Timber Frame and its connection to environmental sustainability

Is there a future for Timber Frame if we look at the environmental sustainability?

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Completion date	**:**	**June 2010**
Major	**:**	**International Timber Trade**

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PREFACE

This research has been written by Erik.I.M. Hartman for his final thesis in the major International Timber Trade on Larenstein University of Applied Sciences in the Netherlands. It has been written in compliance with Centrum Hout and the VHSB.

The goal of this research was examining the strengths and weaknesses of the timber frame method in comparison to traditional methods, particularly in the areas of environmental sustainability. This lead to distinctions in the environmental costs and benefits that the building methods have.
It shows the possibilities in reducing the CO2 emissions by using more timber frame on the Dutch market.

This thesis is realised with the help of the following people. I would like to thank my thesis coordinator from Larenstein University of Applied Sciences, Mister J. Raggers, my coordinator at Centrum Hout Mister E. de Munck and Mister P. de Graaf of the VHSB.

Erik I.M. Hartman
June 2010

SUMMARY

This project is made to get an understanding of the part that the Timber Frame method plays inside the Dutch market, and the view towards environmental sustainability. The need for this originates from the inexplicability for the market share of the Timber Frame method which is already known on the Dutch market for more than 25 years.

The main question of this research is:

- **How can we ensure that timber frame housing will be used more in the future and could the issue of sustainability help us succeed this?**

This is answered by sub-questions concerning the market, environment and several analyses.

The problem that the Timber Frame method isn't being used that much hasn't got anything to do with the fact that this method isn't known on the market; on the contrary, it is known among all the project developers and building companies that were approached.

The government has set up policies to reduce their CO2 emissions. They implemented the 'Schoon en Zuinig' policy which aims for an overall 30% greenhouse gas reduction in 2020 compared to 1990 and for the building environment they aimed for a CO2 reduction of 6-11 megatonnes by lowering the EPC. The current figures show that they aren't going to reach these reductions.

For every m3 of timber that is used it saves 2 tonnes of CO2, so by using more timber frame it reduces CO2 emissions. Many studies emphasize this and these reductions are also emphasized in the calculations by Eco-Quantum based on the calculation of four building methods.

Based on the results that can be seen in the SWOT analysis it is getting more difficult to reach the EPC levels. Timber frame is easier and cheaper to insulate according to the UKTFA.
The UKTFA has calculated the cost differences for reaching the HLP levels. To reach HLP 1.3, 1.1 and 0.8 the additional costs are lower for timber frame than a masonry building. Also the total costs of reaching Code levels 3-6 are also lower with timber frame. In the UK the builders and project developers are already slightly moving towards the timber frame method as we speak.

The conclusion is that when looking at the results for CO2 reduction it's shown that timber frame is the better choice. So the main importance for getting a higher market share of timber frame is to convince the government not to look only at the renewables in buildings (to reduce the CO2 emissions) but to look at the fabric itself first, because based on the UKTFA, the timber itself already provides up to 44% of achieving the zero carbon goal.

Further research of the difference in costs when lowering the EPC levels could lead to an increasing use of timber frame in the Netherlands and further research of the Code of Sustainable Homes regarding the CO2 reduction it causes for the United Kingdom could lead to more benefits for using timber frame.

The recommendations for the government are to look at the building fabric first to reduce CO2 emissions of a building, afterwards look at the renewables that should be added and also look at the different CO2 emissions of the building materials and analysis like Eco-Quantum for reductions in CO2. Looking at the United Kingdom and the Code of Sustainable Homes in which they reduce the CO2 emissions could be also of great help.

CONTENT

1 INTRODUCTION

1.1 Problem

This project is made to get an understanding of the part that the Timber Frame method plays inside the Dutch market and the view towards environmental sustainability. The need for this originates from the inexplicability for the market share of the Timber Frame method which is already known on the Dutch market for more than 25 years.

The author of the project is Erik Hartman who is studying International Timber Trade at Larenstein University, the Netherlands. It is made in collaboration with Centrum Hout and the VHSB (Vereniging van Houtskelet Bouwers) in the Netherlands. The first contact with Centrum Hout was in November 2009.

The main question of this research is:

- **How can we ensure that timber frame housing will be used more in the future and could the issue of sustainability help us succeed this?**

1.2 Goal

The goal of this research is examining the strengths and weaknesses of the timber frame method in comparison to traditional methods, particularly in the areas of environmental sustainability. This leads to distinctions in the environmental costs and benefits that the building methods have.

1.3 Constraints

This research serves as a report that shows potential for reducing CO2 emissions in the Netherlands by the use of Timber Frame. It does not take into account the difference in building costs of the building methods in the Netherlands nor the differences between the building regulations in the Netherlands and the UK. There is also no market research and SWOT analysis for the timber frame builders and developers as the traditional builders have to be convinced, and not vice versa.

1.4 Method

The goal will be worked out on basis of the following sub questions:

Dutch building market

- *Which building methods are commonly used in the Netherlands?*
- *How does the market look at the Timber Frame method?*
- *How does the market look towards the future in regards of the environment sustainability of timber?*
- *What is the market share of the different building methods in the Netherlands?*

Environment

- *What are the differences in CO2 emissions and environmental impacts of different building materials and buildings?*
- *What is the policy in regards to the needed greenhouse gas reductions in the Netherlands and how are they converted towards the building market energy reductions?*
- *How far are we with reducing the CO2 emissions in the Netherlands?*

Analysis

- *What are the strong and weak points of the building methods that are implemented by the traditional builders on the Dutch market at this moment and what do they experience as opportunities and threats?*
- *What does the Timber Frame market look like in another country like, the United Kingdom, and can we learn from this?*
- *What are the differences in CO_2 emissions and environmental effects when we look at the different building methods?*

The structure of this research is as follows: In the first chapter, the theoretical background in order to understand this research project is explained. In the second chapter there is explained by which method the empirical data has been found. In the third chapter there is the empirical data concerning the market, CO_2 emissions and the policy regarding CO_2 reductions. The fourth chapter contains the SWOT analysis, UK market analysis, the Eco-quantum analysis and the BRE analysis. Finally there are the conclusions and recommendations.

2 THEORY

In this chapter the theory is being explained that is used for the different analysis that are done in this research. Furthermore the different building methods are explained that are mentioned by the project developers and building companies and that are used in the Eco-Quantum environmental effects analysis.

2.1 Research methods

In this paragraph the SWOT analysis is being explained that is used to define the strengths, weaknesses, opportunities and threats of the project developers and building companies in the Netherlands. It gives an idea in how far the market is ready to be penetrated by timber frame. Furthermore the theory explains the LCA analysis that is being applied to assess the environmental impact of a product through its total life cycle. In sequence to this, the Eco-Quantum method is explained that is used as a tool to calculate the environmental impacts of four building methods. The EPC and HLP are 2 standards in governmental policies to lower the CO2 emissions of a building which is mentioned as a link towards the Netherlands in the analysis of the UK market. After this the Code of Sustainable Homes is explained which is a governmental Code that is used in the UK that measures the sustainability of a home as a complete package. Finally the BRE Green Guide is explained which is an environmental rating scheme for buildings that is used in the Code of Sustainable Homes.

2.1.1 SWOT Analysis

The SWOT analysis is an extremely useful tool that helps businesses and organisations in all kinds of situations with decision making and a general better understanding. SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. Information about the origins and inventors of SWOT analysis is below. The SWOT analysis headings provide a good framework for reviewing strategy, position and direction of a company or business proposition, or any other idea.

A SWOT analysis is a subjective assessment of data which is organized by the SWOT format into a logical order that helps understanding, presentation, discussion and decision-making. The four dimensions are a useful extension of a basic two heading list of pro's and con's in figure 1.

The SWOT analysis template is normally presented as a grid, comprising four sections, one for each of the SWOT headings: Strengths, Weaknesses, Opportunities, and Threats. The free SWOT template below includes sample questions, whose answers are inserted into the relevant section of the SWOT grid. The questions are examples, or discussion points, and obviously can be altered depending on the subject of the SWOT analysis. Note that many of the SWOT questions are also talking points for other headings. It is important to clearly identify the subject of a SWOT analysis, because a SWOT analysis is a perspective of one thing, be it a company, a product, a proposition, and idea, a method, or option, etc.

Figure 1: SWOT Analysis

2.1.2 LCA (Life Cycle Analysis)

LCA is a technique that assesses the environmental impacts of a building component throughout its life. It is becoming increasingly important as more and more specifiers are required to consider the environmental impacts of the products and materials they select. They have to take into account where the material comes from, how it is used or converted into a product, its use in a building, right up to its disposal or re-use/recycling. It considers the impact of a material or product's use during 3 specific phases that is shown in figure 2:

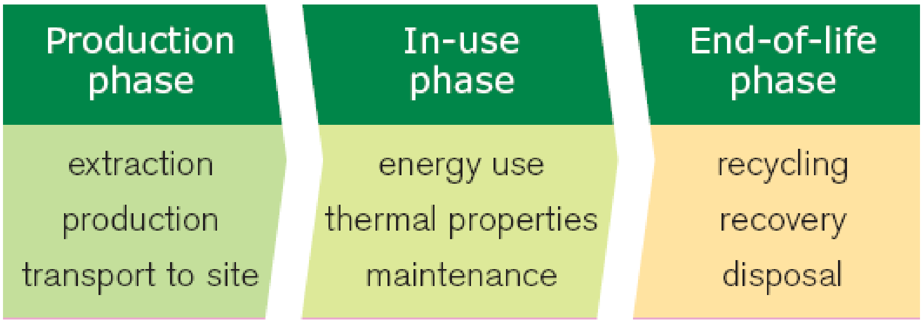

Figure 2: LCA 3 phases

2.1.3 Eco-Quantum

Eco-Quantum calculates the environmental burdens of a building. Hereby the score is determined by the used materials and the energy- and water usage during the total life cycle of the building.

The total lifecycle of building materials are also being considered: From sourcing of the raw materials, to the production of building materials, to manufacturing and building, and eventually to the demolition of the building or the recycling from the demolitions' products. Also the maintenance and replacements are taken into account. This total calculation results in a weighted mark for the building: the Eco-Quantum environmental indicator.
This indicator is constructed as follows. For the materials, the user inserts material choices and amounts. The energy usage data is being copied from an EP calculation. For the water data it's sufficient to insert installation descriptions. Afterwards, the environmental marks are calculated by using the submitted data of Eco-Quantum, and the LCA methods. These marks are being converted into the environmental indicator with a set of weights.

The following environmental effects are being calculated:

- **Exhaustion** (ADP) in kg Sb equivalence per kg
- **Greenhouse effect** (GWP100) in kg CO2 equivalence per kg
- **Ozone degradation** (ODP) in CFK-11 equivalence per kg
- **Smog** (POCP) in kg ethylene equivalence per kg
- **Human toxicity** (HTPinf.) in kg 1,4-DCB equivalence per kg
- **Ecotoxicity Water** (FAETPinf.) in kg 1,4-DCB equivalence per kg
- **Ecotoxicity sediment** (FSETPinf.) in kg 1,4-DCB equivalence per kg
- **Ecotoxicity terrestrial**(TETPinf.) in kg 1,4-DCB equivalence per kg
- **Acidification** (AP) in kg SO2 equivalence per kg
- **Eutrophication** (EP) in kg PO4 equivalence per kg
- **Energy** in MJ per kg (or m3 of MJ)
- **Dangerous waste** in kg per kg
- **Waste** in kg per kg

2.1.4 EPC (Energy Performance Coefficient)

In the Netherlands more and more measures are taken to reduce the energy usage and thus reducing the CO2 emissions. One of these measures is that new homes have to meet a minimum Energy Performance Standard (EPN). This standard is expressed in the Energy Performance Coefficient (EPC) and indicates how energy efficient a home is.

The EPC is based on building characteristics, building-related equipment and a standardized behavioural of the residents. The lower the number, the more energy-efficient building the building is.

There are several resources that can be deployed to meet EPC requirements. Think of:

- Better insulation of the building
- Heat recovery from ventilation air
- Heat recovery from shower water
- Larger window area on the south
- Buffering through unheated spaces to build more compact exterior
- High efficiency heating and high efficiency hot water preparation
- Contribution of a solar energy system
- Reduce energy use by fans such as DC motors
- Air tightness of the building

At this moment the current EPC demand is 0.8. This will be upgraded in 2011 to EPC 0.6, and in 2015 it will be EPC 0.4. Eventually, energy neutral homes have to be built after 2020.

2.1.5 Heat Loss Parameter United Kingdom

The Heat Loss Parameter is a part of the code of sustainable homes to reduce the CO2 emissions of a house. It is an indication of the heat loss through a unit area of the building fabric and is a function of the thermal performance and air tightness of the fabric as well as its exposed surface area.

In Dutch it is translated into: Totaal warmteverlies gebouw / m2 vloeroppervlak

2.1.6 The Code of Sustainable Homes United Kingdom

In December 2006 the Code of Sustainable homes was implemented on the UK market. This code has been introduced to reduce the CO2 emissions caused by homes. It is intended as a single national standard to guide industry in the design and construction of sustainable homes.
The Code measures the sustainability of a home against design categories, rating the 'whole home' as a complete package.

The design categories included within the Code are: Energy/CO2 – pollution – water – health and well-being – materials – management – surface water run-off – ecology – waste

The Code for Sustainable Homes has been developed using the Building Research Establishment's (BRE) EcoHomes System, which has already achieved success in reducing the impact of affordable housing projects, in particular within the social housing sector.

The Code uses a sustainability rating system – indicated by 'stars', to communicate the overall sustainability performance of a home. A home can achieve a sustainability rating from one (★) to six (★★★★★★) stars depending on the extent to which it has achieved Code standards. One star (★) is the entry level – and six stars (★★★★★★) is the highest level.

Flexibility of the Code	
Categories	**Flexibility**
Energy/CO2 Water	Minimum standards at each level of the Code
Materials Surface water run-off Waste	Minimum standard at Code entry level
Pollution Health and well-being Management Ecology	No minimum standards

Achieving a sustainability rating					
	Minimum Standards				
	Energy		Water		
Code Level	Standard (Percentage better than Part L[1] 2006)	Points Awarded	Standard (litres per person per day)	Points Awarded	Other Points[4] Required
1(★)	10	1.2	120	1.5	33.3
2(★★)	18	3.5	120	1.5	43.0
3(★★★)	25	5.8	105	4.5	46.7
4(★★★★)	44	9.4	105	4.5	54.1
5(★★★★★)	100[2]	16.4	80	7.5	60.1
6(★★★★★★)	A zero carbon home[3]	17.6	80	7.5	64.9

Notes
1. Building Regulations: Approved Document L (2006) – 'Conservation of Fuel and Power.'
2. Zero emissions in relation to Building Regulations issues (i.e. zero emissions from heating, hot water, ventilation and lighting).
3. A completely zero carbon home (i.e. zero net emissions of carbon dioxide (CO2) from all energy use in the home).
4. All points in this document are rounded to one decimal place.

2.1.7 BRE Green Guide

The Green Guide is part of BREEAM (BRE Environmental Assessment Method), an accredited environmental rating scheme for buildings. The Green Guide contains more than 1500 specifications used in various types of buildings. Since the previous edition, information on the relative environmental performance of some materials and components have altered reflecting both changes in manufacturing practices, the way materials are used in buildings, and our evolving environmental knowledge.

Materials and components are arranged on an elemental basis so that designers and specifiers can compare and select from comparable systems or materials as they compile their specification. The elements covered are:

- External walls
- Internal walls and partitions
- Roofs
- Ground floors
- Upper floors
- Windows
- Insulation
- Landscaping
- Floor finishes

The Green Guide methodology takes a cradle to grave approach over a 60-year building life, taking into account maintenance and refurbishment over this period and demolition at the end of its life. It expresses the relative impacts on a simple environmental scale running for 'A+' (minimal) to 'E' averaged across all twelve environmental impact categories.

By evaluating the performance of materials and building systems against these specific environmental impacts, which have also been ranked on an A+ to E basis, it is possible for the specifier to select specifications on the basis of personal or organisational preferences or priorities, or take decisions based on the performance of a material against a particular environmental impact. The following categories are used:

- Climate Change (kg CO_2 eq. (100 yr))
- Water Extraction (m^3 water extracted)
- Mineral Resource Extraction (tonne of minerals extracted)
- Stratospheric Ozone Depletion (kg CFC-11 eq.)
- Human Toxicity (kg 1,4 dichlorobenzene (1,4-DB) eq.)
- Higher Level Nuclear Waste (mm^3 high level waste)
- Ecotoxicity to freshwater and land (kg 1,4 dichlorobenzene (1,4-DB) eq.)
- Waste Disposal (tonne solid waste)
- Fossil Fuel Depletion (tonnes of oil eq. (toe))
- Eutrophication (kg phosphate (PO_4) eq.)
- Photochemical Ozone Creation (kg ethene (C_2H_4) eq.)
- Acidification (kg sulphur dioxide (SO_2) eq.)

A+ represents the best environmental performance / least environmental impact, and E the worst environmental performance / most environmental impact. BRE has provided a summary of the environmental rating, The Green Guide rating, which is a measurement of the overall environmental impact.

2.2 Building methods

In this paragraph the building methods are mentioned that are commonly used on the Dutch market and used in the calculations of Eco-Quantum to calculate their environmental sustainability. There are four building methods used in this market, namely the timber frame method, the calcium silicate method, the prefab concrete method and finally the concrete formwork method.

2.2.1 Timber Frame

What is timber frame?
In forested areas, wood is already used for centuries for the construction of homes and buildings. Over time it has been developed into a number of building techniques, for example the log cabin, windmills and wooden houses that are still in great numbers common in villages and ancient cities.

Timber Frame is also one of those technologies. Originally created in North America, it has grown into a highly reliable, global applied building method. The principle of timber frame is simple: the walls, floors and roofs of an open-framework are composed of standardized construction timber that is, where needed, filled with the appropriate insulation. This leads easily and without loss of space to a very high insulation value. After that the frame is covered with the required paneling. The wood and insulation panels each have their specific properties in terms of integrity, stability, heat and sound insulation etc. The big advantage is that, with changing requirements for certain components, the principle of the building can remain unchanged: you only need the adjust the thickness or the quality of the materials.

Moreover, the technique lends itself as no other for automated production in a factory. This leads to a high dimensional stability and high production speed and to an affordable price. This creates a durable, fireproof and well insulated house that is not required more maintenance than a house built with a different building method.

How timber frame is used in the Netherlands is explained in figure 3.

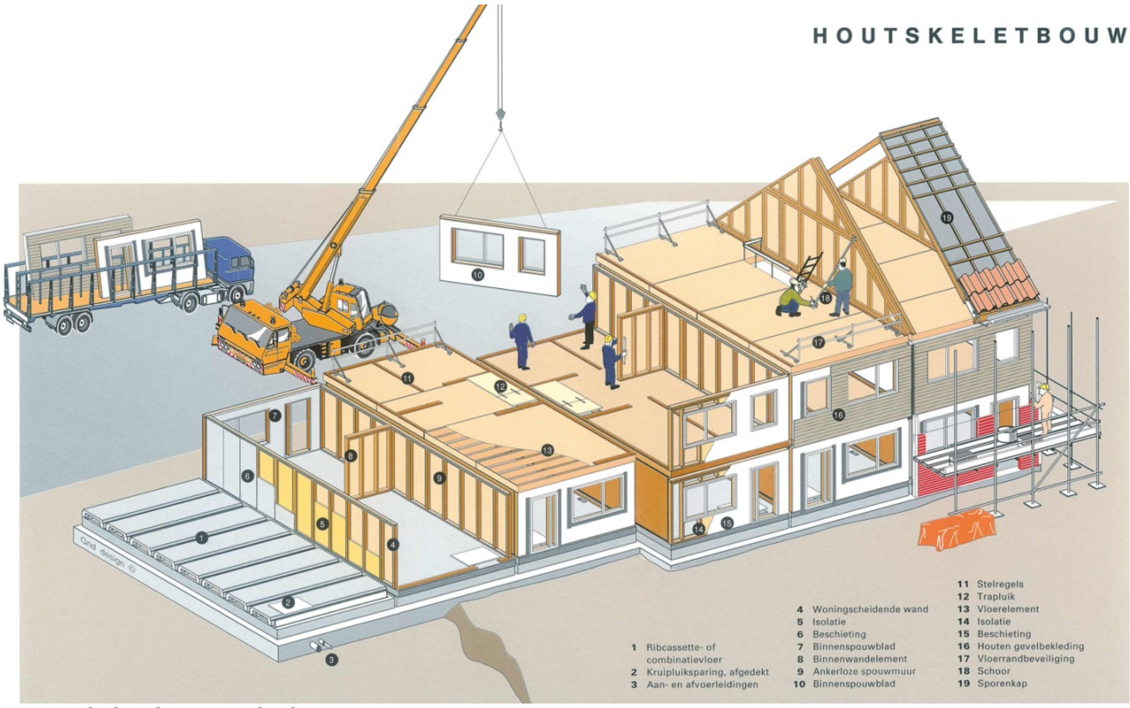

Figure 3: Timber frame method

How long is it known on the Dutch market?
In the early 80's it becomes clear that it is impossible to not think of timber frame on the Dutch market. Architects and builders are beginning to discover the possibilities of this building method. This technique is still relative new and by non-professional use it was easy to make essential mistakes.
Therefore, there were two issues of great importance, namely the establishment of a responsible quality and integrating the technical aspects in existing legislation. A task which the 'Vereniging van Houtskeletbouwers (VHSB) has taken on.

On March 8, 1984, the VHSB is founded by six construction companies, while encouraged by the government. An association with the objective to encourage and monitor the development of a quality, targeted specifically at Dutch conditions, timber frame method with a competing price / product ratio.

At this moment the members of the VHSB consists of 14 timber frame builders and 30 timber frame manufacturers that can be found on their website.

2.2.2 Calcium Silicate

The first Dutch calcium silicate factory goes back to 1898.
The calcium silicate method consists of a stack of piled stones, blocks or (non-storey) elements that are cemented or glued together. Between the actual shell and foundation (substructure) there is generally a transition structure, the ground floor, which serves as the basis of the structure. The separation between inner and outer environment is the shell (casing) of the building, consisting of walls and the roof.

The building of the substructure, walls and the roof can be carried out independently of the construction method. When choosing for the calcium silicate method it should be taken into account to keep sufficient space for the housing blocks.
This method is explained in figure 4.

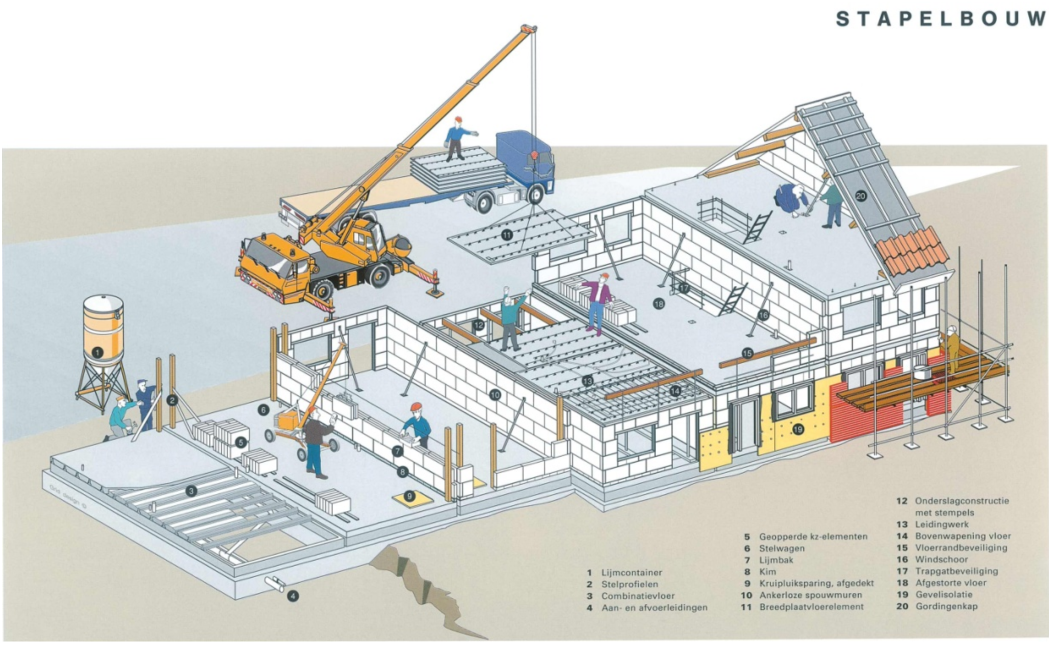

Figure 4: Calcium silicate method

2.2.3 Prefab concrete

This system is also called the major build of construction elements. From the precast ground-slab, the prefab concrete walls, hollow-core floorings, the cavity sheets, roofs, and sometimes as a complete package the interior walls, are assembled into a building. This may well be single-family homes and apartments. Hollow-core floors are mostly used for the storey floors. Stability is provided by means of concrete in inner leaves of cavity wall or shear walls. Interior walls can be made of plaster, aircrete, metal stud, wood or concrete.
This method is explained in figure 5.

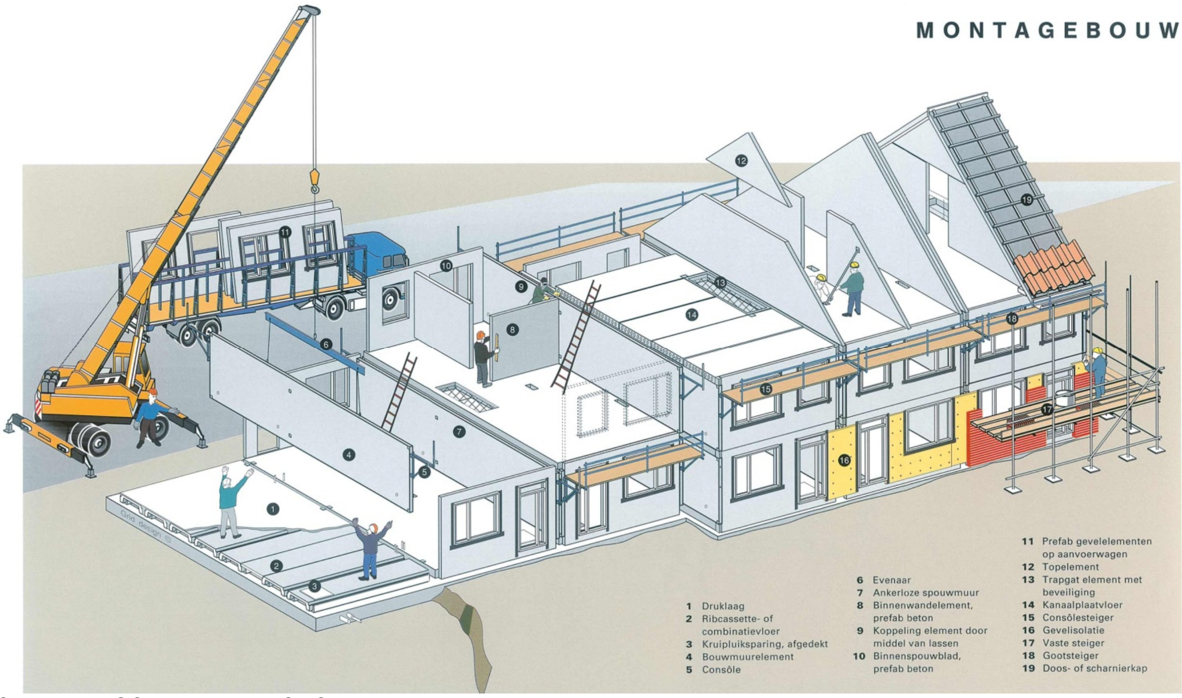

Figure 5: Prefab concrete method

2.2.4 Concrete formwork

Concrete formwork is a building method where fresh concrete is deposited in a formwork at the building site. The formwork is provided in advance of steel and various depositing facilities. When designing a home it is wise to take into account the default dimensions of the formwork system.
Except for large homes, the concrete formwork is also suited to the smaller series homes.

In this research the ‘wanden-breedplaatsysteem’ is used with steel wall formwork.

The method is explained in figure 6.

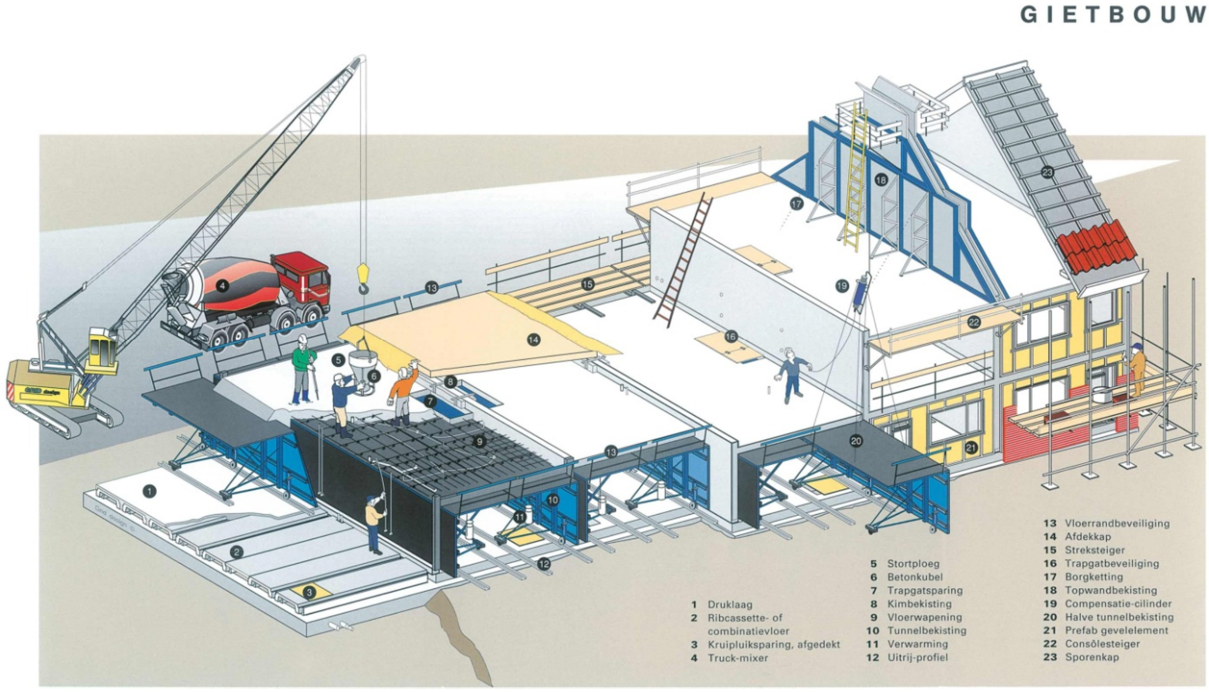

Figure 6: Concrete formwork method

3 METHODS TO FIND EMPIRICAL DATA

To get the needed information there are two ways in which information can be gathered. This can be done by desk research and field research. In this research a large part of the information has been found by doing field research. The benefit by using field research is that the gathered information is adapted on the research itself.

The following methods have been used to find the empirical data.

3.1 Desk research

The internet was a big source in finding the right information. Especially for the environmental part the internet played a large part in finding the right information. All the information regarding CO2 reductions could be found on government websites and websites of research institutions.

In order to get the information about the CO2 emissions of building materials, the use of internet only wasn't sufficient to get the right information. Also a book has been consulted to find this information. The remaining information regarding the building materials' CO2 emissions was found by the use of internet.

3.2 Field research

To get a good view of the Dutch building market, actual project developers and building companies had to be contacted. For this, 30 companies have been approached for an interview and 16 of these companies were able to participate. These interviews gave a good view about how the companies look towards their own building methods, the market and to the timber frame method.

For the market share it wasn't really sufficient to use only the internet because the market shares that were able to find were out of date. Because of this, several research institutions have been contacted. Only 1 of these companies had the actual market share numbers but asked a large amount of money for this. This lead to the use of older and less trustful market shares that could be found on the internet.

4 EMPIRICAL DATA

In this chapter the empirical data is being explained. In the first chapter, a market research of the traditional project developers and building companies in the Netherlands has been done in order to get a good view on how these companies look towards the market and timber frame. After this there are the CO2 emissions mentioned of different building materials and methods that are being used in the building market. This has been divided into the material level, house level and environmental impact level of different building methods. After this, the policy of reducing CO2 emissions in the Netherlands is being explained and the current state of these policies. This chapter ends with the market shares of the building methods that are being used in the Netherlands.

4.1 Market research of traditional project developers and building companies

In this paragraph, project developers and building companies have been reached to get a view of the Dutch market. The main importance of this market research is how they look towards the timber frame method that is already known on the Dutch market for more than 25 years. This is of importance to see if the market is open for this method and to find out if they are able to be triggered for using the timber frame method instead of the traditional building methods.

4.1.1 Interviews project developers and building companies in the Netherlands

To get a better view on how the project developers and building companies look at themselves and the overall market 30 of them have been approached to participate in an interview. 16 of these companies were able to participate. The companies differ in time of existence, amount of employees, the amount of houses they build in a year, the aimed project size and the building methods they apply. The companies can be found in Appendix 1

They were asked to answer the following questions:

- How long does your company exists?
- What is your function within the company?
- How many employees are working at your company?
- How many houses are build each year?
- Do you focus on the larger house building projects or also the smaller ones?
- Which building methods do you apply while building a house?
- What are the strengths of your building method?
- What are the weaknesses of your building method?
- Which opportunities do you see on the Dutch market?
- Which threats do you encounter on the Dutch market?
- Have you heard about the timber frame housing method?
- What do you think about this method?
- Do you have experience with this method?
- What is your consideration to choose for the traditional methods instead of timber frame?
- If there is proof that timber frame housing is a good alternative for building a house, would you start applying this method?
- And which means could convince you to use this method? For example Breeam scores, cost studies, reports about fire safety and sound isolation of ‘TNO/Bouwend Nederland’
- If you look at the Dutch market, do you think there is a good need for timber frame houses?
- Do you think the Netherlands is a ‘stone’ building country or a ‘wood’ building country?
- With the focus on the future by means of environmental sustainability, do you think that timber will be applied more?

4.1.2 Outcomes of interviews with project developers and building companies in the Netherlands

The questions that were asked lead to the following results:

Building methods that are being used by the project developers and building companies
The building methods that the project developers and the building companies use are mostly the traditional methods. The means that the following methods are used mostly:

- Concrete tunnelling
- Calcium Silicate
- Prefab concrete
- Concrete formwork
- Timber Frame (partly)

Knowledge of the timber frame method in the Netherlands
All the approached companies have heard about the timber frame building method but only 1 of the companies is actually using this building method. Only a few are using this method partly, for example in roofs.

Opinions about the timber frame method
In figure 7 it can be seen that the opinions about the timber frame method are on equal level. Most companies are using this method partly so they haven't really got experience in building a total building with the timber frame method but they are slightly positive. Though there are also opinions that are negative towards using timber frame.

+	-
• Houses can be heated way faster than calcium silicate bricks houses • Interesting for smaller house building projects • Building time • Flexible building method • Not suitable for everything but it's fine • Nothing wrong with it but no experience with a whole building • If you go down on the environmental sustainability road you almost can't escape of using timber frame	• More contact noise • Bad accumulative capacity • Flooring noise • Bad commercial image • For buyers often negative because it isn't considered as solid • Not flexible in means that everything (walls) has to be known beforehand • Fire safety

Figure 7: The opinions about the timber frame method

Consideration choice traditional method instead of timber frame method

In figure 8 the considerations to choose for the traditional method instead of timber frame are mentioned. It is clear that the project developers and building companies are leaning towards their own building methods and they think that the market for timber frame isn't ready yet.

+-	-
• You have to do in what you are good at • Not focused at timber frame	• Traditional method is more sustainable, it has a more solid construction • Marketability: The Dutch buyer wants a solid building, they don't have that feeling with timber frame houses. You can set a higher price for a masonry house compared with a timber frame house while having equal building costs • Sound: by using heavy constructions sound leaks are prevented. With timber you need to put a lot of attention in details and engineering • Fire safety: Calcium silicate and concrete house already have a fire resistance of 60-120 minutes, timber needs extra panelling • The buyer's market isn't asking for timber frame housing at this moment

Figure 8: The considerations to choose for the traditional method instead of the timber frame method

The need for timber frame

In figure 9 the need for timber frame is mentioned. These needs are based on the opinions that the project developers and building companies have towards the timber frame method. It can be seen that they are still positive about the need for timber frame but mostly they think it can only be implemented for the private sector and not for the larger housing projects. Also one company states that most users want a virtue and sustainable house to live in, so basically a traditional building.

+	+-
• Yes but only for detached houses, bungalows • Yes but it needs an image improvement towards fire safety, virtue, the actual feeling • For the private sector it could be an advantage • If the price is good, then it could be possible • There is lot to be done still. The consumers are just as traditional as all the project developers	• In the private sector yes but not for terraced houses on project level • Not for the bigger housing projects
-	
• No, the most users want a virtue and sustainable house to live in	

Figure 9: The need for timber frame by project developers and building companies

The opinions of the project developers and building companies about a growing need in the future for timber with the focus on environmental sustainability

Figure 10 shows the answers that were given by the project developers and building companies about the future of timber usage in regards to the environmental sustainability issue. Most companies are sure that there will be a growing need for the use of timber because

+	-
• The chances are pretty big • It's possible, it's a good way to raise the FC values • Good possibility, the facades have to get thicker and thicker and isolation values are still increasing • This will be a growing item, especially for the future. No doubt that timber will be applied more but I don't think that consumers will get enthusiastic about it • Definitely because if you focus on sustainability then there's almost no other way than to choose for the timber frame method • If it's reasonably priced and produced durable than it could be possible	• No you need better accumulative capacity, you need mass • Little future in major usage • I don't know, the timber frame idea is different than the traditional. The traditional methods are more virtue despite that maybe all objections can be wiped away. But the choice is still at the consumer • Depends on the buyer

Figure 10: Timber use in the future with the link towards sustainability

4.2 Differences in CO2 emissions of building materials

This paragraph explains the CO2 emissions of building materials on three different levels; the material level, house level and environmental impact of a house level. For a lot of products there are many differences when it comes to how much CO2 it emits in its total life cycle. This differs by how much energy you have to put in a product through manufacturing, use, demolition and, when possible, recycling. For this, the LCA assessment also plays a role in order to asses this amount.

4.2.1 CO2 emissions on material level

Figure 11 shows the total CO2 savings from combined carbon store and substitution effect of 1m3 wood. It means that 1 m3 of wood stores 0.9 tonnes of CO2 and substitutes 1.1 tonnes of CO2 when using wood instead of other building materials. So it means that by using more wood you can reduce a lot of CO2 emissions only by using this particular product.

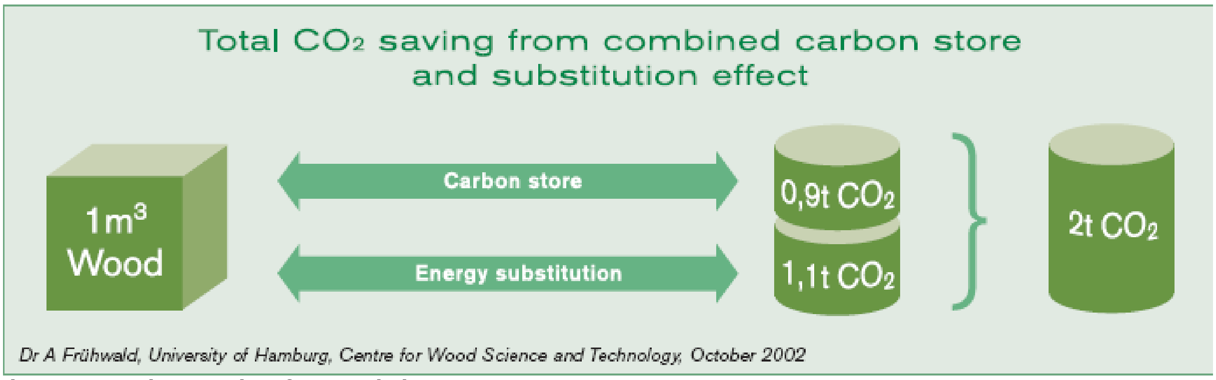

Figure 11: Total CO2 savings for 1m3 timber

Figure 12 and 13 both show the differences in CO2 emissions of the building materials that are used when building a house. In figure 8 it is shown that aluminium has the highest CO2 emissions of all the building materials that are mentioned in this figure.

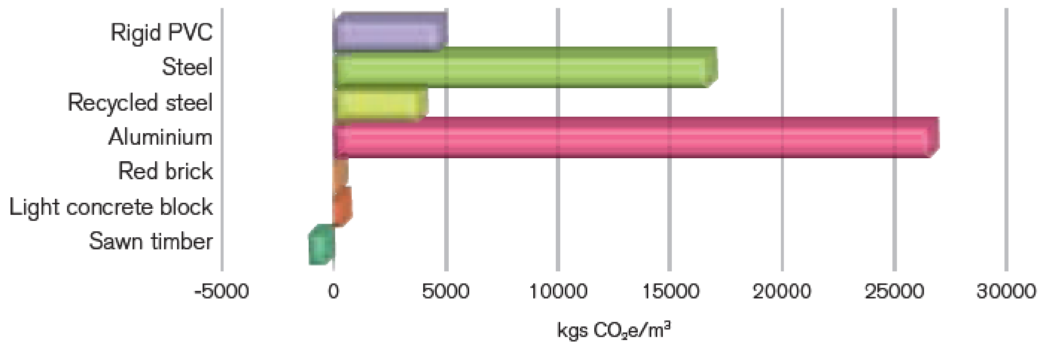

Figure 12: A comparison of the CO2 production of different materials (net CO2 emissions including carbon sink effect)

Almost all the building materials that are currently used in the Netherlands are mentioned in Figure 13. Also in this figure it can be seen that the metals have the highest CO2 emissions /m3 during their total life cycle and that the wooden products have lowest emissions per cubic meter. In contrary, the wooden products don't even emit CO2 but they store it as it's also shown in this figure.

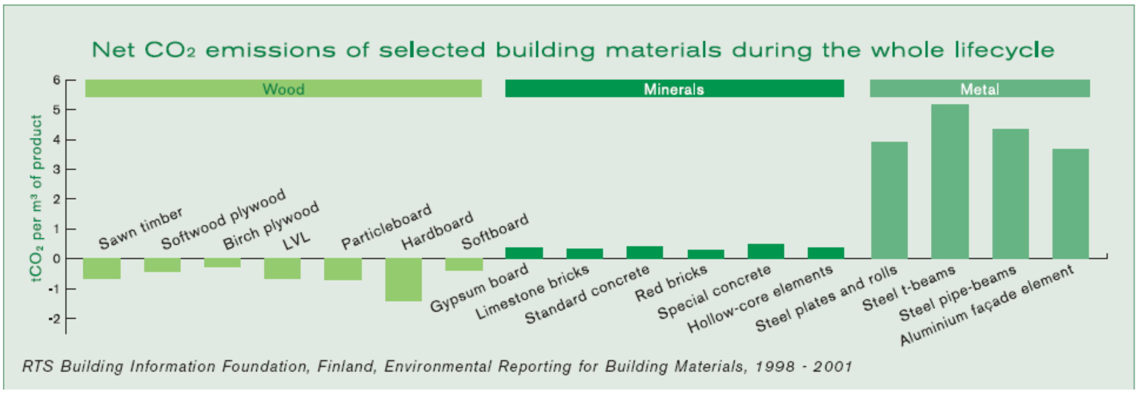

Figure 13: Net CO2 emissions of building materials during the total lifecycle

4.2.2 CO2 emissions on total house level

Figure 14 shows the difference in wood content of 2 different types of houses. One is a timber frame house and the other is a masonry house. As shown, a timber frame contains around 11m3 of timber. It shows that a timber frame house contains about 5m3 more timber compared to a masonry house.

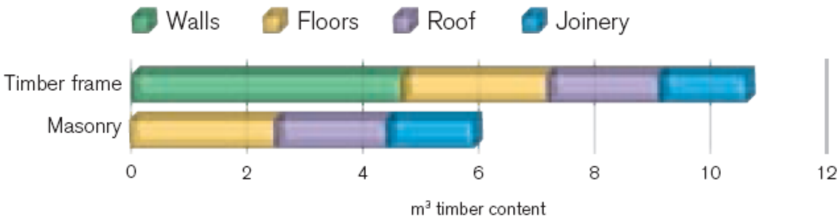

Figure 14: A comparison between the timber content of a 100m2 two-storey detached house using 140mm studs timber frame and masonry

Figure 15 shows the CO2 emissions from different house constructions, a timber frame house emits 370kg CO2/m2 less than a concrete and steel house.

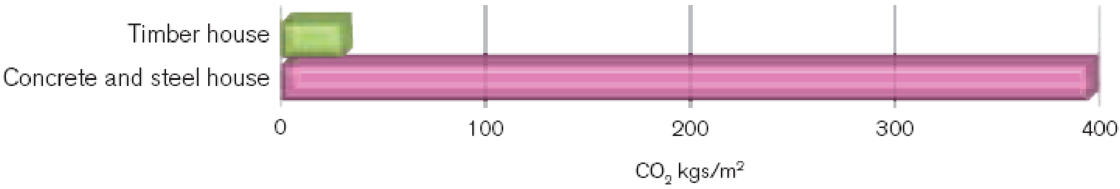

Figure 15: The difference in CO2 emissions from the materials and construction content of two houses is 370 kg/m2

If you look at the emissions of different wall constructions that are used it is shown that the constructions that use timber frame have the lowest CO2 emissions of all the other wall constructions that are mentioned in figure 16. This means when a brick and dense block (concrete) wall is compared to a brick and timber frame wall, the timber frame wall has around 1.5 tonnes fewer CO2 emissions than the concrete wall per 50m2 of wall.

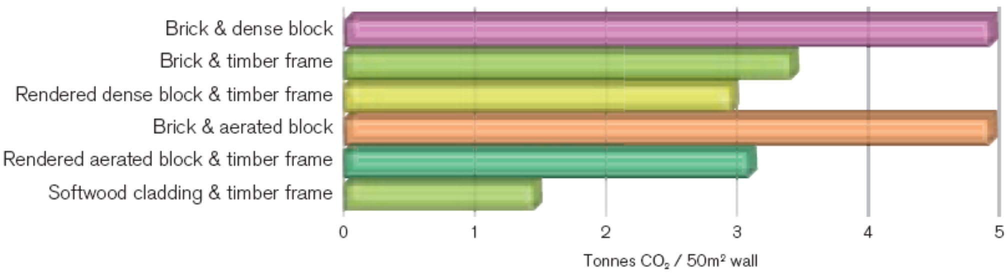

Figure 16: A comparison of CO2 emissions over the lifecycle of different wall constructions, based on a 60 year life

4.2.3 Environmental impacts level of different building methods

On the environmental impact level, wood shows an advantage over a steel house that is stated in figure 17. Compared to steel, the differences in the environmental effects are huge compared to the wooden building. The only exception is for the solid wastes a wooden house provides.

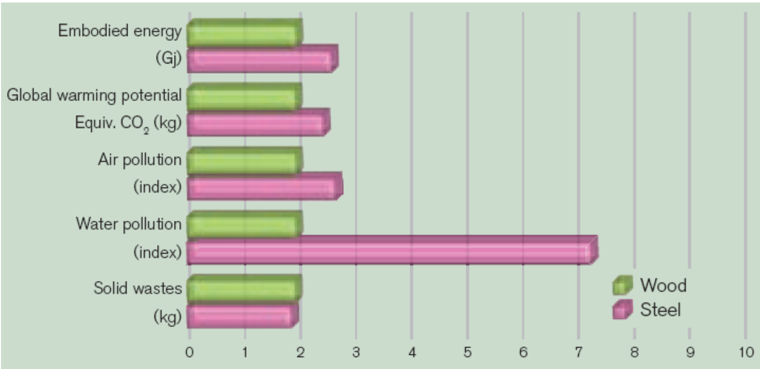

Figure 17: Environmental results for typical residential dwellings in wood and steel

In figure 18 a wooden house compared to a concrete house and shows smaller differences compared to the steel house. But it still shows that a wooden house has fewer environmental impacts than a concrete house.

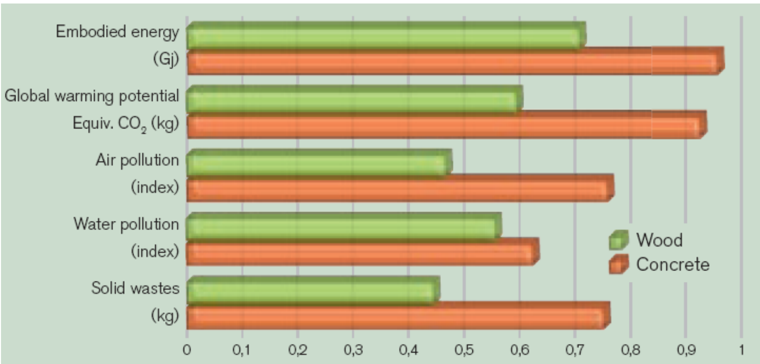

Figure 18: Environmental results for typical residential dwellings in wood and concrete

Figure 19 shows the differences in percentage for the environmental impact of a wooden house, a steel house and a concrete house. It shows that the wooden house has lower environmental impacts on all the impact types besides the solid waste.

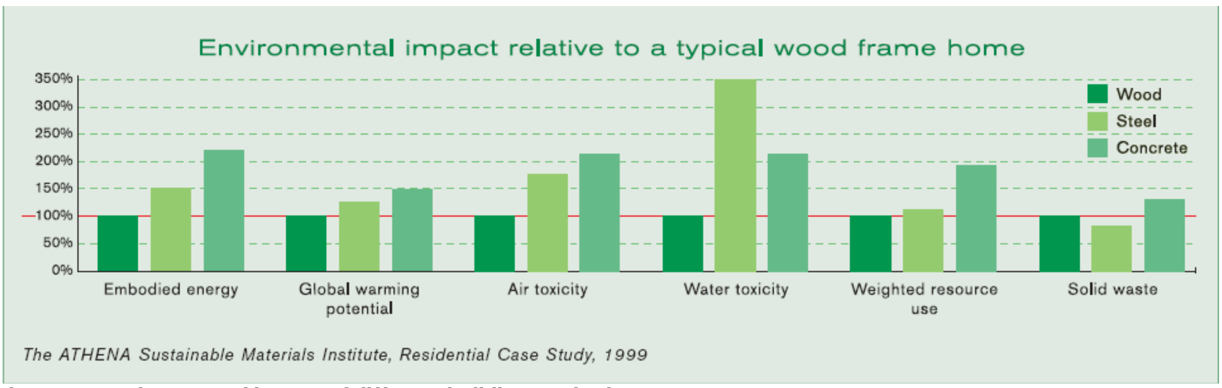

Figure 19: Environmental impact of different building methods

4.3 Policy energy savings in the Netherlands: 'Schoon en Zuinig'

In this paragraph the governmental policies to save energy are mentioned. It shows the goals that the government wants to reach, the current state of the reductions and the results of the goals that have been set in order to reach these.

4.3.1 The policy 'Schoon en Zuinig'

Because of the changing environment the government set up goals to reduce the environmental impact.
The government wants to make the Netherlands one of the cleanest and most energy efficient countries in Europe. How they want to do that is explained in the 'Schoon en Zuinig: New energy for climate' policy. It contains the ambitions for energy conservation, renewable energy and CO2 storage.

The cabinet wants to reach the following:

- To lower the emissions of greenhouse gasses, especially CO2, in 2020 with 30 percent compared to 1990 as the base year
- To double the rate of energy savings upcoming years from 1 percent to 2 percent each year
- To increase the share of sustainable energy in 2020 from 2 till 20 percent of the total energy usage
- Tightening of the EPC of buildings: Goal: zero carbon buildings by 2020

In European context the Netherlands aims to joint efforts in continuation of the Kyoto-protocol. The Kyoto-protocol (1997) is an addition on the Climate convention (1992), that's also called the 'United nations framework convention on climate change'

The Climate convention has to decrease the amount of greenhouse gasses. This prevents people from having a dangerous influence on the climate. The countries that signed this convention agreed that they would emit the same amount of greenhouse gasses as in 1990.

The Kyoto-convention continues. The Netherlands has obligated to decrease the amount of greenhouse gasses even further. Between 2008 and 2012 the emissions have to be 6 percent lower than in 1990. That's about 13 megaton CO2 less each year. Yearly the Netherlands emits 220 megaton of CO2. Around 25% is originated from households.

4.3.2 Additional policy: 'Lente-akkoord': Energy savings in new buildings

The 'lente-akkoord' is an agreement between the government and the market to build more energy efficient on the short term.

With this they want to save the climate, finite fuels and the living charges.

The key findings of this agreement are:

- The cabinets' plan 'Schoon en Zuinig' aims a CO2 reduction of 6 to 11 megatonnes in the building area in 2020
- The cabinets' plan 'Schoon en Zuinig' aims to tighten the Energy Performance Standard of new residential buildings with 25% in 2011 and 50% in 2015. All parties aim to build energy neutral in 2020

4.3.3 How far are we with reducing the CO2 emissions in the Netherlands?

In figures 20 and 21 the greenhouse gas emissions and their shares are shown from 1990 till 2007. It is shown that the overall emissions are decreasing whereas the CO2 emissions are increasing.

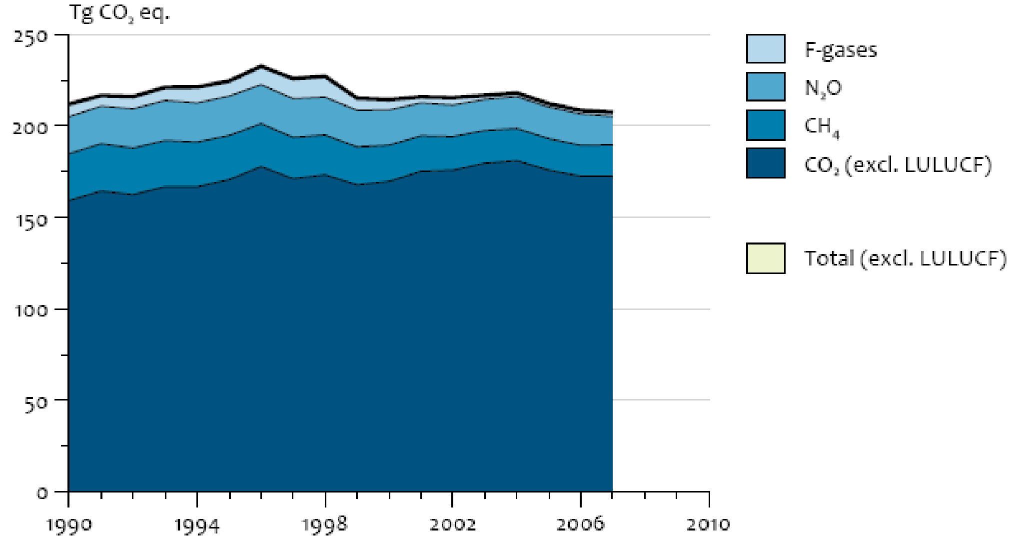

Figure 20: Green house gas emissions (excl. LULUCF) (excluding emissions from Land Use, Land Use Change and Forestry, LULUCF)

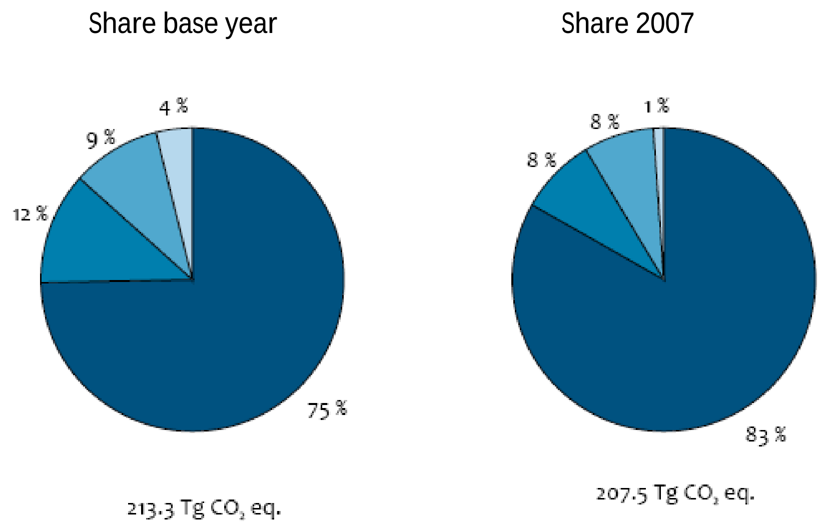

Figure 21: Share base year **Share 2007**

As seen in Appendix 2 there is an 8.4% increase in CO2 emissions in 2007 compared to 1990. It is shown that the total CO2 emissions in 2008 were 175700 which means if this is compared to 1990 it is an increase of 10.28%. From this 18.27% originates from the total industry, 10.30% originates from households and 1.31% of the building material industry.

4.3.4 The current state of the 'Schoon en Zuinig' Policy

In figure 22 the current state of the 'Schoon en Zuinig' policy and the goals are shown for the total greenhouse gas equivalents together with the CO2 emissions. The goal to reach in 2020 is 150 megatonnes of CO2 equivalents. In figure 23 this is translated into the CO2 emissions in the building environment. It can be seen that both goals are still far away to reach.

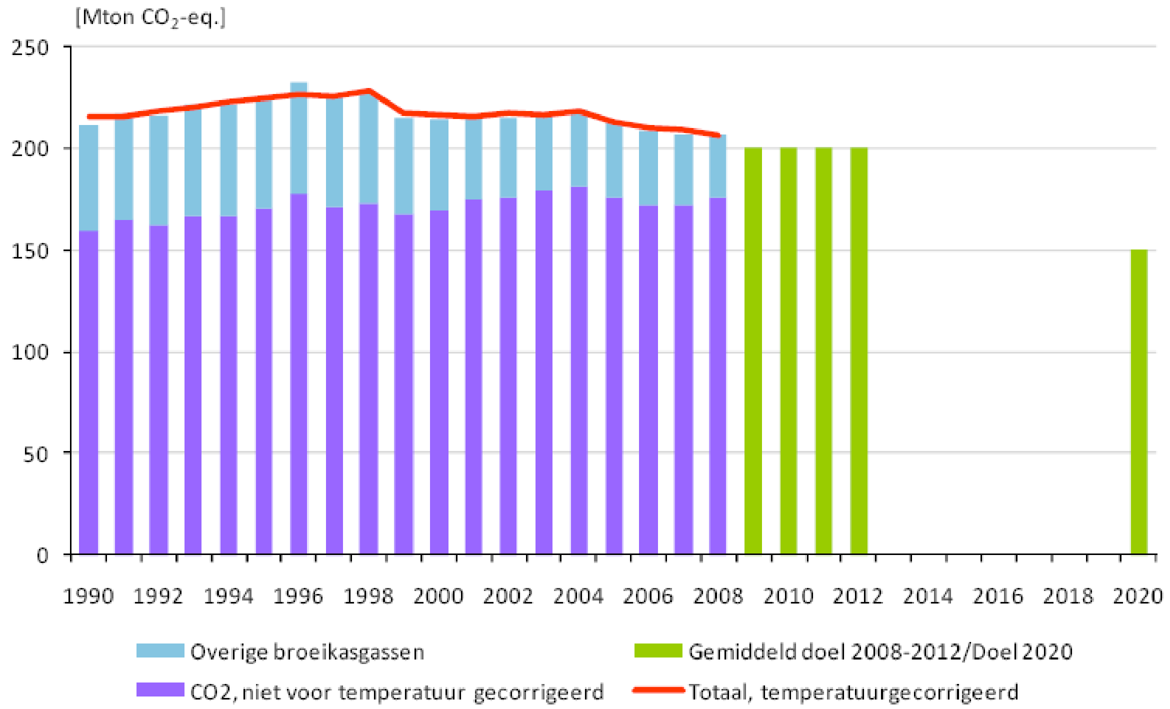

Figure 22: Development Green house gasses emissions in the Netherlands

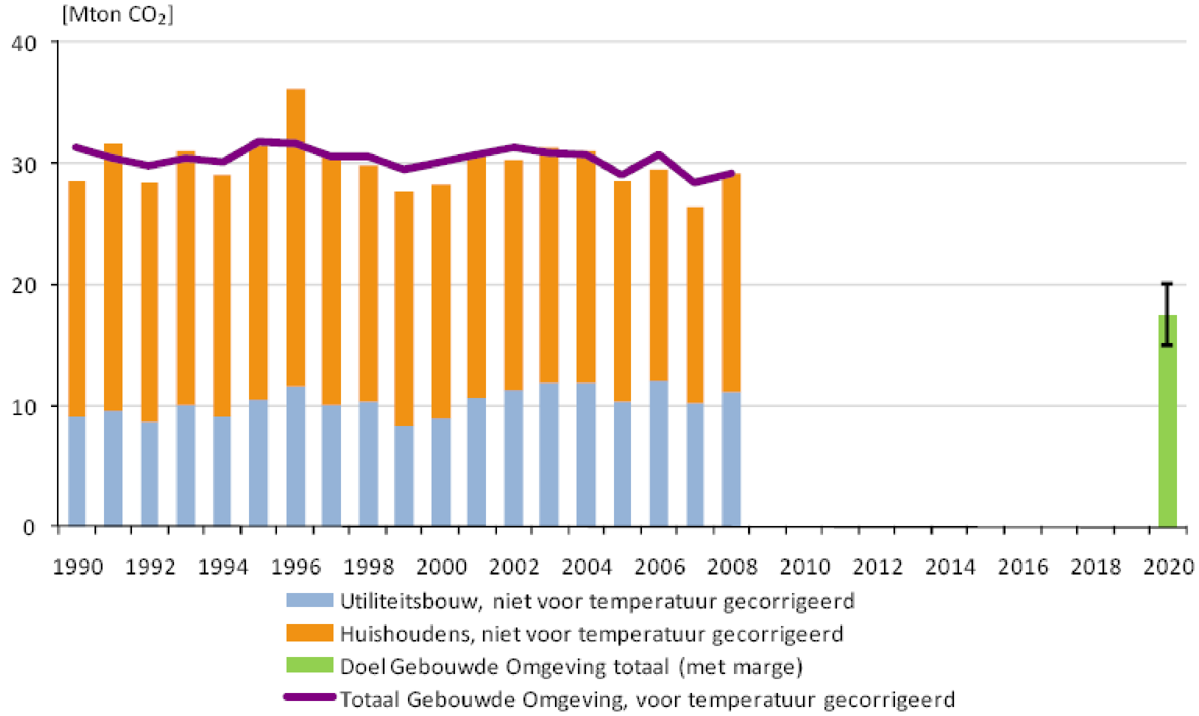

Figure 23: Development CO2 emissions building environment

To what extend the government's policy have realized the goals that have been set for 2020 is shown in figure 24. This figure is divided in 3 parts, the greenhouse gases, energy savings and renewable that is also stated in governments' goals. There are the following 3 options mentioned:

1. RR2010-0 Policy option without 'Schoon en Zuinig' policy
2. RR2010-V Policy option with established policies
3. RR2010-VV Policy option with established and proposed 'Schoon en Zuinig' policy

Greenhouse gases Energy savings Renewable

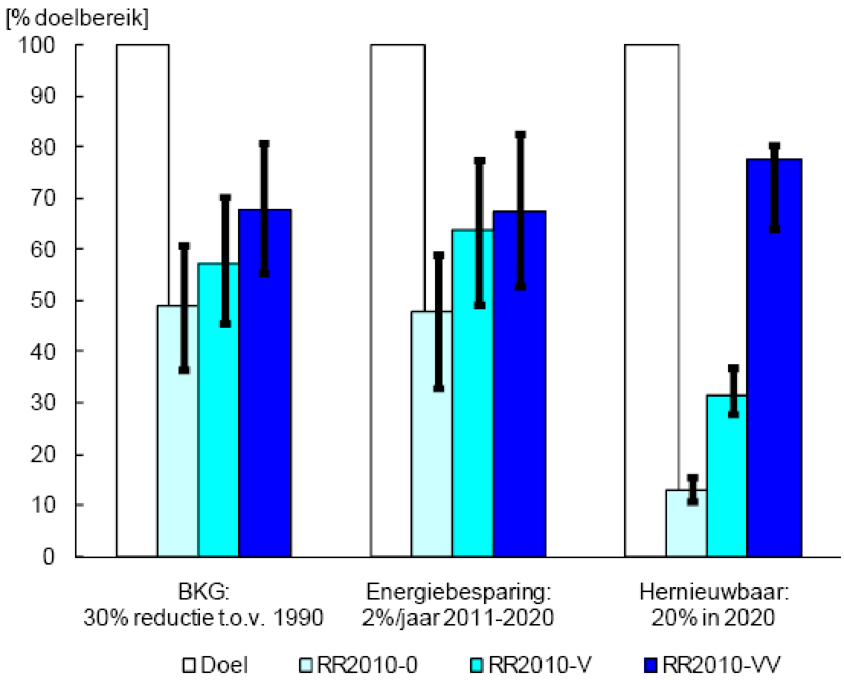

Figure 24: Reference projections energy and emissions 2010-2020

With the total established and proposed government policy the emission of greenhouse gases still remain 21 megatonnes higher than the target of 150 megatonnes in 2020. That means that with the established and proposed 'Schoon en Zuinig' policy it only reaches 75% of the goal.
The share of renewable energy increases from nearly 4 percent in 2009 to 15 percent if the subsidy funds will be increased to 3 to € 4 billion a year.
The total 'Schoon en Zuinig' policy increases the savings rate from 0.7 to 1.2 percent to 1.1 to 1.6 percent annually. Both plans like 'Schoon en Zuinig' and the established policies thus contribute to achieve the goals but full implementation of the planned policy is inadequate to reach the government's goals. This means that there have to change a lot of things in order to reach the governments' goals.

4.4 Market share of building methods in the Netherlands

In this paragraph the market share of the building methods that are used in the Netherlands are explained. The four building methods are: Concrete formwork, prefab concrete, calcium silicate and timber frame.

4.4.1 The market share

To get the current market shares of the house building methods it wasn't sufficient to consult the internet. The market shares could only be obtained at one market research company which asked a great amount of money for it, so the following market shares are estimated on older numbers of market shares that have been found by consulting the internet.

- The 'Gietbouwcentrum' states that in 2006 the market share of concrete formwork was 33% and that prefab concrete had a market share around 8%.
- In 2008 the 'Bouwwereld' states that both concrete formwork and prefab concrete had a combined market share around 50%.

The market shares of the building methods are as follows for the house building market:

- Concrete formwork 38%
- Prefab concrete 12%
- Calcium silicate 45%
- Timber Frame 5%

5 ANALYSIS

In this chapter there are shown several analysis in order to get to a conclusion of this research. The following analysis have been made: There has been made a SWOT analysis which shows the Strengths, weaknesses, opportunities and threats of the project developers and building companies in the Netherlands. The analysis of the market in the United Kingdom shows the current state of timber frame usage in the UK and how they have been able to grow this market share. Afterwards the Eco-Quantum analysis is shown which assesses the environmental effects of the four building methods that are mentioned in this research project. Finally the environmental sustainability assessment of a house by using BRE can be found.

5.1 SWOT analysis Project developers and Building companies in the Netherlands

In this paragraph the SWOT analysis is shown that has been made from the answers that were given by the approached project developers and building companies in the Netherlands in order to get an idea in how far the market is ready to be penetrated by timber frame.

The SWOT analysis in figure 25 shows the strong and weak points of the building methods that the project developers and the building companies apply. It also shows the opportunities and threats they encounter on the Dutch market.

	INTERNAL	EXTERNAL
POSITIVE	STRENGTHS ● Flexible ● Sustainable ● Good accumulative capacity ● Solid construction ● Sound proof ● Well known around the market ● High fire safety	OPPORTUNITIES ● Combination timber frame housing/ concrete ● Aiming at house building corporations and care institutions ● Building more energy efficient
NEGATIVE	WEAKNESSES ● Cost price ● Building time ● Laborious ● The actual construction of traditional housing is depended on weather	THREATS ● it is getting more difficult to reach the Dutch EPC energy label ● More governmental demands regarding building energy efficient can cause new buildings to get more expensive compared to the existing housing

Figure 25: SWOT Analysis building methods traditional Project developers and Building companies within the Netherlands

Strengths
As seen in this figure the strengths of the building methods are commonly known for traditional building methods. They are flexible by means that a lot of things can be altered on the building site. The sustainability is referred to how long the building method lasts and also includes the solid construction of the building. And by a good accumulative capacity is meant that these building methods are all made of minerals like concrete which holds the warmth longer.
Also the biggest strength of all the traditional building methods is that these methods are well known around the market.

Weaknesses
The weaknesses of the building methods that are mentioned depend on the method that is used. For example the calcium silicate method is laborious because of the extra work that has to be done on the building site. Also the building time is an important weakness.
Maybe the biggest weakness is that all the traditional methods depend on the weather which has had large effects as could be seen in the past half year.

Opportunities
There weren't a lot of opportunities mentioned that the project developers and building companies experienced. The combination with timber frame with concrete was mentioned by 1 company as well as the remaining 2 opportunities.

Threats
As well as for the opportunities there weren't many threats mentioned by the approached companies. Only the difficulties in reaching the EPC and the growing governmental demands were mentioned by 1 of the companies.

5.2 Analysis UK Market

In this paragraph the analysis of the market in the United Kingdom is explained. It shows the current market share of the timber frame method and how the timber frame method got its high market share in this market. Furthermore it is explained how to get to Code 6 by the Code of Sustainable Homes, which includes the link from HLP to the Dutch EPC standard, and the additional costs that are included to get to level 6 of this Code.

5.2.1 Market share of timber frame in the United Kingdom

In the United Kingdom the market share of timber frame housing is a lot higher compared to the Netherlands.
Ten years ago the timber frame market share was 10.1% and this year it has grown to 25.6%. This means that one out of four homes is now build using the timber frame method.

If you look at the history of the UK, the UK is also a stone building country just like the Netherlands. The most common method is the Brick and Block method where concrete blocks are used internally and bricks externally.

5.2.2 How timber frame got its high market share in the UK

In the beginning the UK also had difficulties obtaining a higher market share. What got them to a higher share was by lobbying. The legislation was changing and went on the eco routes, and it lend itself to build with timber frame solutions and the insulation it provided.

The Code of Sustainable Homes was a progression for the UK Timber Frame Association to get a higher market share. It states that in 2016 a home has to be zero carbon, which means: Zero net emissions of carbon dioxide (CO2) from all energy use in a home.

At this moment the timber frame system is getting higher insulation and has reached level 3 of the Code so far.
The brick and block builders are looking at this, they see the advantage, and slightly move towards the timber frame method.

Also, the UKTFA has launched an advertising campaign called ‘Fabric first’ to communicate with project developers, architects, builders and self builders. It tells you to look at the fabric first and afterwards look at the required renewables. It will still require renewables to get to level 6 when you build a timber frame house, but timber already provides up to 44% of achieving zero carbon.

5.2.3 Code of Sustainable Homes: Getting to level 6

The UK Timber Frame Association has published the ‘Comfort and Cost: Low carbon timber frame in a changing climate’ guide, it explains how to get from level 3 to level 6, and they also added several studies.

One of the studies describes the Heat Loss Parameter and the costs to achieve the HLP of 1.3, 1.1 and 0.8 which can be linked to the Dutch EPC Standard in which a building in the Netherlands has to reduce its CO2 emission. It compares Timber Frame with a brick and block masonry building.

The timber frame house generally shows a lower additional cost to achieve compliance HLP of 1.3, 1.1 and 0.8 than a typical masonry house.

The cost differential has been assumed to be in the order of 2.2% to 5.2%, depending on the house type:

- The comparative difference is largest at HLP 1.3, with timber showing an additional cost ranging from 0.3% to 4.4%, compared with masonry's 1.2% to 8.3%.
- At HLP 1.1 the comparative cost increases are 1.4% to 9.7% for timber and 2.3% to 13% for masonry.
- At HLP 0.8 the comparative cost increases are 7.9% to 15.5% for timber and 8.8% to 19.9% for masonry.

Costs

In figure 26 it is shown that in order to reach level 3-6 there are additional costs added. These costs are for example the extra insulation costs and the added renewables like solar heating.

Code level	3	4	5	6
Timber	5.6 to 18.6%	8.4 to 24.2%	17.3 to 40.6%	33.4 to 58.3%
Masonry	7.0 to 19.7%	10.7 to 29.9%	18.7 to 46.3%	34.6 to 61.5%

Figure 26: Indicative additional costs associated with achieving Code compliance

To get to Code level 3 it means that for timber frame the additional costs in total are 2.5% lower than for a masonry building. In order to get to level 4 the additional costs are again 8% lower for timber frame than for masonry.
For reaching Code level 5 this difference is again 7.1% and for level 6 this is 4.4%.

In figure 27 are the total additional costs mentioned in pounds when reaching higher levels of the Code. The results are shown for 4 different building types.

Code level	3		4		5		6	
	Timber	Masonry	Timber	Masonry	Timber	Masonry	Timber	Masonry
Detached	£8,655 - £11,835	£12,352 - £15,532	£11,933 - £24,008	£16,308 - £28,216	£24,433 - £40,248	£27,932 - £43,640	£40,988 - £53,918	£44,380 - £57,310
End terrace	£5,756 - £10,800	£6,538 - £13,290	£8,214 - £17,341	£9,614 - £19,514	£18,454 - £30,881	£19,038 - £32,238	£31,601 - £42,751	£32,958 - £44,108
Mid-terrace	£5,323 - £12,245	£6,157- £12,956	£7,781 - £13,853	£16,308 - £28,216	£24,433 - £40,248	£27,932 - £43,640	£40,988 - £53,918	£44,380 - £57,310
Flat	£4,287 - £14,093	£5,175- £14,472	£6,387 - £15,568	£7,851 - £16,523	£13,099 - £26,306	£13,747 - £25,944	£25,350 - £35,500	£25,489 - £35,639

Figure 27: Summary of costs for Code compliance

Detached

In order to reach level 3 for a detached home the difference in costs are £3697 pounds when a timber frame home is build instead of masonry home. For level 4 this difference is £4291,5 pounds, for level 5 this is £3445,5 pounds and for getting to level 6 this difference is £3392 pounds.
So the total difference in costs to get a detached building to Code level 6 is approximately £14826 pounds if you choose for the timber frame method.

End terrace
In order to reach level 3 for an end terraced home the difference in costs are £1636 pounds when a timber frame home is build instead of masonry home. For level 4 this difference is £1786,5 pounds, for level 5 this is £970,5 pounds and for getting to level 6 this difference is £1357 pounds. So the total difference in costs to get a end terraced building to Code level 6 is approximately £5750 pounds if you choose for the timber frame method.

Mid terrace
In order to reach level 3 for a mid terraced home the difference in costs are £772,5 pounds when a timber frame home is build instead of masonry home. For level 4 this difference is £11445 pounds, for level 5 this is £3445,5 pounds and for getting to level 6 this difference is £3392 pounds. So the total difference in costs to get a end terraced building to Code level 6 is approximately £19055 pounds if you choose for the timber frame method.

With the studies of the UKTFA the CO2 emissions have also been taken into account in various house types. In figure 28 there is a detailed breakdown of carbon emissions by a timber frame house and a concrete house. Four types of building are shown; an end terrace, mid terrace, detached and a flat.

House type and component	t/CO2e							
	end terrace		mid terrace		detached		flat	
	timber	concrete	timber	concrete	timber	concrete	timber	concrete
external and dividing walls	-3.3	8.4	-2.5	4.9	-4.5	13	-1.9	5.7
internal walls	-0.06	0.6	-0.06	0.6	-0.22	2.04	-0.08	0.77
foundations	0.9	0.9	0.9	0.9	1.6	1.6	0.7	0.7
windows	0.07	0.07	0.06	0.06	0.15	0.15	0.11	0.11
exterior doors	-0.007	-0.007	-0.007	-0.007	-0.008	-0.008	-0.003	-0.003
roof	1.6	1.6	1.6	1.6	2.9	2.9	0.96	0.96
concrete slab	5.2	5.2	5.2	5.2	5.7	5.7	2.3	2.3
floors and ceilings	-0.4	4.3	-0.37	4.3	-0.6	6.9	-1.3	9.6
Totals	**4**	**21**	**4.8**	**18**	**4.96**	**32.4**	**0.7**	**20.1**

Figure 28: Detailed breakdown of carbon emissions by construction and building type

The CO2 emissions for an end terraced house differ by 17 tonnes of CO2 of you build a house in concrete instead of timber frame. For a mid terraced building this difference is 13.2 tonnes of CO2. For a detached house this difference is 27.44 tonnes of CO2 and 19.4 tonnes for a flat. This means that the timber frame method has a lot lower CO2 emissions compared to the concrete method.

5.3 Eco-Quantum environmental effects analysis of different building methods

In this paragraph the environmental effects analysis of four different building methods is shown by using the Eco-Quantum tool which uses the LCA mythology to assess the environmental burdens of different building materials. These burdens are calculated for two types of houses; a detached house and a terraced house. The following comparisons are made:

- Calcium silicate vs. timber frame in a detached and terraced building
- Prefab concrete vs. timber frame in a detached and terraced building
- Calcium silicate vs. prefab concrete in a detached and terraced building
- Concrete formwork vs. timber frame in a terraced building

5.3.1 Eco-quantum analysis

By using Eco quantum the environmental impacts of a building can be calculated as explained in the theoretical background. For calculating the environmental effects there will be two types of buildings used. One building type is a detached residential building and the other type is a terraced residential building.

These two houses will be calculated in the following building methods:

- Calcium Silicate method
- Prefab Concrete method
- Concrete Formwork method (only terraced)
- Timber Frame method

Afterwards, the outcomes between the different methods are compared. This will give a good view of the differences in the environmental effects of the different types of building methods.

The construction data that is used for calculating the environmental effect is coming from a house building project in the Netherlands.

For the details of the different buildings in this building project consult Appendix 3 and 4

5.3.2 Results of the different building methods for a detached building

The results of the Eco-Quantum calculations for the detached residential building are shown below. It shows the difference in environmental effects between the two different building methods.

Calculation Calcium Silicate vs. Timber Frame detached building
The differences between the calcium silicate and the timber frame method are shown in Appendix 3.1. It is shown that most environmental effects are similar with both building methods. The only major differences are shown at the greenhouse effect (CO_2), acidification, Eutrophication, and waste. The greenhouse effect emissions differ by 6.41% between both methods. In total environmental effects, the differences between the methods are 1.17% if favour of Calcium Silicate. This is mainly due to the large part of dangerous waste that timber frame has.

Calculation prefab Concrete vs. Timber Frame detached building
The differences between the prefab concrete and the timber frame method are shown in Appendix 3.2. If you look at the differences between the two methods, you can see that the timber frame method has the best scores on almost all environmental effects. Especially the Greenhouse effect (CO_2) and smog have the biggest advantage when using timber frame instead of prefab concrete. For CO_2 emissions this difference is 14.11%. Also, if you look at the total environmental effects, timber frame has 7.93% fewer environmental effects.

Calculation Calcium Silicate vs. prefab Concrete detached building
The differences between the calcium silicate and prefab concrete method are shown in Appendix 3.3. If you look at the figure it can be seen that the calcium silicate method scores better on all effects compared with the concrete method. For the Greenhouse effect (CO_2) it differs by 8.96% and if you look at the total emissions it has a difference of 9.88% in favour of calcium silicate.

The results of the Eco-Quantum calculations from the terraced residential building are shown below. It shows the difference in environmental effects between the two different building methods.

Calculation Calcium Silicate vs. Timber Frame terraced building
The differences between the calcium silicate and the timber frame method are shown in Appendix 4.1. It is shown that the biggest differences between the two building methods can be seen in the greenhouse effect (CO_2), Ozone degradation, ecotoxicity terrestrial, acidification, Eutrophication and waste. The greenhouse effect in CO_2 differs by 9.81% in favour of Timber frame. The total environmental effects differ by 3.23% in favour of the calcium silicate method.

Calculation Concrete vs. Timber Frame terraced building
The differences between the prefab concrete and the timber frame method are shown in Appendix 4.2. It can be seen that the timber frame method differs a lot in ways of emissions compared to the prefab concrete method. On almost all the effects it scores less. For the greenhouse effect, measured in CO_2, this difference is 18.38%. If you look at the total environmental effects the difference is 8.04% in favour of timber frame.

Calculation Concrete Formwork vs. Timber Frame terraced building
The differences between the concrete formwork and the timber frame method are shown in Appendix 4.3. It can be seen that the timber frame method has less emissions on almost all the calculated effects. For the greenhouse effect this difference is 20.83% in favour of timber frame. If you look at the total effects this differs with 11.38% in favour of timber frame.

Calculation Calcium Silicate vs. Concrete terraced building
The differences between the calcium silicate and prefab concrete method are shown in Appendix 4.4. It can be seen that the Calcium Silicate method has fewer emissions on all calculated environmental effects. The emissions of the greenhouse effect (CO2) differ by 10.50% in favour of calcium silicate. If you look at the total effects this difference is 12.25% in favour of calcium silicate.

5.3.3 Greenhouse effects (CO2) improvement, and total environmental effects improvement when using Timber Frame compared for 3 building methods

This table concludes the CO2 improvement and the total environmental effects improvement when using timber frame instead of the other building methods calculated by Eco-Quantum.

	Greenhouse effect CO2 improvement when using Timber Frame	Greenhouse effect CO2 improvement when using Timber Frame	Total environmental effects improvement when using Timber Frame	Total environmental effects improvement when using Timber Frame
	Detached res. building	Terraced res. Building	Detached res. building	Terraced res. Building
Calcium Silicate vs. Timber Frame	6.41%	9.81%	-1.17%	-3.23%
Prefab Concrete vs. Timber frame	14.11%	18.38%	7.93%	8.04%
Concrete formwork vs. timber frame	-	20.83%	-	11.38%

It shows that the CO2 emissions improvement for a detached residential building is minimum 6.41% and maximum 14.11%. For a terraced residential building the minimal CO2 improvement is 9.81% and maximum 20.83%.

5.4 Environmental sustainability of a house by BRE

By using the Green Guide material rating, the environmental sustainability of a house can be calculated. The Green Guide methodology takes a cradle to grave approach over a 60-year building life, taking into account maintenance and refurbishment over this period and demolition at the end of its life. It expresses the relative impacts on a simple environmental scale running for ‘A+’ (minimal) to ‘E’ averaged across all twelve environmental impact categories.

The following table shows the difference between a timber frame house and a concrete house.

Construction	Timber Frame house	Average Marking	CO2 Marking	Concrete house	Average Marking	CO2 Marking
Internal wall	Timber stud, plasterboard, paint	A+	A	Aircrete blockwork, painted finish only	A+	A
External wall	Brickwork, cement mortar, cement-bonded particle board, timber frame with insulation, vapour control layer, plasterboard on battens, paint	A+	A	Brickwork outer leaf, insulation, dense solid blockwork inner leaf, cement mortar, plaster, paint	A+	A
Upper Floor construction	T&G floorboards on timber joists	A+	A+	Screeded hollow precast prestressed concrete planks	C	C
Ground floor construction	Screed on insulation laid on grouted hollow prestressed precast concrete planks.	C	C	Screed on insulation laid on grouted hollow prestressed precast concrete planks.	C	C
Domestic windows	Durable hardwood window, double glazed, solvent borne gloss paint (TWAS)	A+	A+	Durable hardwood window, double glazed, solvent borne gloss paint (TWAS)	A+	A+
Roof construction	Timber trussed rafters and joists with insulation, roofing underlay, counterbattens, battens and reclaimed slates	A+	A+	Timber trussed rafters and joists with insulation, roofing underlay, counterbattens, battens and reclaimed slates	A+	A+

This concludes that on average bases and on CO2 bases a timber frame house is more environmental friendly compared to a concrete house.

6 CONCLUSIONS

In this conclusion the main question of this research is being answered.

- **How can we ensure that timber frame housing will be used more in the future and could the issue of sustainability help us succeed this?**

The project developers and building companies look positive towards the growing need for timber with the focus on environmental sustainability.

A lot of sources have already shown for a long time that by using timber the CO2 emissions can be reduced.

The government has set up policies to reduce their CO2 emissions. The current figures show that they aren't going to reach these reductions as is shown in the text.

For every m3 of timber that is used it saves 2 tonnes of CO2, so by using more timber frame it reduces CO2 emissions. Many studies emphasize this and these reductions are also emphasized in the calculations by Eco-Quantum. It compared 2 building types and the different building methods that are used on the Dutch market. The results are that timber frame has the lowest CO2 emissions of all building methods. The Green Guide material ratings also emphasize the same results.

Based on the market shares of the building methods that are used in the Netherlands a lot of CO2 can be reduced when choosing for timber frame instead of other building methods.

Based on the UKTFA the total costs for reaching higher levels in the Code of Sustainable Homes are lower in timber frame houses compared to traditional built houses. In the UK the builders and project developers are already slightly moving towards the timber frame method as we speak. In order to reach the zero carbon level, timber itself already provides up to 44% of achieving this goal for a zero carbon home as stated by the UKTFA.

Further research regarding the difference in costs when lowering the EPC levels could lead to an increasing use of timber frame in the Netherlands.

Further research of the Code of Sustainable Homes regarding the CO2 reduction it causes for the United Kingdom could lead to more benefits for using timber frame.

7 Recommendations

7.1 Recommendations Project developers and Building companies

- Look at the 'Comfort and Cost' publication by the UKTFA which shows the additional cost increase when reaching higher levels of the Code of Sustainable Homes

7.2 Recommendations Government

- Look at the building fabric first to reduce CO2 emissions of a building, afterwards look at the renewables that should be added
- Look at the different CO2 emissions of the building materials and analysis like Eco-Quantum for reductions in CO2
- Look at the United Kingdom and the Code of Sustainable Homes in which they reduce the CO2 emissions

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- http://www.bre.co.uk/greenguide/ggselectelement.jsp?buildingType=Housing
- http://www.uktfa.com/
- http://www.fabricfirst.co.uk/#

Appendix

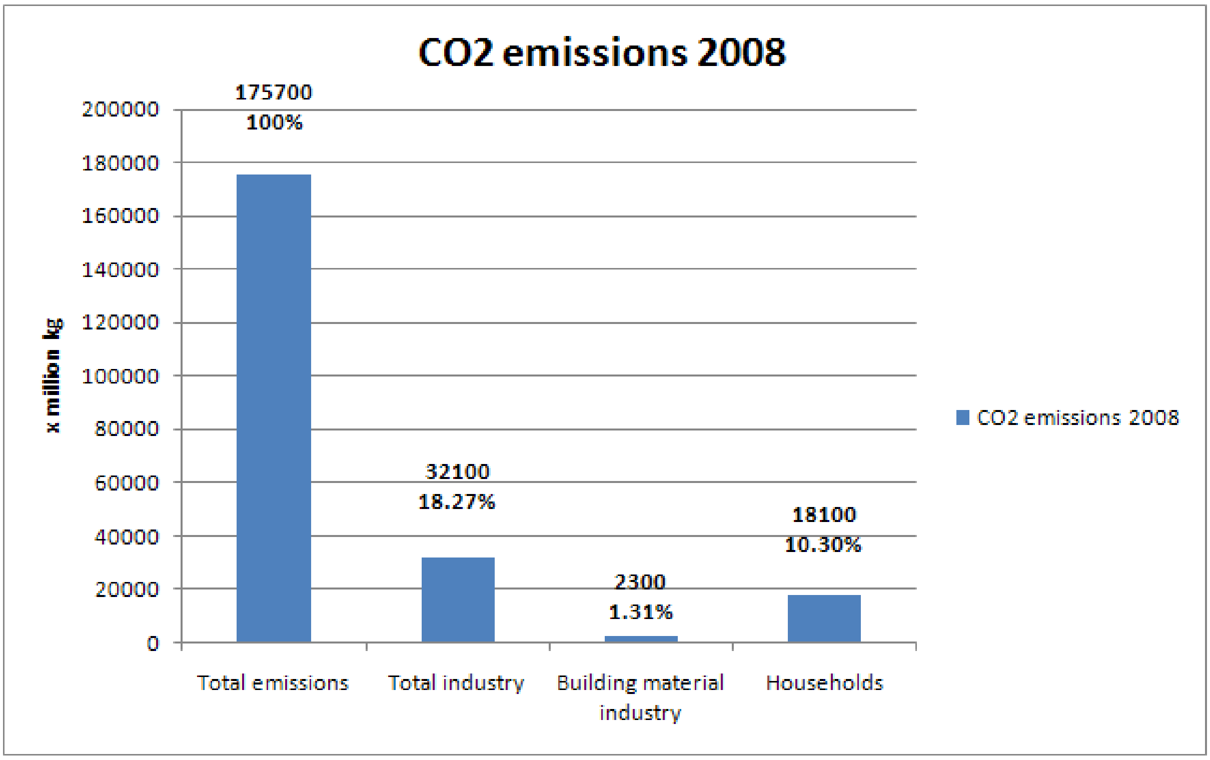
Appendix 1: Interviews Project developers

Company name	Website Address
AM	http://www.am.nl/
Groothuis	http://www.groothuis.nl
Moes Bouwgroep	www.moesbouwbedrijf.nl
Planoform	http://www.planoform.nl/
Ten Brink Bouw	http://www.tenbrinkebouw.nl/
Trebbe	http://www.trebbe.nl/
Ursum	www.ursem.nl
VanRhijnbouw	http://www.vanrhijngroep.nl/
VORM	www.vorm.nl
Van Oostrum en Van Laar	www.vovl.nl
Selekthuis	http://www.selekthuis.nl/
Bun Projectontwikkeling B.V.	http://www.bun.nl/
Grouwels Daelmans Projectontwikkeling	http://www.grouwels-daelmans.nl/
Ter Steege Bouw Rijssen	www.tsvastgoed.nl
Timpaan	http://www.timpaan.nl

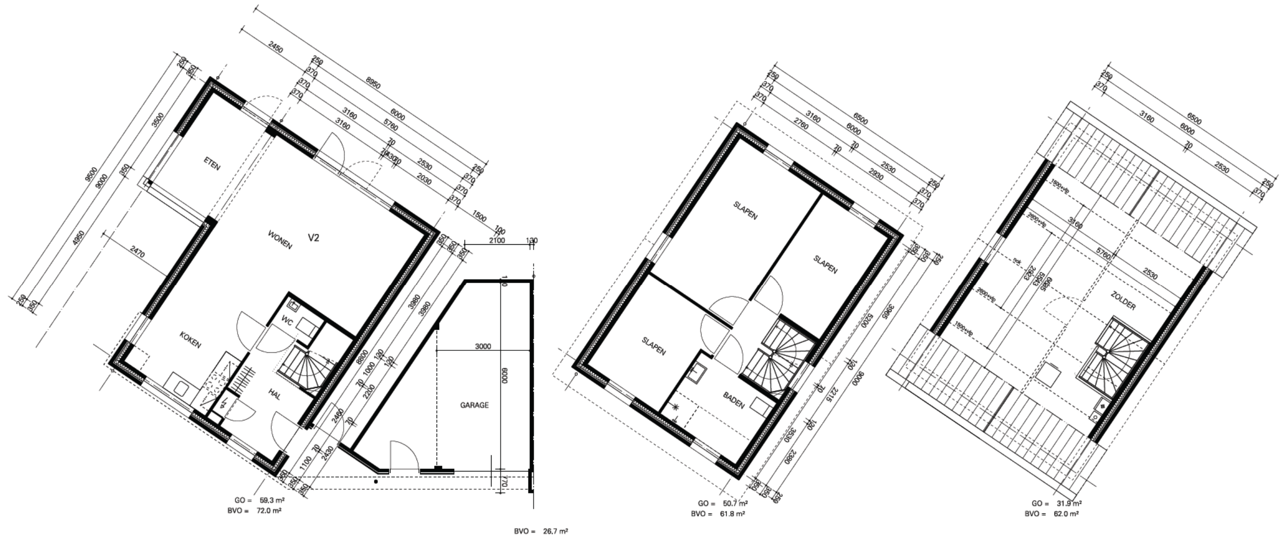
Appendix 2: Emissions of Greenhouse Gasses from 1990 till 2007 and CO2 emissions in 2008

Greenhouse gas	Base year[b]	1990	1995	2000	2005	2006	2007	Change base year–2007 (%)
	Gg CO_2 eq							
CO_2	159 311.79	159 311.79	170 706.23	169 619.18	175 779.99	172 510.04	172 656.94	8.4
CH_4	25 545.87	25 545.87	24 153.23	19 793.60	17 228.17	16 831.52	16 963.50	–33.6
N_2O	20 225.11	20 225.11	21 540.89	19 285.53	17 311.95	17 141.78	15 604.70	–22.8
HFCs	6 019.54	4 432.03	6 019.54	3 828.94	1 357.71	1 566.39	1 737.59	–71.1
PFCs	1 937.81	2 264.48	1 937.81	1 581.54	266.20	256.54	327.07	–83.1
SF_6	301.26	217.32	301.26	318.71	237.92	202.17	213.95	–29.0

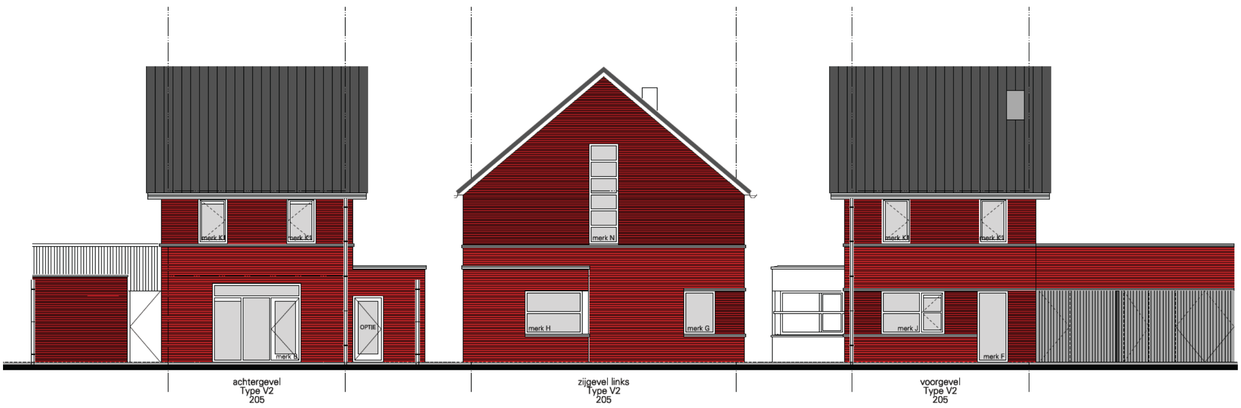
The total CO2 emissions in 2008 were 175700. 18.27% originates from the total industry, 10.30% of the emissions originates from households and 1.31% of the building material industry.

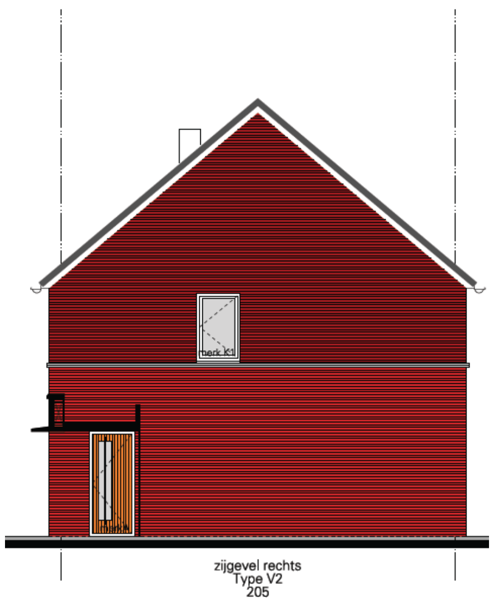


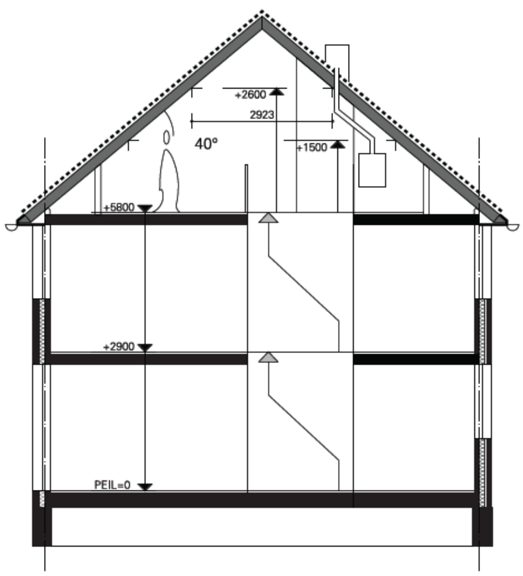
Appendix 3: Project 1: Detached residential house



BEGANE GROND 1° VERDIEPING 2° VERDIEPING

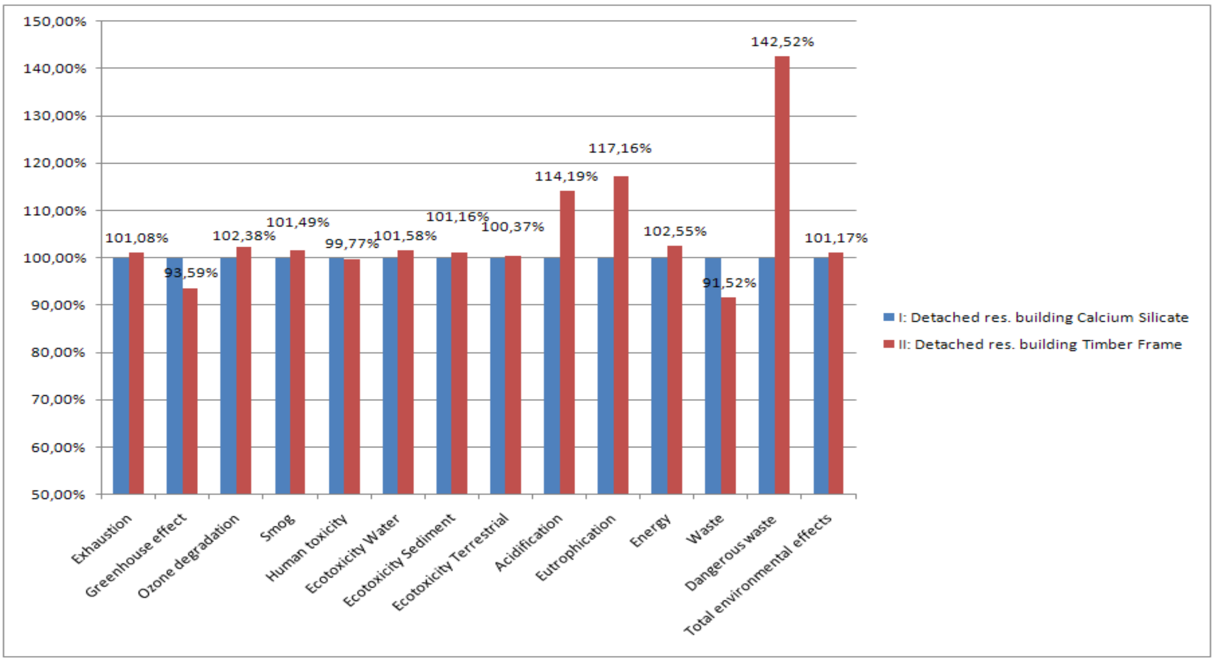




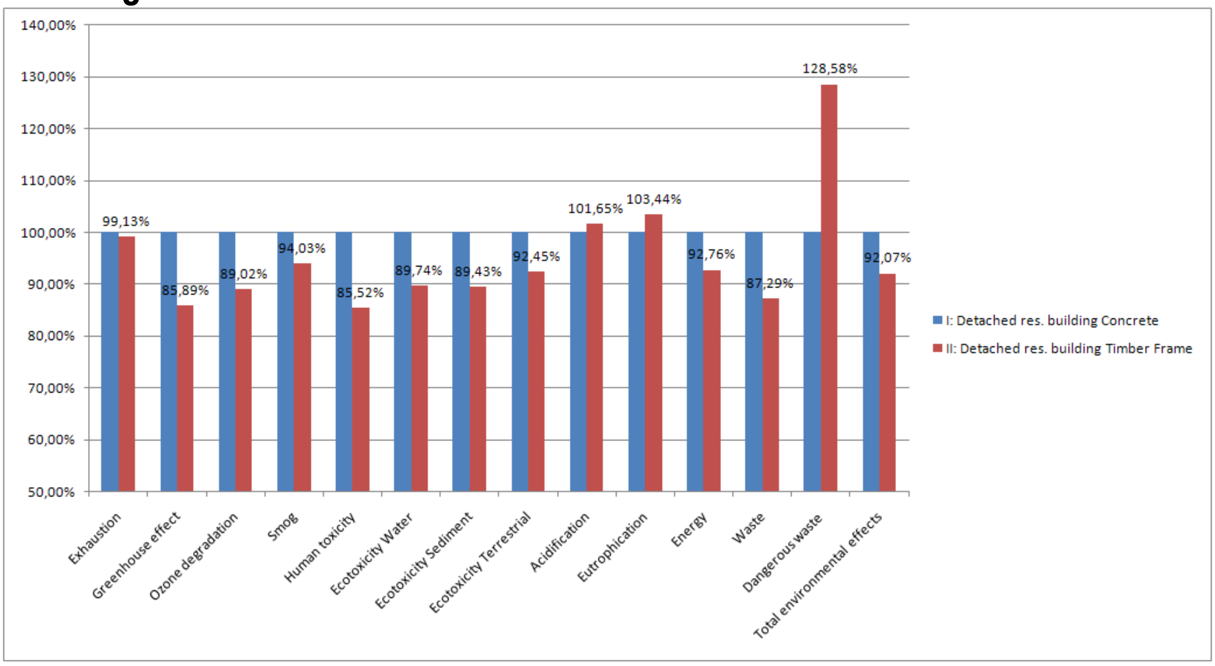


DOORSNEDE

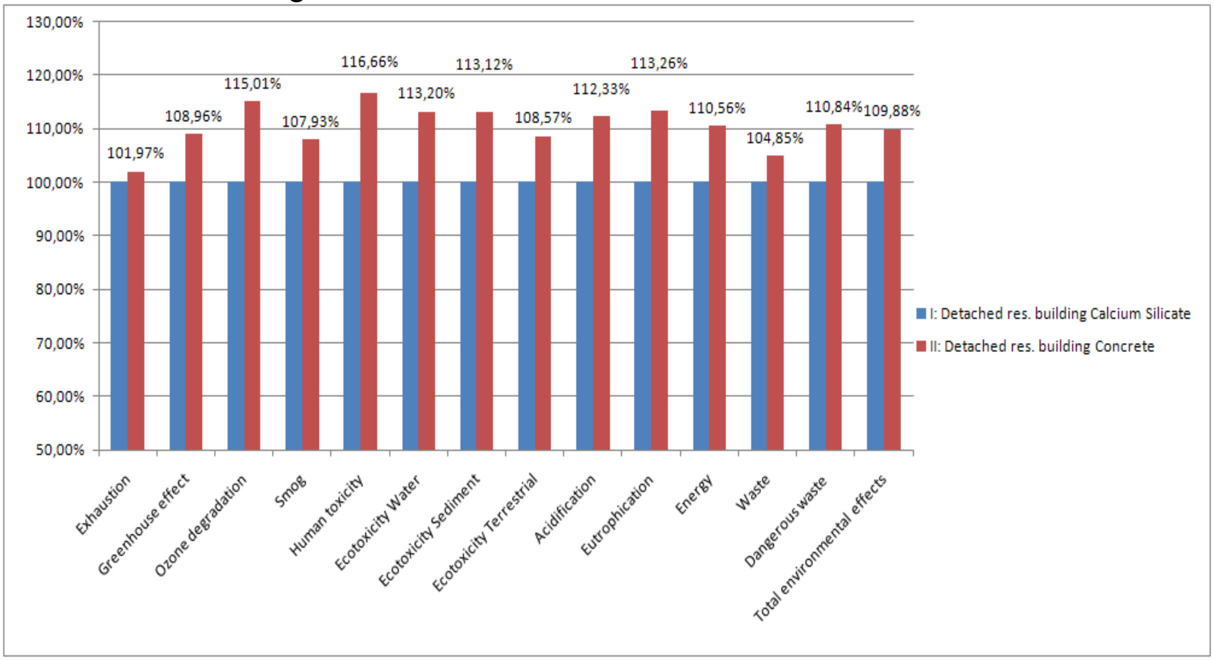
Appendix 3.1: Calculation Calcium Silicate vs. Timber Frame detached building



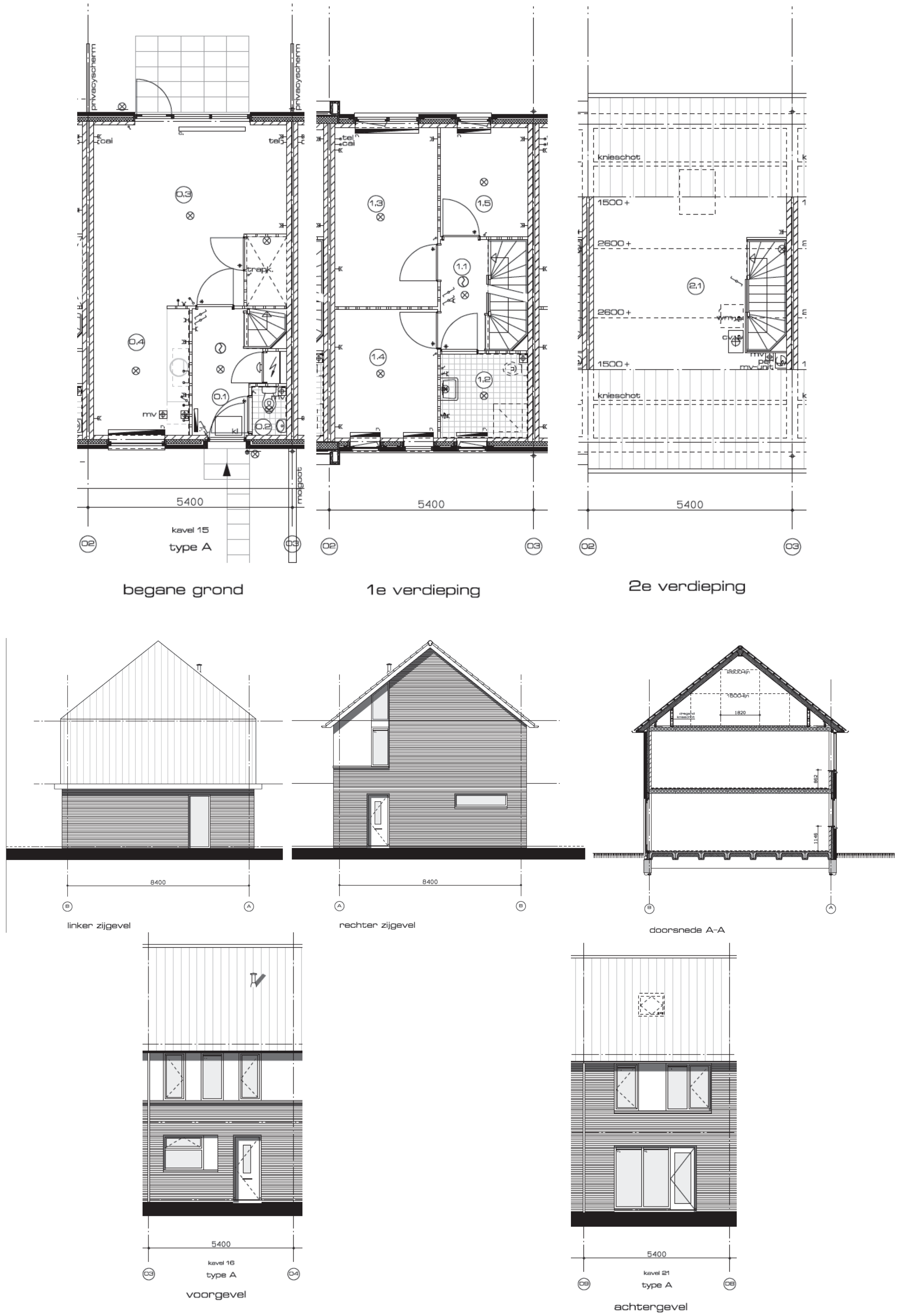
Appendix 3.2: Calculation prefab Concrete vs. Timber Frame detached building



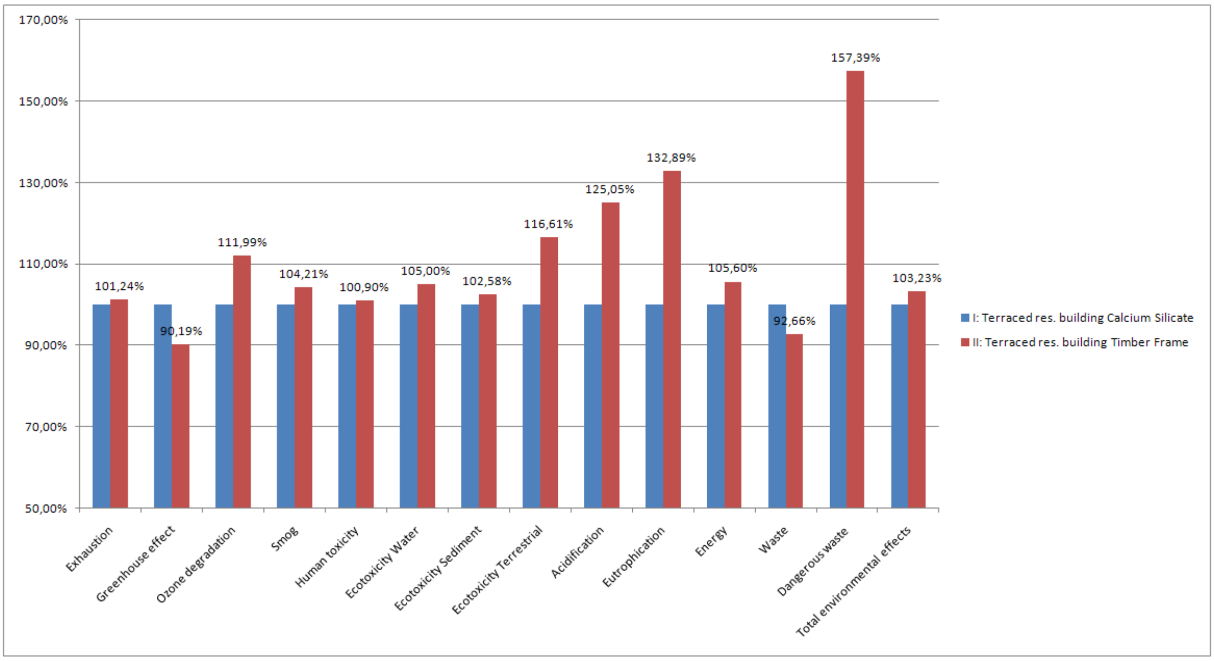
Appendix 3.3: Calculation Calcium Silicate vs. prefab Concrete detached building



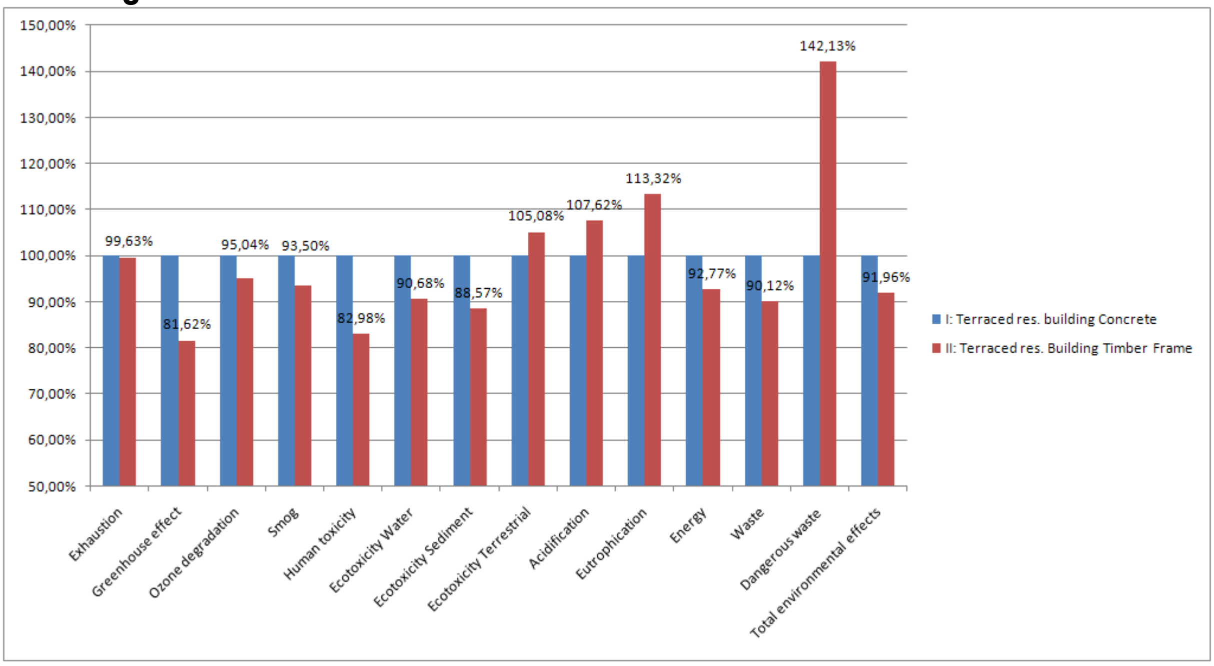
Appendix 4: Project 2: Terraced residential house



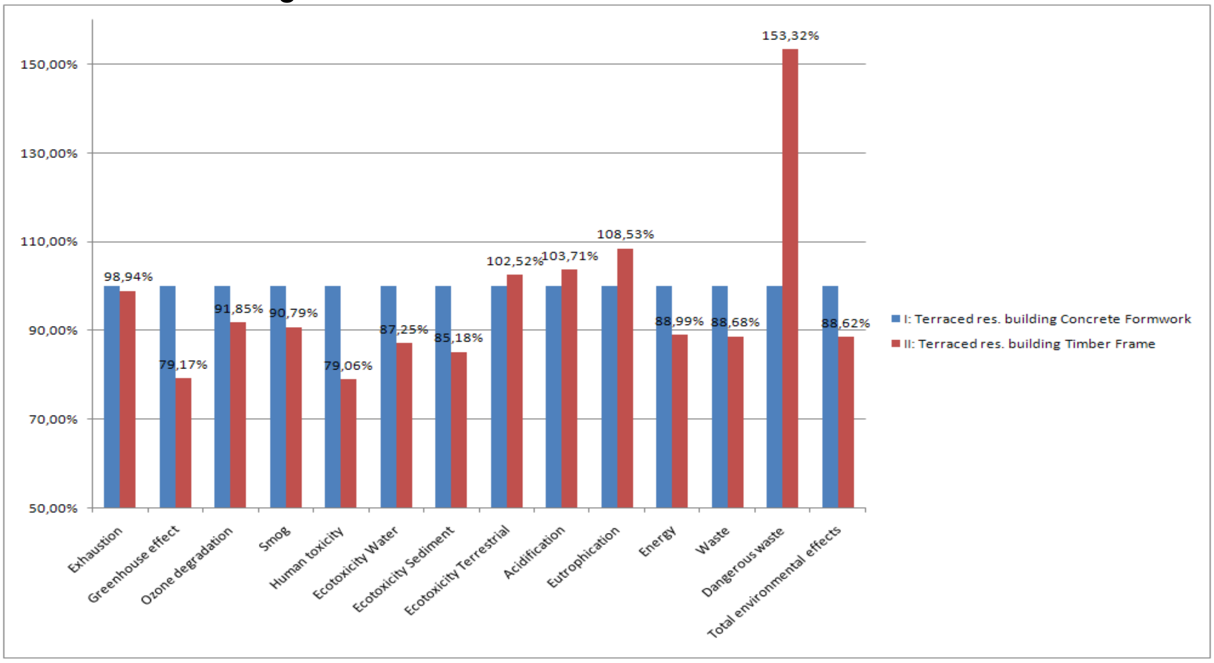
Appendix 4.1: Calculation Calcium Silicate vs. Timber Frame terraced building



Appendix 4.2: Calculation Concrete vs. Timber Frame terraced building



Appendix 4.3: Calculation Concrete Formwork vs. Timber Frame terraced building



Appendix 4.4: Calculation Calcium Silicate vs. Concrete terraced building