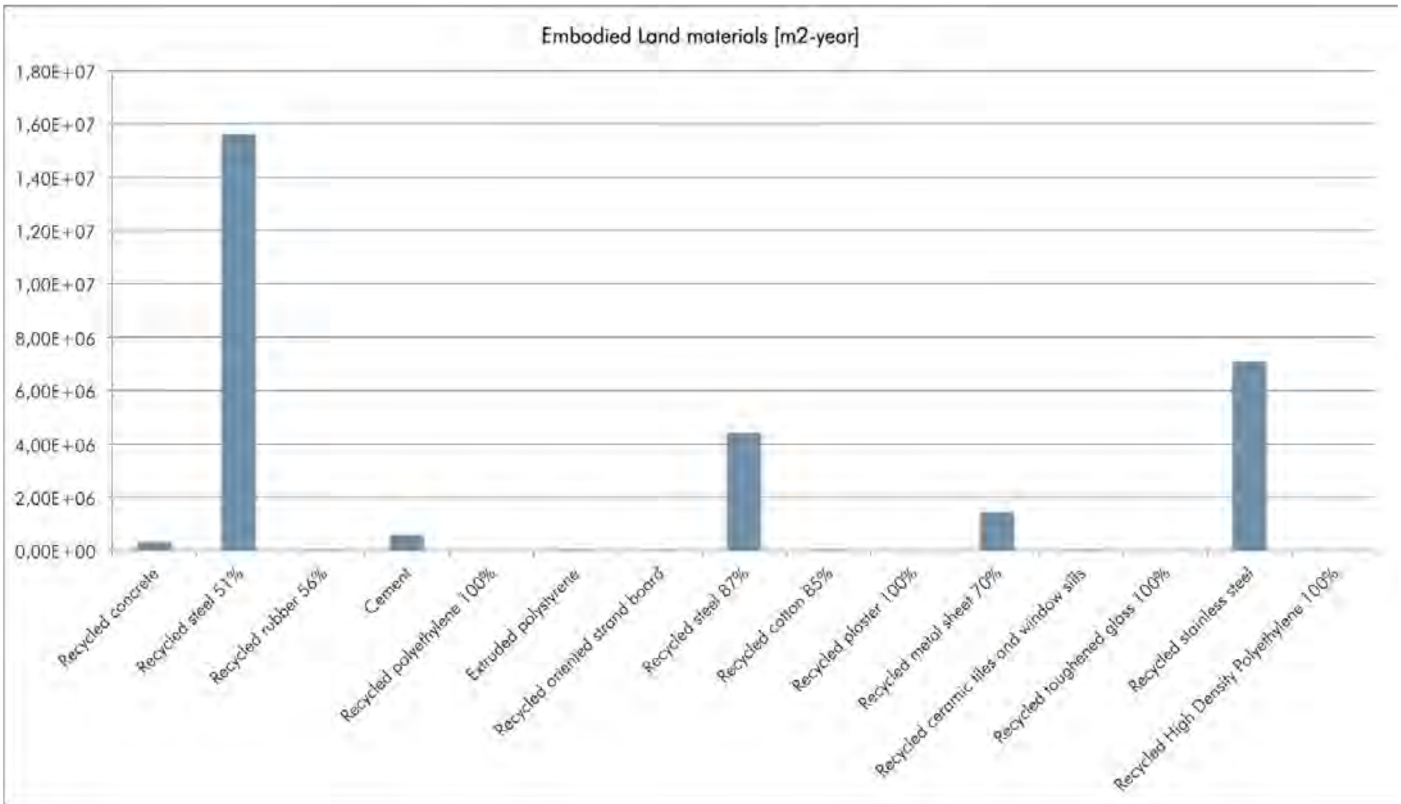


Fig. 26: Embodied Land of all materials

DRAWINGS

> PLANS
Ground floor, 1st floor

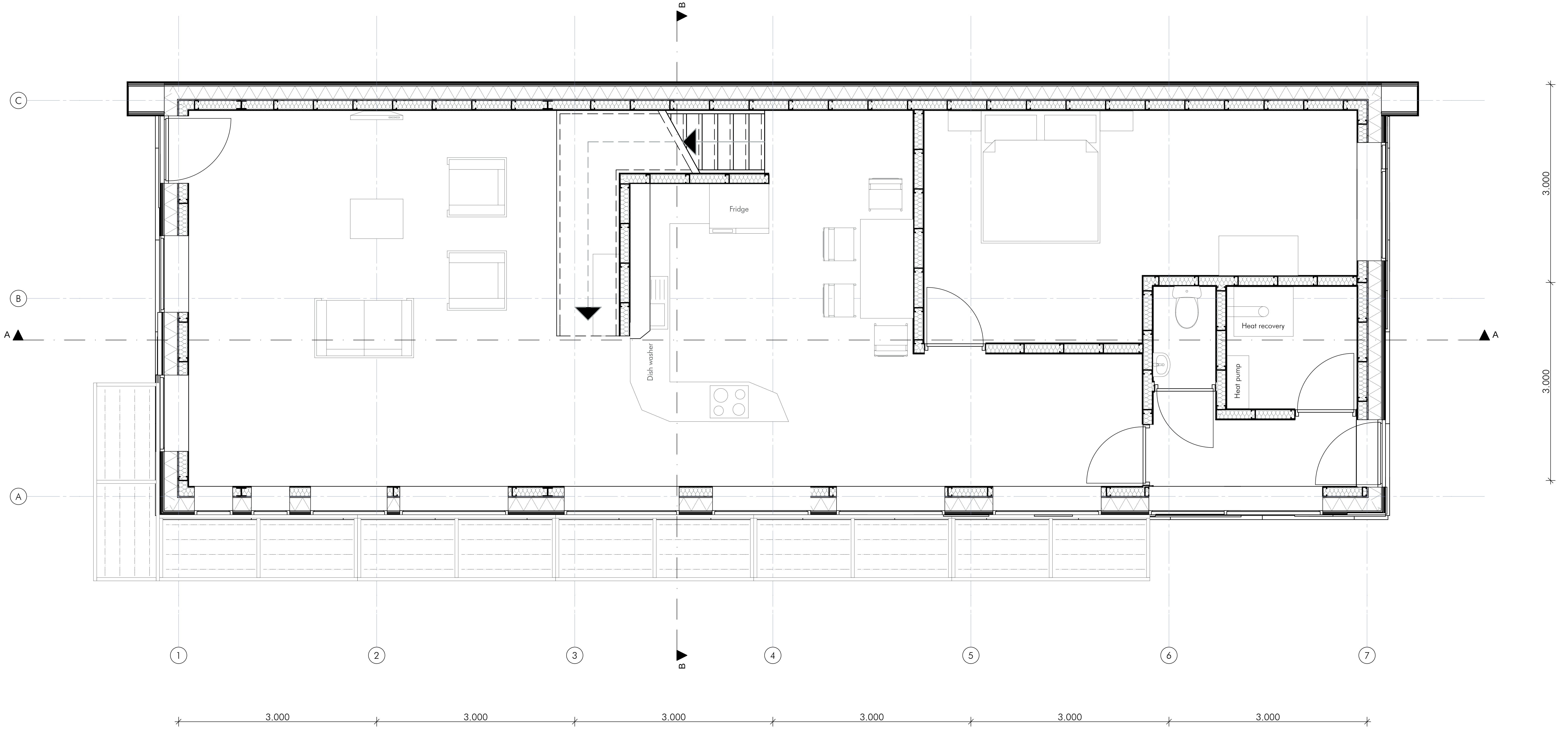
> SECTIONS
AA, BB

> ELEVATIONS
North, East, South, West

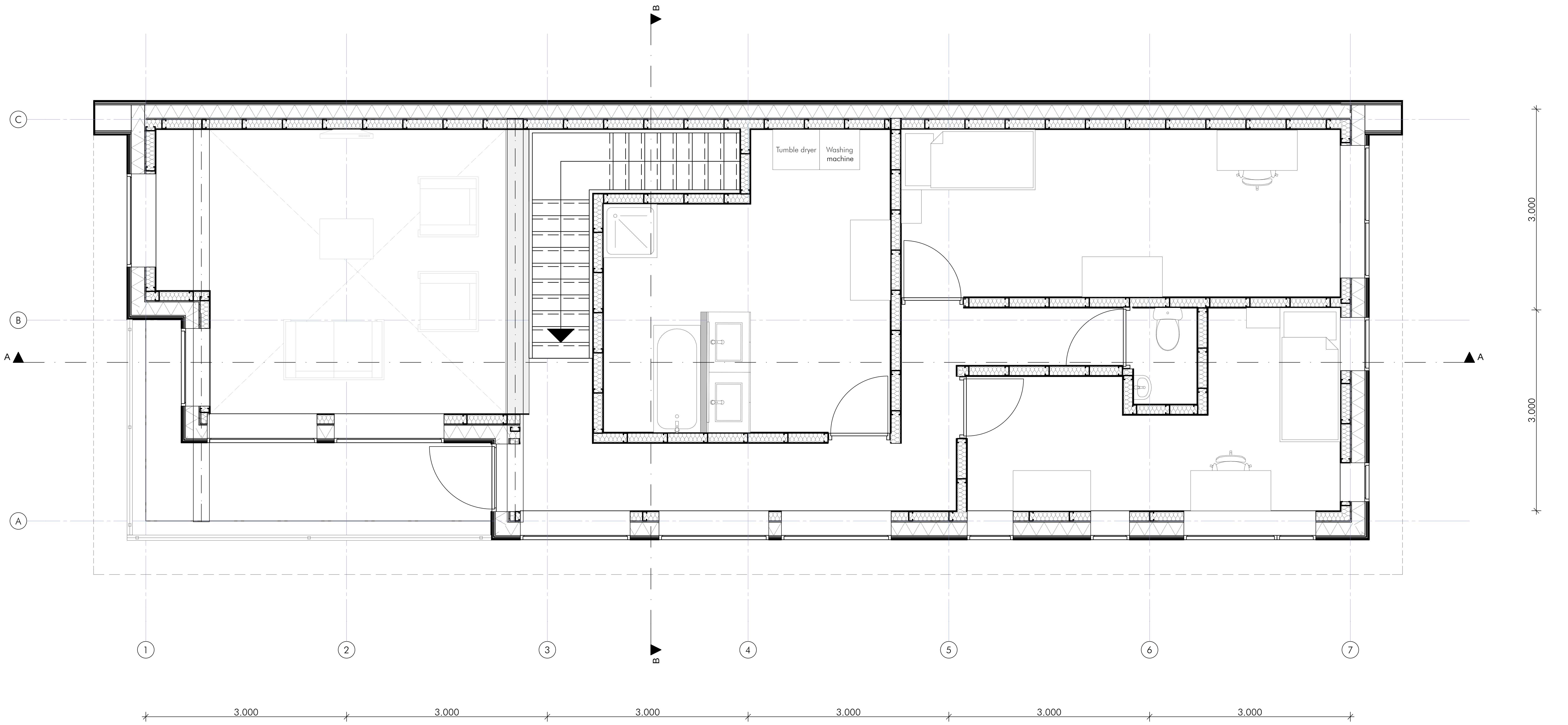
> DETAILS
A.01 t/m A.05, B.01 t/m B.05

> 3D
Exterior, interior

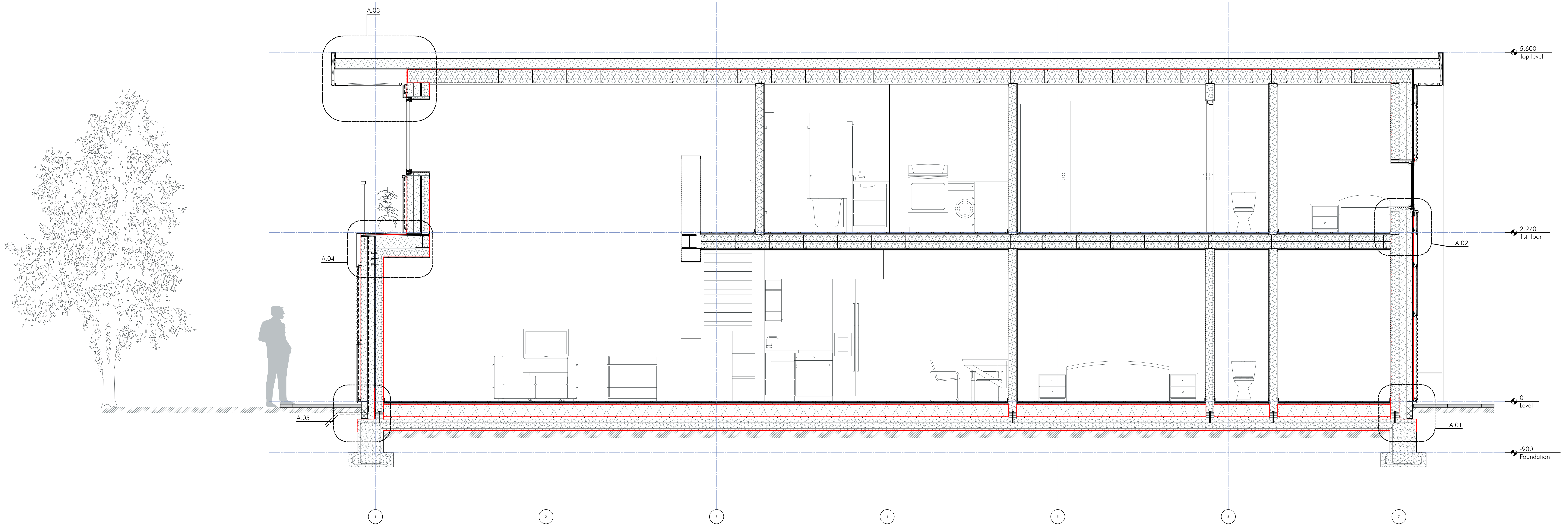
PLAN GROUND FLOOR 1:50



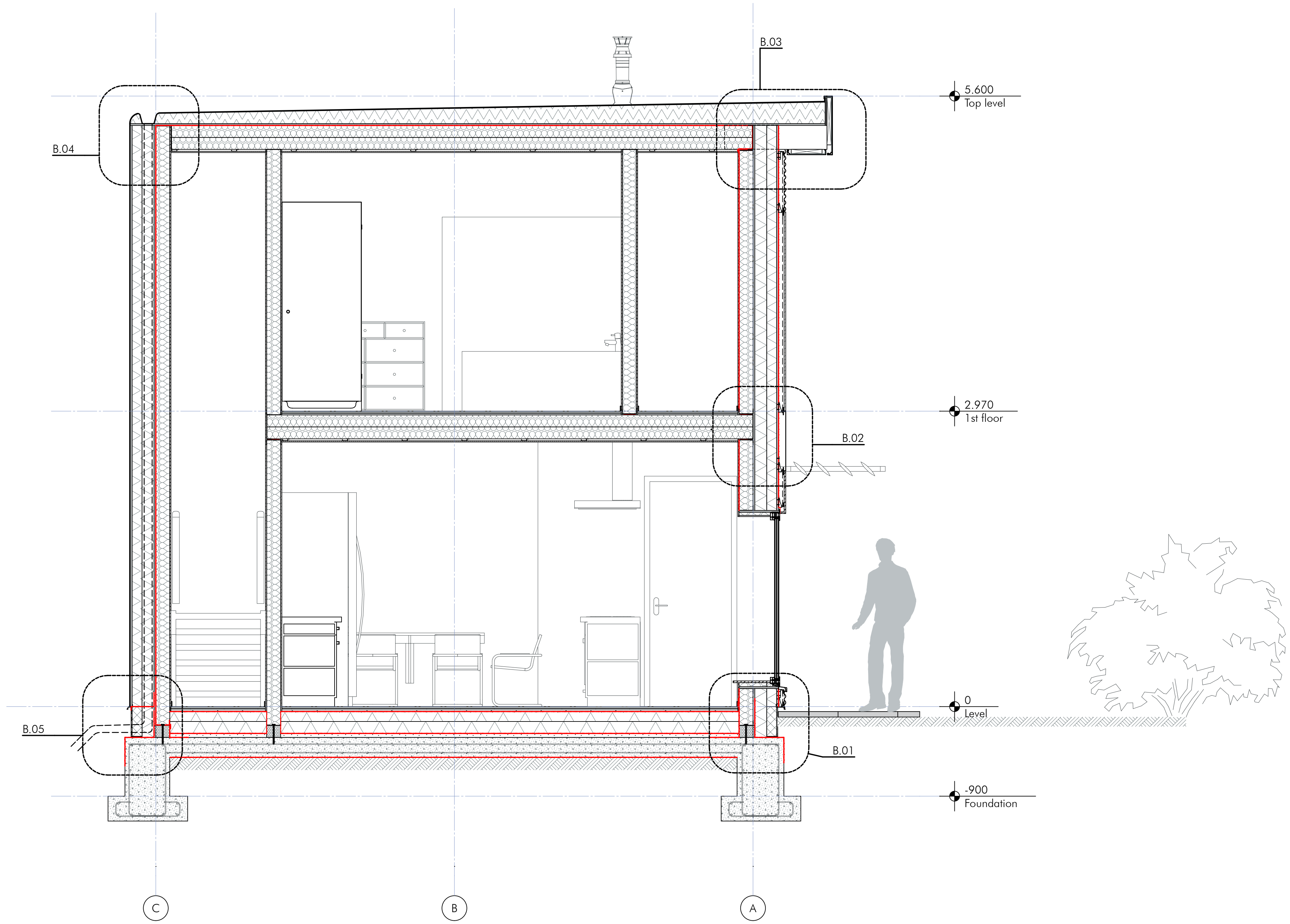
PLAN FIRST FLOOR 1:50



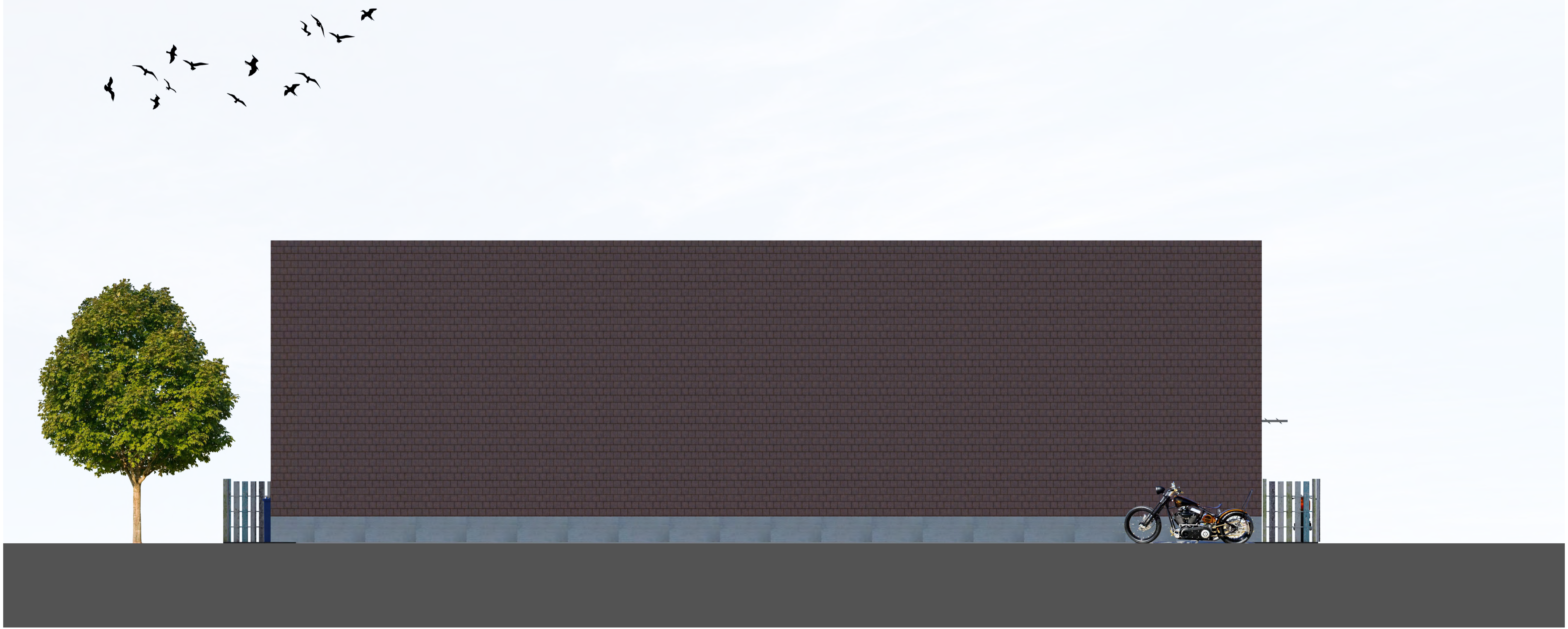
SECTION A-A 1:50



SECTION B-B 1:50



ELEVATION NORTH 1:50

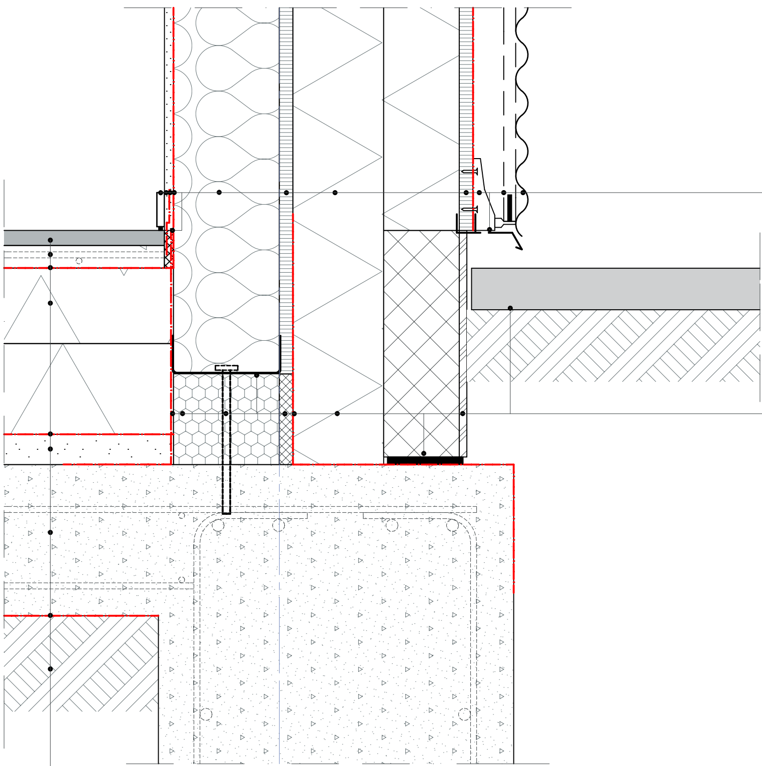


ELEVATION EAST 1:50

ELEVATION SOUTH 1:50

ELEVATION WEST 1:50

DETAIL A.01 1:10



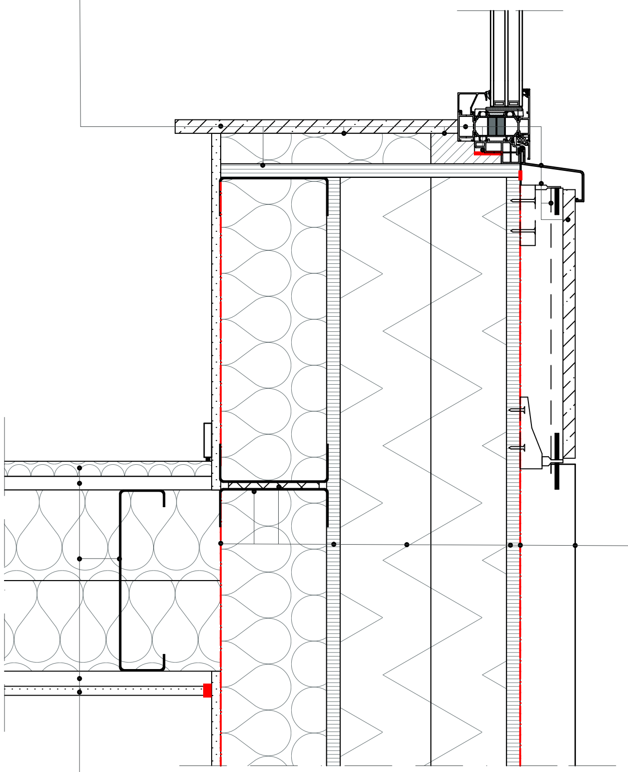
- Skirting
- 'Grey' plasterboard 12 mm
- Airtightness connecting piece
- Airtightness membrane
- Edge insulation
- Cotton insulation Metisse 140 mm
- C-profile Star-Frame 140
- OSB 18 mm
- Wood fibre insulation 120-100 mm
- OSB 18 mm
- Vapor-open, water-repellent membrane
- Aluminium weathering
- Halfen BA Body-anchor stainless steel
- Aluminium L profile for auxiliary structure
- Corrugated metal sheet 2 mm

- Airtightness membrane
- Foamglass Perinsul block 140 mm
- Bolt
- U-profiel Star-Frame 140
- Compressive XPS insulation 18 mm
- Vapor-open, water-repellent membrane
- Wood fibre insulation 120-100 mm
- Mortar layer with compressive strength
- Insulated edging 108 mm
- Rubber granulate terrace tile 55 mm

- Rubber granulate 20 mm
- Reinforced cement screed 30 mm
- PE-membrane
- Compressive XPS insulation 220 mm
- PE-membrane
- Cement layer 40 mm
- Reinforced concrete floor, poured on-site 200 mm, in accordance with engineer
- PE-membrane
- Full soil

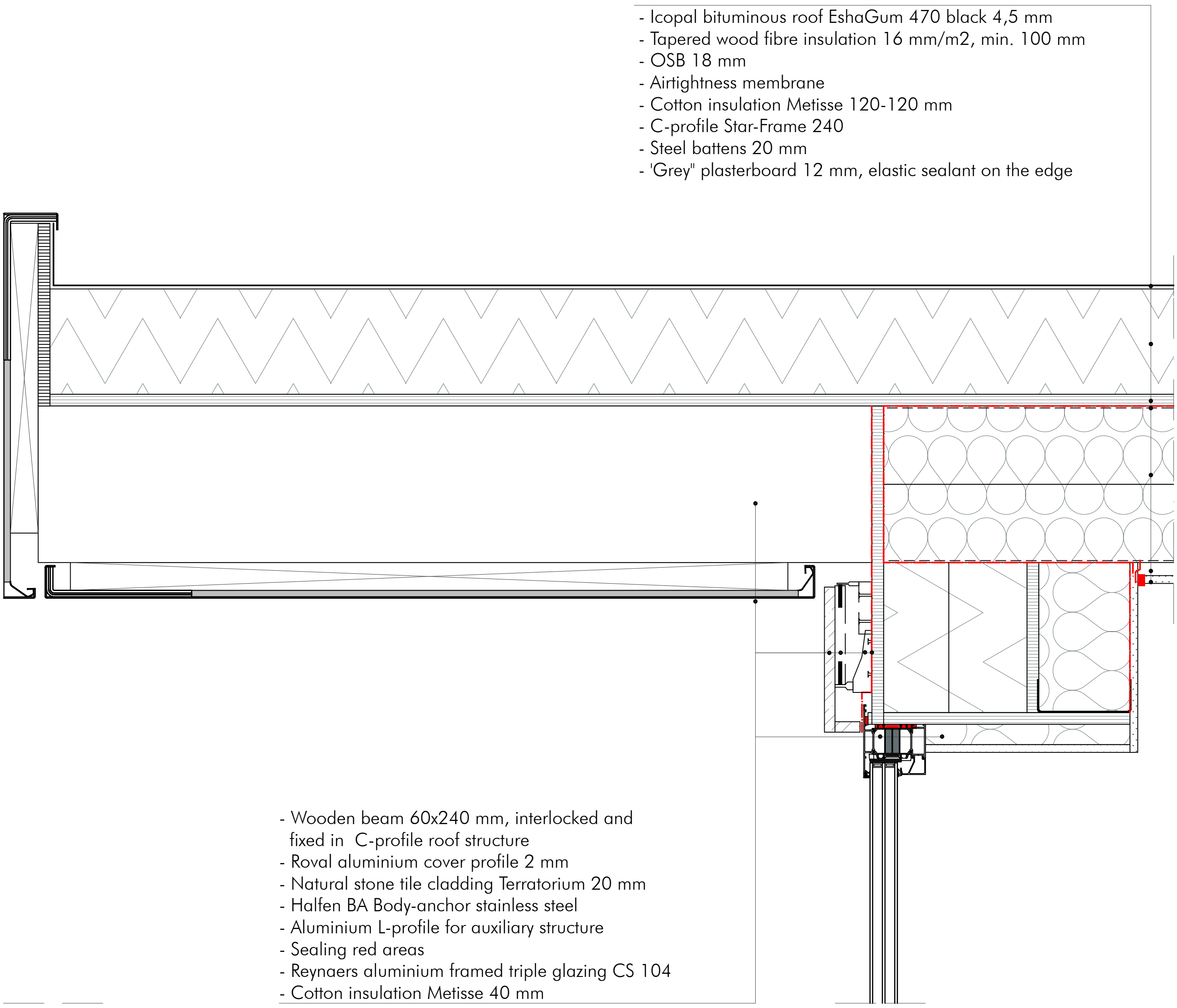
DETAIL A.02 1:10

- Window sill ceramic
- OSB 18 mm
- Cotton insulation Metisse 40 mm
- Wooden buck
- Reynaers aluminium framed triple glazing CS 104
- Sealing red areas
- Aluminium weathering
- Halfen BA Body-anchor stainless steel
- Aluminium L profile for auxiliary structure
- Ceramic tile cladding 20 mm

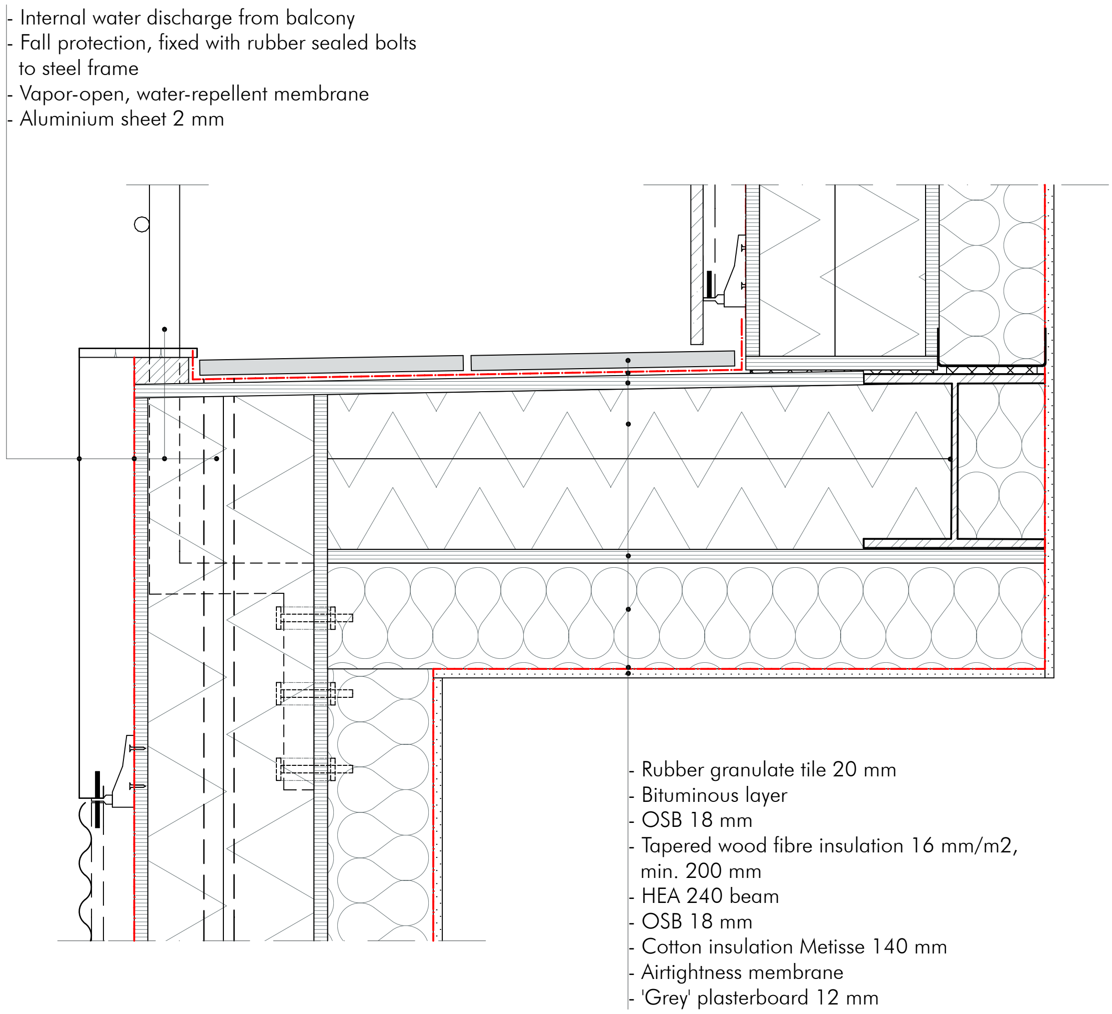


- Airtightness membrane
- U-profiel Star-Frame 140
- Felt and sealing
- Cotton insulation Metisse 140 mm
- OSB 18 mm
- Wood fibre insulation 120-100 mm
- OSB 18 mm
- Vapor-open, water-repellent membrane
- Aluminium sheet 2 mm

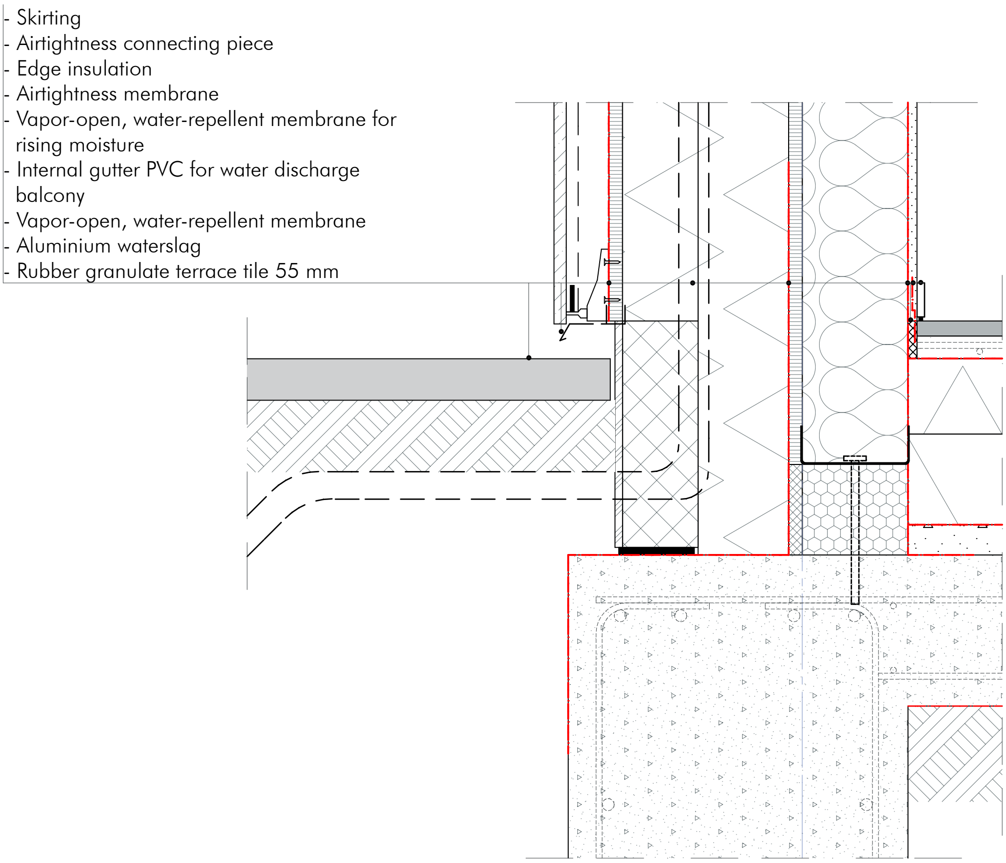
- Rubber granulate 20 mm
- OSB 18 mm
- Cotton insulation Metisse 240 mm
- C-profile Star-Frame 240
- Steel battens 20 mm
- 'Grey' plasterboard 12 mm, elastic sealant on the edge


- Icopal bituminous roof EshaGum 470 black 4,5 mm
- Tapered wood fibre insulation 16 mm/m2, min. 100 mm
- OSB 18 mm
- Airtightness membrane
- Cotton insulation Metisse 120-120 mm
- C-profile Star-Frame 240
- Steel battens 20 mm
- 'Grey" plasterboard 12 mm, elastic sealant on the edge
- Wooden beam 60x240 mm, interlocked and
fixed in C-profile roof structure
- Roval aluminium cover profile 2 mm
- Natural stone tile cladding Terratorium 20 mm
- Halfen BA Body-anchor stainless steel
- Aluminium L-profile for auxiliary structure
- Sealing red areas
- Reynaers aluminium framed triple glazing CS 104
- Cotton insulation Metisse 40 mm

DETAIL A.04 1:10



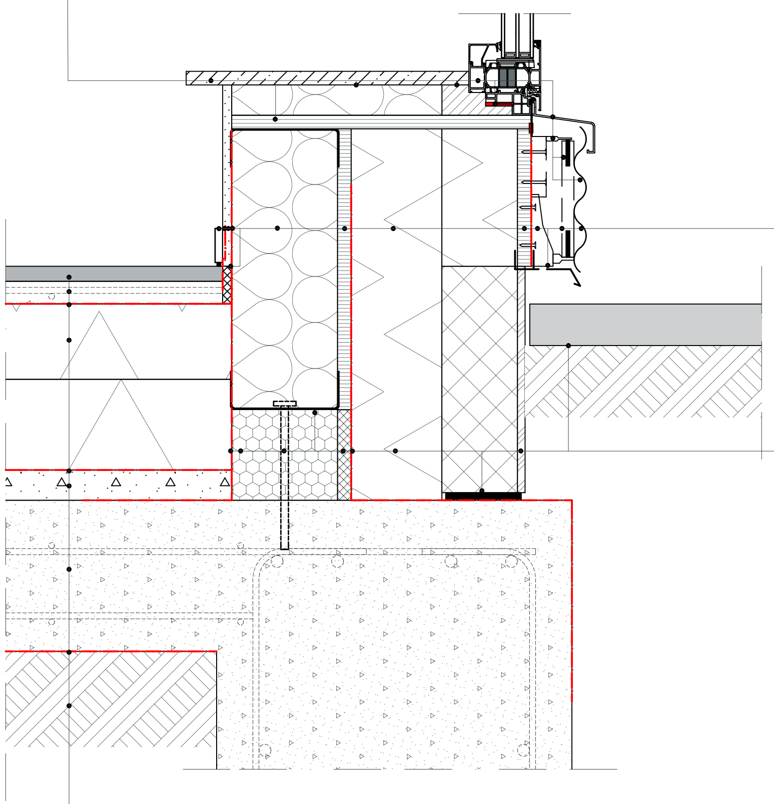
DETAIL A.05 1:10



DETAIL B.01 1:10

- Window sill ceramic
- OSB 18 mm
- Cotton insulation Metisse 40 mm
- Wooden buck
- Reynaers aluminium framed triple glazing CS 104
- Sealing red areas
- Aluminium weathering
- Halfen BA Body-anchor stainless steel
- Aluminium L profile for auxiliary structure
- Metal sheet cladding 2 mm

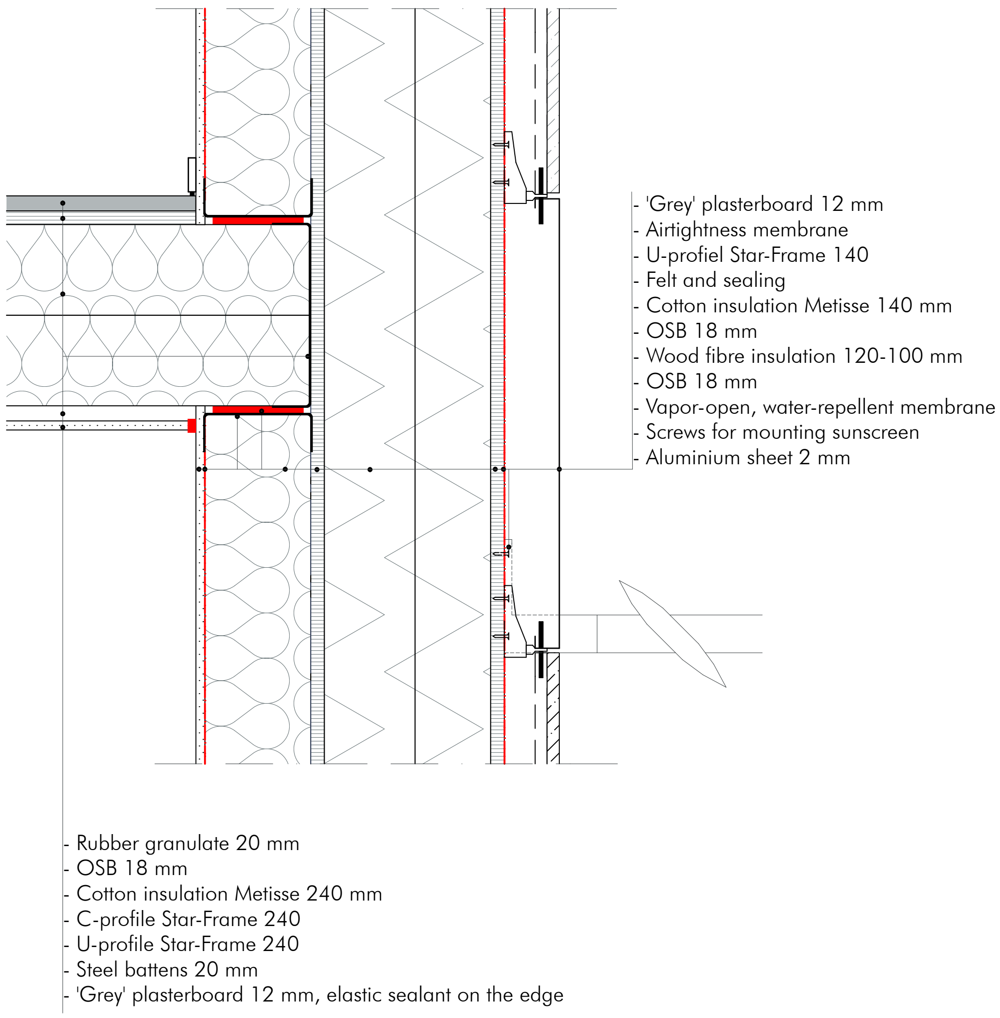
- Skirting
- 'Grey' plasterboard 12 mm
- Airtightness connecting piece
- Airtightness membrane
- Edge insulation
- Cotton insulation Metisse 140 mm
- C-profile Star-Frame 140
- OSB 18 mm
- Wood fibre insulation 120-100 mm
- OSB 18 mm
- Vapor-open, water-repellent membrane
- Aluminium weathering
- Halfen BA Body-anchor stainless steel
- Aluminium L profile for auxiliary structure
- Corrugated metal sheet 2 mm



- Airtightness membrane
- Foamglass Perinsul block 140 mm
- Bolt
- U-profiel Star-Frame 140
- Compressive XPS insulation 18 mm
- Vapor-open, water-repellent membrane
- Wood fibre insulation 120-100 mm
- Mortar layer with compressive strength
- Insulated edging 108 mm
- Rubber granulate terrace tile 55 mm

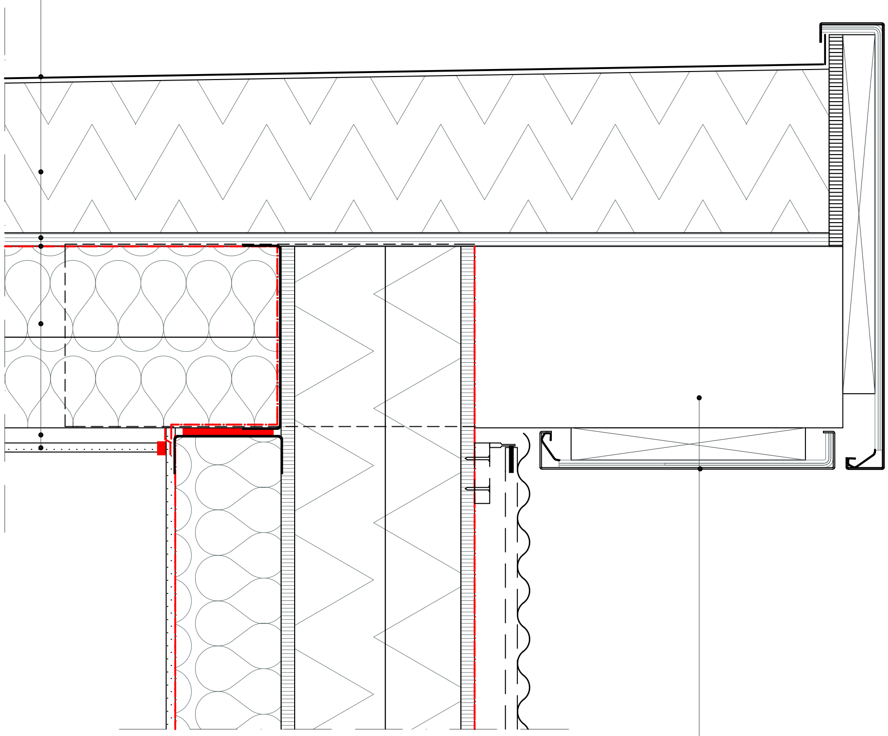
- Rubber granulate 20 mm
- Reinforced cement screed 30 mm
- PE-membrane
- Compressive XPS insulation 220 mm
- PE-membrane
- Cement layer 40 mm
- Reinforced concrete floor, poured on-site 200 mm, in accordance with engineer
- PE-membrane
- Full soil

DETAIL B.02 1:10



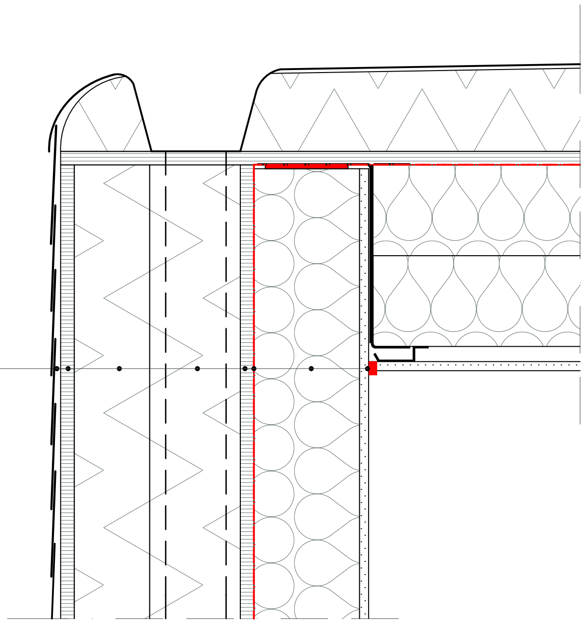
DETAIL B.03 1:10

- Icopal bituminous roof EshaGum 470 black 4,5 mm
- Tapered wood fibre insulation 16 mm/m2, min. 100 mm
- OSB 18 mm
- Airtightness membrane
- Cotton insulation Metisse 120-120 mm
- C-profile Star-Frame 240
- Steel battens 20 mm
- 'Grey" plasterboard 12 mm, elastic sealant on the edge



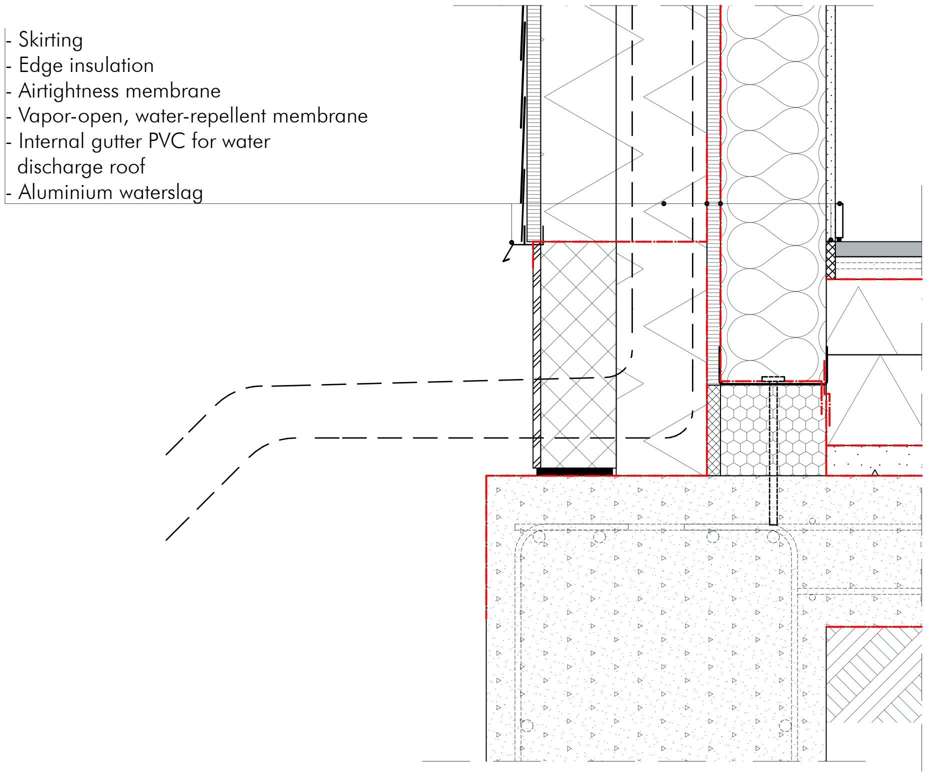
- Wooden beam 60x240 mm, interlocked and
  fixed in C-profile roof structure
- Roval aluminium cover profile 2 mm

DETAIL B.04 1:10



- 'Grey" plasterboard 12 mm, elastic sealant on the edge
- Cotton insulation Metisse 140 mm
- C-profile Star-Frame 140
- Airtightness membrane
- OSB 18 mm
- Interal water discharge from roof
- Wood fibre insulation 120-100 mm
- OSB 18 mm
- Icopal bituminous shingles black 4,5 mm

DETAIL B.05 1:10



CONVENTIONAL HOUSE

CONCEPT

The conventional house consists of materials that are mostly used in typical Dutch houses past decades. According to a dictionary (Van Dale) conventional literally means: ‘prescribed by the habit’.

For the housing design this means that the main body will consist of a traditional cavity wall: brick, insulation and lime-sandstone. Other conventional materials that will be used for an important part in the design are concrete, ceramic tiles, plaster and glass.

Having this idea of habits in mind, it would be interesting to project this to the appearance of the design. This meant basically following commonly used plans and arrangements: entrance with toilet and stairs, living room and kitchen on the ground floor, sleeping rooms and bathroom on the first floor.

This, together with the custom materials, resulted in a shape that is optimized for its function: the house prescribed by the habit.

The design of this concept did not bring along any compromises, since it should function as a baseline measurement. The only thing men could argue about, is the fact that ‘conventional’ can be personal as well, an therefore is will not mean the same to everybody.

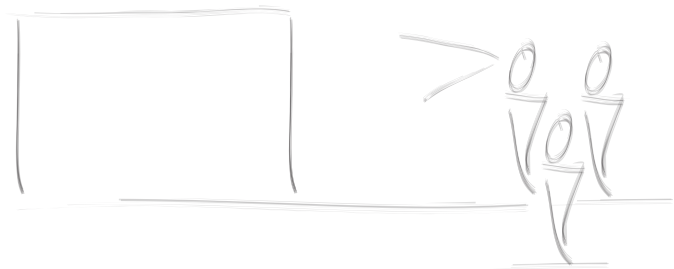


Fig. 27: Concept sketch conventional house

The structure consists of lime-sandstone for all walls, reinforced concrete slabs for the floor and wooden beams for the roof. One extra concrete column and beam is needed to support the floor there where large openings are made.

On the next pages you will find the list of materials, the Rc-values and the EPC-calculation (the result of this software is unfortunately in Dutch). After that follows the Maxergy result and all technical drawings.

Volume	583 m3
Floor space	179 m2
Bruto facade	251 m2
Windows east	11%
Windows south	39%
Windows west	14%

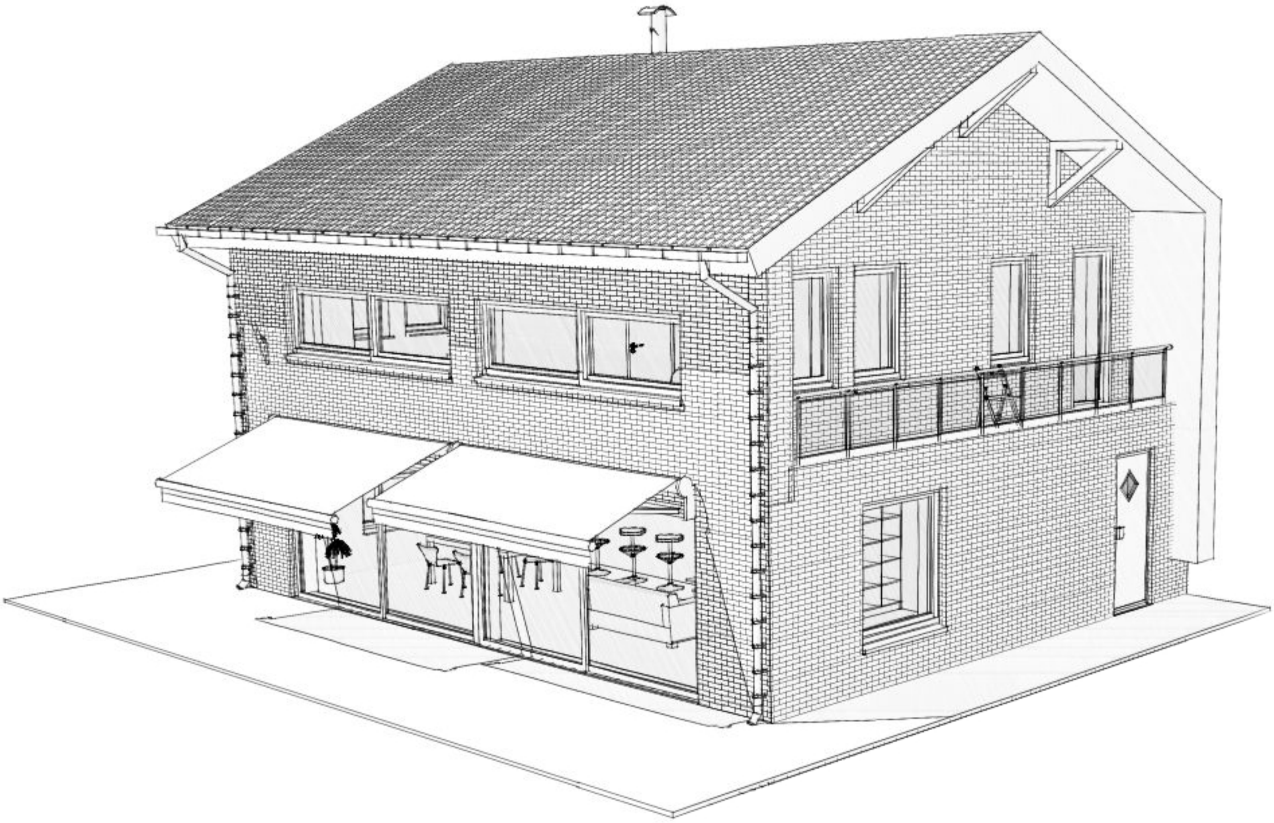


Fig. 28: 3D sketch conventional house

LIST OF MATERIALS

Building component	Material	Color	Thickness (m)	Surface (m2)	Specific weight (kg/m3)	Total weight (kg)
Foundation						
Reinforced concrete strip footing 39,2 m	Concrete			0,47	2400	44.217,60
	Steel				70 kg/m3	1.289,68
Ground floor						
Ceramic floor tiles	Clay	Grey	0,016	88,01	2000	2.816,32
Reinforced cement screed	Cement		0,05	88,01	2100	9.241,05
	Steel			88,01	5,175 kg/m2	455,45
PE membrane (3x)	Polyethylene		0,0002	88,01	0,94	0,05
Compressive XPS insulation	Extruded polystyrene		0,22	88,01	28	542,14
Cement layer	Cement		0,04	88,01	2100	7.392,84
Reinforced concrete floor	Concrete		0,2	88,01	2400	42.244,80
	Steel (2x)			88,01	5,175 kg/m2	910,90
Exterior wall // Ground floor // North						
Ceramic gable tile Wienerberger	Clay	Red		31,66	46 kg/m2	1.456,36
Battens 25x38 mm hoh 600	Deal wood			21 laths 2,600 m	460	13,63
PIR insulation	Polyisocyanurate		0,2	31,66	30	189,96
Lime-sandstone Silka	Lime-sand		0,12	31,66	1900	7.218,48
Stucco	Stucco	White	0,01	31,66	920	291,27
Exterior wall // Ground floor // East						
Brick Wienerberger Mangaan HW	Clay	Dark red	0,1	21,89	1450	3.174,05
PIR insulation	Polyisocyanurate		0,2	21,89	30	131,34
Lime-sandstone Silka	Lime-sand		0,12	21,89	1900	4.990,92
Stucco	Stucco	White	0,01	21,89	920	201,39
Window sill	Clay		0,016	0,2672	2000	8,55
Hardwood framed triple glazing	Glass		0,012	2,09	2500	62,70
	Eucalyptus wood	RAL 8014	0,114	0,90651	710	73,37
Hardwood framed door	Eucalyptus wood	RAL 8014	0,04	2	710	56,80
Window ledge	Concrete		0,165	2,088	1900	654,59
Exterior wall // Ground floor // South						
Brick Wienerberger Mangaan HW	Clay	Dark red	0,1	11,55	1450	1.674,75
PIR insulation	Polyisocyanurate		0,2	11,55	30	69,30
Lime-sandstone Silka	Lime-sand		0,12	11,55	1900	2.633,40
Stucco	Stucco	White	0,01	11,55	920	106,26
Hardwood framed triple glazing	Glass		0,012	18,24	2500	547,20
	Eucalyptus wood	RAL 8014	0,114	1,844	710	149,25
Window ledge	Concrete		0,165	7,1888	1900	2.253,69
Exterior wall // Ground floor // West						
Brick Wienerberger Mangaan HW	Clay	Dark red	0,1	21,8	1450	3.161,00
PIR insulation	Polyisocyanurate		0,2	21,8	30	130,80
Lime-sandstone Silka	Lime-sand		0,12	21,8	1900	4.970,40
Stucco	Stucco	White	0,01	21,8	920	200,56
Window sill	Clay		0,016	0,5344	2000	17,10
Hardwood framed triple glazing	Glass		0,012	4,18	2500	125,40
	Eucalyptus wood	RAL 8014	0,114	0,9112	710	73,75
Window ledge	Concrete		0,165	2,56	1900	802,56
Interior wall // Ground floor						
Stucco	Stucco	Brown	0,01	61,1	1900	1.160,90
Lime-sandstone Silka	Lime-sand		0,2	61,1	50	611,00
Stucco	Stucco		0,01	61,1	1900	1.160,90
Upper floor						
Parquet floor	Oak wood		0,016	90,72	700	1.016,06
Cement screed	Cement		0,05	90,72	2100	9.525,60
Wide slab floor	Concrete		0,28	90,72	2400	60.963,84
	Steel (3x)			90,72	5,175 kg/m2	1.408,43
Exterior wall // First floor // North						
Ceramic gable tile Wienerberger	Clay	Red		41,28	46 kg/m2	1.898,88
Battens 25x38 mm hoh 600	Deal wood			21 laths 3,374 m	460	30,96
PIR insulation	Polyisocyanurate		0,2	41,28	30	247,68
Lime-sandstone Silka	Lime-sand		0,12	41,28	1900	9.411,84
Stucco	Stucco	White	0,01	41,28	920	379,78
Exterior wall // First floor // East						
Brick Wienerberger Delttageel	Clay	Yellow	0,1	27,66	1450	4.010,70
PIR insulation	Polyisocyanurate		0,2	27,66	30	165,96
Lime-sandstone Silka	Lime-sand		0,12	27,66	1900	6.306,48
Stucco	Stucco	White	0,01	27,66	920	254,47
Window sill	Clay		0,016	0,501	2000	16,03
Hardwood framed triple glazing	Glass		0,012	4,54	2500	136,20
	Eucalyptus wood	RAL 8014	0,114	1,454034	710	117,69
Window ledge	Concrete		0,165	3,2272	1900	1.011,73
Exterior wall // First floor // South						
Brick Wienerberger Mangaan HW	Clay	Dark red	0,1	25,29	1450	3.667,05
PIR insulation	Polyisocyanurate		0,2	25,29	30	151,74
Lime-sandstone Silka	Lime-sand		0,12	25,29	1900	5.766,12
Stucco	Stucco	White	0,01	25,29	920	232,67
Window sill	Clay		0,016	1,336	2000	42,75
Hardwood framed triple glazing	Glass		0,012	5,52	2500	165,60
	Eucalyptus wood	RAL 8014	0,114	1,474	710	119,31
Window ledge	Concrete		0,165	6,4	1900	2.006,40

Exterior wall // First floor // West						
Brick Wienerberger Mangaan HW	Clay	Dark red	0,1	28,44	1450	4.123,80
PIR insulation	Polyisocyanurate		0,2	28,44	30	170,64
Lime-sandstone Silka	Lime-sand		0,12	28,44	1900	6.484,32
Stucco	Stucco	White	0,01	28,44	920	261,65
Window sill	Clay		0,016	0,668	2000	21,38
Hardwood framed triple glazing	Glass		0,012	3,76	2500	112,80
	Eucalyptus wood	RAL 8014	0,114	0,67	710	54,23
Window ledge	Concrete		0,165	3,2	1900	1.003,20
Interior wall First floor						
Stucco	Stucco	White	0,01	150,5	1900	2.859,50
Lime-sandstone Silka	Lime-sand		0,2	150,5	50	1.505,00
Stucco	Stucco	White	0,01	150,5	1900	2.859,50
Structure						
HEA 140 beam	Steel		0,0816	1 beam 4,300 m	25,01 kg/m	107,54
HEA 140 column	Steel		0,048	1 column 2,600 m	25,01 kg/m	65,03
Roofbeam wood 100x300	Douglas			5 beams 9,750 m	530	755,13
Stair	Oak wood		0,06	5,24	700	220,08
Roof						
Ceramic roof tile Wienerberger	Clay	Red		121,55	46 kg/m2	5.591,30
Battens 25x38 mm hoh 600	Deal wood			18 laths12,336 m	460	97,03
Counter battens 20x30 mm hoh 600	Deal wood			72 laths 5,500 m	460	109,30
Bearing stiffener 19x45 mm	Deal wood			96 Laths 5,500 m	460	207,66
PIR insulation	Polyisocyanurate		0,225	121,55	30	820,46
S-membrane (2x)	High Density Polyethylene		0,0002	121,55	0,96	0,02
Chipboard (2x)	Particle wood		0,003	121,55	600	218,79
Plasterboard	Plaster		0,012	121,55	1000	1.458,60
Fascia board WBP	Plywood	RAL 9002	0,018	20,68528	510	189,89
Gutter	Sink	Grey	0,001	8,296	7200	59,73

Total materials	**Weight (kg)**
Concrete	155.158,40
Steel	4.237,03
Cement	26.159,49
Polyethylene	0,05
Extruded polystyrene	542,14
Clay - Ceramic floor tiles and window sills	2.922,13
Clay - Brick	19.811,35
High Density Polyethylene	0,02
Polyisocyanurate	2.077,88
Lime-sand	49.897,96
Stucco	33.020,74
Glass	1.149,90
Eucalyptus wood	644,40
Clay - Ceramic gable tile	8.946,54
Deal wood	677,38
Particle wood	218,79
Plywood	189,89
Plaster	1.458,60
Oak wood	1.236,14
Sink	59,73
Douglas wood	755,13
	309.163,71

RC-VALUE GROUND FLOOR

Ti = 20 °C
Te = -10 °C

φi = 60 %
φe = 50 %

Ri en Re = Vloer in contact met gro

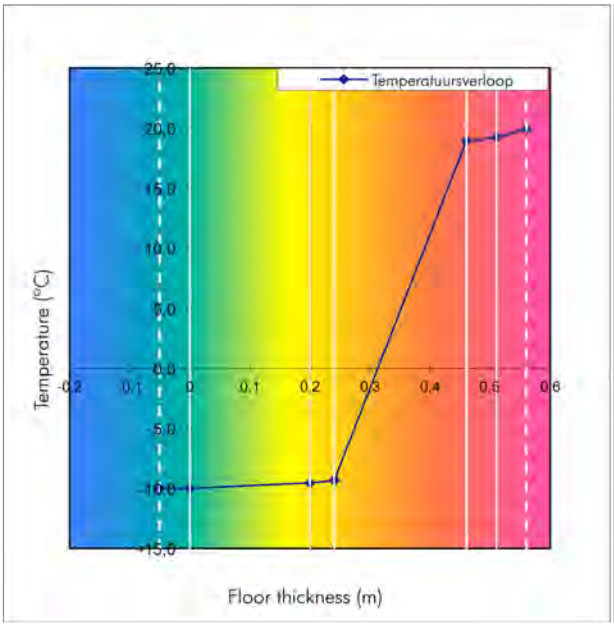
Element = α -

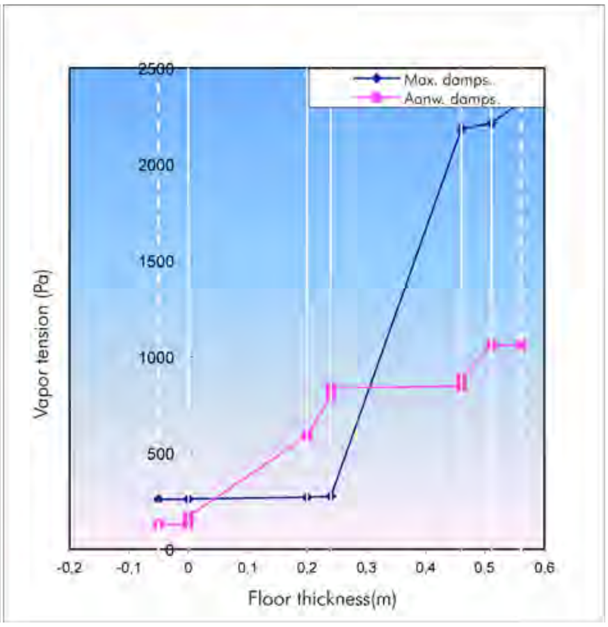
Gebruiksfunctie Woonfunctie

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,00	0,0						
					-10,0	260				130
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	42	
					-10,0	261				172
Reinforced concrete	0,2	2	0,10	0,4			10	2	417	
					-9,5	271				589
Cement layer	0,04	0,9	0,04	0,2			25	1	208	
					-9,3	276				797
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	42	
					-9,3	276				839
XPS insulation	0,22	0,035	6,29	28,3			0,159	0,03498	7	
					18,9	2184				846
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	42	
					18,9	2184				888
Reinforced cement screed	0,05	0,9	0,06	0,2			16,67	0,8335	174	
					19,2	2212				1061
Ceramic floor tiles	0,016	1,5	0,01	0,0			100	1,6	334	
Ri			0,17	0,8						
Inside air					20,0	2325				1061
Totaal:	0,53	Rl =	6,67	30,00			μ =	6,07	1265	

Vapor pressure difference	Temperature factor thermal bridge
Dampsp. = 1395 Pa	(F) Eis = 0,65
Dampsp. = 130 Pa	F = (Tio-Te) / (Ti-Te)= 0,97 Sufficient
Δ Dampsp = 1265 Pa	

Rc = 6,5 m²K/W	Rl = 6,67 m²K/W	U = 0,15 W/m²K





RC-VALUE EXTERIOR WALLS

Ti = 20 °C
Te = -10 °C

φi = 60 %
φe = 50 %

Ri en Re = Buitenmuur Bi»Bu

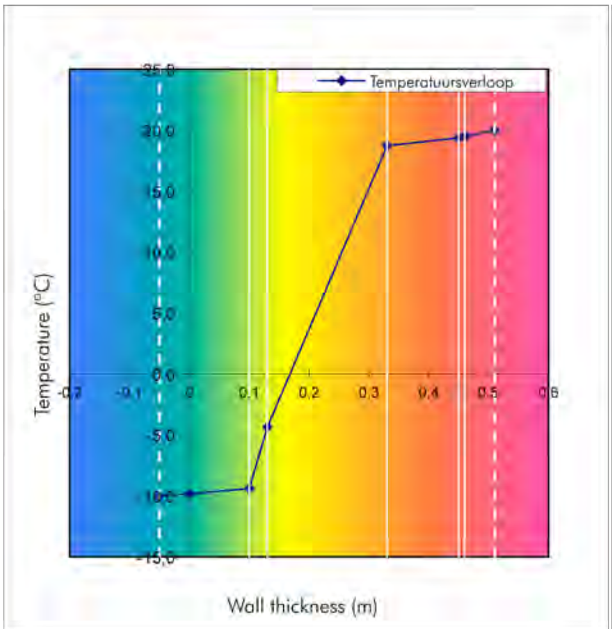
Element = α -

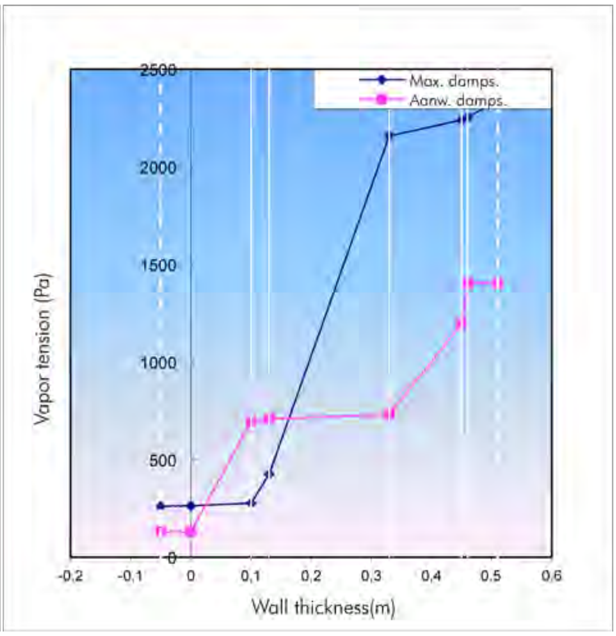
Gebruiksfunctie Woonfunctie

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,04	0,2						
					-9,8	264				130
Brick	0,1	0,91	0,11	0,4			9,09	0,909	565	
					-9,4	276				695
Air cavity	0,03	0,024	1,25	5,0			0,8	0,024	15	
					-4,3	425				710
PIR insulation	0,2	0,035	5,71	23,1			0,175	0	22	
					18,7	2157				731
Lime-sandstone	0,12	0,75	0,16	0,6			6,25	0,75	466	
					19,4	2240				1197
Stucco	0,01	0,37	0,03	0,1			33,3	0,333	207	
					19,5	2253				1404
	0	1	0,00	0,0			0	0	0	
					19,5	2253				1404
	0	1	0,00	0,0			0	0	0	
					19,5	2253				1404
Ri			0,13	0,5						
Inside air					20,0	2340				1404
Totaal:	0,46	Rl =	7,43	30,00			μ =	2,05	1274	

Vapor pressure difference	Temperature factor thermal bridge
Dampsp. = 1404 Pa Dampsp. = 130 Pa Δ Dampsp = 1274 Pa	(F) Eis = 0,65 F = (Tio-Te) / (Ti-Te) = 0,98 Sufficient

Rc = 7,3 m²K/W	Rl = 7,43 m²K/W	U = 0,13 W/m²K





RC-VALUE ROOF

Ti = 20 °C
Te = -10 °C

φi = 60 %
φe = 50 %

Ri en Re = Vloer in contact met gro[nd]

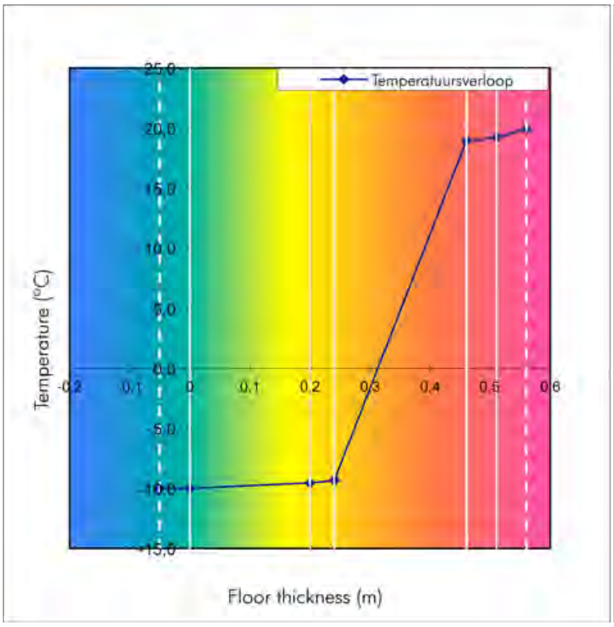
Element = α: -

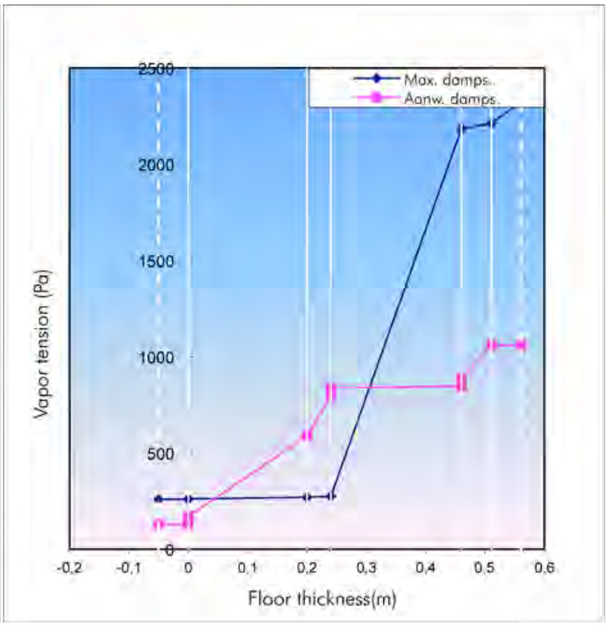
Gebruiksfunctie: Woonfunctie

	d	λ	R	ΔT	T	Pmax	μ	μ*d	ΔPw	Pw
Structure layer	m	W/mK	m²K/W	°C	°C	Pa	-	m	Pa	Pa
Outside air					-10	260				130
Re			0,00	0,0						
					-10,0	260				130
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	42	
					-10,0	261				172
Reinforced concrete	0,2	2	0,10	0,4			10	2	417	
					-9,5	271				589
Cement layer	0,04	0,9	0,04	0,2			25	1	208	
					-9,3	276				797
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	42	
					-9,3	276				839
XPS insulation	0,22	0,035	6,29	28,3			0,159	0,03498	7	
					18,9	2184				846
PE membrane	0,0002	0,2	0,00	0,0			1000	0,2	42	
					18,9	2184				888
Reinforced cement screed	0,05	0,9	0,06	0,2			16,67	0,8335	174	
					19,2	2212				1061
Ceramic floor tiles	0,016	1,5	0,01	0,0			100	1,6	334	
Ri			0,17	0,8						
Inside air					20,0	2325				1061
Totaal:	0,53	Rl =	6,67	30,00			μ =	6,07	1265	

Vapor pressure difference	Temperature factor thermal bridge
Dampsp. = 1395 Pa	(F) Eis = 0,65
Dampsp. = 130 Pa	F = (Tio-Te) / (Ti-Te) = 0,97 Sufficient
Δ Dampsp = 1265 Pa	

Rc = 6,5 m²K/W	Rl = 6,67 m²K/W	U = 0,15 W/m²K





EPC-CALCULATION

ALGEMENE GEGEVENS

Projectomschrijving	:	Conventional
Bestandsnaam	:	L:\EPW v2.0\Conventional.epw
Omschrijving bouwwerk	:	
Adres	:	
Soort bouwwerk	:	Woonfunctie
EPC-eis	:	0,6

INDELING GEBOUW

Type	*Omschrijving zone*	*Ag [m²]*
Verwarmd	Begane grond	88,01
Verwarmd	1e Verdieping	90,72
		------------- +
totaal		178,73

BOUWKUNDIGE GEGEVENS - TRANSMISSIE

Definitie scheidingsconstructies zone: Begane grond

constructie	*begrenzing*	*constructiedeel*	*A*	*Hkr*	*Rc*	*U*	*ZTA*	*helling*	*zon-*	*beschaduwing*
			[m²]	*[m]*	*[m²K/W]*	*[W/m²K]*	*[-]*	*[°]*	*wering*	
Vloer	grond	Beton	88,0		6,50	0,09				
Gevel noord	buiten, N	Spouwmuur pannen	31,7		8,00	0,12				
Gevel oost	buiten, O	Spouwmuur	21,9		7,30	0,13				
		Deur	2,0		0,60	1,30				
		Ramen	2,1			0,80	0,50	90	nee	maximale belemmering
Gevel zuid	buiten, Z	Spouwmuur	11,6		7,30	0,13				
		Ramen	18,2			0,80	0,50	90	ja	minimale belemmering
Gevel west	buiten, W	Spouwmuur	21,8		7,30	0,13				
		Ramen	4,2			0,80	0,50	90	nee	maximale belemmering
			---------- +							
Totaal			201,4							

Definitie scheidingsconstructies zone: 1e Verdieping

constructie	*begrenzing*	*constructiedeel*	*A*	*Hkr*	*Rc*	*U*	*ZTA*	*helling*	*zon-*	*beschaduwing*
			[m²]	*[m]*	*[m²K/W]*	*[W/m²K]*	*[-]*	*[°]*	*wering*	
Gevel noord	buiten, N	Spouwmuur pannen	41,8		8,00	0,12				
Gevel oost	buiten, O	Spouwmuur	27,7		7,30	0,13				
		Ramen	4,5			0,80	0,50	90	nee	constante overstek
Gevel zuid	buiten, Z	Spouwmuur	25,3		7,30	0,13				
		Ramen	5,5			0,80	0,50	90	nee	constante overstek
Gevel west	buiten, W	Spouwmuur	28,4		7,30	0,13				
		Ramen	3,8			0,80	0,50	90	nee	maximale belemmering
Dak	buiten, boven	Unidek met pannen	121,5		8,00	0,12				
			---------- +							
Totaal			258,6							

BOUWKUNDIGE GEGEVENS - BELEMMERINGEN EN OVERSTEKKEN

Definitie beschaduwing zone: 1e Verdieping

constructie	*constr.deel*	*beschaduwing*	*belemmeringen*				*overstekken*				*besch.factor*
			1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	
Gevel oost	Ramen	constante overstek	20	20	20	20	20	90	90	20	0,80
Gevel zuid	Ramen	constante overstek	20	20	20	20	20	90	90	20	0,90

BOUWKUNDIGE GEGEVENS - LINEAIRE KOUDEBRUGGEN

Er is gerekend volgens de forfaitaire methode m.b.t. de koudebruggen.

Bij de forfaitaire methode wordt een correctie op de U-waarde toegepast.

Definitie lineaire koudebruggen zone: Begane grond

constructie	*begrenzing*	*koudebrug*	*P*
			[m]
Vloer	grond	Perimeter	37,78

Definitie lineaire koudebruggen zone: 1e Verdieping

Voor deze zone zijn geen gegevens voor lineaire koudebruggen ingevoerd

BOUWKUNDIGE GEGEVENS - INFILTRATIE

qv10;kar/m² van de woonfunctie: 0,150 [dm³/sm²]

BOUWKUNDIGE GEGEVENS - THERMISCHE CAPACITEIT

bouwtype van de woonfunctie: traditioneel, gemengd zwaar

INSTALLATIE W - VERWARMING EN HULPENERGIE

Verwarmingssysteem 1 - Verwarming 1

verwarmingstoestel	type toestel	: individuele electrische warmtepomp, voldoet aan tabel B2
	bron warmtepomp	: bodem
	aanvoertemperatuur	: 35°C < T <= 45°C
installatiekenmerken	individuele bemetering	: ja
	installatie voorzien van buffervat	: nee
	type verwarmingslichaam	: overig (bijv. radiatoren)
	opwekkingsrendement (Nopw;verw)	: 1,950 [-]
	systeemrendement (Nsys;verw)	: 0,950 [-]
hulpenergie	aantal ketels-cv/luchtverwarmers met waakvlam	: 0
	gasketels-cv	: niet voorzien van ventilator
		: niet voorzien van elektronica
		: geen circulatiepomp aanwezig
	warmtepomp	: geen circulatiepomp aanwezig
	individuele warmtepomp	: geen parallel buffervat aanwezig
	gebouwgebonden warmte-kracht	: lengte circulatieleiding 0,00 km
aangewezen zones:	Begane grond	
	1e Verdieping	

INSTALLATIE W - WARMTAPWATER

nr.	opwekkingstoestel	klasse	Nopw;tap [-]	qv;wp [dm³/s]	aantal badr	aantal aanr	Lbadr [m]	Laanr [m]	Lcirc [m]	d;inw [mm]
1	warmtepomp, retourlucht als bron (Bijlage C)	1	0,850	0,00	1	1	6-8	8-10	0,0	<= 10

INSTALLATIE W - VENTILATIE

Ventilatie verwarmde zone: Begane grond

ventilatievoorziening	:	mechanische luchttoe- en afvoer
type warmteterugwinning	:	tegenstroom-warmtewisselaar
Nwtw	:	0,75
regelbaar door bewoners	:	ja
toevoer in zomer	:	toevoer uitschakelbaar
bypass aanwezig	:	luchttoevoerventilator uitschakelbaar of 100% bypass
type voorverwarming	:	voorverwarming door warmteterugwinning

Ventilatie verwarmde zone: 1e Verdieping

ventilatievoorziening	:	mechanische luchttoe- en afvoer
type warmteterugwinning	:	tegenstroom-warmtewisselaar
Nwtw	:	0,75
regelbaar door bewoners	:	ja
toevoer in zomer	:	toevoer uitschakelbaar
bypass aanwezig	:	luchttoevoerventilator uitschakelbaar of 100% bypass
type voorverwarming	:	voorverwarming door warmteterugwinning

INSTALLATIE W - VENTILATOREN

omschrijving zone	*type ventilator*
Begane grond	gebalanceerde ventilatie, wisselstroom
1e Verdieping	gebalanceerde ventilatie, wisselstroom

INSTALLATIE W - KOELING

koelsysteem:	type toestel	:	geen koelmachine aanwezig
	vrije koeling	:	nee
	opwekkingsrendement voor koeling (Nopw;koel)	:	0,000 [-]
	systeemrendement voor koeling (Nsys;koel)	:	0,000 [-]

INSTALLATIE E - VERLICHTING

omschrijving zone	*Ag [m²]*	*Qprim;vl [MJ]*
Begane grond	88,0	4965
1e Verdieping	90,7	5118
	------------ +	------------ +
totaal	178,7	10082

RESULTATEN - ENERGIEPRESTATIEGEGEVENS

verwarming	Qprim;verw	11406 MJ
hulpenergie	Qprim;hulp;verw	0 MJ
warmtapwater	Qprim;tap	19259 MJ
ventilatoren	Qprim;vent	8744 MJ
verlichting	Qprim;vl	10082 MJ
zomercomfort	Qzom;comf	1424 MJ
koeling	Qprim;koel	0 MJ
bevochtiging	Qprim;bev	0 MJ
comp. PV-cellen	Qprim;pv	0 MJ
comp. WK	Qprim;comp;WK	0 MJ
		---------------- +
totaal	Qpres;tot	50915 MJ
	Qpres;toel	97624 MJ

Qpres;totaal /	((330 *	Ag;verw	+ 65 *	Averlies	) *	Cepc	) =	EPC	
50915		178,7		433,6		1,12		0,53	Epc voldoet

RESULTATEN - INFORMATIEF

CO2-emissie	3435 kg	

Risico te hoge temperaturen [TOjuli]

Omschrijving zone	*TOjuli*	
Begane grond	0,69	(laag - matig risico)
1e Verdieping	0,65	(laag - matig risico)

RESULTATEN - AANDACHTSPUNTEN

Verwarmingssysteem '1 - Verwarming 1': er is geen hulpenergie gespecificeerd.

Er is nog geen waarde voor de luchtvolumestroom qv;wp ingevuld.

Indien geen gemeten waarde beschikbaar is geldt qv;wp=0.44*Ag;verwz met een minimum van 44 dm3/s.

The intention to keep the operational energy on the same level for all the houses, seems to work out quite well: see figures [29] and [30] to confirm that there is, just as well as in the other two houses , a large difference between the Embodied Land of the operational energy and of the materials.

Something else that results from this baseline measurement is the notion that the Embodied Land of the materials is almost of exactly the same level as the recycled house.

Again, the weight of the materials is fully out of proportion compared to the Embodied Land of all individual materials, see the figures [29] en [30]. It is actually quite remarkable that all other materials are completely dwarfed by concrete, steel and cement.

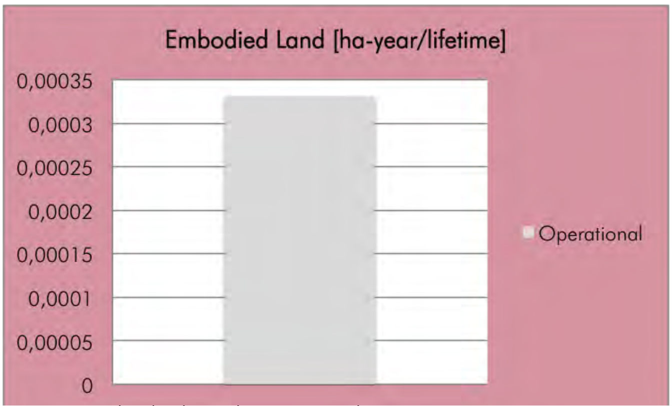


Fig. 29: Embodied Land operational energy

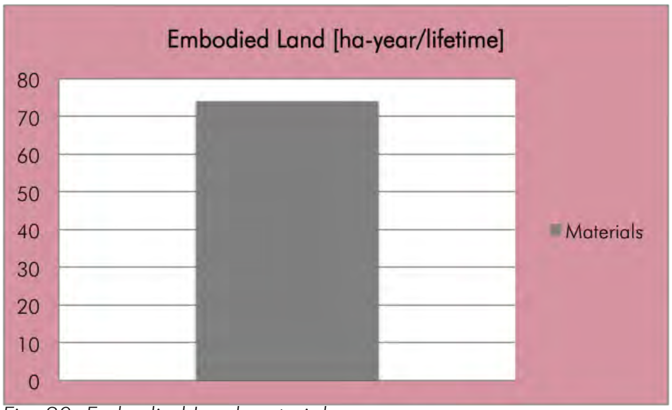


Fig. 30: Embodied Land materials

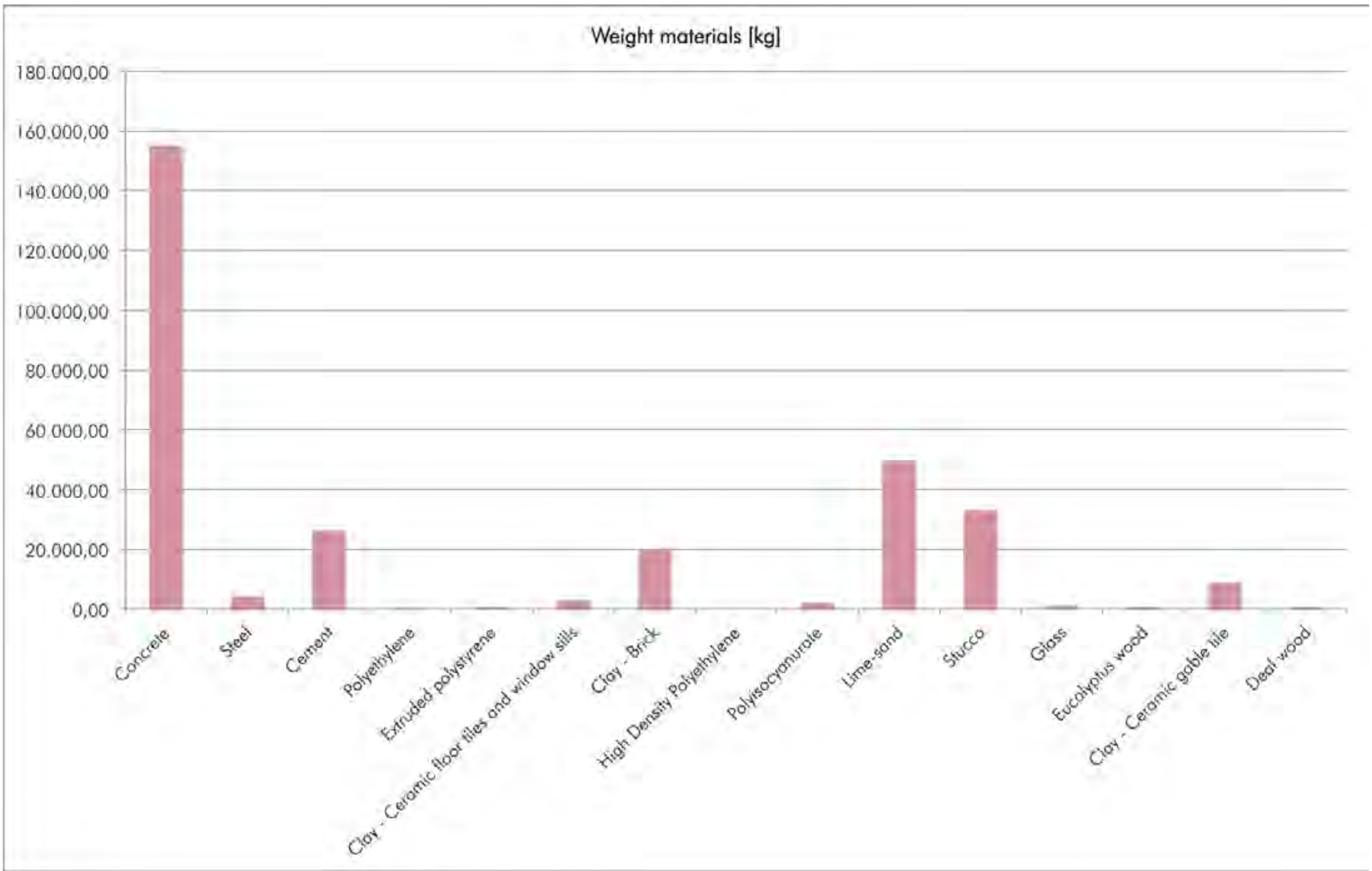


Fig. 31: Weight of all materials

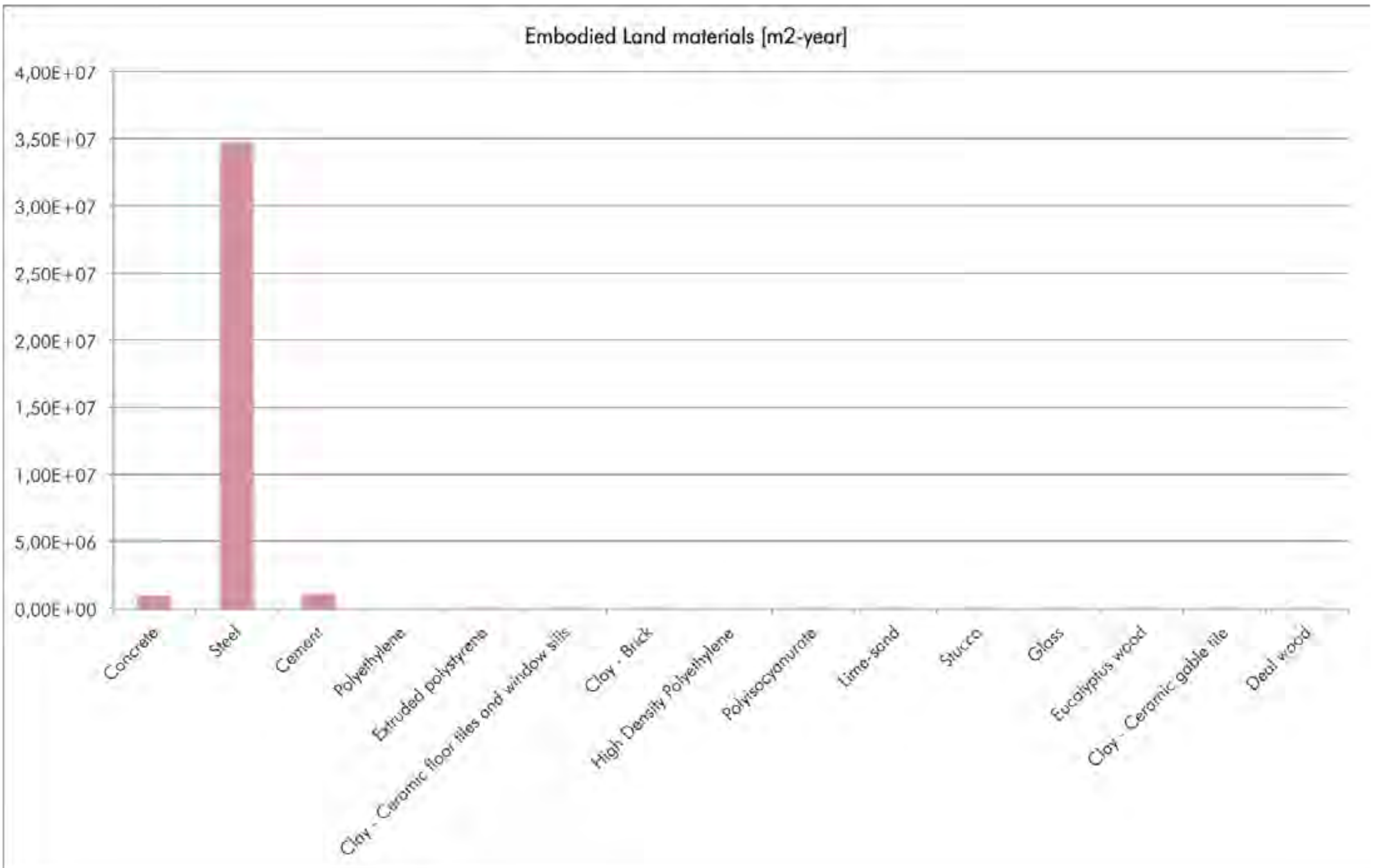


Fig. 32: Embodied Land of all materials

DRAWINGS

> PLANS
Ground floor, 1st floor

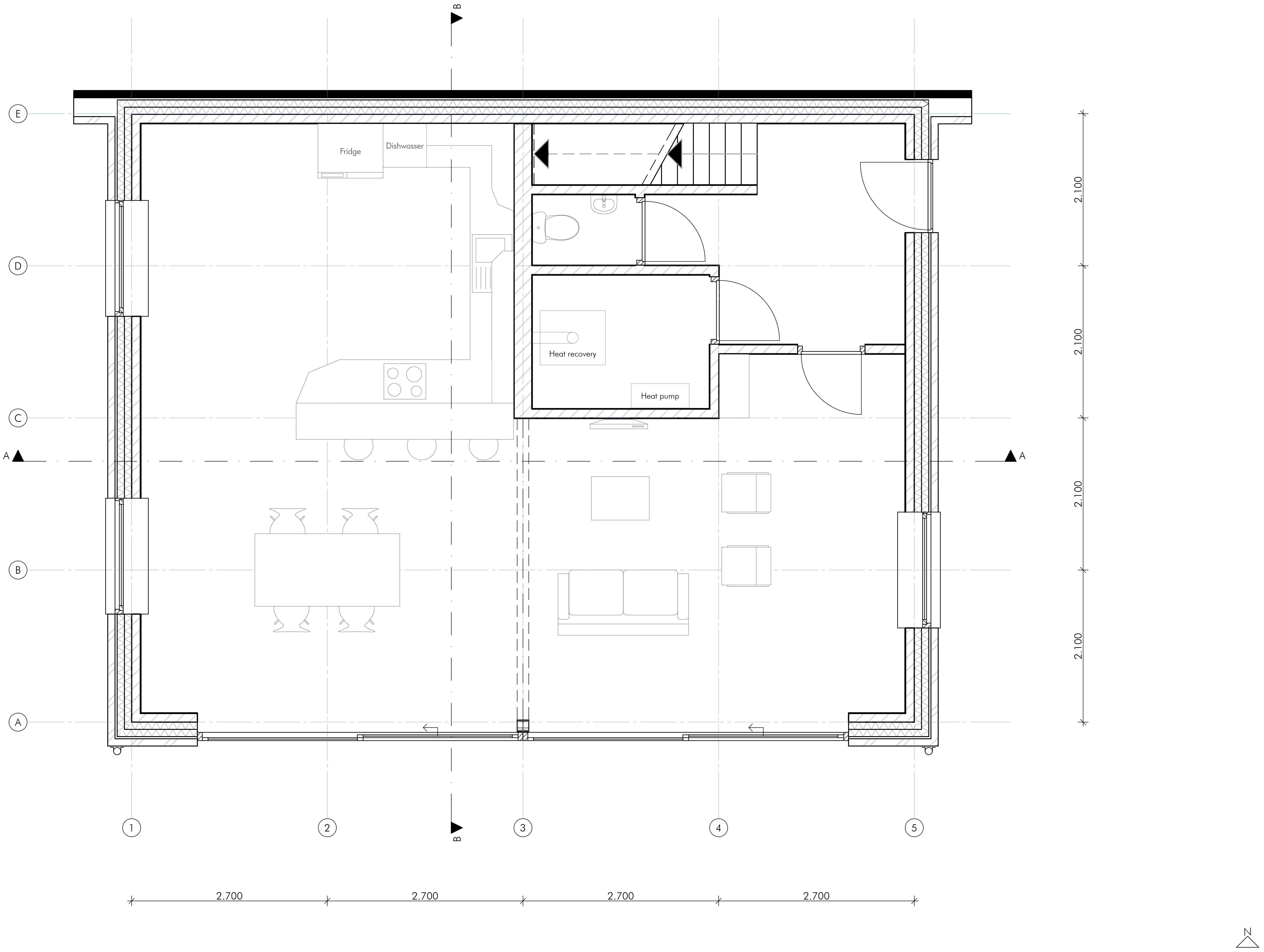
> SECTIONS
AA, BB

> ELEVATIONS
North, East, South, West

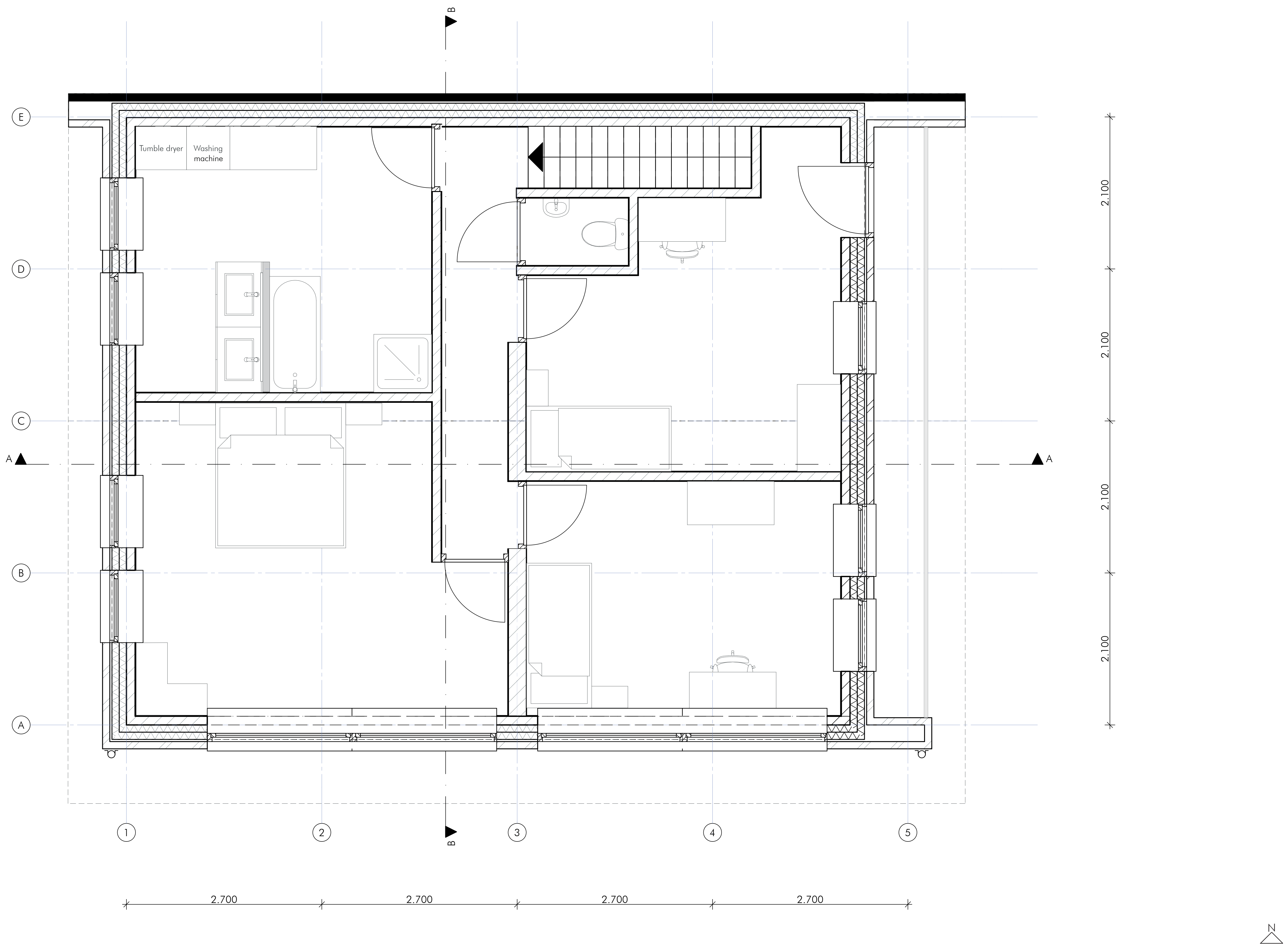
> DETAILS
A.01 t/m A.04, B.01 t/m B.06

> 3D
Exterior, interior

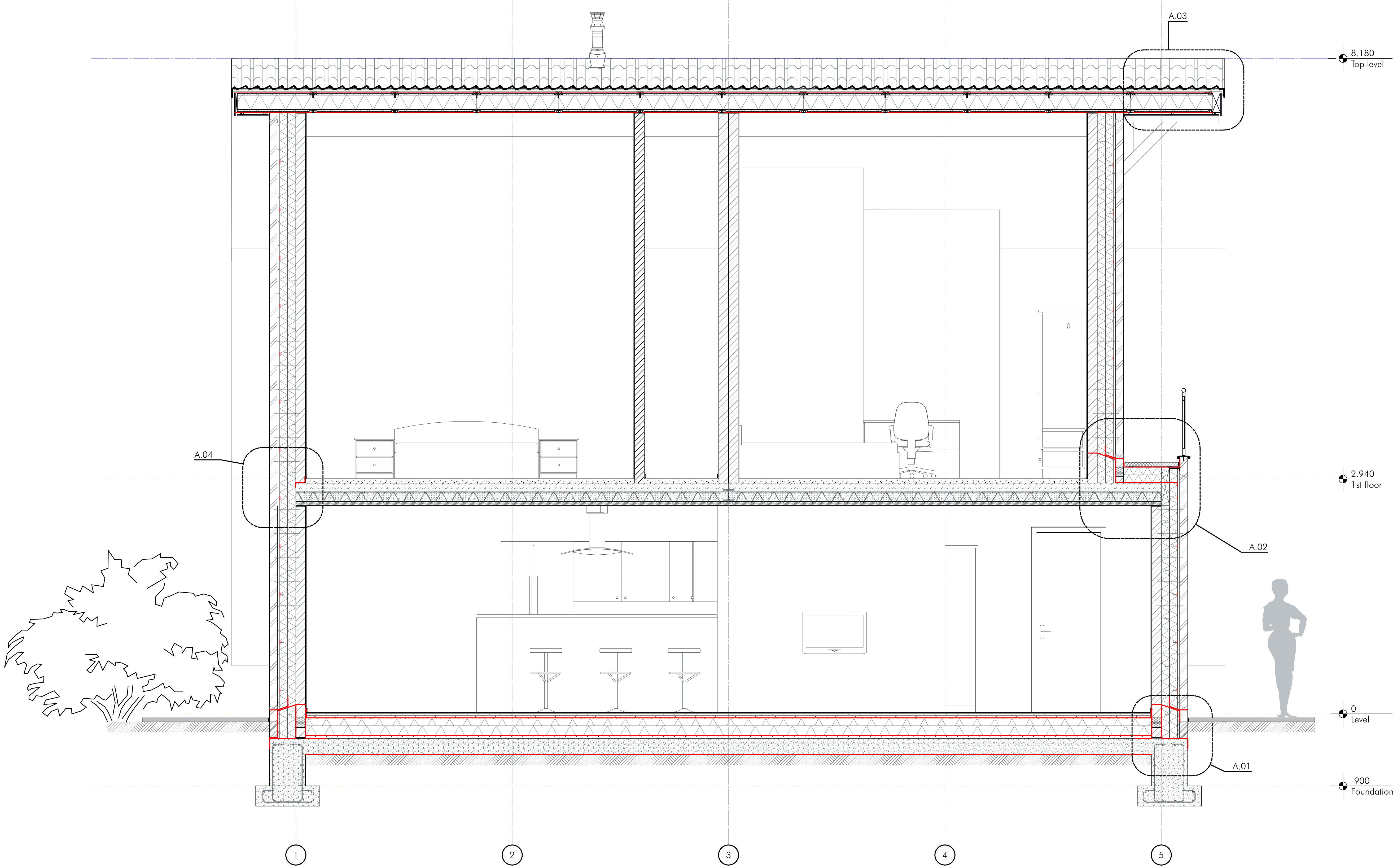
PLAN GROUND FLOOR 1:50



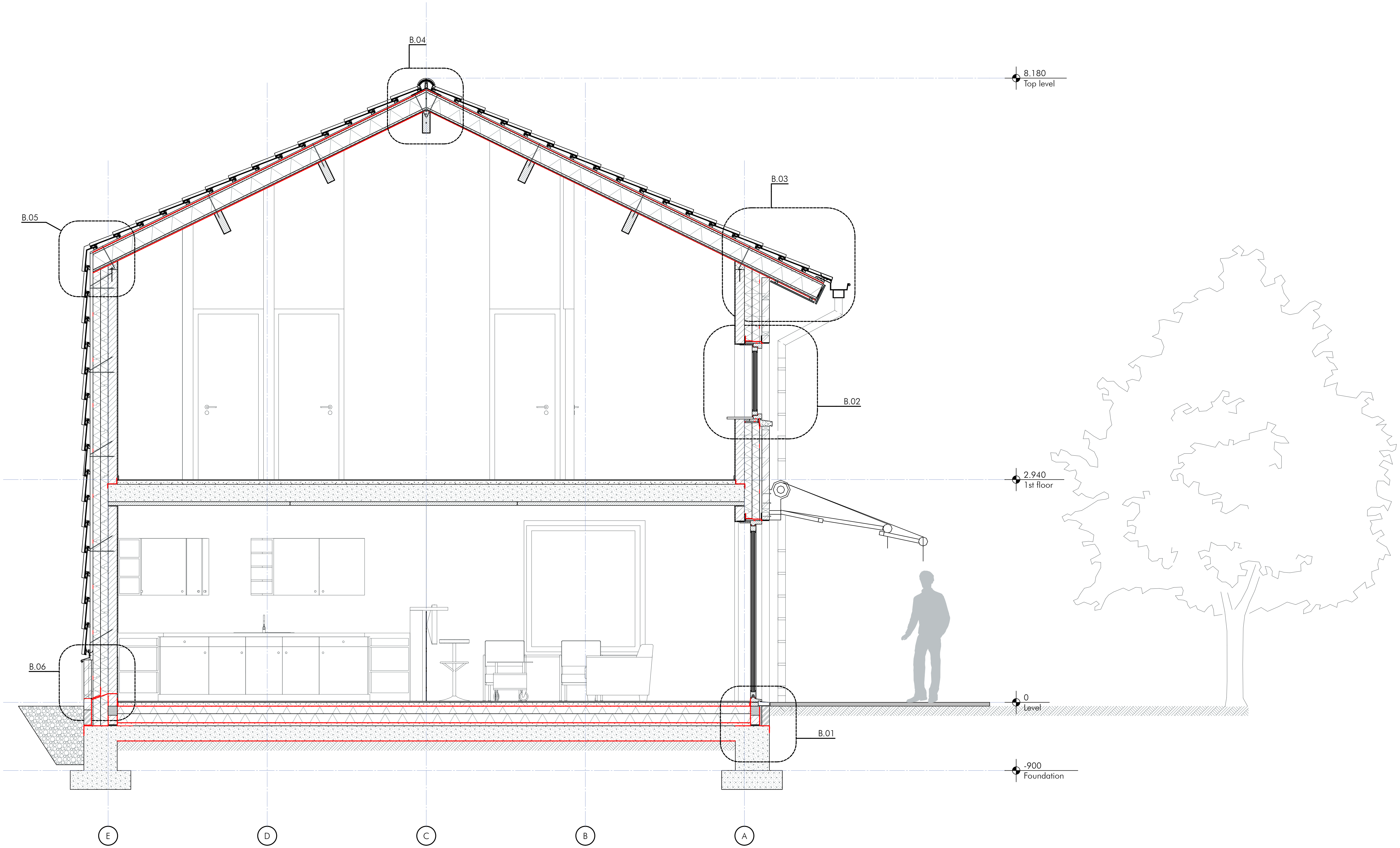
PLAN FIRST FLOOR 1:50



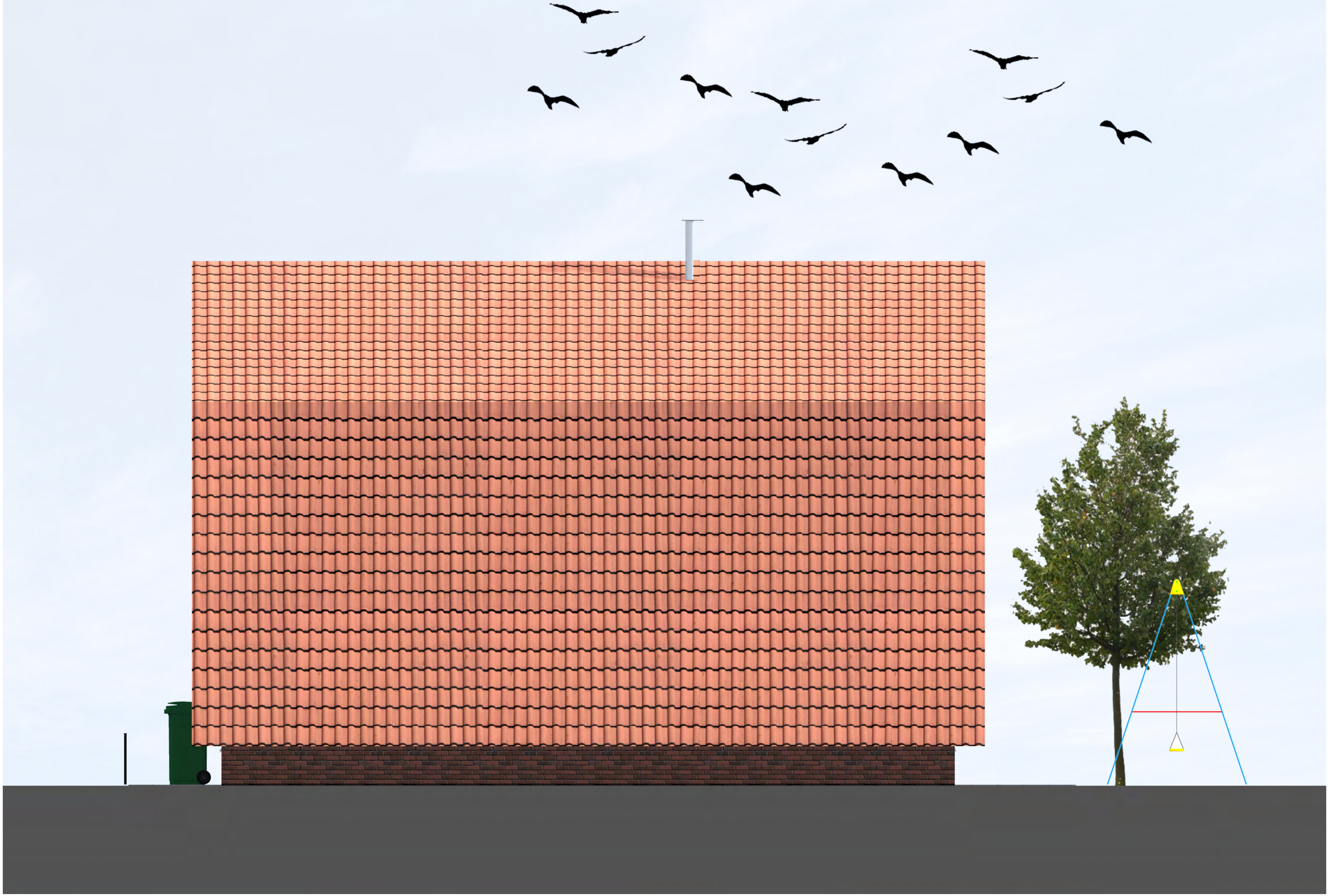
SECTION A-A 1:50



SECTION B-B 1:50



ELEVATION NORTH 1:50

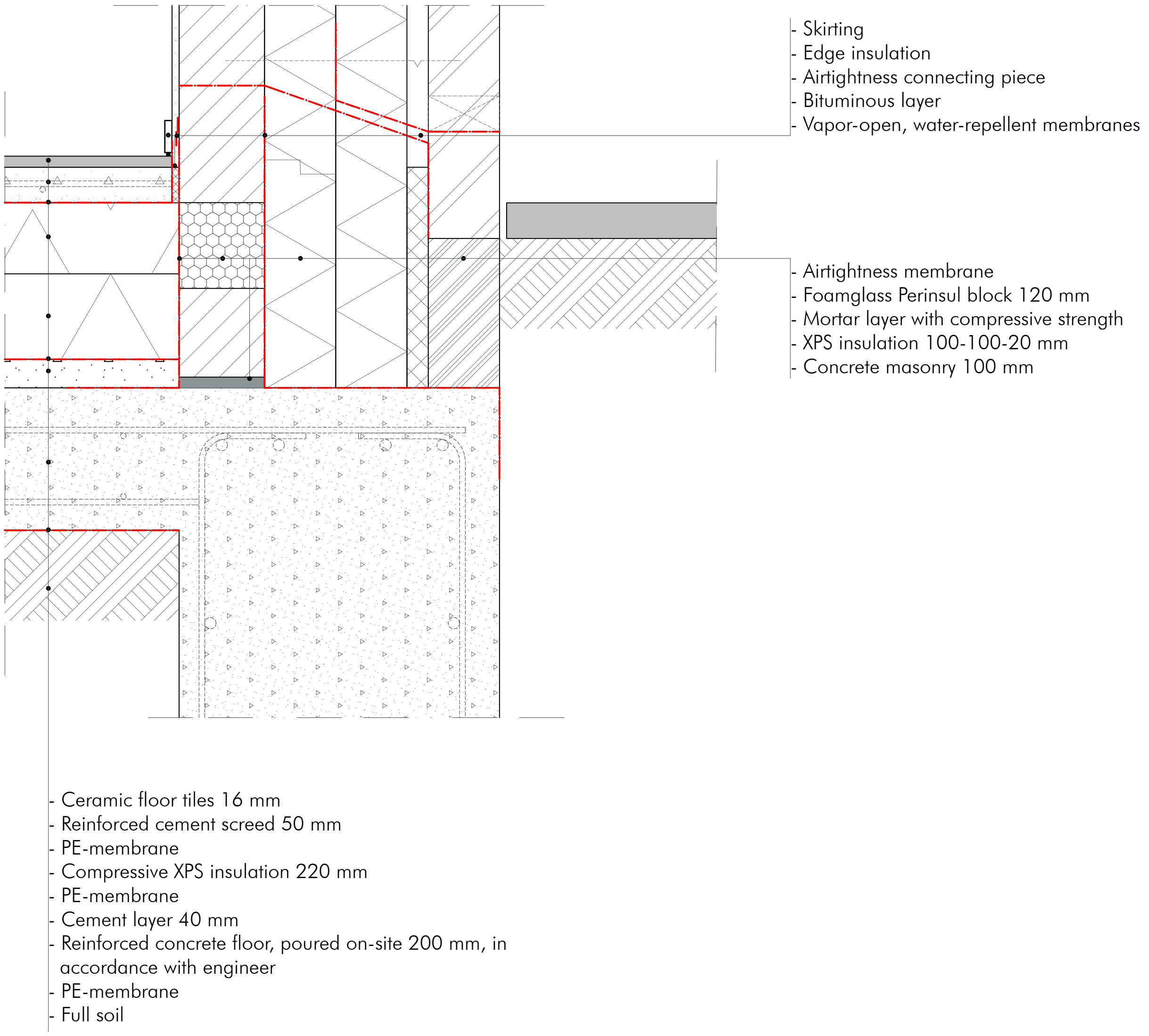


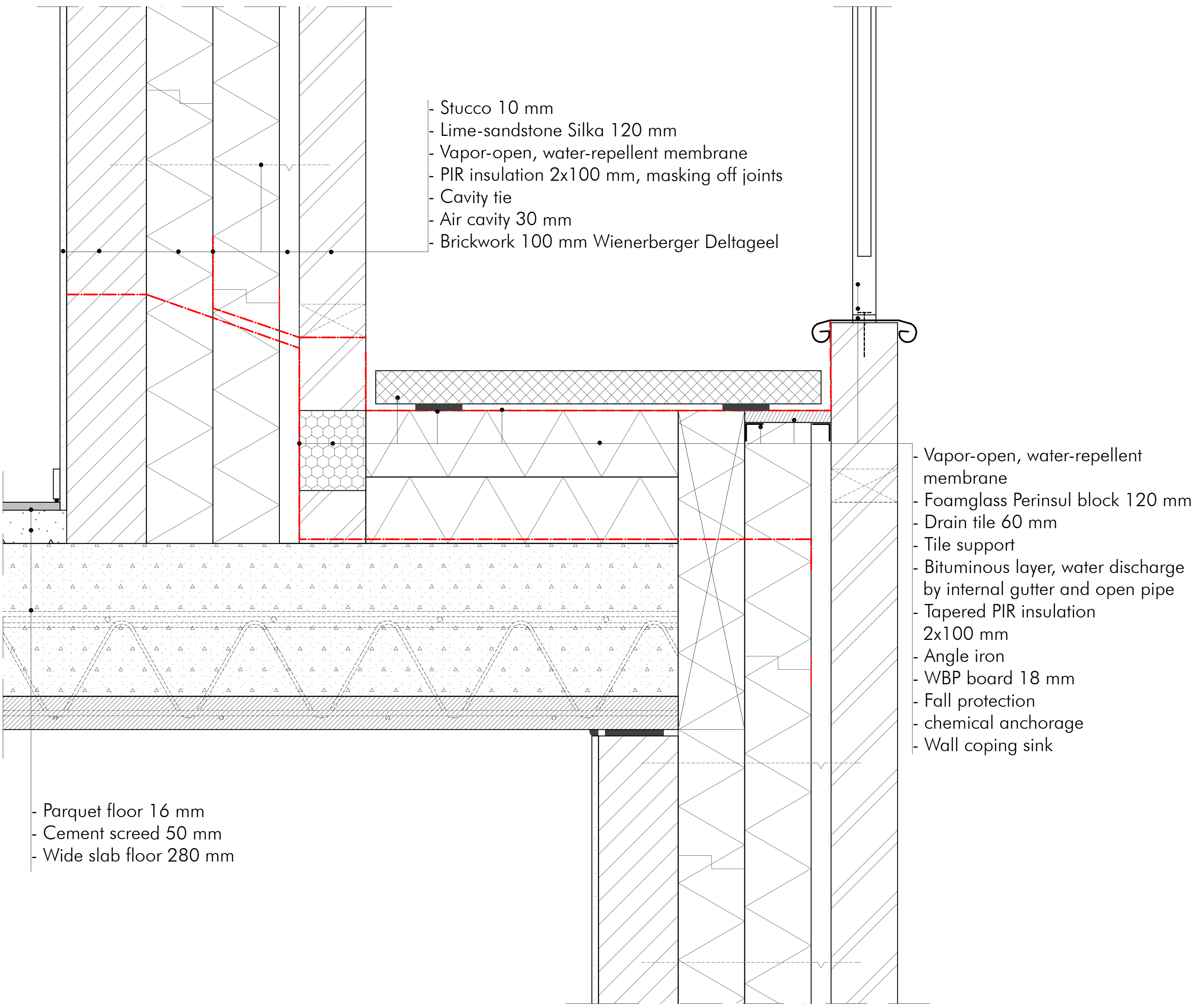
ELEVATION EAST 1:50

ELEVATION SOUTH 1:50

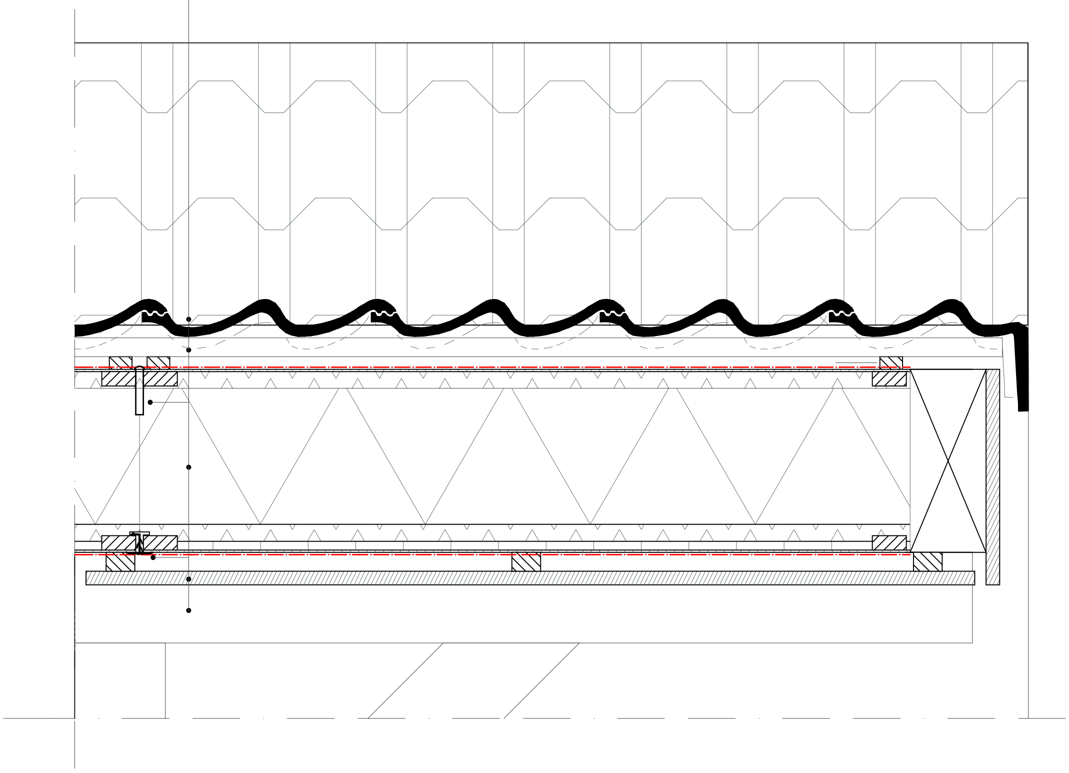
ELEVATION WEST 1:50

DETAIL A.01 1:10

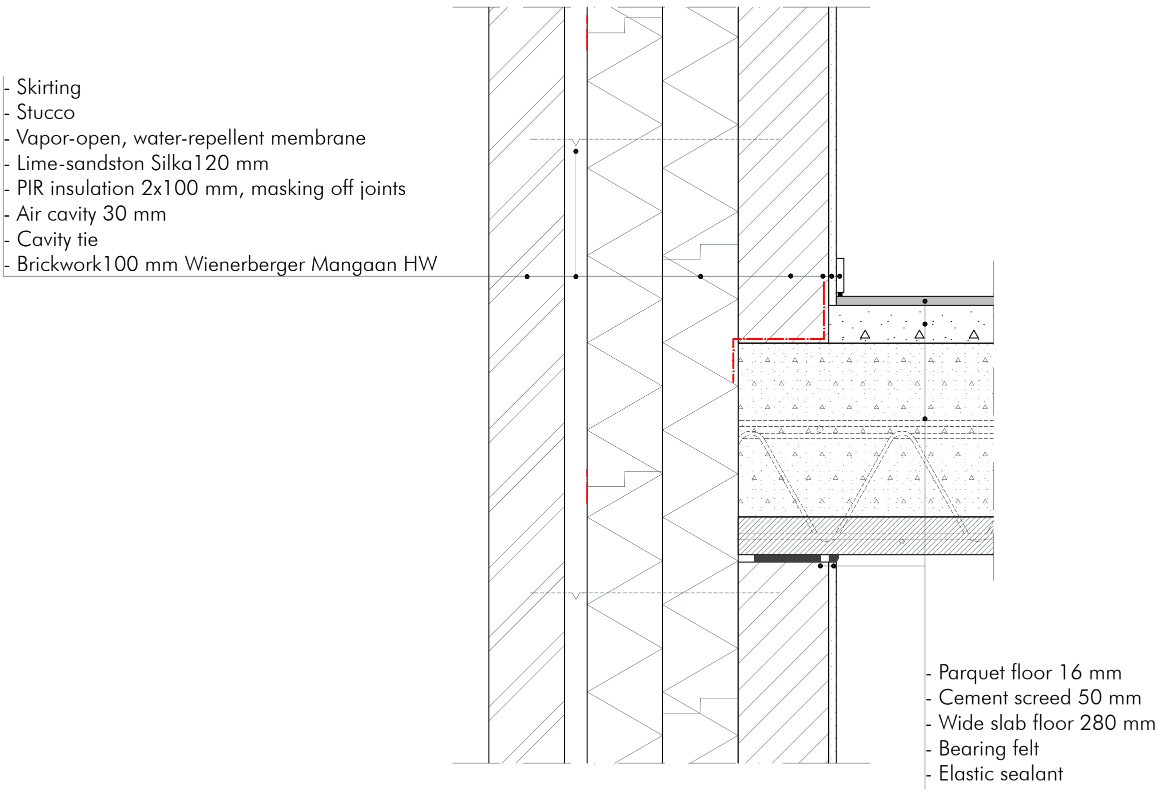



- Stucco 10 mm
- Lime-sandstone Silka 120 mm
- Vapor-open, water-repellent membrane
- PIR insulation 2x100 mm, masking off joints
- Cavity tie
- Air cavity 30 mm
- Brickwork 100 mm Wienerberger Deltageel
- Vapor-open, water-repellent membrane
- Foamglass Perinsul block 120 mm
- Drain tile 60 mm
- Tile support
- Bituminous layer, water discharge by internal gutter and open pipe
- Tapered PIR insulation 2x100 mm
- Angle iron
- WBP board 18 mm
- Fall protection
- chemical anchorage
- Wall coping sink
- Parquet floor 16 mm
- Cement screed 50 mm
- Wide slab floor 280 mm

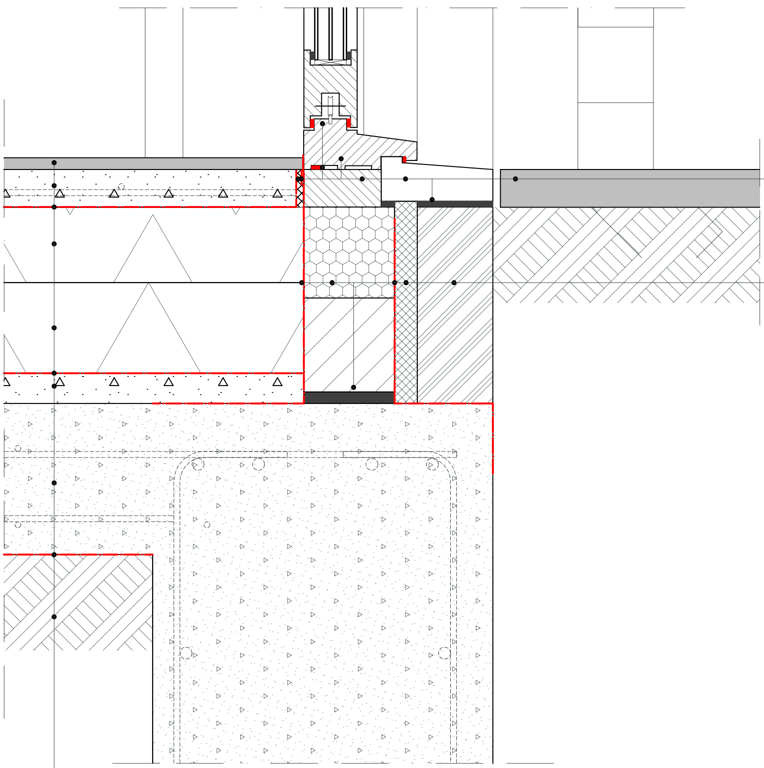
- Ceramic roof tile Wienerberger Madura natuurrood
- Battens 25x38 mm
- Unidek assembly foam
- Unidek roof element:
  > Counterbattens 20x30 mm
  > Unidek S-membrane
  > Chipboard 3 mm
  > EPS/PIR insulation 225 mm with bearing stiffener 19x45 mm
  > Plasterboard 12 mm
  > White chipboard 3 mm
  > Unidek S-membrane
- Synthetic cover profile
- Fascia board WBP 18 mm RAL 9002, ventilated
- Wooden support, dimensions in accordance with engineer



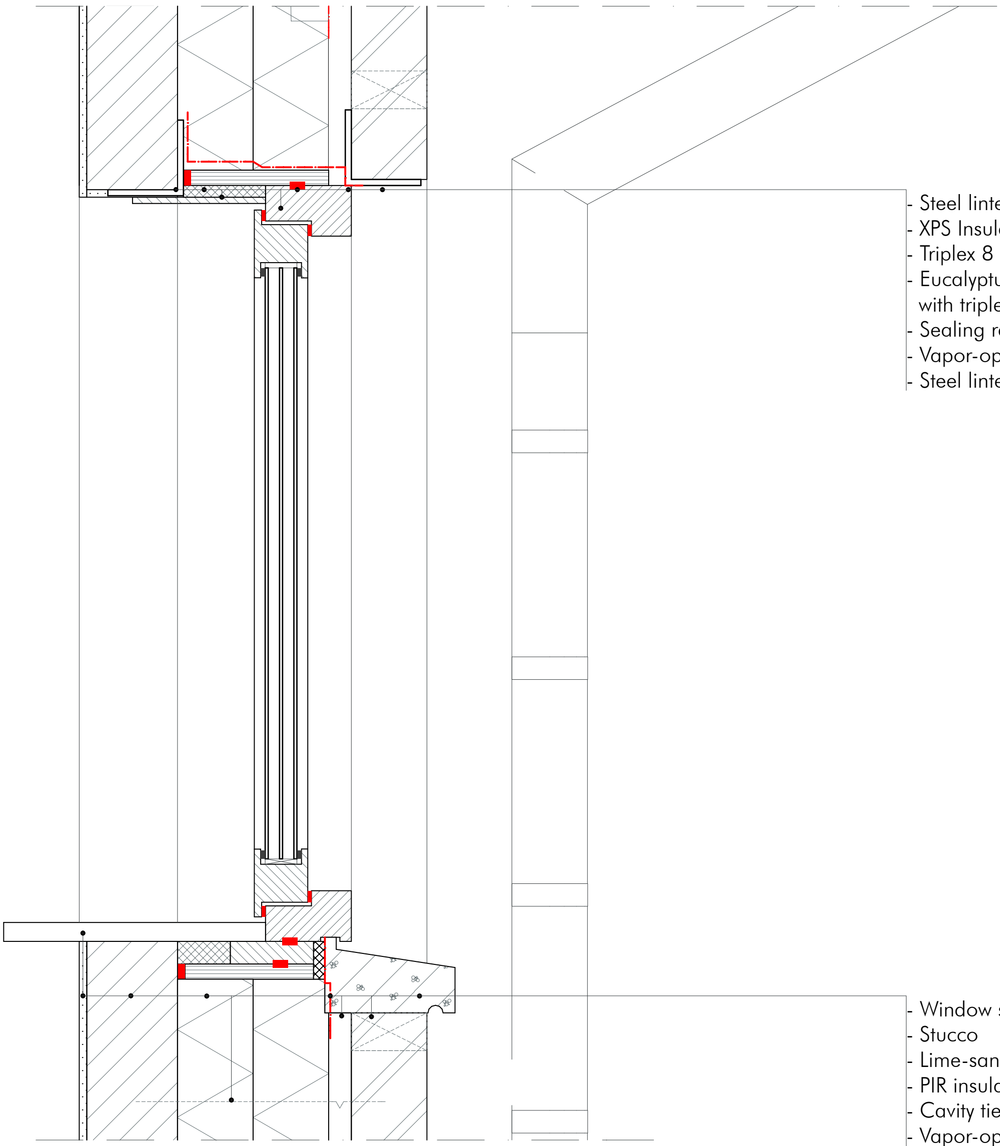
DETAIL A.04 1:10



DETAIL B.01 1:10



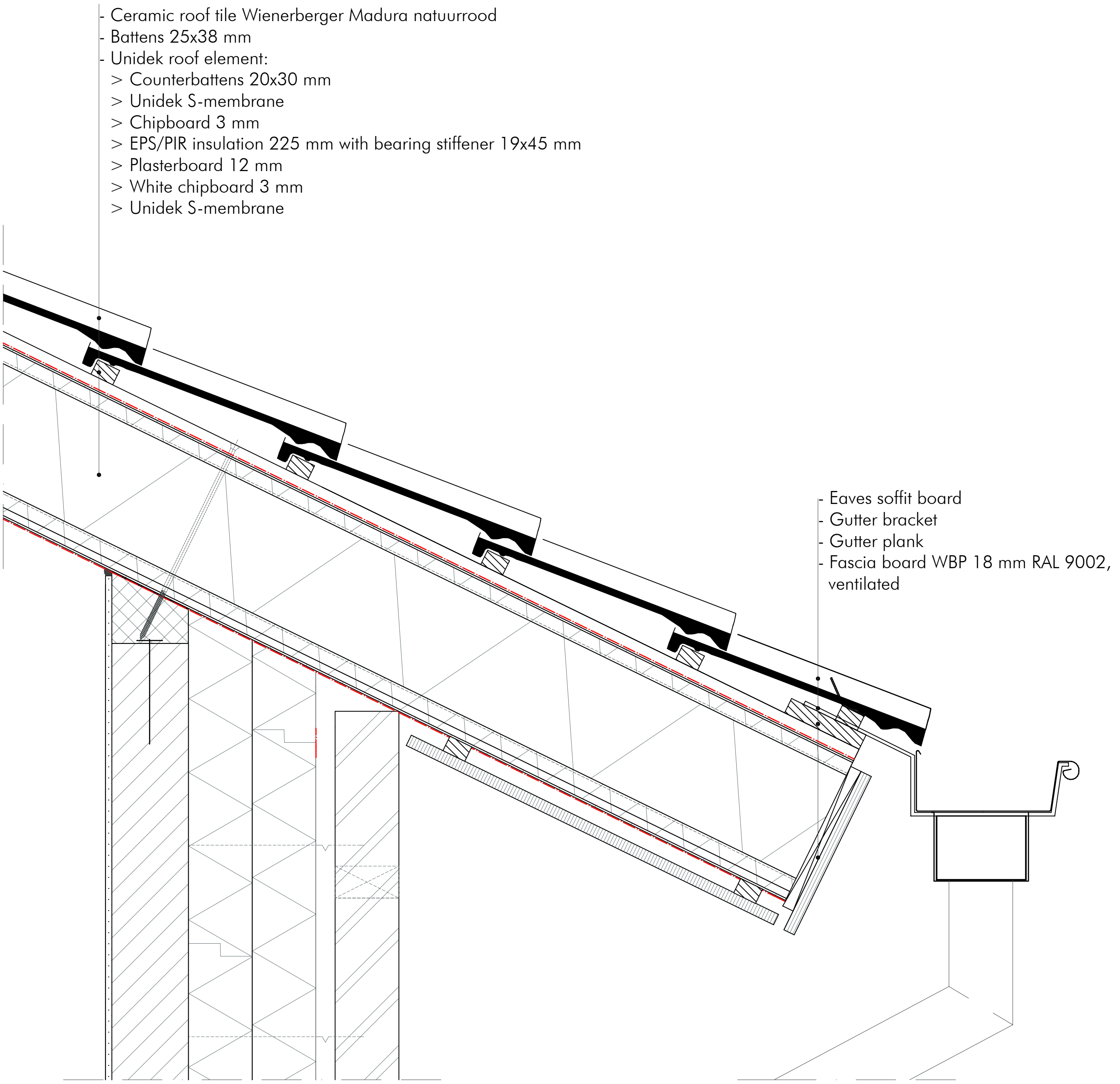
DETAIL B.02 1:10

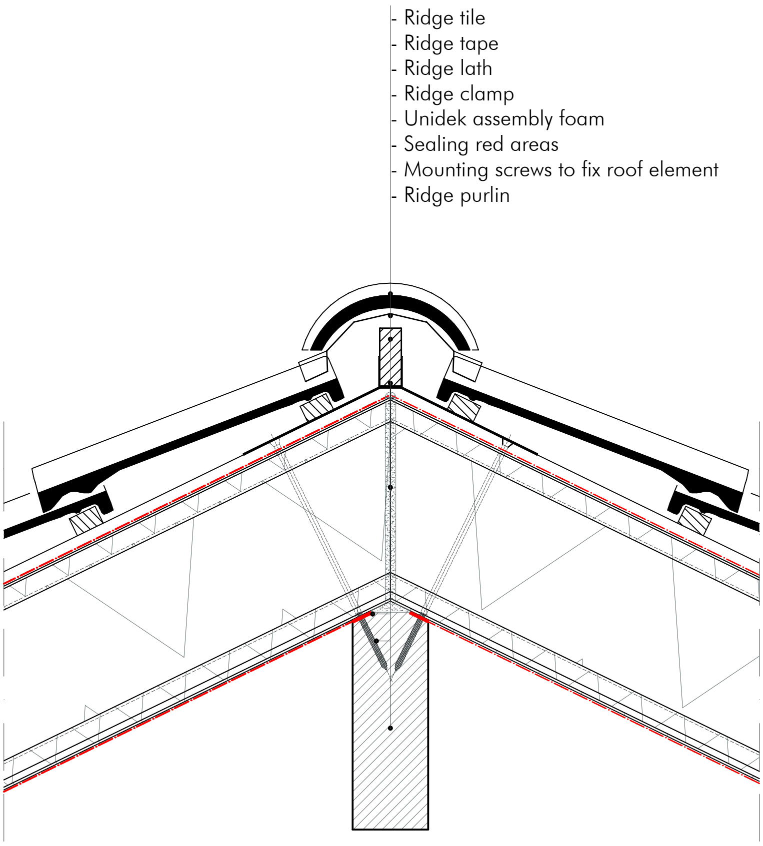


- Steel lintel
- XPS Insulation
- Triplex 8 mm
- Eucalyptus wood framed window RAL 8014 with triple glazing
- Sealing red areas
- Vapor-open, water-repellent membrane
- Steel lintel

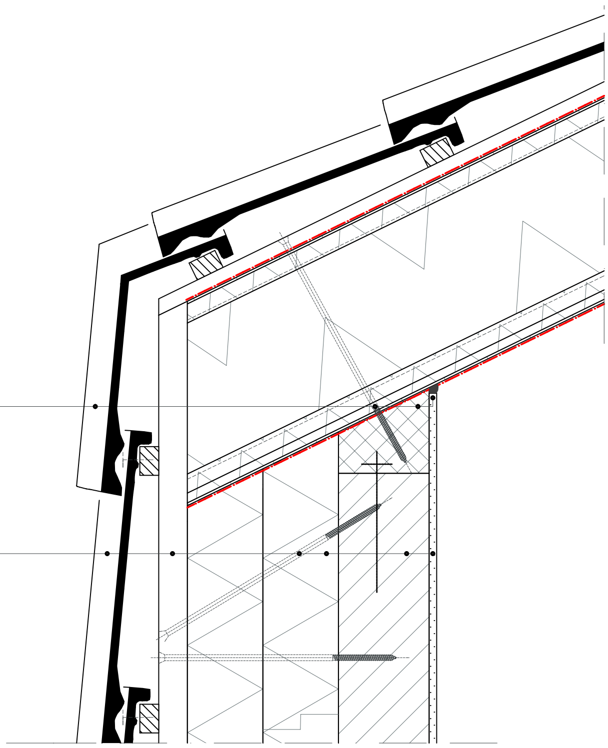
- Window sill ceramic
- Stucco
- Lime-sandstone Silka 120 mm
- PIR insulation 2x100 mm, masking off joints
- Cavity tie
- Vapor-open, water-repellent membrane
- Air cavity 30 mm
- Brickwork 100 mm Wienerberger Mangaan HW, open perpend
- Concrete window ledge

DETAIL B.03 1:10




- Ridge tile
- Ridge tape
- Ridge lath
- Ridge clamp
- Unidek assembly foam
- Sealing red areas
- Mounting screws to fix roof element
- Ridge purlin

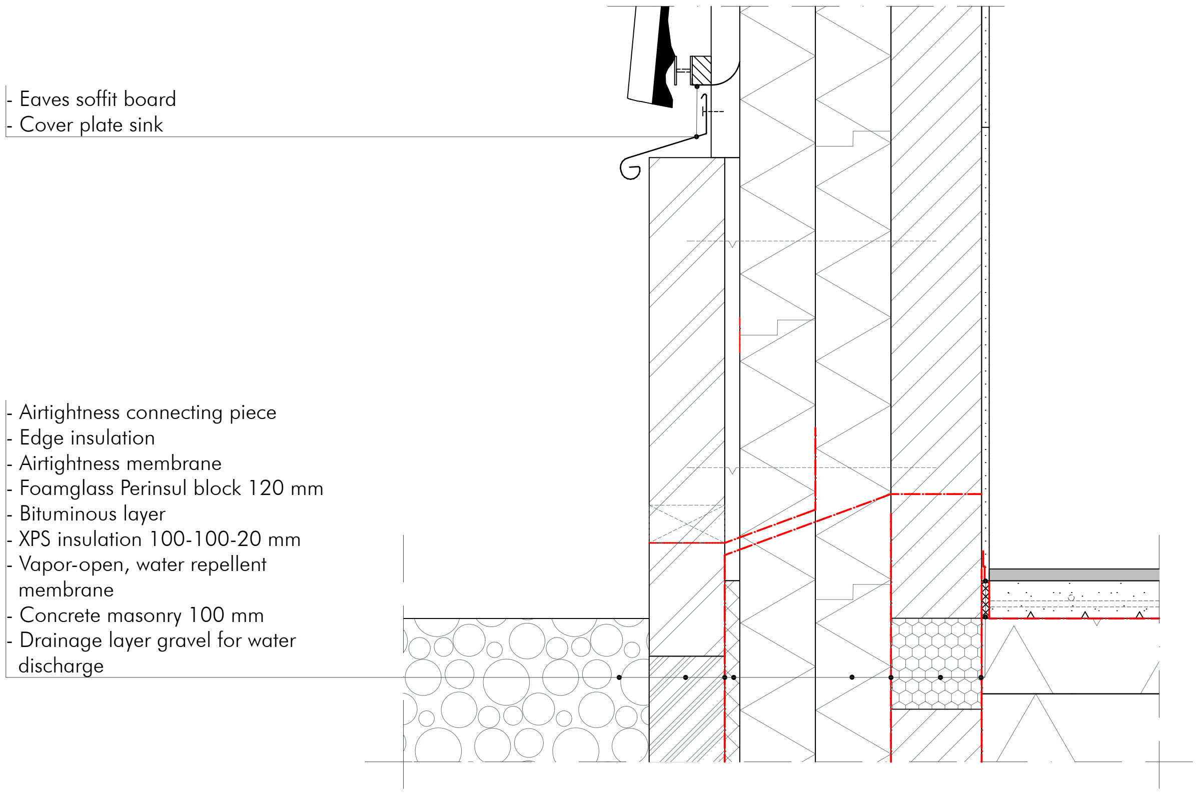
DETAIL B.05 1:10



- Elastic sealant
- Wall plate, fixed with molt
- Mounting screw to fix roof element
- Curb tile Wienerberger Madura natuurrood

- Stucco 10 mm
- Lime-sandstone Silka 120 mm
- PIR insulation 2x100 mm, masking off joints
- Adjustment screw to fix battens on inner leaf
- Air cavity with vertical battens 38x75 mm
- Ceramic gable tile Wienerberger Madura natuurrood, screwed on tile batten

DETAIL B.06 1:10



7. OVERVIEW OF THE RESULTS

The table below and the graphs on the next page; figure [33], [34], [35] and [36] are showing an overview of the Maxergy results comparing all three houses together.

Already from the results given in between chapter six, can be abstracted that the difference in Embodied Land between the operational energy and the materials is quite large. This confirms the need to put more attention to materials.

Furthermore, the first observation that becomes evidentially clear, is that the biobased house shows the best result: its total Embodied Land is almost six times lower than the recycled house as well as the conventional houses. These two are almost of same level.

The primary unit used by Maxergy to express the Embodied Land is ha-year, but it seems useful to compare houses by floor square meters, when the houses are not of the same size. Although, the size of the house also affects other aspects like the operational energy, so I tried to keep the dimensions as much as possible of the same size. Therefore the differences in the second column of the table below will not vary that much from the results in the first column.

The third and fourth column are taking the lifetime of a building in account as well. This way the calculation for a house becomes more and more precisely: you could make an assumption what materials will probably be replaced in the life-span of the house. Making this assumption, means that you also have to fill out the input of the material twice (or more when the material is replaced more than once during the life-span of the house). In the calculations of this research the assumption of replacing materials has not been taken in account, because in order to make a proper assumption an extra research towards the durability of materials will be necessary.

	ha-year	ha-year/floor-m2	ha-year/lifetime-floor-m2	ha-year/lifetime
BIOBASED				
Operational	2,15E-02	1,23E-04	2,46E-06	0,000429711
Materials	6,41E+02	3,66E+00	0,073214068	12,81246192
Total	**6,41E+02**	**3,66E+00**	**0,073216524**	**12,81289163**
RECYCLED				
Operational	1,81E-02	1,04E-04	2,09E-06	0,00036289
Materials	3,74E+03	2,15E+01	0,430106189	74,83847692
Total	**3,74E+03**	**2,15E+01**	**0,430108275**	**74,83883981**
CONVENTIONAL				
Operational	1,66E-02	9,25E-05	1,85E-06	0,000331307
Materials	9,81E+05	2,07E+01	0,413822532	74,07424257
Total	**3,70E+03**	**2,07E+01**	**0,413824435**	**74,07457388**

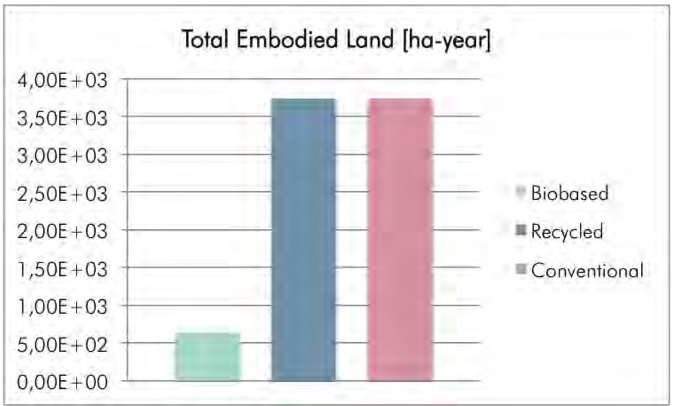


Fig. 33: Comparing the houses on ha-year

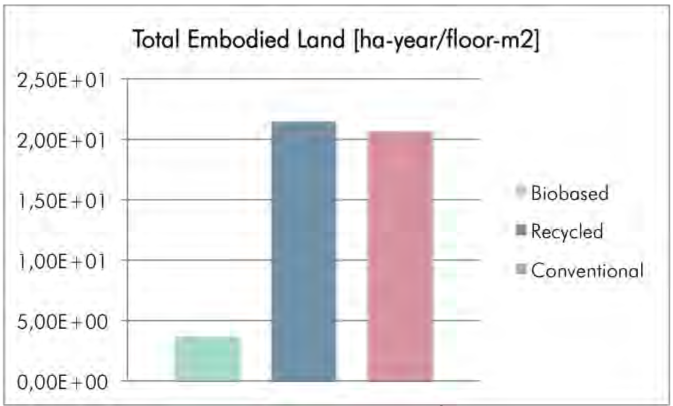


Fig. 34: Comparing the houses on ha-year/floor-m2

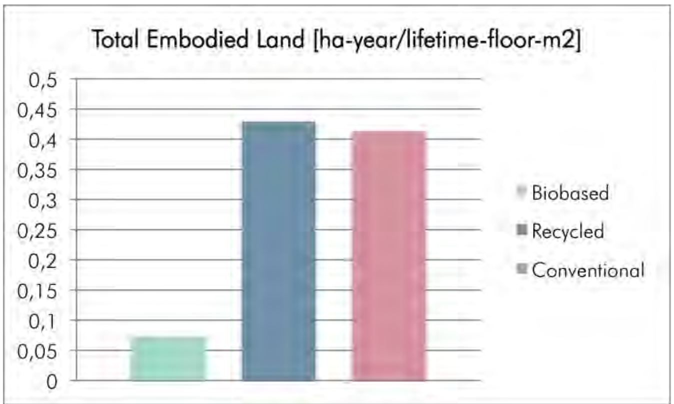


Fig. 35: Comparing the houses on ha-year/lifetime-floor-m2

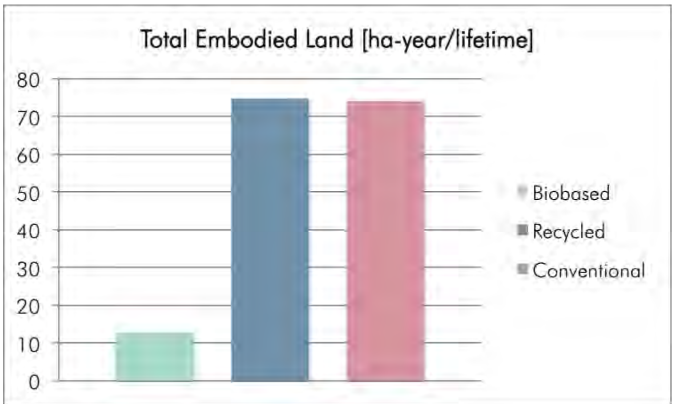


Fig. 36: Comparing the houses on ha-year/lifetime

8. CONCLUSION

The individual results already showed that the relation between the amount of materials in kilograms is not per definition in proportion to the Embodied Land of a material, it is even stronger out of proportion than I would have expected before. This means that not the amount but something else will be a determining factor that contributes more to the Embodied Land.

Steel for example, is a material that turned out really badly in this research, so what causes this?
An useful building product of steel needs an extensive process before it has its final shape. The raw materials are not found in their pure form, but as a percentage of another rock, also could ore. The winning of ore also causes logging of tropical forest. Moreover, a lot of litter remains while removing the ground and dividing the metal from the ore. Processing metal brings along air pollution and there is also a lot of transport needed.

Such aspects as mentioned above will bring along a large impact on the Embodied Land, not necessary the weight of a material.

Concluding this, we should be more aware of the materials we use: where are these materials coming from and where are they composed of? These things are really important notions regarding the Embodied Land of a material.

From the result of the biobased house can be concluded that building with biobased materials has a definite positive effect on the environment.

The result of the recycled house shows that the recycling of steel not by definition has a persuasive positive effect on the environment. Since the steps in the technical cycle remain such an unclear process, the effect can not been calculated really well.
In order to make the recycling process more clear, something needs to change in the building industry: you need to know where the material comes from, the origin of the specific recycled piece. Only then you will be able to say something about if there will be some land compensated for it. This could then result in a lower Embodied Land impact.

Having these conclusions in mind, the research question as formulated in chapter 4 can be answered:

>What is the difference in exergetic performance between a house with mainly new, biobased materials and a house with mainly recycled materials?

>The exergetic performance of a house with mainly new, biobased materials is substantially better than a house with mainly recycled materials due to the fact that the natural cycle is much more clear than the technical cycle.

9. DISCUSSION AND RECOMMENDATIONS

Reviewing this research some aspects can be a point of discussion. Firstly, I want to remark that the use of calculation software brings along some questions about reliability: you do not have the knowledge how the program is built, which creates a small unclear field that you can not control yourself.

Only the Maxergy tool provided me background information about how the software works. I even got the chance to contribute something to the tool: since it does not contain all building materials yet, I have added two extra materials. It made me understand the general principles a lot better. This way you will also be able to communicate your findings regarding the tool with the developers of it.

A large part of the information on embodied energy in Maxergy is based on the ICE database. This is one thing that could be improved: this database is unfortunately not complete and there is also a lot of variation with other databases. There should be one method to determine the embodied energy, bundled in one document. This will make it easier to develop Maxergy more, something which I would also like to recommend.

Although, presuming that the programs are correct, this research tends to give a better notion of what sustainability really involves, because I have to remark that there are a lot of misunderstandings regarding the definition of sustainability that should be discussed more often.

Furthermore, I would like to mention some recommendations that are following out of the research. In the conclusion it became obvious clear that steel has a huge impact on the Embodied Land, but trying to avoid the use of steel completely would not be a realistic option. Of course I would like to spread the word to moderate the use of it, but I think a better chance or research is given by improving on the aforesaid lack of transparency of the technical cycle. To take the natural cycle as reference: here we have for example the FSC-Label in order to recognize wood that comes from a responsible managed forest. Something like that might be an option for recycled steel as well. A label has all its information and regulations clear written down, so this can function as a steady base which makes it also more reliable to integrate in software. And this in turn could improve the result that comes out of the tool.

10. EPILOGUE

Already in the beginning of the Smart Living studio, I noticed that the formulation of the graduation assignment was quite individual and free, which made it quite personal as well. This can be an advantage since you can almost formulate your own project. But this freedom can also be dangerous: sometimes it takes some time before the project is really clear defined. In the beginning I was a bit searching as well, but after a while I got really confident with the subject I choose and I fully supported it, which is really important in order to keep it interesting and challenging for yourself. I have done exactly what I wanted to do, also with an eye on the future. As mentioned before are the environment and innovation two important things to me, so I would like to continue with these aspects in my daily life after graduation. Furthermore I gained more knowledge on some aspects that are not implemented in the regular Architecture, Building and Planning curriculum at the TU/e, but which you definitely need to know as an architect. To mention one example: the EPC-calculation is really informative to do before you graduate.

Although I have a tendency to think a lot about aspects regarding building technology, I think this could be my personal signature as well. I think it is an advantage and challenge to think different about materials and finding solutions in this, it often delivers me creative input for a design.

Thinking different also underlies the layout of this booklet. Why would you create a tile size? In my opinion you will throw a way a lot of unused paper by cutting this size, which is quite a pity. So why not using a standard paper size, but doing something different with it, like a different material? In my case I choose for a visibly recycled material, but there is a lot more to explore. The only thing is that you need to do some research and you might also get confronted with other problems. But that is just the fun part: solving these problems.

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ILLUSTRATIONS

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