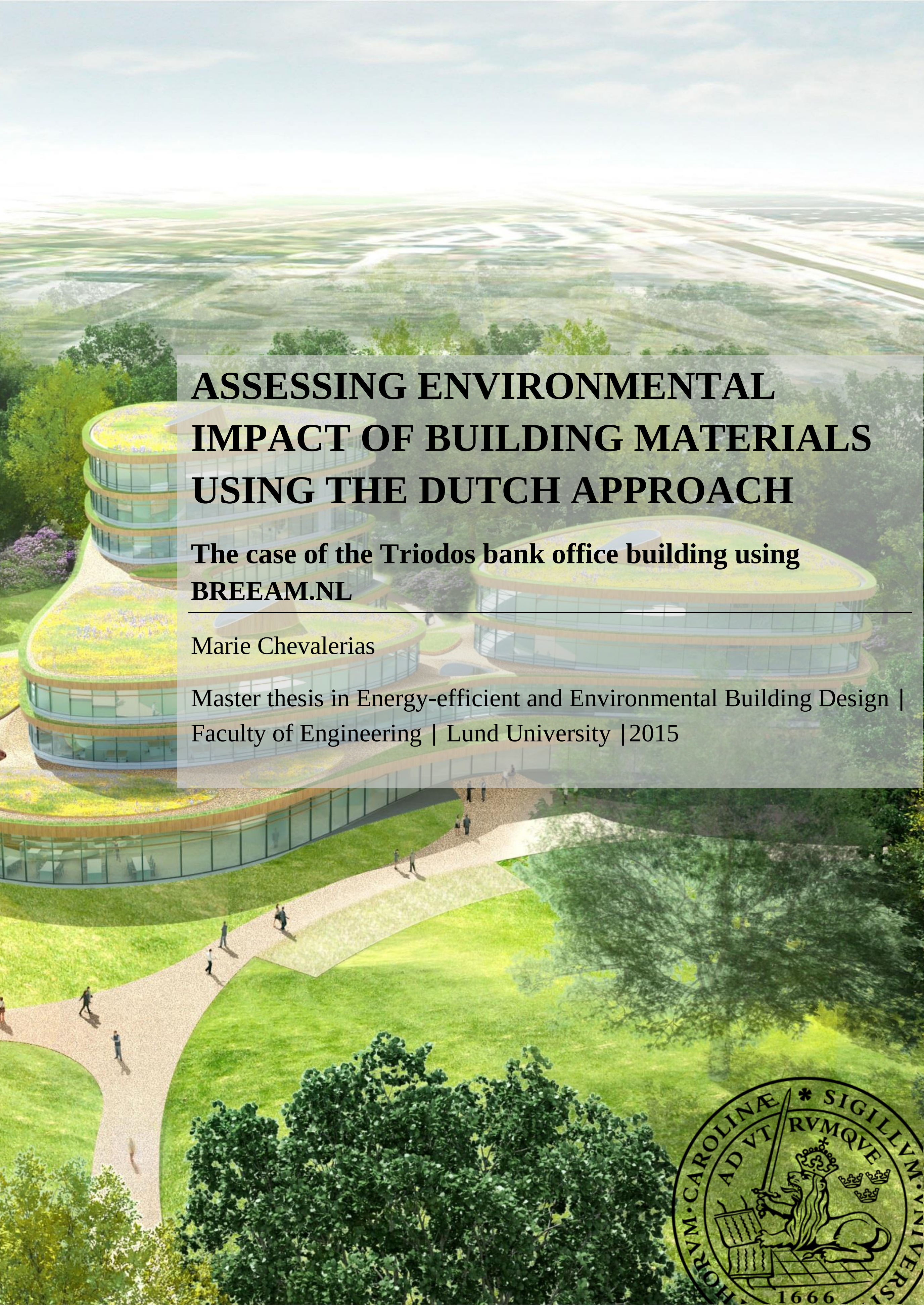

ASSESSING ENVIRONMENTAL IMPACT OF BUILDING MATERIALS USING THE DUTCH APPROACH

The case of the Triodos bank office building using BREEAM.NL

Marie Chevalerias

Master thesis in Energy-efficient and Environmental Building Design | Faculty of Engineering | Lund University |2015

Lund University

Lund University, with eight faculties and a number of research centres and specialized institutes, is the largest establishment for research and higher education in Scandinavia. The main part of the University is situated in the small city of Lund which has about 112 000 inhabitants. A number of departments for research and education however, are located in Malmö and Helsingborg. Lund University was founded in 1666 and today has a total staff of 6 000 employees and 47 000 students attending 280 degree programmes and 2 300 subject courses offered by 63 departments.

Master Programme in Energy-efficient and Environmental Building Design

This international programme provides knowledge, skills and competencies within the area of energy-efficient and environmental building design in cold climates. The goal is to train highly skilled professionals, who will significantly contribute to and influence the design, building or renovation of energy-efficient buildings, taking into consideration the architecture and environment, the inhabitants' behaviour and needs, their health and comfort as well as the overall economy.

The degree project is the final part of the master programme leading to a Master of Science (120 credits) in Energy-efficient and Environmental Buildings.

This thesis was presented in June 2015.

Keywords: Environmental Impact, Shadow cost, building materials, BREEAM.NL, office building, The Netherlands, National MilieuDatabase

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Cover picture: Courtesy of RAU Architects

Abstract

With the increasing importance accorded to environmental performance of buildings, the goal of this master thesis is to study the Dutch assessment method for evaluating the environmental impact caused by the material of an office building project with the Dutch version of the BREEAM certification scheme.

After doing a literature review to comprehend the current state of affair concerning the assessment method for environmental impact of building material in the Netherlands, the MaterialenTool using the National MilieuDatabase was used to assess different scenarios aiming to reduce the total shadow cost of the building. Along the study, different actors and users of the Dutch method were interviewed on their expertise and opinions.

In this specific case, the shadow cost of the building was reduced by 25% in total. Reducing the basement was better than removing it completely, a massive wood construction was preferred over a laminated wood structure to replace the concrete elements of the building, the potential of introducing a new type of climate ceiling in the database was demonstrated and the importance of having reviewed data was shown by changing the type of expanded polystyrene.

The Dutch environmental impact assessment method revealed itself to be a valuable tool for the design team although important limitations were revealed, the main one being the incompleteness of the product database.

Keywords: e*nvironmental impact, LCA, shadow cost, building materials, BREEAM.NL, office building, National MilieuDatabase.*

Preface

This study is performed as a degree project within the master programme Energy-efficient and Environmental Building Design from Lund University (Sweden) as well as part of an internship at the architectural firm RAU Architects located in Amsterdam (The Netherlands).

During my bachelor in Architecture and my master in Building Sciences, I have developed a technical approach of the design process and I am very thankful that RAU Architects has allowed me to find a role to play in one of their many sustainable projects. I would like to thank Willem Wijnbergen for accepting to meet with me in the first place and making my internship as pleasant as possible. I want to thank all the employees of RAU architects for welcoming me in the company and especially Marijn Emanuel and Dennis Grootenboer for their support and supervision of my work.

I am very grateful to Martin Bijleveld from DGMR, René Klaassen from SHR and Rick Scholtes from NIBE for accepting to be interviewed and for sharing their experiences with me.

A special thanks to the Triodos bank for setting an example for a more sustainable world and for allowing me to take their project as a study case, promoting the spread of knowledge about the best practice for sustainable design.

I also want to greatly thank Evian Elzinga whose thesis and lectures made me particularly interested in the field of LCA and the importance of environmental impact aside from energy-efficiency. I would like to thank Saqib Javed, my supervisor, for his clear feedbacks and support all along my thesis work, and Dennis Johansson, my examiner, for his detailed correction.

Finally, I want to express my gratitude to the Hans Eliasson Foundation for supporting our Master Programme.

Amsterdam, June 2015

Marie Chevalerias

Table of content

Terminology

AHU: Air Handling Unit

BREEAM: Building Research Establishment Environmental Assessment Methodology

BREEAM.NL: Building Research Establishment Environmental Assessment Methodology for the Netherlands

BVO: Bruto-VloerOppervlak (Gross Floor Area)

C2C: Cradle-to-cradle

DGBC: Dutch Green Building Council

DGMR: Consultant engineering office

EPD: Environmental Product Declaration

EPS: Expanded Polystyrene Styrofoam

LCA: Life Cycle Assessment

MAT1: section 1 of the material part of BREEAM.NL

MPR: Bepaling van de milieuprestaties van gebouwen en gww-werken (Determination method of the environmental performance of buildings and civil engineering works)

NIBE: Nederlands Instituut voor Bouwbiologie and Ecologie (Dutch Institute for Building biology and Ecology.)

NMD: National MilieuDatabase (Dutch Environmental Database)

OSB: Oriented Strand Board

PCR: Product Category Rules

SBR: Stichting Bouw Research (Foundation for Building Research)

SBK: Stichting Bouw Kwaliteit (Foundation for Building Quality)

SHR: Stichting Hout Research (Foundation for Timber Research)

TNO: Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organization for Applied Scientific Research)

TIC: Technische Inhoudelijke Commissie (Technical Content Commission)

VLCA: Vereniging voor LCA's in de bouw (Association for LCA in construction)

VO: Voorlopig Ontwerp (Preliminary Design)

Environmental Impact Categories:

ADPE: Abiotic Depletion Potential for Non-fossils resources, expressed in kg Sb equivalent.

ADPF: Abiotic Depletion Potential for Fossils resources, expressed in kg Sb equivalent.

AP: Acidification Potential, expressed in kg SO_2 equivalent.

EP: Eutrophication Potential, expressed in kg PO_4 equivalent.

FAETP: Fresh water Aquatic Eco-Toxicity Potential, expressed in kg 1,4-DB equivalent.

GWP100: Global Warming Potential for time horizon 100 years, expressed in kg CO_2 equivalent.

HTP: Human Toxicity Potential, expressed in kg 1,4-DB equivalent.

MAETP: Marine Aquatic Eco-Toxicity Potential, expressed in kg 1,4-DB equivalent.

ODP: Ozone Depletion Potential expressed in kg CFC-11 equivalent.

POCP: Photochemical Oxidant Creation Potential, expressed in kg C_2H_2 equivalent.

TETP: Terrestrial Eco-Toxicity Potential, expressed in kg 1,4-DB equivalent.

Terms and definitions

Product Category Rules (PCR): Common harmonized calculation rules for the creation of EPDs specific to a group of products. (Environdec, n.d.)

Shadow cost: Monetary value of something that does not have a market. In this study, the shadow represent the cost that society is willing to pay to ensure environmental quality.

Re-use: Use of a product a second time after reclaiming it from the waste stream after its first life-cycle and using it without any major transformation.

LCA: Assessment method to quantify the environmental impact caused by a product over its whole lifetime.

Solver: Term designating to a mathematic software or computer program that solves a mathematical problem.

Environmental Impact: Adverse effects caused by substances used or released to the environment from a project or a process.

Different categories of impacts are used to define and quantify the impact caused to the environment. The following categories and their definitions are retrieved from the Handbook on Life Cycle Assessment (Guinée, et al., 2002)

Abiotic Depletion: "Abiotic resources are natural resources (including energy resources) such as iron ore, crude oil and wind energy, which are regarded as non-living. Abiotic resource depletion is one of the most frequently discussed impact categories and there is consequently a wide variety of methods available for characterising contributions to this category."

Acidification: "Acidifying pollutants have a wide variety of impacts on soil, groundwater, surface waters, biological organisms, ecosystems and materials (buildings). Examples include fish mortality in Scandinavian lakes, forest decline and the crumbling of building materials. The major acidifying pollutants are SO_2, NOx and NHx."

Eutrophication: "Eutrophication covers all potential impacts of excessively high environmental levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In addition, high nutrient concentrations may also render surface waters unacceptable as a source of drinking water."

Terrestrial, Fresh water and Marine Aquatic Eco-Toxicity: "This impact category covers the impacts of toxic substances on aquatic, terrestrial and sediment ecosystems."

Global Warming: "Climate change is defined as the impact of human emissions on the radiative forcing (i.e. heat radiation absorption) of the atmosphere. This may in turn have adverse impacts on ecosystem health, human health and material welfare. Most of these emissions enhance radiative forcing, causing the temperature at the earth's surface to rise. This is popularly referred to as the greenhouse effect."

Human Toxicity: "This impact category covers the impacts on human health of toxic substances present in the environment. The health risks of exposure in the workplace are also sometimes included in LCA. These latter risks are often included in a wider impact category encompassing more than exposure to toxic substances (e.g. accidents at work)."

Ozone Depletion: "Stratospheric ozone depletion refers to the thinning of the stratospheric ozone layer as a result of anthropogenic emissions. This causes a greater fraction of solar UV-B radiation to reach the earth's surface, with potentially harmful impacts on human health, animal health, terrestrial and aquatic ecosystems, biochemical cycles and materials."

Photochemical Oxidant Creation: "Photo-oxidant formation is the formation of reactive chemical compounds such as ozone by the action of sunlight on certain primary air pollutants. These reactive compounds may be injurious to human health and ecosystems and may also damage crops. …Photo-oxidants may be formed in the troposphere under the influence of ultraviolet light, through photochemical oxidation of Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx). Ozone is considered the most important of these oxidising compounds, along with peroxyacetylnitrate (PAN). Photo-oxidant formation, also known as summer smog, Los Angeles smog or secondary air pollution, contrasts with winter smog, or London smog, which is characterised by high levels of inorganic compounds, mainly particles, carbon monoxide and sulphur compounds. This latter type of smog causes bronchial irritation, coughing, etc. Winter smog, as far as considered in this Guide, is part of human toxicity."

Land use: "This subcategory of land use impacts is concerned with the loss of land as a resource, in the sense of being temporarily unavailable."

1 Introduction

1.1 Background

As the building sector is making more efforts to reduce the energy consumption of building during their use phase, the importance of reducing the environmental impact of the building throughout its whole lifespan has increased. This has become especially important since the accomplishment of energy-efficient buildings often requires the use of more material, especially for insulation and installations (SBK, 2011). In 2010, material use represented 70% of the climate impact caused by the Dutch construction industry (Bijleveld, et al., 2014). Although Life-Cycle Assessment (LCA) is used to determine the environmental performance of buildings since 1990 (Fava, 2006), it is still a difficult tool to use due to the complexity of the building as a product and the difficulty to predict its lifespan and the changes it may undergo (Khasreen, et al., 2009). Also, completing an LCA is a long and fastidious process, which may be difficult to include in the time accorded to the design process. Besides, the results are not always easy to interpret nor easy to compare to each other if the different LCAs were not conducted in the exact same way.

This study focuses on understanding how the Netherlands is trying to solve these problems by setting up a common method (the SBK method), a harmonized national environmental database of building products (the National MilieuDatabase, NMD) and various certified tools enabling to use of this database in the context of the new Dutch regulation (the Building Act of 2012) and the Dutch version of the Building Research Establishment Environmental Assessment Method (BREEAM.NL).

1.2 Motivation

The main motivation of this study is to examine how the environmental impact of a building is assessed in the Netherlands, to better comprehend the underlying theory as well as to understand the practical and theoretical challenges of its application to the design process of a building. The case of the Netherlands was chosen because it seems to develop an original method compared to its European neighbours which could be seen as an example to follow.

The underlying intention of this report is to evaluate how this method helps the design team to create a building which has the best environmental performance possible. As well as at determining what the advantages and limitations of this method are and which lessons can be learned from the Dutch example.

1.3 Aim and verifiable goals

The Dutch method is used on an office building project being designed by RAU Architects at the time of this thesis. The goal is to create a building with the lowest shadow cost possible by applying strategies from the design team. The shadow cost of a building is a weighted single indicator expressed in euros, representing the virtual cost of environmental quality. This price is constructed since it is does not exist in the actual market and allows users to compare different products (De Bruyn, et al., 2010).

The following questions are examined:

- What is the effect of the design team's strategies on reducing the shadow cost of the building according to the Dutch method?

- What are the pros and cons of the Dutch method for the design team?

1.4 Scope

The study will focus on the specific case of the Triodos bank office building, which is not a standard office since the intention is to test the limits of the Dutch method. Modifications to the building are, however, limited by the level of flexibility of the project, which is at the end of the preliminary design stage.

This project depicts an open plan office of around 13,000 m^2 placed in a park and next to the train station of Driebergen-Zeist in the Utrecht region (The Netherlands). Accordingly, the study focusses on the Dutch version of BREEAM for new office buildings: BREEAM.NL.

2 Literature review

2.1 Certification schemes

A certification scheme is a voluntary assessment that is controlled by the certification provider. Certification schemes usually use a higher benchmark than the country's current regulation in order to encourage progress towards best practice. It allows for recognition of certified buildings in the market and eventually to compare them to each other thanks to a grading system. The certification scheme can also be seen as a guideline to ensure that all objectives are met (BRE, 2015).

2.1.1 BREEAM.NL

The Building Research Establishment Environmental Assessment Methodology (BREEAM) is a certification scheme developed in the UK by the Building Research Establishment (BRE). BREEAM aims to measure and certify sustainable value in the built environment according to a large number of precise criterions based on a set of 5 principles:

- Delivering sustainable solutions.
- Providing a framework.
- Based on sound science.
- Able to support the process of change.
- Delivering value to the occupant of the building.

The grading system is composed of 9 categories: Management, Health and Comfort, Energy, Transport, Water, Material, Waste, Land use and Ecology and Pollution (BREEAM, 2010). Each category has a different weight in the total score as shown in Figure 1.

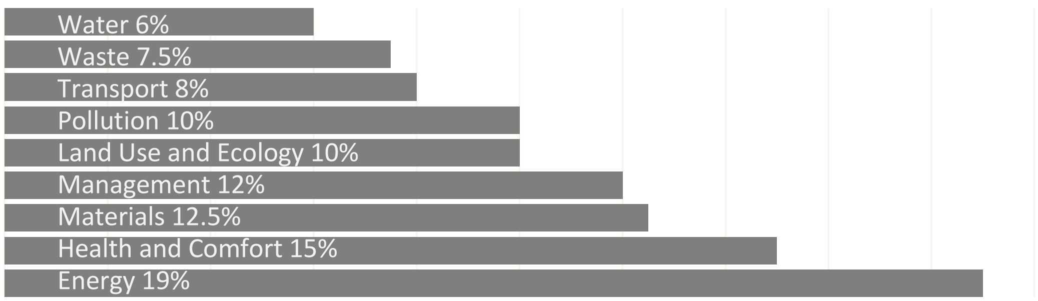

Figure 1 Weight of the different category on the total score of the building.

Once weighted, the scores are added to each other with eventual additional innovation credits. The resulting total score is evaluated according to a rating with the thresholds presented in Table 1.

Table 1 Rating system in BREEAM.NL.

Score	**Rating**
≥30%	PASS
≥45%	GOOD
≥55%	VERY GOOD
≥70%	EXCELLENT
≥85%	OUTSTANDING

Originally developed for the British context, the BRE created an International and European version of BREEAM. However in several countries like Sweden, Spain, Norway and Germany, National Scheme Operators (NSO) in cooperation with BRE developed their own national BREEAM. This is also the case in the Netherlands with BREEAM.NL under the initiative of the Dutch Green Building Council (DGBC). One specific aspect of BREEAM.NL is the section MAT1 which is developed according to Dutch method and tools. The Dutch calculation is also more complete since it includes more building components than the UK version of BREEAM (Schmidt, 2012).

2.1.2 MAT1

Mat 1 is a credit of the section Material of BREEAM.NL. It comes with specific validated calculation tools such as the “MaterialenTool”, which uses the National MilieuDatabase (NMD) further explained in Section 2.2.3. This study has also used the MaterialenTool

The requirement for this section has a significant impact on the design. Table 2 presents the requirements to score points in MAT1. A maximum of 8 points can be awarded for this credit. One additional innovation point can be awarded if a new material, not in the database, is proposed and is proven to reduce the shadow cost of the building by at least 0,05 euro/m².

Table 2 Scale of available points in MAT1 from BREEAM.NL.

1 point	At least three material options are considered that have a significant impact on the shadow price of the building (at least 5% reduction in total).
2 points	The environmental impact of the materials used is below the reference value.
3 points	The environmental impact of the materials used is at least 10% below the reference value.
4 points	The environmental impact of the materials used is at least 20% below the reference value.
5 points	The environmental impact of the materials used is at least 30% below the reference value.
6 points	The environmental impact of the materials used is at least 40% below the reference value.
7 points	The environmental impact of the materials used is at least 50% below the reference value.
8 points	The environmental impact of the materials used is at least 60% below the reference value.

The shadow cost of a building is a weighted price that expresses the environmental impact of the building in one single indicator. This indicator represents the cost that society should be willing to pay to counter the impacts on the environment to a sustainable level. A more detailed explanation of shadow cost can be found in Section 2.3.2.

The lifetime expectancy of a utility building is set at 50 years. The materials of foundation, basement, walls, roofs, floors, interior walls (including finishing of the components) and facilities of the building are taken into the scope of the credits. The interior falls outside the scope, a detailed list of the materials scope can be found in Appendix A.

The current reference value for the BREEAM.NL 2014 is 1 €/m² of Bruto-VloerOppervlak (BVO)(Gross Floor Area)[1] and represents the shadow cost of a standard building without significantly sustainable materials (DGBC, 2015). The documentation does not precise what exactly these reference building looks like nor how it is determined. According to BREEAM.NL expert Martin Bijleveld, it is probably an average of about 10 different buildings (Bijleveld, 2015). A more precise answer was given by the helpdesk of BREEAM.NL which stated:

> *"The original 'referentiewaarde' (reference value) is determined by calculating a small set of "standard", current building practice, buildings. Combined with some expert judgement from LCA specialists.*
>
> *We recently adjusted the 'referentiewaarde' by analysing the certified BREEAM-NL building in recent years and the different databases used for calculation of the shadow cost. Again, expert judgement was used to determine the right 'referentiewaarde'." (van Noort, 2015)*

2.2 Dutch context, method, database and tools.

With the prerequisite that a building should not endanger its users or the environment, the Building Act 2012 states that every new building with a surface area greater than 100 m² should provide an environmental performance declaration when applying for a building permit (Ton, et al., 2015). This decree from the Dutch Building Regulation is in force since January 2013 (Rijksoverheid, n.d.). So far, quantifying the environmental performance of the building is enough and no limit value is given yet but it is expected in the coming years. In BREEAM.NL this limit value is set at 1euro/m²BVO (Dutch Green Building Council, 2014).

In order to ensure comparable results and clarity in the assessment, the Dutch government is recognizing a national method, a harmonized database and several tools which are used both for the national building regulation and BREEAM.NL. Consequently, every assessment in the Netherlands is made with the same assumptions and data (SBRCURnet-Cindy Vissering, 2015).

[1] Since the way of measuring the Gross Floor Area of a building can be different around the world and was here calculated according to the Dutch standard NEN 2580, the GFA will be referred to as BVO in this report.

2.2.1 SBK method

The national method is the "Bepaling van de milieuprestatie van gebouwen en GWW-werken" (Determination method for the environmental performance of building and civil engineer work). This document was made by Stichting for Bouw Kwaliteit (SBK), and is therefore referred to as the "SBK method" in this report.

The SBK method sets Product Category Rules (PCR) for the creation of product cards inserted into the National MilieuDatabase (NMD), it also sets the rules for the solver of the tools using the NMD, see Figure 2. A product card is like an Environmental Product Declarations (EPDs) which is a standardized way to present the LCA results of a product, but is not called EPD since it also follows the requirements of the SBK method.

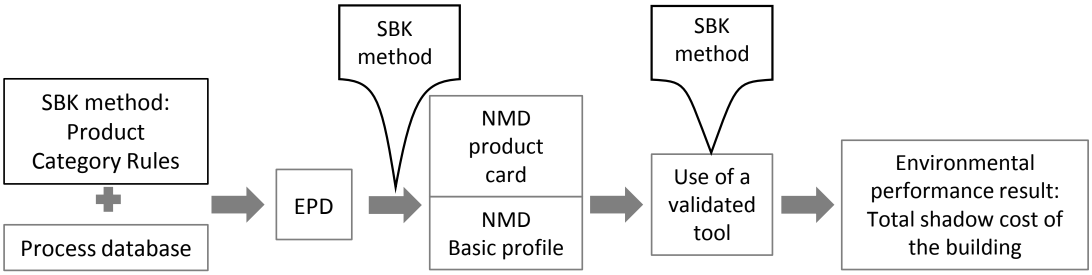

Figure 2 Interaction of method, tool and database to determine the environmental performance of the building (SBK, 2014).

In other words, the SBK method defines how to conduct the Life-Cycle Assessment (LCA) of every building product constituting the NMD. This database of product cards is then used in a tool complying with the SBK method to determine the environmental performance of the building.

The SBK method is based on the European Standard EN 15804 which has been developed for EPDs. The EN 15804 is itself based on a number of international LCA standards:

- ISO 14025:2010: Environmental labels and declarations – Type III environmental declarations – principles and procedures.

- ISO 14044:2006: Environmental management – Life cycle assessment – requirements and guidelines.

- EN 15978:2011: Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method.

The SBK method differs from the EN15804 by important additions and deviations made to fit the Dutch context. Some of these modifications are noted in the following section.

2.2.2 LCA according to the SBK method

In this section the steps to effectuate an LCA are presented with a focus on how these steps are altered by the SBK method to fit the Dutch context. Therefore, it provides a presentation of the main differences between an international EPD and a Dutch product card found in the NMD.

LCA is a technique to assess the environmental impact caused by a product. It is carried out in 4 steps:

1) Goal and scope definition.
2) Inventory Analysis.
3) Impact Assessment.
4) Interpretation.

Although conducted in this order, each decision could influence the other steps, as shown in Figure 3.

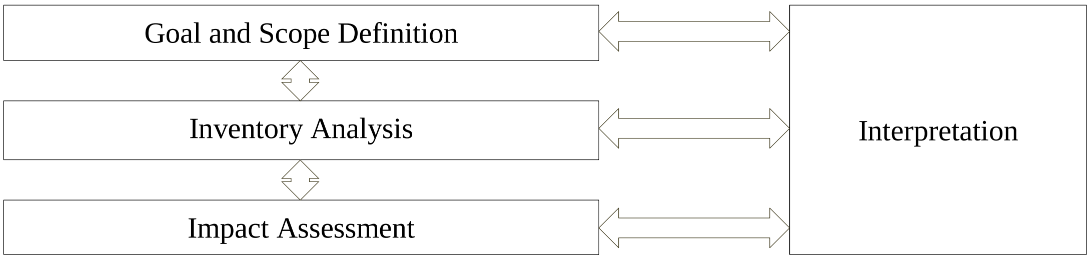

Figure 3 LCA process (Rebitzer, et al., 2004).

1) Goal and scope definition.

The goal and scope definition states how and to whom the results of an LCA are to be communicated. In this case, the main target group is LCA experts who want to add a product card to the NMD (see Section 2.2.3). It also defines the following.

- Functional unit: It is critical to later allow analysis and comparison. According to the LCA handbook (Joint Research Center, 2010), it should clearly describe the product (*what?*), its magnitude (*how much?*), its performance (*how well?*) and its duration (*for how long?*). The single example for a product given in the SBK Method is: “An inclined plane with a minimum angle of 20 degree which meets the requirement of the Dutch Building Regulations having a functional life of 75 years and expressed in m².” (SBK, 2014). It is worthy to note that this example does not seems to comply with the definition stated above since it does not give from which material this inclined plane is made from. Also, if the producer does not give substantial proof of his product lifespan, it will be determined according to the document "levensduur van bouwmaterialen” (lifespan of building materials) from Stichting Bouw Research (SBR).

- System boundaries: It defines which stages of the life-cycle are included in the assessment. An EPD is often only from cradle-to-gate (i.e. Production Stage A1, A2 and A3, see Figure 4) while the product card of the NMD aims for cradle-to-grave corresponding to the whole life-cycle of the product as can be seen in

Figure 4. The stages written in light grey and underlined are not included in the system boundary according to the SBK method.

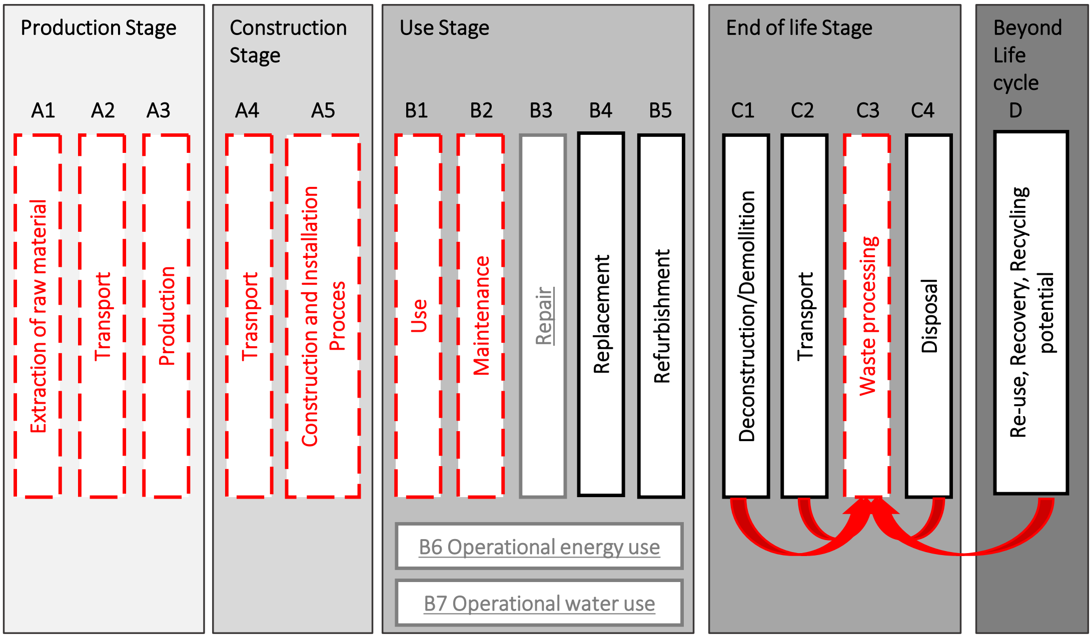

Figure 4 Life-Cycle stages of building products (SBK, 2014).

- Assumptions and limitations: A number of processes are given a standard value corresponding to the Dutch context to avoid unjustified differences in the calculation due to assumptions. In Figure 4, the stages requiring the use of these basic profiles are framed with a dashed red line.

- Allocations methods: The allocation procedures for reuse and recycling are given in the SBK method. The system boundaries are established for use and release of secondary materials through economic cut-off (SBK, 2014).

- Impact categories: The chosen categories can be seen in Table 5. These impact categories are not the only consequences of the building on the environment. They are the ones selected because they are considered to be the most relevant. Eco-Toxicity has been added after a study from TNO (van Harmelen, et al., 2004), whereas the addition of Land-Use is now under discussion.

- Compared to an international EPD, the indicators on Human and Eco-Toxicity are added to satisfy the Dutch conditions. The main reason for this addition is the will to encourage environmental improvements such as the use of "air scrubbers" to improve air quality which are ignored otherwise (SBRCURnet-Cindy Vissering, 2015).

2) *Inventory Analysis.*

The Life-Cycle inventory analysis makes a list of all type and quantity of incoming and outgoing flows. With the SBK method, reference is made to a specific LCA database for raw materials and basic processes (SBRCURnet-Cindy Vissering, 2015). A broad consensus in the Netherlands made SimaPro in combination with the Swiss EcoInvent database, the main tool to execute LCAs.

3) *Impact Assessment.*
This step corresponds to translation of different compounds from inventory analysis into impact categories or a single value indicator. The weighting system is illustrated later in Figure 5. Although weighting is considered a subjective way to create a single indicator, the members that established the SBK method agreed to use of the monetization method which translates different impact categories into a shadow price in euros.

4) *Interpretation.*
In this step the results are used to make decisions, which are mostly made by comparing two or more cases. In our case, the single indicator, the shadow cost of the product, is entered into the NMD to later constitute the shadow cost of the building.

2.2.3 National Milieu Database (NMD)

SBK is the owner and manager of the NMD, the data inside the NMD however, comes from different sources and is not always owned by SBK. Only when owned by SBK, the product cards are accessible to the public from the online database[2]. The NMD consists of different databases: one for the basic profile that are used by LCA expert when creating a product card and one containing the product cards that are visible online and in the tools. The product cards are sorted into three categories, see Table 3.

Table 3 Categories in the NMD.

	Category 1	Category 2	Category 3
Source	LCA from single manufacturer/ producer/supplier. Branded product.	LCA from group of manufacturers or branch association. Unbranded product.	Unbranded data from industry/manufacturer/ producer/supplier/client
3rd party verified according to the SBK assessment protocol	Yes	Yes	No

The data from category 3 is mostly incomplete or expired data which are kept in the NMD due to lack of better data. These, therefore, get a penalty of +30% to account for uncertainties. This factor is applied by SBK as a precaution since experience has shown that unverified results tend to present a low environmental impact due to missing data in the inventory (Schuurmans, 2014). For a number of products, such as laminated wood, this factor is probably underestimated (Klaassen, 2015).

[2] To consult this database, go to: https://www.milieudatabase.nl/viewNMD/

Two committees were formed by SBK in 2010 to manage the NMD:

- The MBG: "Milieuprestatiecommissie Bouw en GWW" (Environmental performance committee for Building and Civil Engeneering Work) is in charge of the policy development: defining project plans, fixing deadlines for the new updates of the NMD, advising SBK on communication, etc.

- The TIC "Technische Inhoudelijke Commissie" (Technical Content Commission) is responsible for the substantive technical aspect of the NMD which goes from elaborating the method and adjusting the product cards to supporting SBK with the helpdesk (SBK, 2011).

2.2.4 Other tools

The TIC mentioned above is also in charge of certifying tools that use the NMD and the SBK method. Thanks to this certification, each consultant company can continue to develop and use their own software while being in compliance with the SBK method. The different tools presented in Table 4 are the most employed (van der Klauw & van Zeijl, 2014) and can be used in compliance with both the Building Act 2012 and BREEAM.NL.

Table 4 Tools to calculate environmental performance of a building.

Name of the tool	Developer	Accessibility
MRPI - MPG	W/E Adviseurs	Free use online[3]
GPR Bouwbesluit GPR Gebouw met MPG	W/E Adviseurs	License fee required
DGBC MaterialenTool	DGMR (NIBE Co-owner)	Free download[4]

The DGBC MaterialenTool was used in this study since it was already being used by the design team of the study case. Based on GreenCalc+, the version 2.21 was used to comply with the version 2014 of BREEAM.NL. This most recent version of the MaterialenTool was also chosen to use the most up-to-date version of the NMD.

The different materials are inserted with their dimensions and their quantity into the program. The tool then delivers the total shadow cost of the building in €/m²BVO as well as the environmental impact of the building with the 11 impact categories in absolute values or weighted shadow cost.

2.3 Shadow cost as weighting method

As suggested above, the environmental performance of a building in the Netherlands includes 11 impact categories, which are stated in Table 5. Each of these selected environmental impact categories is assigned a shadow price per unit which can then add up to a single environmental indicator resulting in the total shadow cost of the building.

[3] Link to the online tool: http://www.mrpi-mpg.nl/Home/Home

[4] The latest Materialentool can be downloaded on the DGBC's web site: http://www.dgbc.nl/content/materialentool-0

This list is subject to changes as the Land-Use category could be included in the future as the Eco-toxicity categories were added before (Scholtes, 2015). Also, the shadow price is not a fixed value but varies with economic and environmental situation as explained further in Section 2.3.2.

Table 5 Weighting of impact categories (SBRCURnet-Cindy Vissering, 2015).

Environmental Impact Category	Unit	Shadow price /unit	Source
Abiotic Depletion Potential for Non-fossils resources (ADPE)	kg Sb eq.	€ 0.16	TNO
Abiotic Depletion Potential for Fossils resources (ADPF)	kg Sb eq.	€ 0.16	TNO
Global Warming Potential for 100 years(GWP100)	kg CO_2 eq.	€ 0.05	CE
Ozone Depletion Potential (ODP)	kg CFC-11 eq.	€ 30	CE
Photochemical Oxidant Creation Potential (POCP)	kg C_2H_2 eq.	€ 2	CE
Acidification Potential (AP)	kg SO_2 eq.	€ 4	CE
Eutrophication Potential (EP)	kg PO_4 eq.	€ 9	CE
Human Toxicity Potential (HTP)	kg 1,4-DB eq.	€ 0.09	TNO
Fresh water Aquatic EcoToxicity Potential (FAETP)	kg 1,4-DB eq.	€ 0.03	TNO
Marine Aquatic EcoToxicity Potential (MAETP)	kg 1,4-DB eq.	€ 0.00001	TNO
Terrestrial EcoToxicity Potential (TETP)	kg 1,4-DB eq.	€ 0.06	TNO

2.3.1 What is weighting?

Figure 5 illustrates the two weighting steps inherent to the shadow cost method with the example of the Global Warming Potential (GWP) and Acidification Potential (AP).

The first weighting (also called characterization) is made according to the CML-2 baseline method developed by the Institute of Environmental Sciences of Leiden University (CML). The characterization factor indicates the contribution of a quantity of a pollutant to a given environmental impact. The higher the characterization factor the greater the contribution (De Bruyn, et al., 2010). In the example given in Figure 5, one kg of methane (CH_4) is 21 times more responsible in causing global warming than one kg of carbon dioxide (CO_2), or in other words, 1/21 kg of methane is equivalent to one kg carbon dioxide in causing global warming. This first weighting is fairly objective and no significant difference is noted when using different methods to evaluate the characterization factor (van Soest, et al., 1997).

The second weighting however is subjective. It requires a decision to be made or consensus to be reached and gives a hierarchy between different environmental impact categories. In this case, AP is more important, thus more expensive, than GWP. This weighting groups different impact categories under a single indicator, in this case the shadow cost of the building.

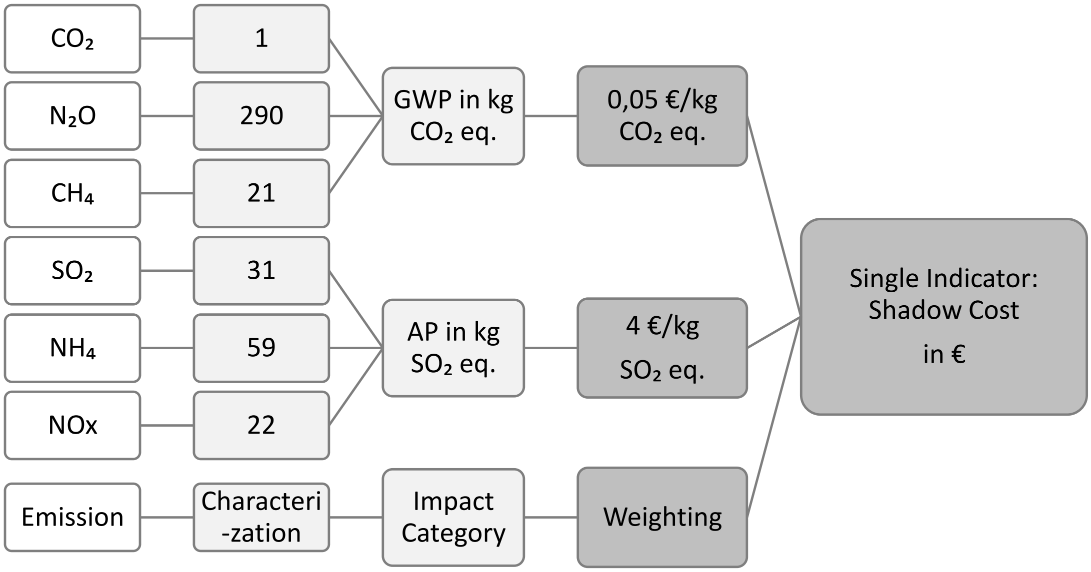

Figure 5 From different emissions to a single indicator.

Different weighting methods exist:

- Panel: Based on the observations of a group of stakeholders, a weighting factor is assigned to the different impact category. The stakeholders may be internal or external experts and/or representatives of community groups (van Soest, et al., 1997). The method is relatively simple but shows how subjective a method can be.

- Target-to-distance: The weighting factor here depends on the extent to which the current emission level exceeds the desired (target) emission level (van Soest, et al., 1997). The target level could be determined by a national or international policy, or global climate boundaries.

- Technology method: A well-known example of technology method is the Ecological footprint which represents the surface necessary to undo the impact caused to the environment (Naber, 2012).

- Monetization: This is the method used and resulting in the shadow cost which is explained further in the following Section 2.3.2. The shadow cost represents the cost that society is willing to pay in order to achieve the environmental target. (NIBE, 2015)

2.3.2 What is the meaning of shadow cost?

Shadow cost is a constructed cost, a virtual cost that does not have a market. In this case, the shadow cost represents the cost of the measures necessary to prevent the environmental damage. The construction of this cost depends on the following societal aspects.

- Economy: The shadow cost represents the maximum sum that society is willing to pay to achieve environmental quality (De Bruyn, et al., 2010). It is therefore dependent on the income level of the society concerned. It can be assessed by direct surveys or by actual market price analysis.

- Policy target: Since the Netherlands is a democracy, the decision made by the politicians is considered to reflect the definition of the environmental quality according to Dutch society.

Figure 6 illustrates how the shadow cost could be determined. The blue curve represents the supply of options for prevention of emissions. Its price increases as the required reduction is greater. The red dashed curve corresponds to the demand of society for limiting impacts. The willingness to pay a higher price to limit the environmental impacts usually increases with the importance of the damage caused by the emissions. To be cost efficient, the emission target set by the government should be placed at the equilibrium point between supply and demand. This point corresponds to the shadow cost.

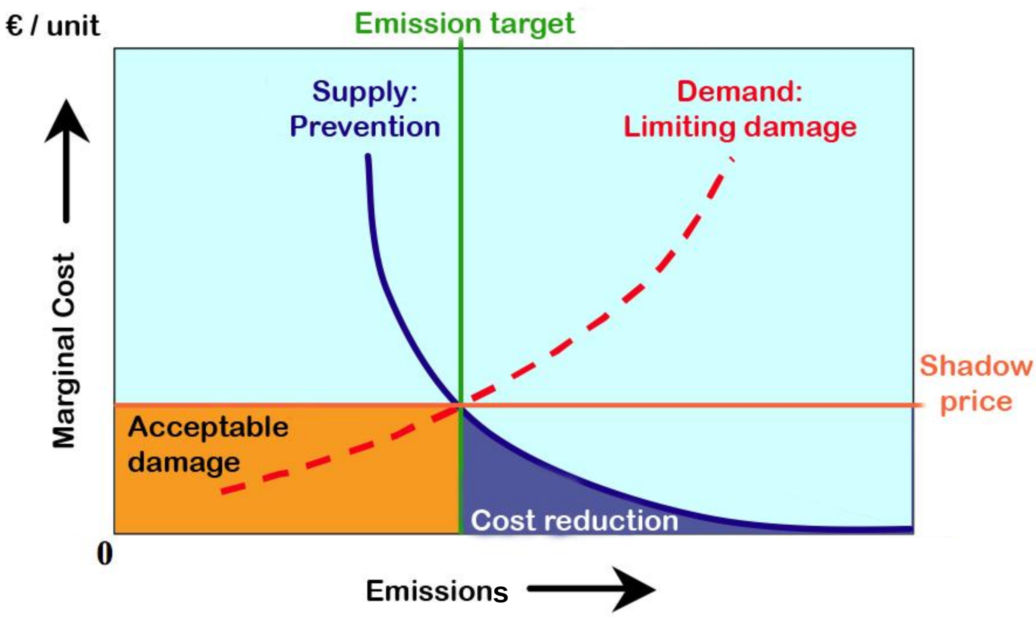

Figure 6 Shadow cost determination (van Soest, et al., 1997).

In addition of being a single indicator under which all impacts can be grouped, the shadow cost weighting method has the advantage of giving to environmental impacts the same unit as real cost, which makes it a convincing unit that all stakeholders of the project can visualize.

2.4 Other labels and certifications used in the Netherlands

Although the NMD is settling as the main tool to assess the environmental impact of building materials in the Netherlands, different independent labels or certifications are complementing or competing with the national method. In this section the DUBOKEUR label and the C2C certification are presented since they are mentioned in the BREEAM.NL concerning the possibility of getting innovation points by using these products. Firstly however, the NIBE's environmental classification is explained to clarify how this collection of product data and their shadow cost is different from the NMD.

2.4.1 NIBE´s Environmental Classification:

The Nederlands Instituut voor BouwBiologie en Ecologie (The Dutch Institute for Building Biology and Ecology) (NIBE) is an independent company that has created an online classification of materials [5] that are ranked according to their shadow cost. The shadow cost of these materials is calculated in the same manner as the NMD product, however, it is not reviewed by a third party. Most importantly, The NIBE decided to take more environmental impact categories into consideration as highlighted in bold in Table 6. The resulting shadow cost for each product is therefore different from the one in the NMD.

Table 6 Impact category and shadow cost applied in the NIBE's environmental classification.

Main category	Environmental impact category	Unit	Method of characterization	Shadow cost in €/unit	Source	Used by:
Emissions	GWP100	kg CO_2 eq.	CML-2 Baseline	0.05	CE	NMD and NIBE
	ODP	kg CFC-11 eq.		30	CE	
	HTP	kg 1,4-DB eq.		0.09	TNO	
	FAETP	kg 1,4-DB eq.		0.03	TNO	
	TETP	kg 1,4-DB eq.		0.06	TNO	
	POCP	kg C_2H_2 eq.		2	CE	
	AP	kg SO_2 eq.		4	CE	
	EP	kg PO_4 eq.		9	CE	
Depletion of raw materials	ADPE	kg Sb eq.		0.16	TNO	
	ADPF	Sb eq.		0.16	TNO	
	Biotic Depletion Potential (BDP)	mbp	TWIN	0.042202	NIBE	Only NIBE
Land use	**Land use**	PDF/m²/yrs	eco-indicator 99	0.20482	NIBE	
Nuisance	**Malodorous air**	OTV m³	CML2 baseline, inverse OTV	0.0000000233	NIBE	
	Road noise	DALY	Müller-Wenk	321.946	NIBE	
	Disturbance by sound	mbp	TWIN	0.00000149	NIBE	
	Disturbance by light	mbp	TWIN	0.024005	NIBE	
	Disturbance by calamities	mbp	TWIN	0.024005	NIBE	

[5] The classification is accessible to the public after a free registration on http://www.nibe.info/nl

However, this classification is very transparent, since each product is clearly described with an extensive functional unit and the results are presented for each impact category in both real value and weighted shadow cost.

A quick overview of the products is possible and allows to rapidly define which product is the most environmental friendly with a ranking system going from best choice (i.e. Class 1) to unacceptable choice (i.e. Class 7). For each class, subcategories a, b or c define preferred options. The ranking is made according to the best product currently available which is automatically 1a, while the other products follow the ranking according to an environmental factor as shown in Table 7.

Table 7 NIBE's classification system (NIBE, 2015).

Class	Sub-class	Definition	Environmental factor
1	a	Best choice	1 – 1,1
	b		> 1,1 – 1,32
	c		> 1,32 – 1,58
2	a	Good choice	> 1,58 – 1,9
	b		> 1,9 – 2,28
	c		> 2,28 – 2,74
3	a	Acceptable choice	> 2,74 – 3,28
	b		> 3,28 – 3,94
	c		> 3,94 – 4,73
4	a	Less good choice	> 4,73 – 5,68
	b		> 5,68 – 6,81
	c		> 6,81 – 8,17
5	a	Not recommended choice	> 8,17 – 9,81
	b		> 9,81 – 11,77
	c		> 11,77 – 14,12
6	a	Bad choice	> 14,12 – 16,95
	b		> 16,95 – 20,34
	c		> 20,34 – 24,40
7	a	Unacceptable choice	> 24,40 – 29,29
	b		> 29,29 – 35,14
	c		> 35,14 – 42,17
>7c		Unacceptable choice	> 42,17

2.4.2 DUBOkeur®:

Since 2004, NIBE has also developed its own product label: DUBOkeur® (from Duurzaam Bouwen Keur: Selection for Sustainable Building). The labelled products go under the same assessment as products in NIBE's environmental classification, except that these are branded while the others are generic products. A product receives a DUBOkeur® label when it is the best product of its kind of application and stands at least on the 2c grade of the NIBE's classification. The product rankings change when new products are added or when products already labelled are checked every second year. A new best product determines whether the older products are still good enough to keep the label. This system pushes the manufacturer to have a competitive product in term of sustainability (Scholtes, 2015). However, the label only gives a pass or fail, it does not allow to compare the products between each other. Also, only the functional unit of the product is given. The label stands for itself and no insight is given about the environmental impact or health characteristic of the product (DUBOKEUR, 2014).

2.4.3 C2C® (or cradle-to-cradle®):

The Cradle to Cradle Products Innovation Institute is a non-profit organization which was created by US architect William McDonough and German chemist Dr. Michael Braungart in 2010 and which administers the *Cradle to Cradle Certified*™ Product Standard. The institute has its headquarter in San Francisco and a satellite office for Europe in Venlo (The Netherlands). The principle of the Cradle-to-cradle® thinking is to continue the life-cycle of the product beyond the end of its life phase, contrasting from the cradle-to-grave system boundary. The certification motto is to make products “More good” instead of “less bad”. The cradle-to-cradle® product certification is assessed by the mean of 5 categories: Material health, Material reutilization, Renewable energy and carbon management and Social Fairness and biodiversity. Each category receives a score: Basic, Bronze, Silver, Gold or Platinum with the lowest score representing the overall score of the product. The requirements are made to prove the quality of the product according to the certification standard as well as a guide to encourage manufacturer toward the next step of the certification. To this day, no product has yet reached the platinum level.

Since 2011, the NIBE provide additional information about the products in their classification with a “bron2bron” (source to source) label. It presents how well the product could comply with the cradle-to-cradle® principle with 4 indicators: material health, material recycling, renewable energy and responsible water management.

2.5 Research conducted with the Dutch method

This literature review section looks at research concerning the Dutch assessment method for environmental impact of building materials. Very few were found in the English language or with an English abstract, mainly because this method was integrated in the Dutch building regulations only three years ago. Three studies focusing on specific building component or practice such as reusing building materials, renovating or using PV panels revealed some limitations of the Dutch method while a fourth study analyses the first results from the application of method in the Building regulations.

Naber (2012), in her thesis about the “reuse of hollow core slab from office buildings to residential buildings” used the LCA software SimaPro in compliance with the Dutch assessment method. A full life cycle assessment tool was chosen rather than a tool using the NMD since the latter do not include products that are not actually used in the industry such as re-usable hollow core slab while SimaPro gives the flexibility to create different processes. The study therefore examined different scenarios in detail such as deconstruction versus disassembly, recycled versus new or simply different percentage of reused material in the building.

Dijkstra (2013) also used SimaPro in his thesis “environmental and economic impact comparison of renovation concepts for Dutch residential buildings”. The author presented the shadow cost results not only for the materials but also for the energy use of different renovation scenarios, which had different lifespan expectancy.

The importance of linking the environmental performance with the energy performance of the building or product was also demonstrated in a report by Alsema and Anink (2014). In their report, the authors used the Dutch method for environmental impact assessment and the NMD with the GPR tool developed by W/E consultants. The study proposed an integrated environmental performance that assigns an environmental impact factor per unit of different type of energy. This allowed to show the shadow cost of a building's materials and the shadow cost of the energy used by the building in the same figure. Although this method still needs to be perfected, it would provide the Dutch method for environmental impact assessment with a valuable additional feature allowing it to balance material and energy use. The study also pointed out the lack of up to date quality data on PV equipment in the NMD and the need for its completion.

This lack of data was also identified by van der Klauw and van Zeijl (2014). Emphasizing another point of view, their article presented the feedback from municipalities and applicants to construction permit since the application of the Dutch environmental performance assessment method in January 2013. The main findings of the survey included:

- Many of the submitted assessments were incomplete or inaccurate mainly due to time or money restrictions.
- The main complaints from the respondents of the survey were the lack of data in the NMD and the lack of consistency in the requirements between different municipalities.
- For many municipalities the lack of a maximum allowed value in the building regulation is the main reason for not being strict about the submission of an environmental performance assessment.

In the same study by van der Klauw and van Zeijl, the analysis of 261 cases revealed that:

- The shadow costs of the majority of buildings were between 0.40 and 0.80 €/m²BVO.
- A value of 1.2 €/m²BVO or above generally meant that the assessment was inaccurate or that the building included a large energy plant such as PV or heat pump.
- Office buildings have a relatively higher shadow cost than houses due to the proportion of installations needed for the building.
- In general, walls, floors and installations are the largest contributors to the total shadow cost.
- It appears that no correlation exists (in this study) between a low energy performance and a high environmental performance.

The literature survey suggests that the tools using the NMD can be insufficient to evaluate certain alternative design that are peculiar or that implement unconventional or new materials. The need for a more complete database is also clearly expressed. However, the Dutch method still serve as a common ground to execute full LCA that are then comparable to each other. Also, the necessity to link the environmental performance of material to the environmental impact of energy use of the building is clearly demonstrated.

3 Method

The study has been structured as follows:

- The first task was to get familiar with the Dutch context, mainly through a literature review and then via practice. This has been done by assessing the environmental impact of a study case of an office building project with the MaterialenTool described in Section 2.2.4.

- Next, the limits of the tool were tested by a parametric study that aimed to reduce the environmental impact of the building as much as possible while conserving its energy-efficiency and overall design.

- Finally, interviews were conducted with different actors and users of the Dutch method to discuss the efficiency and viability of this method.

3.1 Description of study case

The study case is a project for the new office building of the Dutch bank "Triodos" in Driebergen-Zeist, in the Region of Utrecht, The Netherlands. The Triodos bank is highly engaged towards sustainability by supporting sustainable project with a positive social, environmental and cultural value (Triodos, 2015). The idea behind this new building is to bring a positive value to the location with the building acting as a platform encouraging the sharing of knowledge and innovation as well as holding a more traditional headquarter function.

Figure 7 Location of the building project.

The building with around 13000 m² and up to 5 stories, is placed in historical park "de Reehorst", which will stay open to the public. The ground floor of the building should therefore be able to welcome any visitors of the park as well as clients and employees. This location benefits from its close access to the train station'' Driebergen-Zeist'' and to a quick access to the highway.

The design team came up with an organic shape inspired by the shape of living cells which created three towers with a concrete core that merge with each other on the lowest levels (see Figure 8, right). The building is placed on a spot which was once constructed and strive to limit the number of tree necessary to cut for the construction. It is also shaped so that it avoids obstructing the view from the existing historical building Antropia and its height matches the height of the existing surrounding trees (see Figure 8, left).

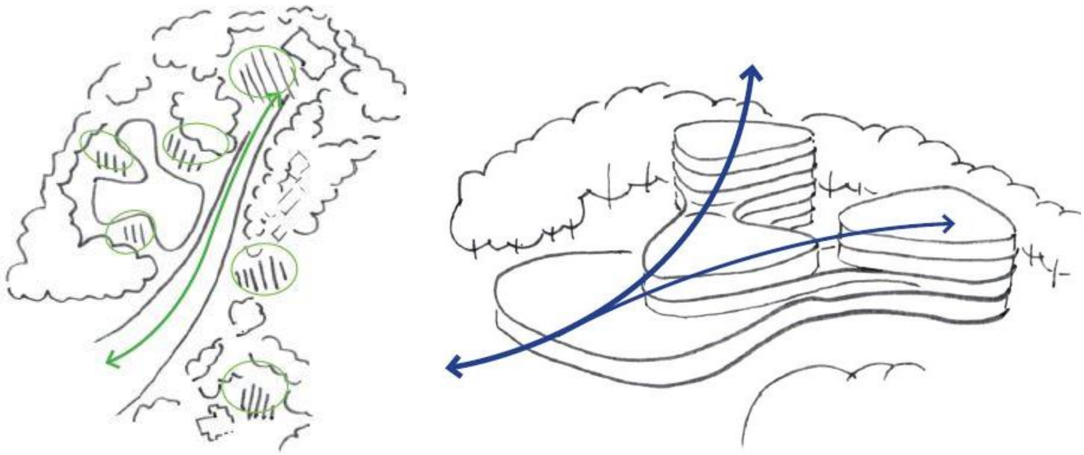

Figure 8 Shaping of the building according to the surrounding landscape elements (Courtesy of RAU Architects).

The facade is entirely glazed with some glass panel being filled with aerogel making the glass translucent according to the orientation and intimacy level requested. The roof welcomes greenery and skylights. Figure 9 gives an overview of the building.

Figure 9 Bird's eye view rendering of the project (Courtesy of RAU Architects).

The structure consists of a concrete core from which the concrete floor extends itself in a wooden floor supported on the outside by steel columns. This shape aims to optimize the use of material and maximize the amount of daylight entering the building. Figure 10 proposes and overview of the main materials of the building in a simplified 3D section of one of the three tower of the building.

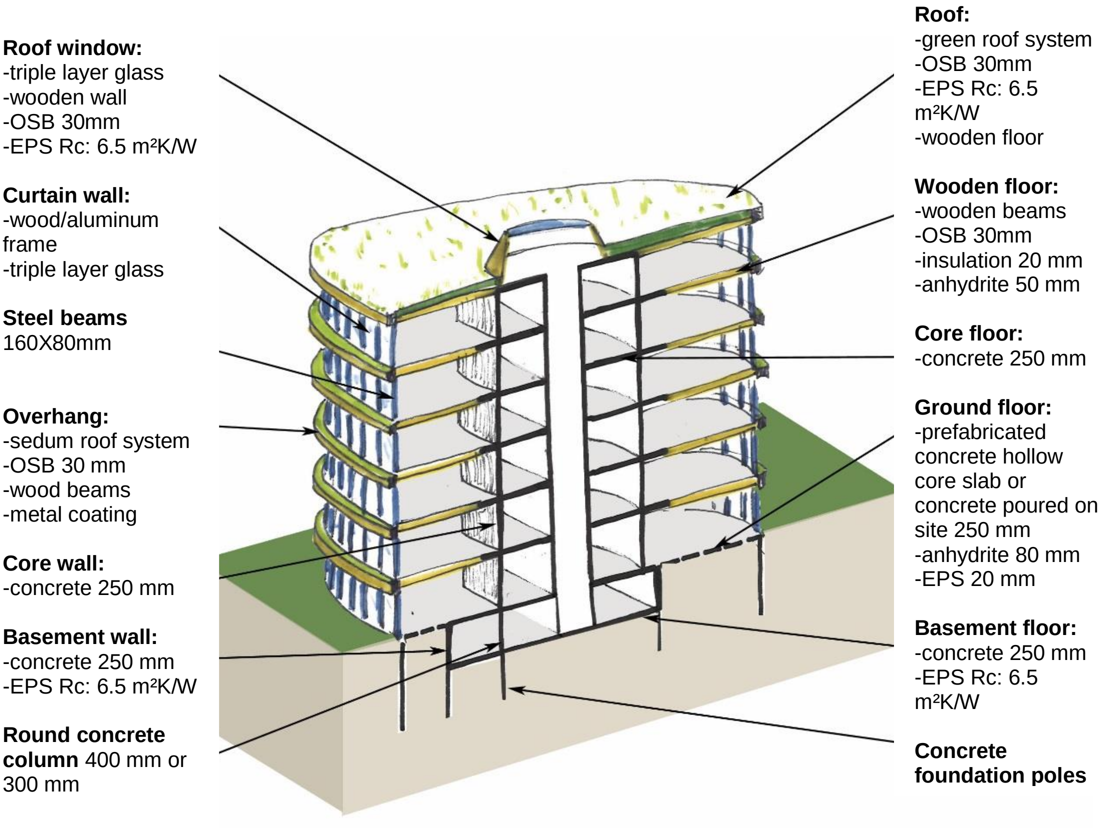

Figure 10 Section showing the structural principle and used materials.

The ground floor has the general function of sharing; it has a restaurant, a conference room, meeting rooms, an exposition space, a library, etc. The top floors are open plan offices while the circulation and other functional rooms (toilets, copy machines, storage, etc.) are placed in the concrete core. The basement holds all facilities that do not require daylight such as: technical spaces (Air Handling Unit, sprinklers basin, server room), storage areas (bicycles parking, waste recycling room, archives and other storage room) and other periodical functions (expedition area, kitchen facilities, showers and locker rooms for employees coming by bike). The detailed floor plans of the building can be seen in Appendix C.

After a period of latency due to issues raised by the development of other surrounding projects, the Triodos group decided to re-evaluate the design instead of rushing into the Definitief Ontwerp phase (definitive design stage). This approach from the client is not such a common decision and illustrate well the commitment of the Triodos group toward sustainability by appreciating the time needed to develop new ideas and concepts.

3.2 Practical requirements of the project

This section proposes a summary of the requirements for the study case that are examined in this study with an illustration of it in Figure 11.

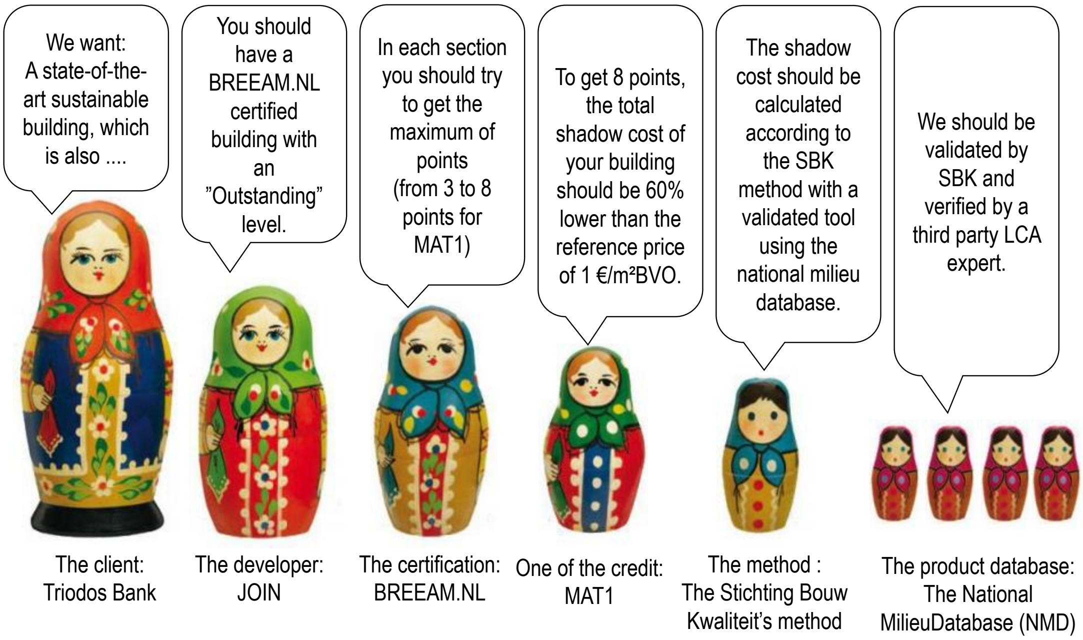

Figure 11 “Russian dolls of project requirements”.

During the design process, requirements are defined by the client (Triodos Bank) via scope statements established by the developer (Join). The Triodos Bank group is highly involved in the development of a sustainable world. The project therefore strives to generate a state-of-the-art sustainable building, which is also appealing to its users and at the same time represents the values of the bank. To achieve this goal the design team aims for an “outstanding” level in the BREAAM.NL certification scheme described in Section 2.1.1. In this study, the focus is on the Material section of the certification scheme and especially on the credit MAT1. This credit is calculated with specific tools, which use the NMD and are regulated by the SBK method.

It is important to keep in mind that these points are only a part of the requirements that the architects have to answer to in the context of the project. The BREEAM.NL certification scheme is used as guideline to the design process but should not prevent the design team from thinking outside the box to develop an innovative design solution.

3.3 Parametric Study

The preliminary design of the study case and its environmental performance was first analysed in order to understand which part of the building influences its shadow cost most. Thanks to the ArchiCAD software used by the architects, it was possible to make a precise inventory of the materials used in the project even at an early design phase. This inventory is presented in Appendix B.

Then, via a parametric study, different concepts and material options were considered. The considered options were chosen based on the strategies intuitively thought of by the design team to reduce the environmental impact of the building and according to the other practical challenges of the project.

- The reduction or removal of the basement was considered to reduce the direct footprint of the building on the land and to rearrange the entry to the building.

- According to the fluctuant level of the ground water on the site, different material for the foundation poles were tested.

- To obtain a warmer atmosphere in the offices and to show the structure of the building, different wooden structures were designed to replace the concrete core and steel columns.

- Different innovative type of climate ceiling were assessed.

- Different combinations of solutions were tested and a substitution of products for the most accurate in the database was effectuated.

Some other ideas to reduce the environmental impact from the building materials were also studied. These included:

- Certified materials and label recommended by the certification scheme were investigated.

- The possibility of using material reclaimed from the waste stream was analysed.

3.4 Interviews

Although the Dutch method has been studied through a literature review and the practicality of the tool has been assessed through its application on the study case, calling on the knowledge of experts was inevitable to make sure that no aspect of the possibilities and limitations of the Dutch method has been left out. This opportunity was taken by conducting extensive discussions about the Dutch method with different actors of the method so that different points of view could be recorded, from the expert to the user. The term “user” here is related to the people that use the tools in combination with the NMD such as the MaterialenTool while “expert” refers to people contributing to the construction of the method or to the addition of products in the NMD by performing LCAs. Since a quantitative survey had already been conducted by Alsema and Anink (2014), a qualitative approach was preferred here, the goal being to sense if the advantages and inconveniences of the Dutch method were seen similarly at the different levels of use.

The name of the interviewees and their relation to the Dutch method is explained in Table 8. The interviews took place on different dates with no specific chronological order and were conducted in the working place of each interviewees. The interviews were conducted as a conversation rather than a precise interrogation. The discussions of about 1 hour were recorded and transcribed in writing in its entirety in Appendix D.

Table 8 Name and functions of the interviewees.

Name of the interviewee	Function as contributor to the Dutch method	Function as user of the Dutch method	Other relevant function
Rick Scholtes	Member of the TIC. Member of VLCA. Third party reviewer for product card to be included in the NMD.		Employee of the NIBE, in charge of the DUBOKEUR label and the NIBE's environmental classification.
René Klaassen	Member of VLCA. Third party reviewer for product card to be included in the NMD.		Researcher at the SHR, in charge of LCA for wooden products.
Martin Bijleveld		Sustainability consultant at DGMR.	BREEAM.NL expert.
Dennis Grootenboer		Technical designer at RAU Architects	C2C expert.

4 Results

4.1 Analysis of preliminary design

The stacked column in Figure 12 presents the total shadow cost of the Triodos' preliminary design for each part of the building. The pie charts present the share of each material's shadow cost in the corresponding building part. The shadow cost per m³, per m² or per piece of each of these materials can be found in the legend. Only the stacked column can be directly extracted from the MaterialenTool. The shadow price per cubic meter of material has to be deduced and may not be looked at as a fixed value for the product.

The total shadow cost of the preliminary design is 0,65 €/m²BVO, which is 35% lower than the reference price of 1€/m²BVO, awarding 5 points in the material section of BREEAM.NL. To obtain the maximum of 8 points in the credit MAT1, the total shadow cost of the building needs to be below 0,40 €/m²BVO. Hence, the shadow cost gives a clear view of where the building stands compared to the reference standard building. However, it is worth noting that it is not stated anywhere what does this reference building looks like. As can be seen in Figure 12, the technical installations are the main cause of environmental impact, closely followed by the floors, the facade and the roofs.

Installations: Approximately, 64% of the shadow cost of the installations comes from the climate ceiling elements. These prefabricated elements composed of a steel plate and copper tubes are implemented in the ceiling of each office floor for heating and cooling purposes. Climate ceiling elements are essential to the comfortable indoor climate of the building and the flexibility of the space. If replaced or modified, they should be able to deliver the same results in term of indoor climate. From the BREEAM expert's experience, this high shadow cost is probably caused by the copper of the tubes (Bijleveld, 2015). An additional 30% of the shadow cost of the installations is due to the cooling coil. The MaterialenTool only allows a choice between heavy or light power. The heavy power option was selected due to uncertainties about the cooling need of the building and the assumption that the high percentage of glazed surface of the building implies a significant cooling demand. Although strategies to reduce the overheating of the building were investigated by the design team, the cooling coil is kept to "heavy" as a precaution.

Floors: Nearly half of the shadow cost of the floors is caused by the concrete and anhydrite, while the Oriented Strand Board (OSB) alone is responsible for 39% of the shadow cost of the floor. The OSB material is necessary to lay the anhydrite on the wooden floors and appears to have the highest shadow cost per cubic meter. Its high shadow cost is due to the high human toxicity potential according to the NIBE database. This is believed to come from the high level of Volatic Organic Compound (VOC) emitted from the resin and the wood used in the panels during its production process as well as during its use. The anhydrite screed is the finishing surface of all floors (wooden and concrete floors), it is an economical and time-efficient alternative to a cement floor. According to the NIBE classification, the anhydrite is also more environmentally friendly than cement floor. According to the same classification, an even more environmentally friendly equivalent is the "Ro-anhydriet" which is composed of sulfur dioxide (SO_2) recovered from exhaust gases of fossil-fuel power plants instead of extracted from the ground. This material however, is not available in the NMD.

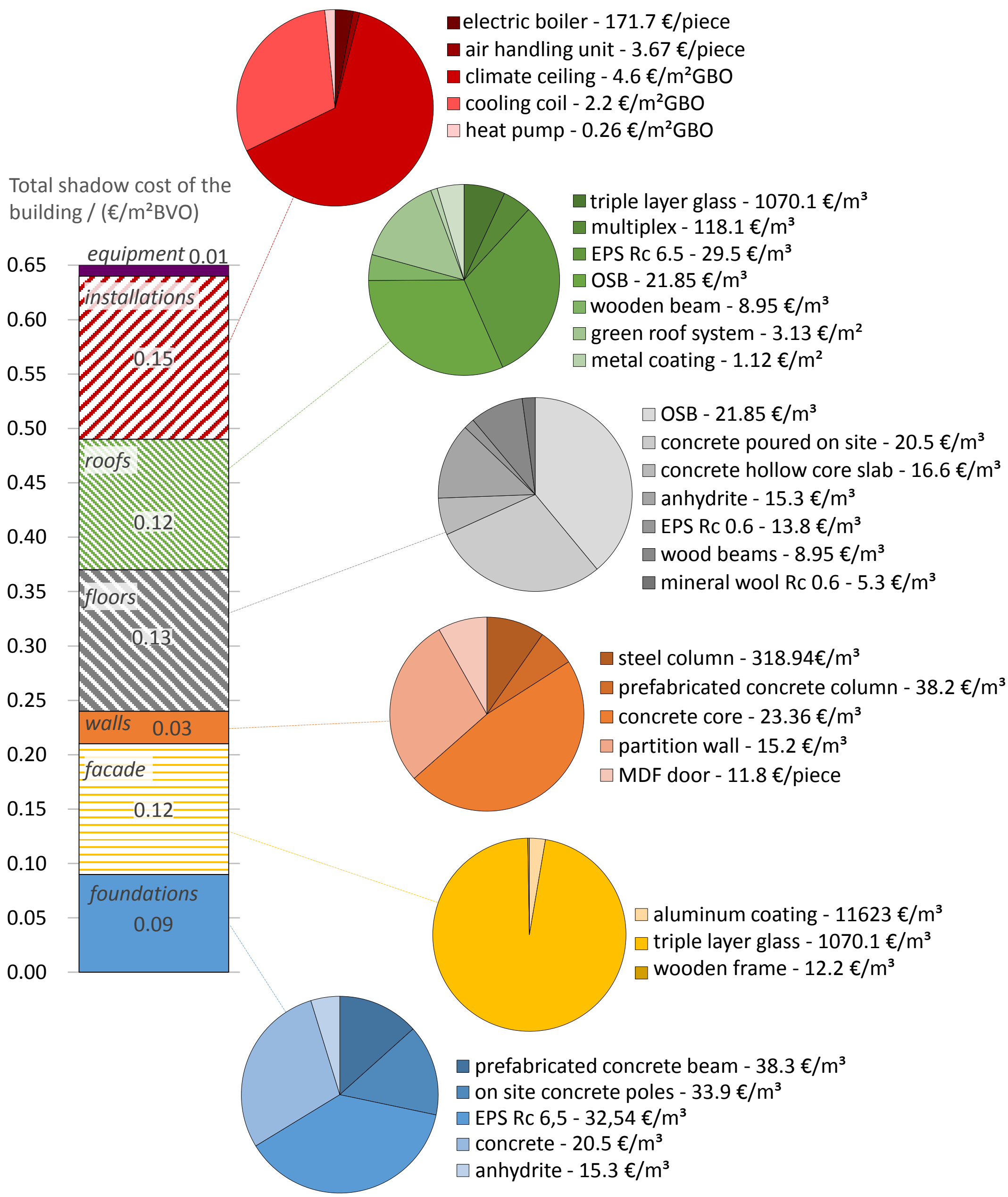

Figure 12 Composition of the shadow cost of the preliminary design.

Facade: The facade is mainly composed of triple layered glass which account for 97% of the facade's shadow cost. The frame holding the triple glass is intended to be a wooden frame with an aluminium coating on the parts of the frame facing the outside. This design choice made by the architects allows to keep the use of aluminium to a minimum.

Indeed, the aluminium has a very high shadow cost per cubic meter, at least 950 times higher than the wooden frame. It is interesting to note that this small quantity still places the aluminium with a 2,7% share of the shadow cost of the facade compared to the 0,3% of the wooden frame.

Roofs: As it is the case for the floors, the OSB forms a big part of the roofs' shadow cost (32%). Additionally, the EPS, which needs to be of a thermal resistance of 6.5 (m-K)/W to ensure good energy performance of the building, represents 31% of the shadow cost of the roofs. Despite its benefits, the system for the green roof also represents a notable 15% of the roofs' shadow cost. This score is believed to be due to the usual plastic components in the drainage system, although, the description of this green roof in the MaterialenTool which is: "green roof; drainage+filter+subtraat+sedum (excluding roofing)" does not specify which kind of drainage system is implemented.

Foundations: The category "Foundation" in the MaterialenTool comprises the foundation poles and the basement exterior and load bearing walls. The use of concrete for the foundations and the basement creates 67% of the shadow cost. The concrete foundation poles alone account for 34%, which is due to their high shadow cost per cubic meter as well as their quantities which was estimated to 200 poles each 10-m long. Also, each of these concrete components is reinforced with steel and the load bearing capacity of the concrete is mostly given in the description. The EPS insulation, as it is the case for the roof, also has a significant share of the shadow cost of the foundations (38%).

This detailed view of the shadow cost of the building allowed the design team to rapidly identify which part of the building is worth focusing on to reduce the environmental impact and, in certain cases which specific product contribute to a high shadow cost of the building. In this study, the roofs, floors and walls are reconsidered altogether as the structure of the building is studied while the effort to reduce the shadow cost of the installations is focused on the climate ceiling elements only. If only one material is entered into the MaterialenTool, it is possible to see the shadow cost of each product. However, little information is given (both in the tool and on the website) about the product itself: the title of the product is the only description. When the product card is related to a specific brand, it can be an option to check the information via the manufacturer but this takes some additional research time. The dimension of a product is entered by the user in the tool but in certain cases the dimension is not the best unit to quantify the product. For the EPS insulation for example, the field reserved for the thickness is used to enter the thermal resistance instead. However, this practice is not clearly stated and was learnt by making the mistake of inserting the thickness of the insulation layer and questioning an experienced user of the tool about the anomaly in the results for EPS.

The MaterialenTool also allows users to look at the building's environmental performance by environmental impact category with or without weighting. It is interesting to compare the readability of the output before and after weighting as shown in Figure 13. Although the environmental impacts are not easily read, it is appreciated that they are accessible. It is regrettable however, that the share of each phase of the product life-cycle is not visible.

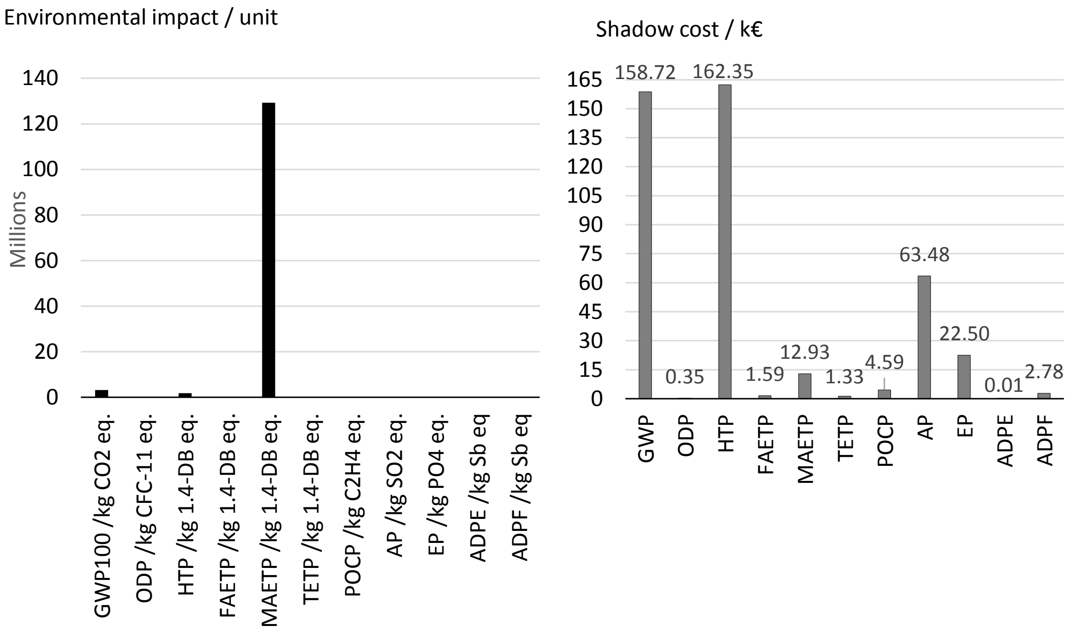

Figure 13 *From environmental impact values (left) to shadow costs values (right) of the preliminary design.*

In the left graph, the environmental impact values are expressed in different units (kg per CO_2 eq, kg per SO_2 eq….) which prevents them from being compared to each other's. Here, the Marine Aquatic Eco-Toxicity Potential (MAETP) is so great that the others environmental impact's effects cannot be read. In the right graph however, the weighted values in euros are comparable as they have the same units. According to this weighting, the building mainly impacts the Human Toxicity Potential (HTP) and the Global Warming Potential (GWP) and it would cost respectively 162 and 159 thousands euros in the virtual market for environmental quality to compensate for it. Compensating for acidification damage would cost 63 thousand euros and 23 thousands euros for the eutrophication damages. After weighting, the MAETP is only the fifth most expensive impact category to compensate for with 13 thousands euros. In conclusion, the shadow cost weighting not only allows for a comparison of different impact categories but also gives an image of what these impacts represent.

4.2 Parametric study

Following the analysis of the environmental performance of the preliminary design, several modifications were tested according to the challenges of the project.

4.2.1 Modification on basement and foundations

The high level of the water table in the park brought the question of the necessity of the basement to the design team which investigated the possibilities of relocating the functions held by the basement. However, this solution was not as beneficial as expected in reducing the shadow cost of the building.

When looking at absolute values in Figure 14, the foundations and basement of the preliminary design (called VO case) represent a total shadow cost of 57000 euros. This shadow cost can be reduced by 3.5 % by using prefabricated concrete foundation poles and by 15.8% by using wooden poles instead of concrete poles poured on site. The wooden poles include a concrete cap that protect the wood from being exposed to air due to a fluctuating water level. Reducing the basement decreases the shadow cost of the foundation by 28% and having no basement at all brings a reduction of 79,2% from the VO case. From this graph, it can be deduced that, in the VO case, the foundations represents 16 000 euros of shadow cost and the basement 41 000 euros. This difference is likely due to the high shadow cost of the EPS insulation layer required for the basement which is otherwise applied to the ground floor.

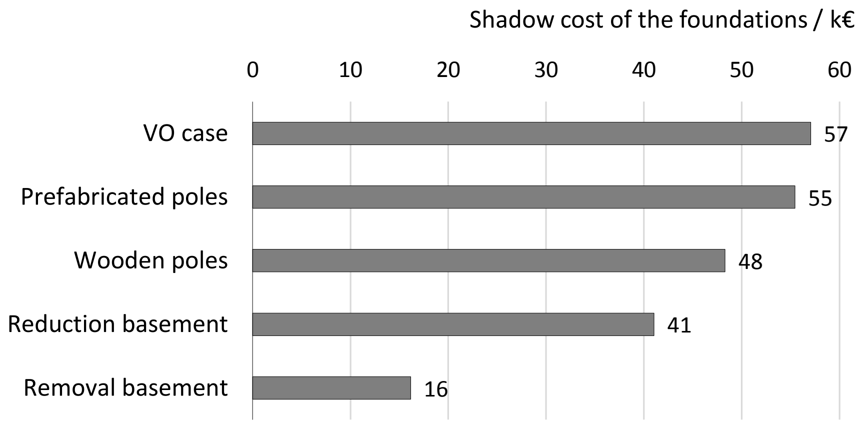

Figure 14 Effects of parametric study on foundation's total shadow cost.

However, the graph in Figure 14 presents the shadow cost in absolute value while the single indicator used to express the shadow cost of the building's materials is expressed relative to its square meter of gross floor area, in €/m²BVO. This unit means that reducing the total BVO increases the final total shadow cost of the building, as can be seen in Figure 15.

When the functions of the basement are relocated outside of the building, the definition of what is included in the BVO of the building can be ambiguous and the decision rest with the BREEAM assessor. To predict what could be the shadow cost of the building according to the assessor's decision, several scenarios are assessed. The different assessed scenarios are presented in Figure 16 and the results in Figure 15.

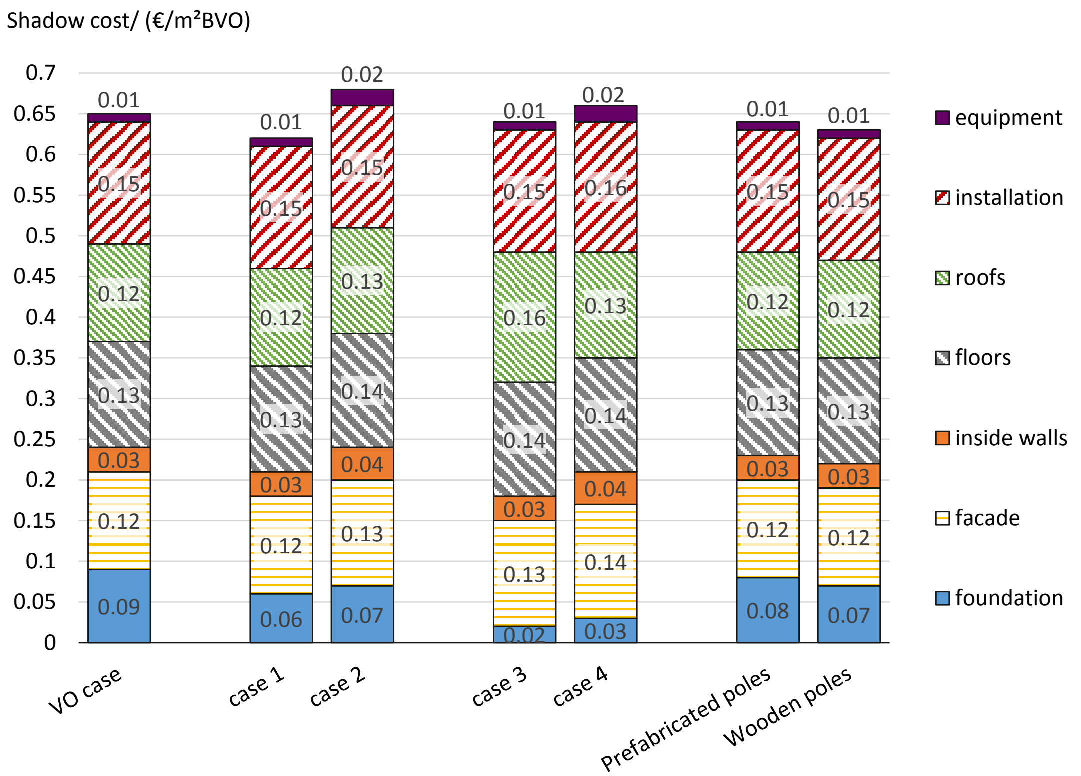

Figure 15 *Effects of different modification of foundation on the total shadow cost of the building.*

VO-case: The base case corresponds to the preliminary design (VO) described in Section 3.1, its shadow cost is analysed in Section 4.1

Case 1: In this case, the basement is reduced but the BVO remain the same, resulting in a reduction of 0.03 €/m²BVO. The Air Handling Unit (AHU) is relocated to the roof top with a very light wooden construction. This way, the surface is still counted in the BVO for a minimum of material use, which does not increase the shadow cost of the roofs. The same strategy is applied for the bike storage. A wooden shed is placed next to the building, keeping to same total BVO for a minimum of added materials. Even though this shed would be next to the building and not in the same envelope, it is assumed that this surface could be accepted as being part of the BVO of the building.

Case 2: The basement is reduced as well as the total BVO resulting in an increase of 0.03 euros/m² BVO. The AHU is placed next to the building and is only enclosed by a simple fence while the bikes are parked in an existing structure. In this case, the BREEAM Assessor could argue that these surfaces are not part of the building BVO, which, on the whole, increases the shadow cost per square meter BVO of the building. As a result, the decrease in shadow cost brought by the reduction of the basement is smaller than the increase brought by the loss of square meter BVO.

Case 3: The basement is completely removed and the BVO remains the same, resulting in a decrease of 0.01 €/m²BVO. Even though the removal of the basement reduces the shadow cost of the building by 0.07 €/m²BVO, the functions relocated on the ground floor increases the roofs', floors' and facades' surfaces and thus increases the shadow cost by a total of 0.06 €/m²BVO.

Case 4: The basement is completely removed, the other functions are relocated on the ground floor without increasing its surface, resulting in an increase of 0.01 €/m²BVO. Although this case is the one where the most material is eliminated, the fact that the BVO decreases as well makes the effort of having a more compact building worthless in order to reduce the shadow cost of the building.

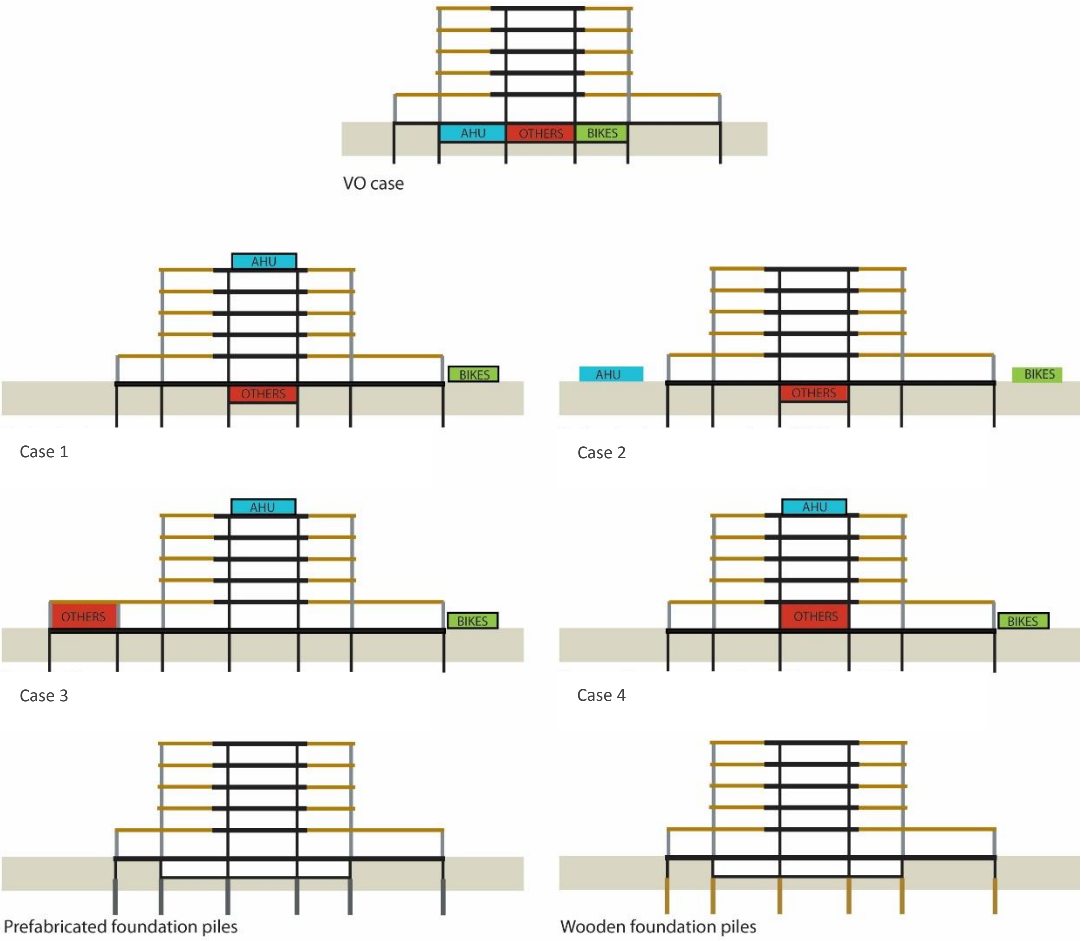

Figure 16 Schematic sections of tested scenarios.

Prefabricated poles: The basement is kept untouched but the concrete foundation poles are replaced by prefabricated concrete foundation poles resulting in a decrease of 0.01 €/m²BVO

Wooden poles: Again, the basement is kept untouched but the concrete foundation poles are replaced this time by wooden foundation poles decreasing the total shadow cost by 0.02 €/m²BVO.

Reducing or removing the basement is a clear example to reveal the weakness of the functional unit. Even though using shadow cost per m² allows users to compare building of different sizes and encourage material efficiency per square meter, it does not encourage a compact design and space efficiency on the scale of the building. This unit could actually have the reverse effect of encouraging to build more basement only to increase the total BVO for a minimum of materials used in order to reduce the environmental performance indicator of the building.

Looking closer at the shadow cost of the foundation poles per m³ in Figure 17, it is noticed that the wooden poles have a negative shadow cost, meaning that they have a positive impact on the environment. This is most likely be due to the CO_2 storing capacity of wood combined with the fact that little process is needed to transform a tree in a pole.

Figure 17 Shadow cost per m³ of different foundation poles.

Although it is not possible to access the data by life-cycle stage, looking at the shadow cost per impact category in Figure 18 gives insight into the cause of this negative value. Indeed, the negative shadow cost of the building is mainly due to the good impact on Global warming Potential (GWP) which is expressed in CO_2 equivalent as well as Marine Aquatic Eco-Toxicity Potential (MAETP).

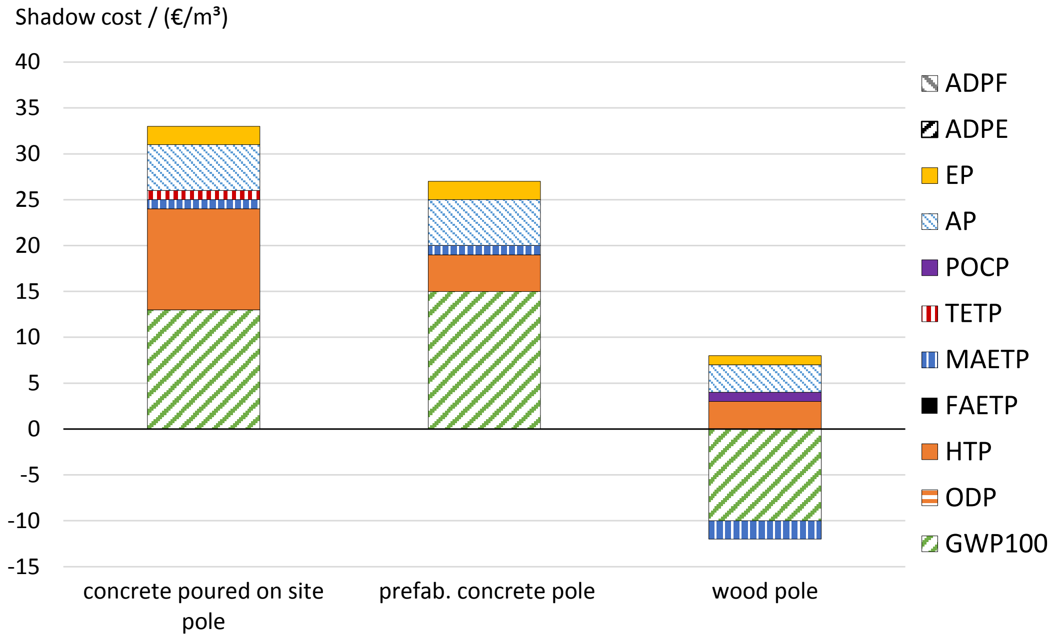

Figure 18 Shadow cost per impact category per m³ of different foundation poles.

The product card of the wooden foundation pole is in category 3, meaning that this result can be doubted, especially if this negative value is abused by implementing too many foundation poles to lower the total shadow cost of the building. The CO_2 storing capacity of the wood is a delicate subject and there are different opinion about how to execute the LCA for wood products. In his interview (see Appendix D), René Klaassen from the Foundation for Wood Research (SHR) explained how this aspect of their first LCA on wood foundations piles was corrected by the third party reviewer:

> *"Well, in the determination method, the wood is CO_2 neutral, which in the case of the foundation pile is not the case since they really sink CO_2, you can leave them in the ground for more than 100 years. So you remove it from your 100 years cycle. It is actually a sink. And that is how you get your advantage."*

A suggestion of the BREEAM Expert to account for this uncertainty is to count zero shadow cost for the wooden foundation pole instead of a negative value.

4.2.2 Modification of structure

Based on the general idea that concrete has a high environmental impact and with a will to integrate more wood in the building, different structural options are tested as shown in Figure 19. A schematic drawing of the tested structures is proposed in Figure 20.

VO case: The structure in VO case is a concrete core with concrete floors extended by wooden floors and steel columns as suggested by the schematic section above. The ground floor and basement are made out of concrete.

Wooden ground floor: Changing the concrete ground floor to a wooden one decreases the shadow cost of the floors by 0.02 €/m²BVO but the brick foundation wall necessary to support it increases the shadow cost of the foundation by 0.01 €/m²BVO, resulting in a total decrease of the shadow cost of the building by 0.01 €/m²BVO.

Traditional wooden construction: Changing the concrete core (walls and floors) and steel columns for a wooden construction reduces the shadow cost by 0.02 €/m²BVO. According to the recommendations of the structural engineer, some laminated wooden beams are implemented in this design to keep a large free space within the core. The steel columns are replaced by massive wooden columns of 320x320 millimetres minimum, instead of the 160x80 millimetres of the steel, to ensure fire resistance.

Tree like structure: With laminated wood construction the shadow cost of the building increases by 0.03 €/m²BVO. The benefice from the laminated wood is the freedom of the shape which is not possible with a more traditional massive wooden structure. This shape consists of “T” shaped profiles with the vertical part of the “T” replacing the concrete wall of the core. It had the big advantage of completely eliminating the columns along the facade, and leaving the view completely interrupted. This original idea is inspired by trees, for which branches derive from the stem.

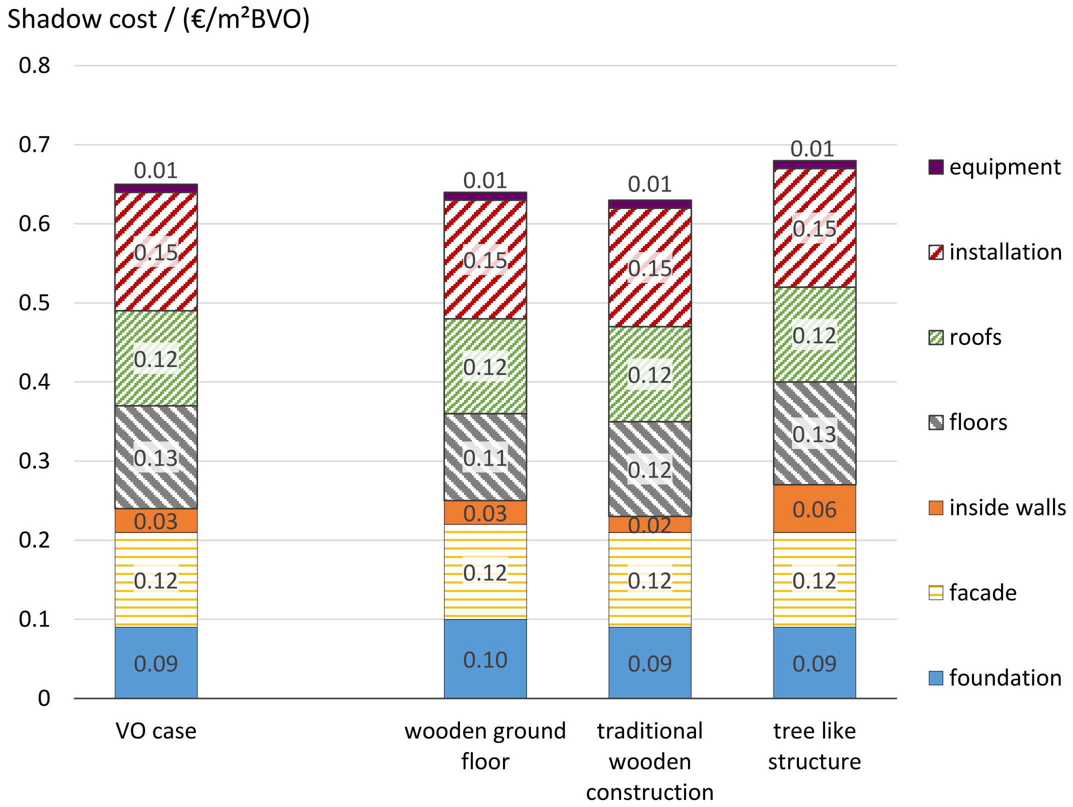

Figure 19 *Parametric study of the structure.*

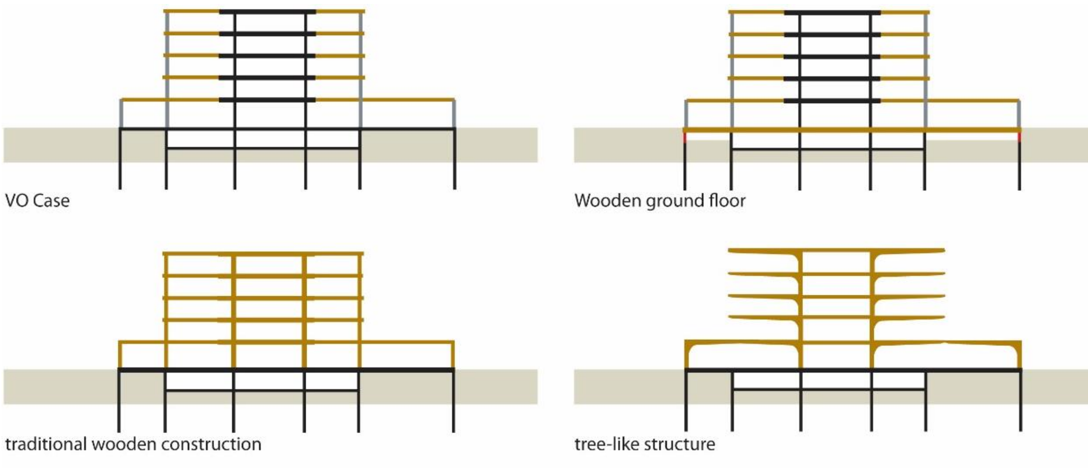

Figure 20 Schematic sections of tested structures.

Looking closer at the shadow cost per m³ for different column's material in Figure 21, the steel clearly has the biggest negative impact on the environment while the massive wood has the lowest. Between the concrete and the laminated wood however, the difference is not so obvious, depending on the amount of steel used to reinforce the concrete. It should be noted that the laminated wood, as many other material in the NMD is from Category 3 whereas the concrete is from category 1 or 2 meaning that the LCA´s results have been verified by a third party.

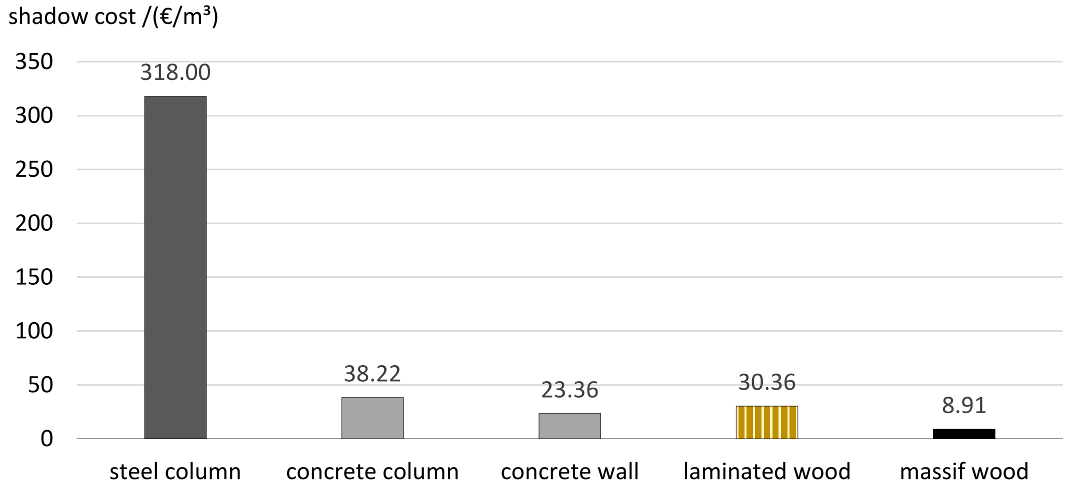

Figure 21 Shadow cost per m³ of different structural materials.

These results come from the amount of material used in each case. The steel column, even though being used every 1.8-m along the facade of the VO case remains a hollow element with a small amount of material while the concrete from the core is a massive element. When using laminated wood for the structure, big elements are required in order to ensure its load bearing capacity. Figure 22 presents the volume of steel and concrete needed in the VO case compared to the volume of laminated wood necessary for the tree like structure.

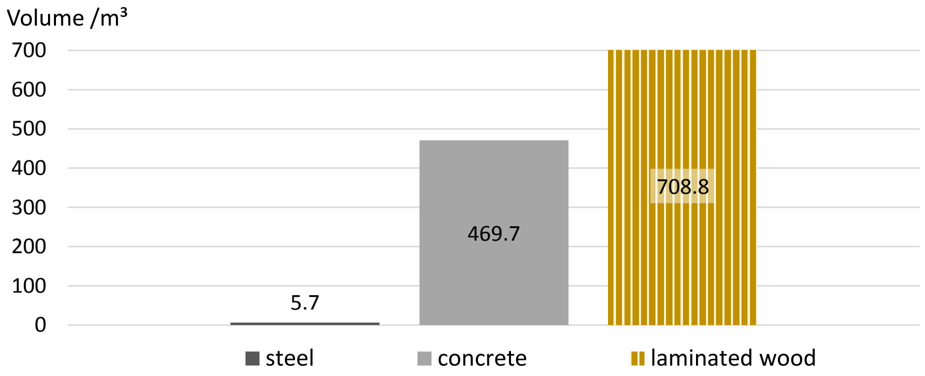

Figure 22 Volume of material for VO case and tree-like structure case.

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It is interesting to look at the different environmental impact categories per cubic meter to estimate the difference between wood, laminated wood and concrete in Figure 23.

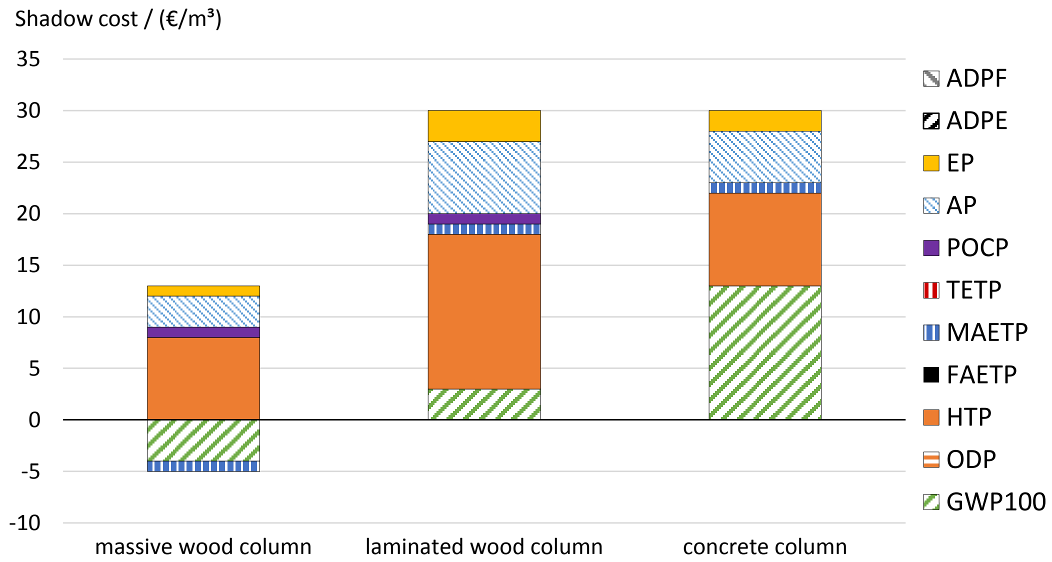

Figure 23 Environmental impact of different materials for the columns.

From Figure 23 it can be assumed that the processes needed for manufacturing laminated wood account for more GWP than the CO_2 storing capacity of the wood used in the product since the GWP goes from -4 euros for the massive wood to 3 euros for the laminated wood. The Human Toxicity Potential (HTP) of the laminated wood column is almost twice the value of both the massive wood and the concrete column. This is assumed to be due to the VOC and glue used in the laminated wood. The Acidification (AP) and Eutrophication potentials (EP) are also higher in the laminated wood case than both the case of wooden or concrete column. According to the interpretation part of a German EPD for laminated wood (Studiengemeinschaft Holzeimbau e.V., 2013) the heat generation on site causes 32% of the AP while 33% of the emissions causing EP are due to wood firing on site. According to the same source, the POCP which is the same in Figure 23 for the massive wood and the laminated wood, is mainly caused by the drying of wood. It is important to note that in NMD all the wooden product are classified in category 3 whereas only 6% of the concrete product cards are in category 3.

4.2.3 Climate ceiling

As explained in Section 4.1, the installations have the largest impact on the shadow cost of building and within these the climate ceilings have the largest impact. Simply removing these elements is not an option since a required indoor climate quality should be kept, however, only one kind of climate ceiling is available in the NMD.

Although the description of the default climate ceiling from the NMD is not very clear in its composition, it is safe to assume that it is made out of copper tubes for the circulation of water and a metal plate to radiate the heat or cold into the room since this represent the most standard climate ceiling element to be found in the market.

A range of climate ceiling types exists in the market, however, none of them have been included in the NMD yet. To get an idea of whether a different kind of climate ceiling would be beneficial in reducing the shadow cost of the building, an estimation of the shadow cost per square meter was made for this study. Figure 24 illustrates different types of climate ceilings studied. MaterialenTool was used to obtain the shadow cost of different climate ceilings by combining shadow costs of different materials together as shown in Figure 25. The details of quantities of material were found using online specifications of products from different manufacturers.

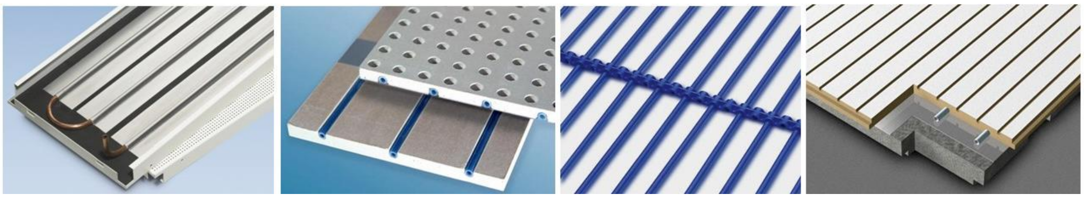

Figure 24 Different types of climate ceilings (from left to right) Standard, CC1, CC2, CC3.

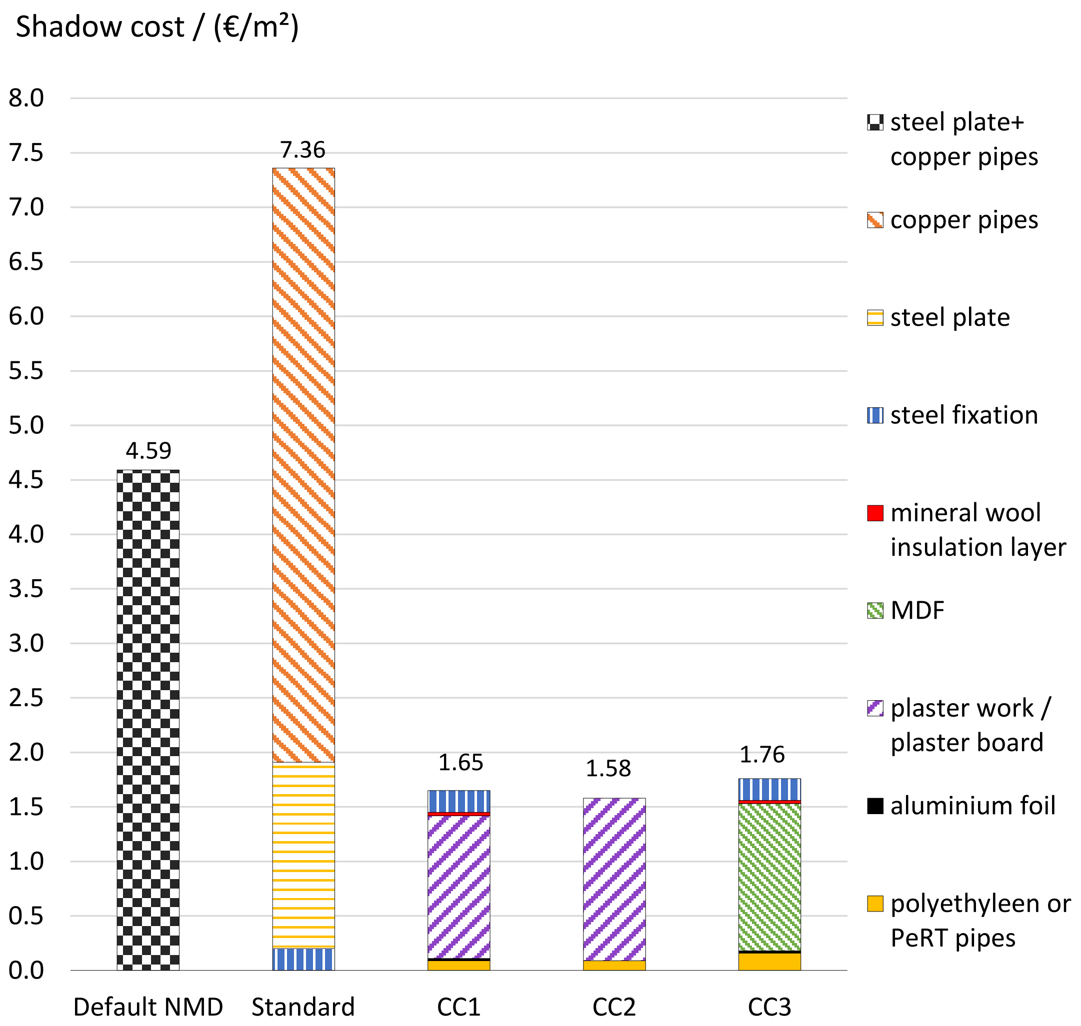

Figure 25 Estimated shadow cost per m² of different climate ceiling.

Default NMD: The only climate ceiling available in the NMD and described as "steel plate + pipe" has a shadow cost of 4.59 €/m².

Standard: A standard climate ceiling which is assumed to be the same kind as the default one from the NMD is composed a copper tube and metal sheet. It also has acoustic advantages with the perforation of the metal sheet. A shadow cost of 7.36 €/m² was estimated. This high value is mainly due to the copper pipes. This price is 160% of the default value with which it is represented in the NMD.

CC1: This product uses polyethylene instead of copper pipe and a plaster board which is covered by an aluminium foil instead of a metal sheet. The small holes in its surface allows it to act as an acoustic ceiling panel as well. It comes with a mineral wool insulation layer and is mounted on steel fixations. Using a plaster panel reduces the shadow cost by 0.40 €/m² compared to sheet metal. The big improvement is made by the polyethylene pipes which are

60 times lower in shadow cost than copper pipes. The total shadow cost of this climate ceiling is estimated to 1.65 €/m².

CC2: This product was studied because even though it does not include any acoustic features, it has the advantages of being applicable to curved surfaces which may be useful for the tree-like structure. The polyethylene tubes are highly flexible and once fixed to the ceiling, a layer of plaster is applied on it. This very simple composition resulted in the lowest shadow cost of 1.58 €/m².

CC3: This innovative product resembles the comfort plafond model except that it replaces the plaster panel by a MDF panel with acoustic features and the polyethylene pipes by PeRT pipes. As with the comfort plafond model, it includes an aluminium foil, a mineral wool insulation layer and metal fixations. The MDF cost 0.04 €/m² more than the plaster and the PeRT cost 0.07 €/m² more than the polyethylene, resulting in a total shadow cost of 1.76€/m².

These estimations show that copper climate ceiling should be avoided to reduce the shadow cost of the building. These results remain only estimations and conducting an LCA for each of these products would be much more accurate than adding shadow cost of components. However, according to the BREEAM.nl expert on the Triodos project, this way of estimating shadow cost could be accepted by the BREEAM.NL assessor if clearly and thoroughly documented. Nevertheless, if the reduction brought by this change is significant, the Assessor might require a more detailed calculation by means of an LCA of the product (Bijleveld, 2015).

Indeed, the next option to include a more environmental friendly climate ceiling in the calculation is to conduct an LCA according to the SBK method, to have it reviewed by a third party and to include it in the NMD. This process can take a lot of time, which is why it is important to first assess whether it is worth the effort, time and money.

The "plaster board" type of climate ceiling is selected because it has the lowest shadow cost per square meter while being both a climate and acoustic ceiling. Figure 26 shows the effect of changing the default climate ceiling for a combination of materials similar to the Comfort Plafond on the total shadow cost of the building. The resulting reduction of 0.06 €/m² proves that it is indeed relevant to implement a more environmental friendly climate ceiling in the construction.

According to BREEAM.NL, one innovation point can be awarded in MAT1 for the introduction of a product which is not already in the NMD and whose shadow cost is at least 0.05 €/m² lower than its alternative in the NMD. The Comfort Plafond is therefore a product worth the effort of being put in the NMD.

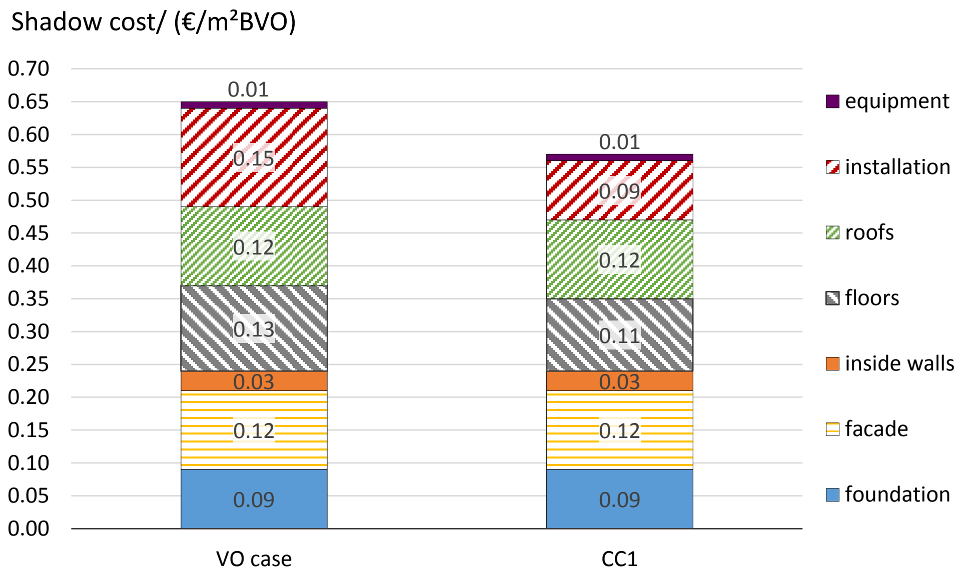

Figure 26 *Effect of changing the climate ceiling on the total shadow cost of the building.*

4.2.4 Combining solutions

Different combinations of solutions are tested to decide which one has the lowest shadow cost as can be seen in Figure 27. Combination A corresponds to the improved design that would have been chosen intuitively while combination B is chosen by selecting all the strategies that proved to be efficient in reducing the shadow cost of the building during the parametric study.

Combination A is the case where:

- The basement is removed by moving AHU to the roof, bike stand to a wooden shed and other functions to the increased ground floor.
- The foundations is made of wooden poles.
- The ground floor has a wooden floor.
- The structure is tree-like made from laminated wood.
- The default climate ceiling is changed to CC1.

Combination B represents the case where:

- The basement is reduced by moving AHU to the roof and bike stand to a wooden shed.
- The foundations is made of wooden poles.

- The ground floor has a wooden floor.
- The structure is the traditional wood construction.
- The default climate ceiling is changed to CC1.

Final case represents the combination B with an EPS from category 1 instead of 3.

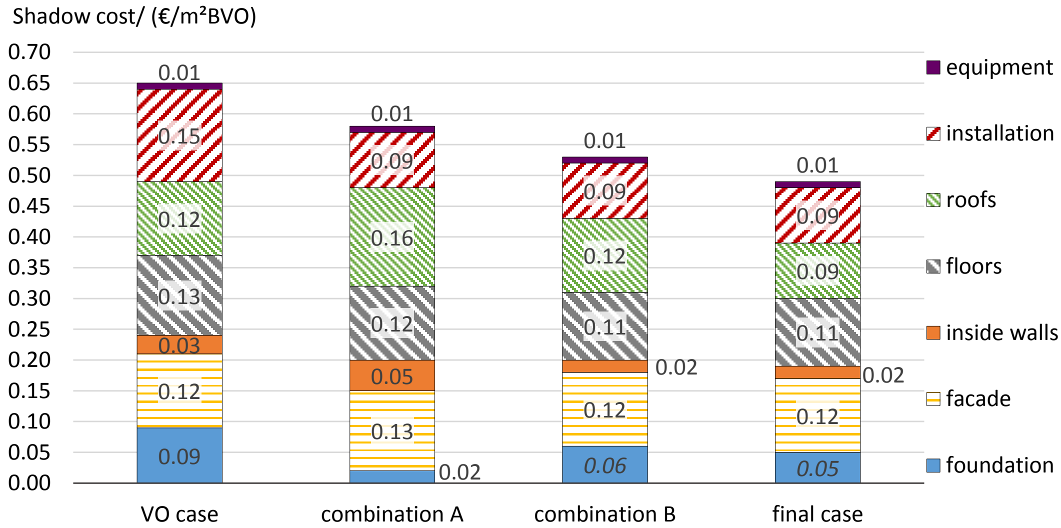

Figure 27 Study of combined improvements.

Combination A results in a total reduction of 0.07 €/m²BVO. Increasing the ground floor raises the façade's and roof's shadow cost while the floors' shadow cost is still reduced by the implementation of a wooden floor. The laminated wood construction also adds to the total shadow cost of the building. However, the climate ceiling CC1 reduces the total shadow cost by 0.06 €/m²BVO and the foundation's shadow cost is reduced by 0.07 €/m²BVO.

Combination B reduces the shadow cost by 0.12 €/m²BVO compared to the VO-case. Reducing the basement and implementing a traditional wooden construction simply reduces the total shadow cost of the building which is subsequently 0.53 €/m²BVO.

After this reduction from combination B, one elements with a high shadow cost is spotted, namely the EPS, which is essential to the energy performance of the building. The example of the laminated wood from Section 4.2.2 showed us earlier the data from category three in the NMD is less reliable since it is not verified by a third party. The fourth column in Figure 27 presents the combination B with an EPS layer of category 1 instead of 3 reducing the total shadow cost of the building by 0.04 €/m²BVO.

This final case, where the changes to the building's shape are kept to a minimum, results in a total shadow cost of 0.49 €/m²BVO or 51% lower than the reference price of 1 €/m²BVO, awarding 7 points for MAT1.

Finally, that final case is compared to the VO case in terms of environmental impact categories in Figure 28. The only increase recorded is for the Photochemical Oxidant Creation Potential (POCP) which was previously linked to the drying of wood. All other impact categories are reduced, especially the Global Warming Potential (GWP) with a reduction of 61%.

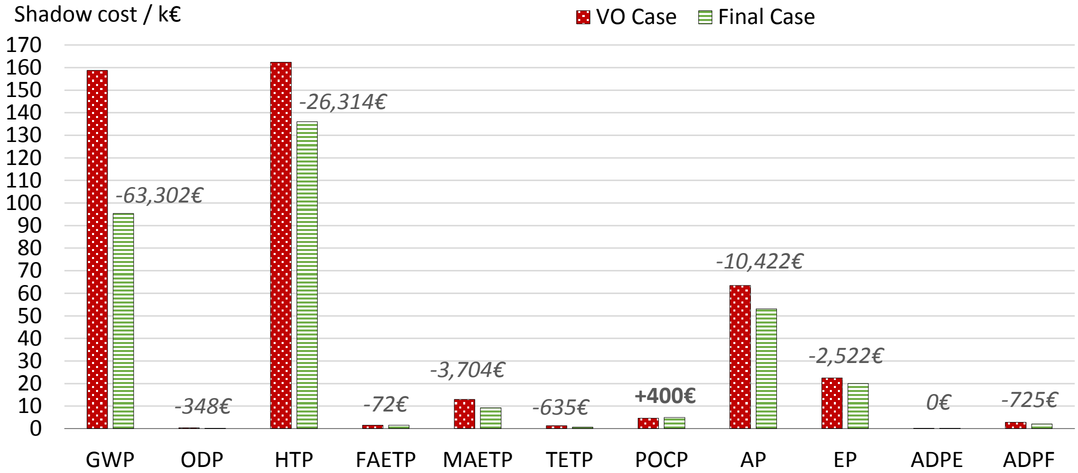

Figure 28 Comparison of the VO and Final case's shadow cost per environmental impact category.

4.3 Other strategies

The solutions suggested in Section 4.2.4 reduced the shadow cost to 0.49 €/m²BVO, however, the question remains: Is it possible to reduce it even more and if yes, how?

4.3.1 C2C® and DUBOkeur® products.

In BREEAM.NL, it is suggested that DUBOkeur® and C2C® labelled products are interesting to investigate and introducing them into the NMD can award one innovation point. The facade is one of the main contributors to the high shadow cost of the building, and no improvement was done since the amount of glazing should stay as designed and the frames are already an environmental friendly and durable solution with the wooden frame protected by aluminum coating on the outside. However, this type of frame does not exist in the NMD, and the same estimation method as for the climate ceiling was applied by selecting a wooden frame and adding a calculated amount of aluminum sheet in the MaterialenTool. Completing an LCA for this type of hybrid frame would verify the reduction brought by this solution and could award one innovation point if the product is introduced into the NMD. Therefore, the hybrid curtain wall system of TGM was examined as a way to further reduce the shadow cost of the building since it is labelled by DUBOkeur® and achieves the bronze level in the C2C®certification.

In terms of information relevant to determine the environmental impacts of the product, the C2C® bronze tells us that each component of the product was identified to some extent and linked to either the technical or biological cycle. It also ensures that no chemical registered in the “banned chemicals list” is to be found in this product. Additionally, it gives a score on the reutilization possibility of the product. Also, the energy used and emission generated on site are quantified and an audit concerning the water usage during the manufacturing of the product is conducted. It also proves how much effort is made by the manufacturer to reach the next level of certification. All this information shows that an LCA of the product could easily be done since most of the information needed from the manufacturer has already been collected.

The DUBOkeur® label does not give a rank but the simple fact that the product holds this label proves that it is at least on the level 2 of the NIBE’s environmental classification which means that an LCA was already conducted for this product.

Although both of these label give useful information about the product’s sustainability, this information does not allow to easily complete a LCA for the TGM façade system. However, the LCA process could be simplified if the information that was already collected to obtain these labels was shared. More directly, it raises the question: “Why are the DUBOKeur® products not automatically included in the NMD?” This question is later discussed with the concerned party in Section 0: Interviews. Another impediment to the implementation of a new product in the NMD is the fact that only one innovation point can be given for this credit. If we assume that this point would have already been used for the climate ceiling, making the LCA for the façade system does not bring a sufficient reward and the estimation in the MaterialenTool is therefore preferred.

4.3.2 Reclaimed materials

Another way to avoid emissions and the depletion of resources is to use building materials that are reclaimed from the waste stream. However, to be used in the MaterialenTool the reclaimed material should be integrated in the NMD. This long process is not coherent with the nature of re-used material which are not standard but often dependent on a one-time opportunity.

In their project for an office building for Alliander, RAU architects made sure that 80% of the materials used in the construction were used for the second time. The clearest example of this is the wooden cladding element from reclaimed palettes that were on or close to the site. Alliander office building project also aimed for the “outstanding” level of BREEAM.NL and therefore needed a calculation with the MaterialenTool. In that calculation, the facade cladding was simply neglected since the shadow cost of this material was already paid for. This argumentation was accepted by the BREEAM assessor and could be illustrated by the graph in Figure 29 where the shadow cost reduces proportionally during the lifespan of the material. If a material has to be re-used after it only served half of its service life, the shadow cost of the re-used material will only be half of its shadow cost when new. However, this simplification does not reflect the reality since the impact created by the transport needed to collect the palettes and the process to cut them into the desired dimension is neglected. It has been shown that the shadow cost of the a square meter of re-used slab is about 80% lower than the shadow cost of a brand new hollow core concrete slab (Naber, 2012).

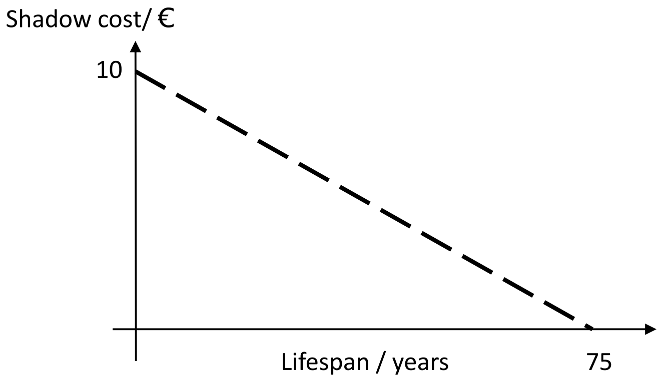

Figure 29 Rules of thumb for secondary use of material.

In our case, the facade cladding does not represent a big share of the shadow cost and is therefore not further researched. The rounded shape of the building also makes it more challenging to find, in large quantities, a material that could be re-used in the project. However, this alternative represents a significant opportunity for reducing the shadow cost of the building and should be studied from the beginning of the project. Another aspect to keep in mind while designing is the possibility for disassembling the building’s components during or at the end of the building’s lifespan for maintenance, flexibility and future re-use.

5 Interviews

The opinion of four protagonists of the Dutch methodology was collected via interviews. From the LCA expert involved in the construction of the NMD to the architect using the NMD, the interviewees all agree that the creation of the NMD is a great initiative and should develop into a very useful tool. However, the NMD is not perfect and the experts' opinion on what problems exist and how they should be solved differ from each other.

Rick Scholtes, member of the TIC and employee at NIBE raises the issue of the selection of the environmental impact category. According to him the LCA should be as precise as possible. The eco-toxicity impacts assessment is already required by the Dutch method while they are optional for an international EPD. NIBE is also in discussion with the NMD to include the Land Use impact category in the shadow cost calculation. He said on this topic:

> *"When you don't take them into account (i.e. the environmental impact categories), it's like saying they are not happening even though they are having an impact on the environment. Of course you need to work on the environmental impact categories to make them very good but in the meanwhile you still need to take them into account otherwise it's like saying they are zero which is more incorrect than using an imperfect impact category."*

He also acknowledges that having a different impact category selection in the NMD compared to an international EPD can create difficulties in the exchange of data but also suggests that it is not the main issue the NMD should be preoccupied about. When asked whether having a database as accurate as possible according to the Dutch context was more important than having a database that allows for the exchange of information between European countries, he answered:

> *"I think it is always a big discussion. Now the discussion between NIBE and the NMD is about the Land Use, I think it's the most important matter now. But between the NMD and Europe, the discussion is about the Toxicity. At the beginning, they didn't want to use the Toxicities in Europe but maybe now they want to, I am not sure what they are doing about it now."*

Therefore it seems that one purpose of the NMD could be to lead the way towards better European standards rather than complying with them and waiting for them to improve. However, LCA practitioner and third party reviewer Rene Klaassen insisted on the impracticality of this situation, when asked the same question he answered:

> *"I don't know exactly but there are many ideas why you should include or not different impact categories in the shadow cost. The whole method is still dynamic let say. That means that foreign EPDs are difficult to include and that is a main problem because making LCA is quite expensive, like 8 000 or 10 000 euros. And then you need to make a review, that's another 15000 euros. If you have many product (as a manufacturer), you cannot afford it."*

It is indeed not possible to directly use the results of a foreign EPD since the Dutch method dictates, for example, how to make assumptions about waste or transportation. This means that the whole LCA has to be done again while a big part of the job was already done. A solution could be found in the open exchange of the information behind the EPD rather than the EPD results only. When this was suggested, Rene Klaassen answered with a positive example:

> -*Marie Chevalerias: "It would be nice if somehow the EPD was so detailed that you could simply extract the information you need."*
>
> -*Rene Klaassen: "Exactly. We have contact now with a Danish company and hopefully we can get the whole calculation from them and then we can introduce it quite easily, so that would be nice."*

Unfortunately, most of the time, producer do not want to share openly their manufacturing process since it might reveal information to their competitors.

In the eyes of BREEAM Expert, Martin Bijleveld, this money and data problem is also the main reason why so many product are not included in the NMD:

> *"What is difficult is that it is quite costly to do a LCA. A lot of producer say: "What's in it for me? Well, not so much!" So they don't do it. And also, they don't want to share they recipe."*

If a manufacturer does not see the importance of introducing his product into the NMD, the motivation can instead come from the architect who may want to add the product in the NMD to get one BREEAM.NL innovation point but the question remains: who should pay for it? The BREEAM.NL Expert, Martin Bijleveld, answers:

> *"It is mostly the person who is willing to go the extra mile. In our case (the Triodos office building project) maybe the client, since they want a very sustainable building, is willing to give more money to do the research. But maybe it is the architect that really wants to use this product, they also have to find the extra money. Same thing for us at DGMR, if we advise people to do it, maybe we take some extra free hours to do some research work to do the LCA."*

When asking the architects if they should be the one to pay for it, the answer of Dennis Grootenboer is more radical:

> *"No, I think it should be the NMD's responsibility. I think, their goal is to have the best database, as complete and correct as possible. Then they should be able to pay for that. And then I think it would be much faster to have it ready, and probably it is the cheapest way as well. If I have to do it, then I will think about the time and money it cost me and I am simply not going to do it. The client already has to spend enough money and it's not really in his interest* [to spend more money on introducing a new product in the NMD] *as long as the building is the best he can get."*

So spending money and sharing information are the main barriers to make the NMD a complete and efficient tool. The other important debate which is not only concerning the Netherlands is the balance between harmonization with the European standard and the precision of the assessment concerning geographically related data such as transport, waste scenarios and national energy mix. There are also other practical problems. Although the NMD has the goal to become a clear language in the building industry (SBRCURnet-Cindy Vissering, 2015) the description of the product card in the NMD is lacking in clarity as Martin Bijleveld notes:

> *"One problem is that the MaterialenTool is a bit like a black box. I think it should give more information about the products. Like for example if you have a window frame, how much material is there when you enter 1-m² in the tool? We should know how much kg/m² or the dimensions in width and length for example. Especially if you want to estimate the shadow cost of an innovative material, you cannot really select similar product if you don't know what is in it."*

This opinion is also shared by Rene Klassen, who points out the confusion that an imprecise description could create:

> *"We made an EPD of a wooden roof the "kanaalplaat" type that include everything, wood, vapour barrier, insulation etc. but you cannot compare it to a concrete or aluminium roof since they often don't include insulation. And when you do the calculation of shadow cost for your building you have to know that you need to add insulation to your aluminium roof yourself or that you do not need to add it with the wooden roof."*

Also from the architect's perspective, a clear database is important to make material choices. In this matter the NIBE's environmental classification is a good alternative solution and is sometimes preferred over the national tool, as Dennis Grootenberg explains:

> *"Well, we use the database which is the most clear, so then it's the NIBE database since it is quicker, it is online and it is really fast to look it up."*

This statement shows how a private/corporate initiative can sometimes compete with national tool. Rick Scholtes, involved in DUBOkeur® label and NIBE's environmental classification mentioned few reasons why their tools work better than the NMD, other than the financial aspect:

> *"The NMD comports* [includes] *several stakeholders and members etc., which is a good thing but also makes things a bit slower, that's why we continue doing our label DUBOKeur®. Another good thing with this label is that it doesn't only state the shadow cost of the building, it shows how good the product is in comparison with similar product […] every two years, we update the DUBOKeur® database and new product are included and can indeed change the order of which product is the best, therefore, every manufacturer really makes the effort to improve its products and the ways it is produced and which material they use."*

In conclusion, the solution to make the NMD a more complete and efficient tool lies in creating interest from the manufacturer to have their product in the NMD. This could be done, by creating an emulation effect as it is done with the DUBOKeur® label or maybe by applying “some political pressure” with the reference price as Martin Bijleveld suggested. Another, more practical, solution would be to cover the financial cost of introducing a product in the NMD as Dennis Grootenboer proposed.

Many other issues were discussed during the interviews such as spread of this model over European countries, the question of the reference shadow price or the content of category 3 product card, etc. The transcripts of the interviews can be found in Appendix C.

6 Discussion and Conclusions

6.1 Discussion

The analysis of the preliminary design showed us that having the environmental impact of a building presented in a single indicator is an easy and quick way to determine the impact of the building on the environment. The possibility to analyse the shadow cost for different part of the building and for each material makes it a valuable tool to identify largest source of an environmental impact and to efficiently modify the design. However, the analysis of the preliminary design included certain products from category 3 in the NMD, which made it less reliable. Also it must be noted that this calculation has been made during the design phase of the building and therefore omits a certain number of materials such as possible finishing materials that could represent an additional shadow cost.

When looking at the modification of the basement, different scenarios with change of the total surface of the building have been developed. These different scenarios are developed because of the ambiguity in the BVO definition. The scenarios strive to imagine how the BREEAM Assessor would argue on calculating the BVO but are based on assumptions only. This part of the parametric study has been done mainly to prove the importance of the functional unit.

In regards to the wooden foundation poles, the negative shadow cost of the wooden foundation poles is still something to verify when a more reliable product card will be introduced into the NMD. As René Klaassen suggested in his interview, this subject is concerning other domain than the construction sector:

> *"We are working together with the University of Wageningen, the forest department which is doing LCA, because they are also saying that countries should store their CO_2 but by harvesting you can increase the growth of your forest so it acts like a sink. So the discussion is going on about this subject."*

In the meanwhile, it is confusing to NMD users who wonder if it is an error of the tool or an opportunity to considerably reduce the shadow cost of the building.

When looking at the results of the modification on the structure, the laminated wood is the main point of debate. The results concerning the laminated wood should be handled with cautions since the product card in the NMD is from category 3. This data is especially questionable since a different trend was found in a study comparing laminated timber to reinforced concrete for a mid-rise office building from cradle to gate. Although this study is not directly comparable to our case, it still shows that eutrophication and acidification potential as well as smog and human health effects are lower for laminated timber than for reinforced concrete (Robertson, et al., 2012).

The results for new climate ceilings have been obtained in the best possible way with the NMD. However, they do not reflect the exact shadow cost that the different products should have with a full LCA but only represent an estimation of their shadow cost. This practice could be facilitated if users could find product cards of material to assemble themselves in the NMD as proposed by Martin Bijleved during his interview:

> *"Maybe it would be nice to have some raw material, like 1 kg of aluminium, 1 kg of ...so you could put together your own product but the difficulties then is that you don't really take the process into account. Maybe then you could apply a percentage of uncertainties to have a reliable data."*

This potential improvement in the NMD is also suggested for the composition of PV panel technology (Alsema & Anink, 2014).

Some comment should be noted about the version of the NMD. The update and addition of product cards in the NMD at every release of a new version makes a considerable difference in the results. Therefore, this study should preferably be compared with calculations using the version 1.6 of the NMD although in BREEAM.NL 2014, the calculation using the version 1.5 have the same reference value of 1€/m²BVO (DGBC, 2015).

Finally, some suggestions are presented for the future work. An idea of continuation to this project would be to execute a full LCA of a new kind of climate ceiling or the hybrid wood/aluminum curtain wall frame and compare it to the estimation made with the MaterialenTool. In order to study the Dutch method more comprehensively, it would be interesting to execute a more extensive literature review looking at the systems developed in other European countries. For the sake of the Dutch method, it would be interesting to study how the financial model of the Dutch method could be improved to optimize the input of new products in the NMD.

6.2 Conclusions

With the use of the Dutch method the initial shadow cost of the building was reduced from 0.65 €/m²BVO to 0.49 €/m²BVO by:

- Placing the AHU on the rooftop and the bikes under a simple shed, thus reducing the basement while keeping the same total BVO of the building.
- Replacing the concrete foundation poles by wooden poles.
- Implementing a wooden ground floor instead of a concrete slab.
- Changing the concrete core by a traditional wood construction.
- Choosing an EPS from category 1 rather than category 3.
- Using a new type of climate ceiling not in the NMD.

However, some generally accepted ideas were challenged by the result of the study:

- Reducing the building surface is not necessarily reducing the shadow cost of building. It was thought that reducing the amount of material by reducing the surface would logically reduce the environmental impact of a building. However, despite the good will of the architects to make the building more compact and to rearrange the functions so that they would be more space efficient, these efforts were not rewarded. This is because the MAT1 credit of BREEAM.NL focuses only on the low environmental impact of the materials and not on the efficiency of the shape of the building.

- Not all forms of wood are better for the environment. Although this still needs to be confirmed when the NMD gains more reliable result from the wood industry. The laminated wood is not better than concrete according to the current data. Wooden foundation poles have a negative shadow cost (i.e. a positive impact on the environment) which divides LCA practitioners and confuses users of the NMD.

The tool using the NMD is an easy tool to handle for the design team to analyse different options for reducing the environmental impact of the building. The difficulty of conducting an LCA rest on the LCA practitioner that provides the NMD with product cards at the request of manufacturers or branch industries. This means, however, that the implementation of new products or unconventional building solutions by the design team is difficult. They either require taking a long and costly path toward the creation of a product card or to make radical simplifications.

Also, little information is available for the users to be completely accurate in their selection of materials. The main reason for this is the lack of detail in the name of the product. The title of the product card should give a precise description of the product in the same way as the functional unit of an EPD does. The NMD was referred to as a “black box” by several users since little or no information is accessible either through the tool or in the online database.

The information delivered by the tool is very clear and explicitly presented but it could be even better if the results were also presented for each life cycle stage. In that case the design team could evaluate other strategies such as re-used material to measure how much shadow cost could be “spared” by avoiding the end of life stage of a material.

The shadow cost as a single indicator for the environmental performance of a building appears to be a very explicit figure that is understandable for everybody. This way of communicating the results is more straightforward than comparing the 11 impact categories and can therefore become a strong argument in the selection of a design. However, the deep understanding on how this shadow cost is determined and how this virtual price is constructed is less widespread, even among the LCA experts. Also, the result still makes more sense when compared to a reference price which is set in BREEAM.NL but not yet determined in building regulations. As explained by the helpdesk of BREEAM.NL, the establishment of a reference value is a delicate task:

> *“The challenging aspect is that we want to tempt developers of buildings to look at material use and set a high standard. But not to set the limit/standard, too high. Making a materials calculation and improving on materials use must be awarding.”*

This brings us to the innovation point in MAT1 which do not seems to be awarding enough to encourage architects, consultants or clients to push the introduction of a product in the NMD. The main obstacle to a better database is the time and most importantly cost of creating a product card.

This financial issue of the Dutch method is currently subject to discussion along with the selection of environmental impact to take into account in the shadow cost and the importance to follow or not the European standards for EPDs to either be closer to the Dutch situation or facilitate the use of foreign EPDs.

In conclusion, the NMD reveals itself to be a valuable tool to evaluate different design options but still needs some improvements especially in regards to the clarity and accessibility of the data. For the design team, database presented as the NIBE's environmental classification with extensive description of the functional unit of the products would be more useful. Moreover, the database should become more exhaustive and include more reliable data so that the design team can use the results more confidently. Finally, not all the strategies could be implemented since it depends on what products are included in the NMD which is itself dependent on financial aspects. Estimations were made by means of simplifications and assumptions, a full LCA thus remain a necessary tool to assess more complex situations.

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Appendix A Material scope for MAT1

Foundation	Soil services	Increment sand
		Bottom valves
	Foundation construction	Foundation on steel (bars and strips)
		Beam grid foundation
		Foundation piles
	Substructure general	Basement wall
		Basement wall insulation
Structural work	Interior walls	Bearing interior walls
		Massive non-bearing walls
		House separative wall
	External walls	Curtain wall style
		Inner leaf
		Outer leaf
		Curtain wall panel
		Façade finishing
		Cavity insulation
	Outer openings	Window frame (outer)
		Doorway (exterior)
		Garage doors
		Glazing (exterior)
		Infilling
		Bibs
	Roofs	Roof underlay pitched roof
		Membranes
		Ballast low
		Flat roof insulation
		Insulation pitched roof
		Support construction flat roof
		Under mounting pitched roof
	Roof finishing	Roofing flat roof
		Roof finishing sloping roof
	Roof openings	Light street (glazing)
		Light street (frames)
		Skylight
	Merge frameworks	Beams
		Columns
		Lintels
	Floor	Ground floor
		Floor on solid foundation
		Floor
		Floor insulation
Finishing	General	Fire upholstery
		Sound proof coating
	Balustrades and handrails	Balustrades
	Interior walls	Profiles element wall
		Wall system
		Panels wall element

		Wall finishing (inside)
		Painting (inside)
		Wall tiling
	Inner openings	Window frame (inside)
		Doorway (inside)
		Interior door
		Glazing (inside)
	External walls	Painting (outside)
	Outer openings	Sills
	Roof finishing	Eaves buoy board
	Remaining	Lath (lath and battens)
		Films
	Ceiling finishes	Profiles ceiling
		Ceiling finish
	Decking	Skirting
		Screed
		Floor tiling
		Data-computer floor
Electricity installations	Electrical facilities	Solar power generation
		Elektra leadership
Heat installations	Disposal	Outside sewer
		Inside sewer
		Rainwater
		Gutter
	Air	Ventilation
		Air distribution
	Heat generation	Revival gear hot water
		Revival heating appliances
	Cold revival	Revival gear cooling
	Delivery system	Cold climate system
		Heat system
	Disposal	Connecting line sewer
	Pipes	Water
		Gas pipeline
Fixed facilities	Transportation services	Stairs housing
		Stairs utility
		Elevator cab
		Lift installation (excluding cab)
	Fixed kitchen facilities	Kitchen units
		Worktops
	Fixed sanitation	Toilets combinations
		Urinals
		Sink combinations
Terrain	Terrain features	Pavements
		Fences
		Privacy scots

Appendix B Inventory of materials of preliminary design (in Dutch)

		description	detail	type	quantity	unit
	BVO	13,029	m2			NVO
		5395.35				
Fundering						
		palen	gewapend mortelschroef rond 400 ca 10 m		2000	m1
		betonbalk	betonbalk 500		664.52	m2
Kelder						
		keldervloer	beton 250	V7	2178.79	m2
		keldervloer isolatie	isolatie Rc 6,5		2178.79	m2
		kelderwanden	beton 250		778.36	m2
		kelderwand isolatie	isolatie Rc 6,5		778.36	m2
		grind	120mm around entrance expedition		84.15	m2
		binnenwanden dragend	beton 250 > 150		156.13	m2
		binnenwanden niet dragend	MS		1144.00	m2
		plafond	geen klimaatplafond		2178.79	m2
		dak			zie vloer BG	
		kolommen	beton rond 300 30 stuks		60.90	m1
			beton rond 400		21.50	
		deuren binnen			109.66	m2
BG						
	vloer	Vloer boven kelder	beton 250	V7	2178.79	m2
		Vloer boven grond	kanaalplaat 250		1004.81	m2
			druklaag 100		1004.81	m2
			isolatie zwevende dekvloer 20 mm		3183.60	m2
		vloerisolatie	isolatie		1004.81	m2
	kolommen	kolommen	beton rond 300		122.4	m1
		kolommen	beton rond 400		21.5	
		kolommen	staal rond 120 binnengevel		see total	m1
		kolommen	ondersteuning dak opgaand 120 mm staal		2381.40	m1
	gevel	gevel	drievoudig glas in hout/alu kozijnen		1275.00	m2
			only glas paneel		1175.00	
			only kozijn		2008.98	m1
		dak	sedum 150 mm	D2	1285.02	m2
			OSB 30 mm		1285.02	m2
			EPDM??		1285.02	m2
		dakisolatie	isolatie 200 mm		1285.02	m2
		dakbalken	hout 300x500		364	m1
		binnenwanden dragend	beton 250	3281.9	1878.77	m2
		binnenwanden niet dragend	MS			m2
		binnen door		39	96.53	m2
		plafond	klimaatplafond		zie installaties	
1e				2309.69		
	vloer	vloer werkvlekken	OSB 30 mm	V5	1658.79	m2
			hoofdbalken hout 600x240 (600x120+600x120)		1155	m1
			tussenbalken hout 450x50		3465	m1
			afwerkvloer 80 mm		1658.79	m2
			isolatie zwevende dekvloer 20 mm		1658.79	m2
		vloer kern	beton 250	V3	150.98	m2
		vloer overloop	beton 250	V2 /V6	401.98	m2
		vloer tussen torens	hout		182	m2
		balken vloer tussen torens	balken hout 300x500		70	m1
		tussenbalken vloer tussen torens	tussenbalken hout 450x50		210	m1
	kolommen	kolommen	kolom rond 400		10.80	m1
			kolom rond 300		50.40	
		kolommen	staal rond 120 mm		voir total	m1
	gevel	gevel	drievoudig glas in hout/alu kozijnen		907.00	m2
			only glas paneel		810.00	
			only kozijn		1939.31	
	overstek	totaal overstek m2	m2		229.6	m2
		rand overstek	staal gecoat (650) x 2?mm		213.2	m2
		sedum overstek	sedum 100 mm		229.6	m2
		OSB overstek	OSB 20 mm		229.6	m2
		onderhangend paneel overstek	Houtpaneel 40 mm		229.6	m2
		hoofdbalken overstek	hoofdbalken hout 600x240 (600x120+600x120)		115.5	m1
		tussenbalken overstek	tussenbalken hout 450x50		346.5	m1
		dak tussen torens A en C dicht	150 mm sedum	D1	108	m2
			30 mm OSB		108	m2
		dakisolatie	isolatie 200 mm		108	m2
		dakbalken	balken hout 300x500		61	m1
		dakbalken tussenbalken	tussenbalken hout 450x50		162	m1
		glasdak tussen 2 torens	glas+kozijn		23	m2
		binnenwanden dragend	beton 250		374.1	m2
		binnenwanden niet dragend	MS			m2
		binnen door			91.45	m2
		plafond	klimaatplafond		zie installaties	

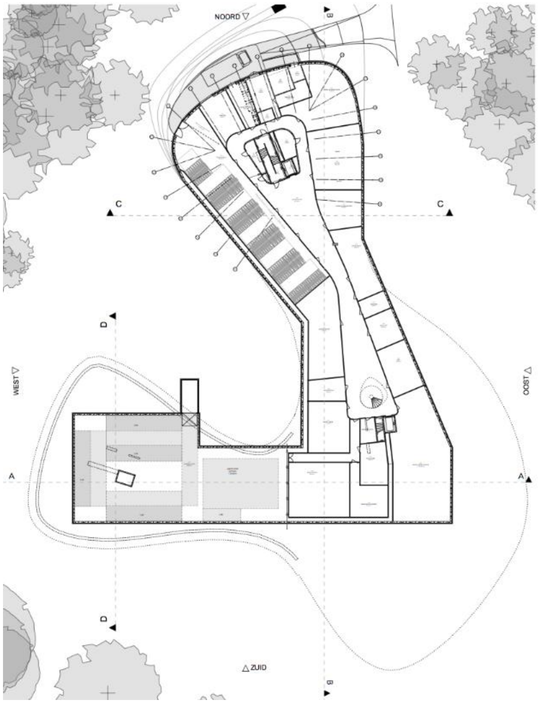
2e					
vloer	vloer werkvlekken	OSB 30 mm	V1	1515	m2
		hoofdbalken hout 600x240 (600x120+600x120)		1155	m1
		tussenbalken hout 450x50		3465	m1
		afwerkvloer 80 mm		1515	m2
		isolatie zwevende dekvloer 20 mm		1515	m2
	vloer kern	beton 250	V3	240	m2
	vloer overloop	beton 250	V2	321	m2
	vloer tussen torens			108	m2
	balken vloer tussen torens	balken hout 300x500		70	m1
		tussenbalken hout 450x50		105	m1
kolommen	kolommen	kolom rond 300		28.80	m1
		kolom rond 400		10.80	
	kolommen	staal rond 120 mm		594	m1
gevel	gevel	drievoudig glas in hout/alu kozijnen		918.00	m2
		only glas paneel		821.00	
		only kozijn		1953.02	m1
overstek	totaal overstek m2	m2		210	m2
	rand overstek	staal gecoat (650) x 2?mm		195	m2
	sedum overstek	sedum 100 mm		210	m2
	OSB overstek	OSB 20 mm		210	m2
	onderhangend paneel overstek	Houtpaneel 40 mm		210	m2
	hoofdbalken overstek	hoofdbalken hout 600x240 (600x120+600x120)		115.5	m1
	tussenbalken overstek	tussenbalken hout 450x50		346.5	m1
	dak	houten dak	D1	795	m2
	dakisolatie			795	m2
	dakbalken	hout		588	m1
	dakbalken dak tussen torens			61	m1
	dak glas	glas+kozijn		30	m2
	binnenwanden dragend	beton 250		374.1	m2
	binnenwanden niet dragend	MS			m2
	binnen deur			93.78	m2
	plafond	klimaatplafond		zie installaties	
3e					
vloer	vloer werkvlekken	OSB 30 mm	V1	1010	m2
		hoofdbalken hout 600x240 (600x120+600x120)		770	m1
		tussenbalken hout 450x50		2310	
		afwerkvloer 80 mm		1010	
		isolatie zwevende dekvloer 20 mm		1010	
	vloer kern	beton 250	V3	160	m2
	vloer overloop	beton 250	V2	214	m2
kolommen	kolommen	staal rond 120 mm		see total	m1
		concrete 400		7.20	m1
gevel	gevel	drievoudig glas in hout/alu kozijnen		662.00	m2
		only glas paneel		556.00	
		only kozijn		1317.33	m1
overstek	totaal overstek m2	m2		140	m2
	rand overstek	staal gecoat (650) x 2?mm		130	m2
	sedum overstek	sedum 100 mm		140	m2
	OSB overstek	OSB 20 mm		140	m2
	onderhangend paneel overstek	Houtpaneel 40 mm		140	m2
	hoofdbalken overstek	hoofdbalken hout 600x240 (600x120+600x120)		77	m1
	tussenbalken overstek	tussenbalken hout 450x50		231	m1
dak	dak	houten dak	D1	675	m2
	dakisolatie			675	m2
	dakbalken	hout		196	m1
	dak glas	glas+kozijn		30	m2
	binnenwanden dragend	beton 250		249.4	m2
	binnenwanden niet dragend	MS			m2
	binnen deuren			69.29	m2
	plafond	klimaatplafond		zie installaties	
4e					
vloer	vloer werkvlekken	OSB 30 mm	V1	505	m2
		hoofdbalken hout 600x240 (600x120+600x120)		385	
		tussenbalken hout 450x50		1155	
		afwerkvloer 80 mm		505	
		isolatie zwevende dekvloer 20 mm		505	
	vloer kern	beton 250	V3	80	m2
	vloer overloop	beton 250	V2	107	m2
kolommen	kolommen	staal rond 120 mm		198	m1
		concrete 400		3.60	m1
gevel	gevel	drievoudig glas in hout/alu kozijnen		311.00	m2
		only glas paneel		278.00	
		only kozijn		658.66	
overstek	totaal overstek m2	m2		70	m2
	rand overstek	staal gecoat (650) x 2?mm		65	m2
	sedum overstek	sedum 100 mm		70	m2
	OSB overstek	OSB 20 mm		70	m2
	onderhangend paneel overstek	Houtpaneel 40 mm		70	m2
	hoofdbalken overstek	hoofdbalken hout 600x240 (600x120+600x120)		38.5	m1
	tussenbalken overstek	tussenbalken hout 450x50		115.5	m1
	dak nvt			nvt	
	binnenwanden dragend	beton 250		124.7	m2
	binnenwanden niet dragend	MS			m2
	binnen deuren			34.03	m2
	plafond	klimaatplafond		zie installaties	

	5e					
	vloer	vloer werkvlekken	OSB 30 mm	V1	505	m2
			hoofdbalken hout 600x240 (600x120+600x120)		385	
			tussenbalken hout 450x50		1155	
			afwerkvloer 80 mm		505	
			isolatie zwevende dekvloer 20 mm		505	
		vloer kern	beton 250	V3	80	m2
		vloer overloop	beton 250	V2	107	m2
	kolommen	kolommen	staal rond 120 mm		198	m1
			concrete 400		3.60	m1
	gevel	gevel	drievoudig glas in hout/alu kozijnen		311.00	m2
			only glas paneel		278.00	
			only kozijn		658.66	
	overstek	totaal overstek m2	m2		70	m2
		rand overstek	staal gecoat (650) x 2?mm		65	m2
		sedum overstek	sedum 100 mm		70	m2
		OSB overstek	OSB 20 mm		70	m2
		onderhangend paneel overstek	Houtpaneel 40 mm		70	m2
		hoofdbalken overstek	hoofdbalken hout 600x240 (600x120+600x120)		38.5	m1
		tussenbalken overstek	tussenbalken hout 450x50		115.5	m1
		dak	houten dak	D1	675	m2
		dakisolatie			675	m2
		dakbalken	hout		196	m1
		dak glas	glas+kozijn		30	m2
		binnenwanden dragend	beton 250		124.7	m2
		binnenwanden niet dragend	MS			m2
		binnen deuren			26.24	m2
		plafond	klimaatplafond		zie installaties	
installaties W						
	Afvoeren	52.01 Buitenriolering			5395.35	m2 BVC
		52.03 Binnenriolering			5395.35	m2 BVC
		52.05 Hemelwaterafvoer				m1
		52.04 Dakgoten			1320	m1
	Luchtbehande	57.01 Ventilatiesysteem			3?	stuks
		57.02 Luchtdistributiesystemen			5395.35	m2 BVC
	Warmte opwel	51.01 Opwekkingstoestel warmtapwater			16	stuks
		51.03 Opwekkingstoestellen verwarming			5395.35	m2 BVC
	Koude opwekl	55.01 Opwekkingstoestel koeling			5395.35	m2 BVC
	Afgifte systeei	55.03 Koudeafgiftesysteem			3177.354	m2 BVC
		56.02 Warmteafgiftesysteem			zie koude	
	Afvoeren	52.02 Aansluitleiding riolering				m1
	leidingen	53.01 Waterleiding			5395.35	m2 BVC
		54.01 Gasleiding			5395.35	m2 BVC
inrichting						
	transportvoor:	24.02 Trappen utiliteitsbouw	vluchtrappen huis beton			stuks
			helixtrappen staal			stuks
		66.01 Liftcabine			3	stuks
		66.02 Liftinstallatie (ex cabine)				stuks
	Vaste keukenv	73.01 Keukenblokken			20	VO
		73.02 Aanrechtbladen			20	VO
	Vaste sanitair	74.01 Toiletcombinaties	Toiletcombinatie; porselein		60	VO
		74.01 Urinoirs			20	VO
		74.02 Wastafelcombinaties	Wastafelcombinatie; porselein		37	VO
	Terreinvoorzi	90.03 Verhardingen	asfalt parkeerterrein			
			asfalt excl onderlagen			
			voetpaden grind			
		90.01 Erfafscheidingen			nvt	
		90.02 Privacyschotten			nvt	

Appendix C Plans of study case

Courtesy of RAU Architects

Basement

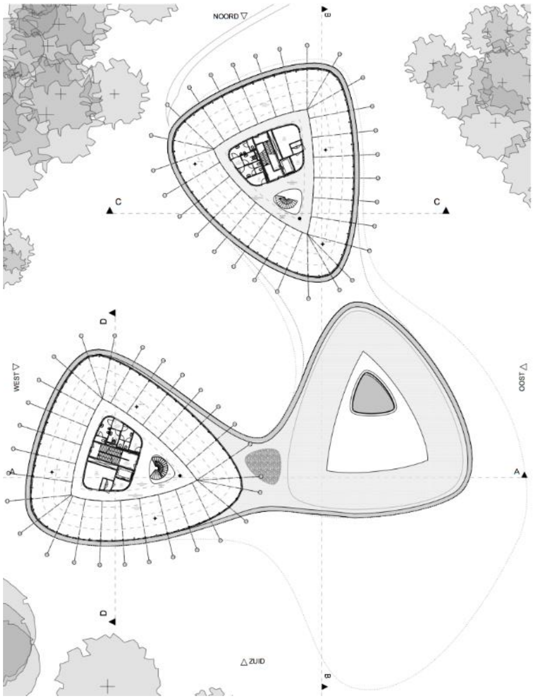


Ground floor

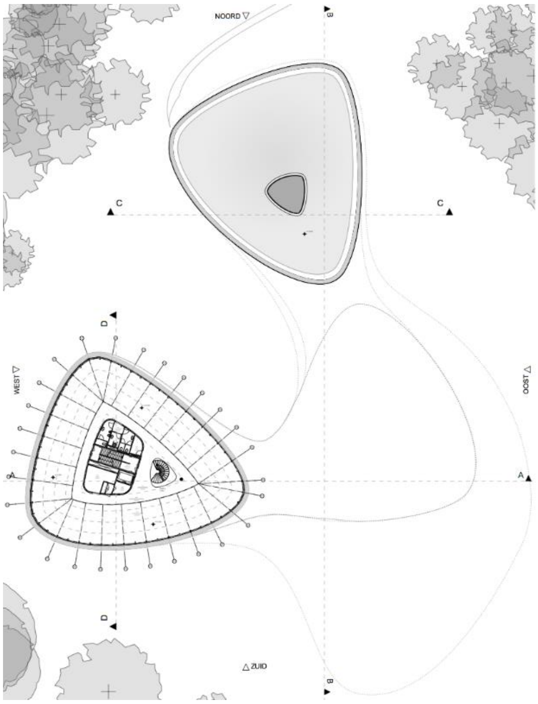
1st floor

2nd floor

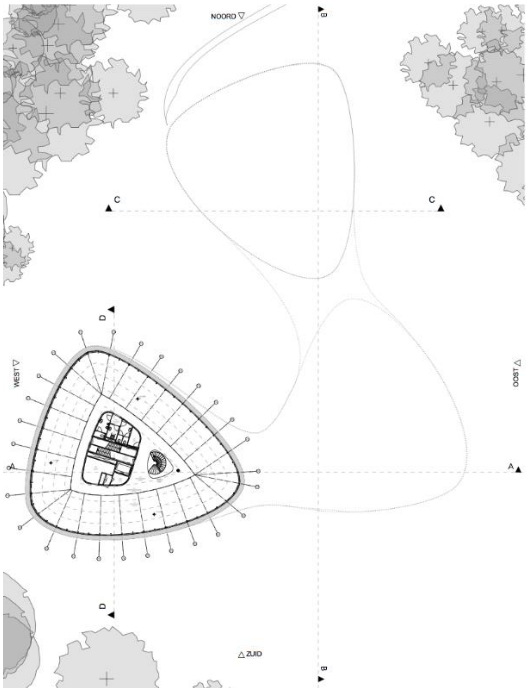
3rd floor



4th floor



5th floor



Appendix D Interviews (Unedited)

Interview with René Klassen at SHR.

2nd of April 2015.
Rene Klaassen: RK
Marie Chevalerias: MC

MC: I understood that you are a third party LCA reviewer, can you tell me a bit more about it?
RK: Yes, so, we were ask by the Dutch timber wood organization to be involved as a research institute in the environmental calculation in relation to the NMD. Because from 2012 onwards, you are obliged when you want to make a building to make an environmental calculation. And that's why it's a very strong tool. So every building company and manufacturer of building elements has to deal with it. It's a quite ambitious project. The Dutch government is leading it and they asked SBK to achieve it. And it's quite complicated. They started in 2012, so everyone has to work with it but there is no restrictions yet. If you do the calculation, that's enough. The level of you shadow cost is not regulated, yet. Probably next year or 2017 there will be a regulation. That means that it is important for the Dutch industry to be in the NMD with reliable and actually low environmental cost for their products. So in order to start with such a database, it should be filled. They made 3 categories. 1, 2 and 3 and they started with category 3 data. So they permitted many LCA to enter the database (un-reviewed data).

MC: Is it data from EcoInvent?
RK: It was data from everybody. Actually I was not involved with that, but somehow they judged the data and put it in the database. So it is something but it is not really reliable. What we see is that it is very positive for wood, even too positive and very negative for concrete. So for the concrete industry it was very important to make as soon as possible reliable data instead of the category 3 data in the NMD to get better more accurate data. And they did it. So if you have data in the system that is done with the determination method (description how to make your EPD) and there is a reviewer that check if you did it in the right way. Then you can enter it in the database as category 2 which mean that if for example if you have a wooden window , category 2 is for all wooden windows while category 1 is from a specific manufacturer who maybe produces his window in a better way so its environmental load is lower. For the NMD as a whole it is important to have as much category 1 or 2 as possible because 3 is not reliable. So that was the start of it. In the members we have NIBE which is a big player in the field of LCA and IVAM which may be even bigger. And then we have Ernst and Young, SJS, TNO applied research. They are involved in creating the NMD. And then we have in the Netherlands organizations that can make LCA and they are members of VLCA. We did some studying and we had to pass an exam to be able to review LCA but we are also able to make LCA. And we are quite new since we started in 2012 when the Dutch wood industry told us : ''Please be involved as a wood research institute in the world of LCA because we don't understand anything about it and we think things are going the wrong way for wood'' and they were right. We were also in the UN workshop to understand why wood was behaving so badly in LCAs.

MC: So, that were the answers of this workshop?
RK: Well, first we tried to understand how the world is working in LCA, we made several LCAs and now we are analysis the wood EPDs in the NMD in order to understand what's happening but it's quite complicated because all the data is closed it's like a black box. So the only thing you can do is go to the database and take a software and take $1m^2$ or something and then compare concrete with wood for example or look at the shadow cost. Some of the data category 3 are open.

MC: Yes, I saw that but I don't really see how these information are useful?
RK: So, don't see a lot because it is category 3 data, and you cannot see how it's constructed. To construct this data they took some EcoInvent data or transformed it into SBK data but they are more or less the same which just makes it a little bit more confusing. For instance, for a window they took a little bit of wood, a little bit of iron, a little bit of glass, etc., they took some transport from the production to the construction site and they put some end of life protocol, and that's it! And that is of course something completely different as a real LCA. So actually it doesn't tell you anything.

MC: But that is a problem since most of the value in the NMD are category 3.
RK: Yeah, that is the situation in which we are now. And if you have category 3 data you get a 30% extra loads. We made as a branch we made a new EPD for a wooden frame and a wooden door and a roof etc. and they are, 10 times, 20 times, 30 times… worst in shadow cost than what category 3 is saying. So those extra load of 30% that is not very bad for the wooden product. Actually, they should rely on the category 3 data and not include their category 2 data that are worst in environmental load. But that wouldn't be correct. We also if you compare a wooden door and a plastic door, you see that the wooden door also has a plastic cover during transportation which is probably not the case for plastic door but a wooden door is insulating while the plastic door does not include insulation material. So it is not very comparable.

MC: But it should be.
RK: Yes, and they are working on that but it is still a long way to go. The NMD but also the determination method which is based on European standard, the EN 15804. It is a standard made by ETC (European Technical Committee) in which also other material are involved. And other material branch are richer than wood with more people involved in the committee. There it's decided what is more important in your calculation. The improvement of the method is still going on, so at the moment the NMD is working with 11 impact categories. But they are talking now about including another one which is land conversion and land occupation. And this is of course very bad for the forest.

MC: Is it really?
RK: Well, timber takes a lot of times to grow: 60, 100 years. So, the occupation time is long. So if you are changing the impacts then everything is changing. But why are the shadow costs for each impact made like this? Many study there done but I don't know exactly.

MC: and if we look at these impact category, we can see that they are not the same as a random EPD (like this one from Germany)
RK: Yes, and that is a problem!

MC: And do you think it is better to be able to exchange EPD between countries or to be more precise for the Dutch context?

RK: Well, those impact are for every country. I don't know exactly but there are many ideas why you should include or not different impact categories in the shadow cost. The whole method is still dynamic let's say. That means that foreign EPDs are difficult to include and that's a main problem because making LCA is quite expensive, like 8 000 or 10 000 euros. And then you need to make a review, that's another 15 000 euros. If you have many product, you cannot afford it. So we combine them, we are doing LCA for the Dutch timber market. At the moment we are working on different timber species. In EcoInvent there is only softwood or hardwood and they transfer that to the tropic but things are different there. So we are making now EPD for timber from Malaysia, timber from South America, timber from North America, timber from the Netherlands. And then you combine that so you can work more efficiently but it is still a lot of money.

MC: And how do you do that?

RK: well we went to Malaysia and we made interviews there: ''do you know the normal way your timber is harvested?" "Do they use chainsaw? Or big harvester?" that is quite important to know "how do you remove the stamps from the forest?" "How long is the road from the forest to the Sawmill?" etc… That way we got some quite reliable information because as a research institute we have contact within the wood industry. It is not so easy but we can do that because of our status. And we do that also for Sweden or Finland...

MC: But then do you keep them as different product?

RK: That is another thing which is quite difficult because you have to make really clear title of your EPDs so people like to know what it is and what to choose. So if you are using a hardwood timber frame you are using the EPD that we made. Another thing is that you need to renew your EPD every five year. Which is understandable but cost a lot of money because you need to hire again an office to do it and another one to review it again. At least 2 000 euros, I think.

MC: You have to do the LCA all over again?

RK: No, when people ask us to make an EPD, we have our calculation and our report, the only thing we have to do is to check if things are still the same or if there is mistake . For example if the transportation ways are still the same or not? Also, here in the Netherlands if you are planning wood you need electricity and the electricity here at the moment is mainly based on burning charcoal but it will change and in 5 five year it will be more environmental friendly with solar panel and so on. So you have to adapt that in your calculation. The Environmental load of your product will be lower so there is many benefices from doing it even if it is expensive and time consuming. Another thing is that the product card from the NMD are quite difficult to compare. When we compare them to what we did it's totally different and you cannot understand how it is build.

MC: And when you review someone else EPD, do you also only check or..?

RK: Well, there is the determination method to follow and yes you check if everything is there and you also check if the assumptions are made correctly and of course you should check the data themselves. So you don't redo the calculation but you check the method and specific element and value. We made an EPD of a wooden roof the "kanaalplaat" type that include everything, wood, vapour barrier, insulation etc. but you cannot compare it to a concrete or aluminium roof since they often don't include insulation. And when you do the calculation of shadow cost for your building you have to know that you need to add insulation to your aluminium roof yourself or that you do not need to add it with the wooden roof.

MC: Yes, I don't understand why, like with an EPD the functional unit is not stated more clearly?
RK: I agree but that is not in our hands, we are like you, we see the problem and we will report them to SBK and wait that they change it. I think it is still a long way to go to have a perfect system that provide a real objective way to perform environmental calculation. Another important factor is the life time of your product, everybody claims that his product is very durable and there is no objective method to prove that. In the Netherlands we have a book, with all the lifetime expectation of products. For wooden products, we were not involved but many of them are too short, some are too long. I don't think it is very reliable.

MC: Is there other wood research centre in the Netherlands?
RK: There are two big institutes, TNO which is doing everything in building, they had a very good wood department but 2 years ago they removed it and it's a pity because now we are the only big one and it is not a fine situation. It would be nicer if people could go to another institute as well. Competition only makes things stronger. So life time is a problem, also maintenance.

MC: Why?
RK: Well, how to estimate the maintenance. Because the theory and the practice is different. And finally there is the question of the end of life. Wood has quite a beautiful end of life because you can burn it and it produces energy, heat or electricity. Calculation at the moment says that if you burn you get a specific ratio of heat or electricity so you avoid using fuel. And the mix that we have at the moment in the Netherlands is mainly from charcoal which is bad for the environment but by burning wood you can avoid using charcoal and your environmental load gets lower, sometimes so low that it becomes positive! I think that is beautiful for wood but people think it is a mistake from the calculation and want to change it. That is another discussion point. In the method wood is CO_2 neutral. The Netherlands should produce more durable energy, at the moment only 4% of our energy production is from a durable source. And most of those 4% are based on biomass, biomass being wood. And they are importing pellets from Canada for example. We have to fulfil our promise to the EU by 2020 so burning wood is a solution. Burning wood even if it release CO_2 is quite environmental friendly since it's a short circle process. With wood you absorb CO_2 and within 100 years it is also releasing it so you get heat without an extra CO_2 load while slow processes you have depletion of fossil fuel. We are working together with the University of Wageningen the forest department which is doing LCA because they are also saying that countries should store their CO_2 but by harvesting you can increase the grown of your forest so it acts like a sink. So the discussion is going on about this subject.

MC: What would be the other option for the end of life scenario of the wood?
RK: It's called "cascadering". For example with the palette they often talk about "cascadering" because they use low quality segment, a wood with lots of knots etc. then the palette are chopped in small parts which are used in plywood and the plywood is then burned. But every step takes managing and processing and transportation and sometimes it is much better to just cut a new tree, because cutting tree is a good thing, the forest grow fast and

renewing them is good. So it must be wood from sustainably managed forest. So recycling and re-using in the LCA perspective is not always better. Like in the paper industry, they are using a lot of used paper but there is ink in it so they use a lot of chloride… That is why it is interesting to really make the calculation in term of LCA what is better for the environment. And wood it is growing! Of course it is different in the tropic though. In the determination method, there is a standard way to divide your waste over burning, landfill or recycling which is decided according to the current use.

MC: Let's talk now about laminated wood. Is it worth it to have laminated wood since it doesn't have the same energy performance as massive wood?
RK: Next week we have an interview with a bit laminated wood company to start an LCA but it depend on the type of glue. Certain are based on melamine. Some are supposed to be very good in term of durability, moisture and strength but I don't know how they react on environmental calculation.

MC: So do you think the poor score of laminated wood comes from the glue?
RK: Maybe we don't know for sure yet. There is also a lot of managing, sawing, pressing, using heat…So there is quite an intensive process to manufacture laminated wood.

MC: So this is something still to investigate?
RK: Yes, it would be nice to know exactly.

MC: And as I understand the 30% of uncertainties are not overestimated?
RK: It is not as bad as it seems it is even positive I think. I don't know if it is the case for all the wooden products but at least the 7, 8 we analysed it was the case. And there is something else, in the NMD of have to show your impact categories but also your "milieumaat", that is energy (from renewable and from non-renewable sources), waste (toxic and non-toxic) and water. You only need to declare them. But we saw that architects are calculating with energy in order to promote energy neutral buildings etc. And it is not correct to use this value, still they are using them and we are fighting against that for almost two years now. Inside those value are also the potential energy which is inside a tree. To calculate energy they start from the tree, saying "oh we have a lot of energy in it, so much mass. 1 kg is 20 MJ energy so if you have 1000 kg= 20000 MJ energy. And it's incorrect because it's not a tree anymore. It is impossible to get so much out. To do so, you would have to dry the wood, which requires a lot of energy and then you get a fraction of this energy out. But nobody really knows that is it not correct and they use it. We did a very simple LCA on wooden foundation piles. If you compare them to concrete piles, they are much cheaper because of transportation, you don't have to manage anything, you just cut it and transport it to the site while a concrete pile, and first you need to make the cement, you need to get the sand from different faraway places, and then the mixing also cost energy and to make it and to transport it. Of course you need more wooden pile than concrete pile to support a house.

MC: But then if the wooden piles store CO_2, the more you use the better it is. No?
RK: Yes, we thought so too. Because they are put in the ground and left there. They never come out.

MC: So that is a good thing, right?
RK: Yes, quite good. We tried to include that in our calculation but the reviewer did not like that so we removed it.

MC: Because now in the NMD the wooden foundation pile which is category 3 has a negative shadow cost, so a positive impact.
RK: Oh really? Well, we did not include our calculation in the NMD yet.

MC: And do you know why the reviewer did not agree?
RK: Well, in the determination method, the wood is CO_2 neutral, which in the case of the foundation pile is not the case since they really sink CO_2, you can leave them in the ground for more than 100 years. So you remove it from your 100 years cycle. It is actually a sink. And that is how you get your advantage. (Talking about the wooden foundation piles problem in the Netherlands). We actually started with LCA in 2012 with a comparison of wooden and concrete foundation piles. We did our LCA according to the ISO standards and if you are making comparable LCA you have to ask the people from the other material branch to agree with your calculation. So we showed them, and concrete was not as good as wood so they did not read it, they did not want to spend time on something that is not positive for their material. And that's a real problem. So it didn't go further, of course we included their reaction in the report but that's all we could do.

MC: Yes, everybody is protecting his business.
RK: Yes and of all the material, wood is the one to compete with! Everyone wants to be as good as wood. And the wood sector thought they are so good they don't need to make any effort. But now they don't use the system as efficiently as the other materials, so they don't appear to be so good.

MC: That's really interesting. What about the OSB? It has a quite high shadow cost which surprised me, any idea why? Is it from the glue? Since the wood part is mainly coming from recycled wood.
RK: Yes, but they don't have the advantage of wood then. In the life cycle, the end of life is quite positive and if you are recycling you make allocations and if the recycling is all put in the first use, you don't have the advantage anymore. But I don't know exactly. That is also something we have to check, because there are many EPD made from the USA and we will adapt them hopefully.

MC: What do you mean adapt them? You don't need to redo the whole LCA?
RK: no , we do need to redo the whole LCA because the impact factor are not always the same that is the problem and we have our own things in the Netherlands stated by the NMD on how to deal with waste or how to deal with transportation. I think it is stupid but that is the way it is organized at the moment.

MC: But it make sense that it is different.
RK: Of course it makes sense but you have to redo a work that was already done for a part. And because we are dealing with so many product, money wise it is a problem.

MC: Yes, it would be nice if somehow the EPD was so detailed that you could simply extract the information you need.

RK: Exactly. We have contact now with a Danish company and hopefully we can get their whole calculation from and then we can introduce it quite easily, so that would be nice. And then it is not so much work but still you have to make your report, comments and background information. We make that in SimaPro. With it we have a license so any new update of EcoInvent is included which is nice. But also the NMD have their own database that you can import in SimaPro.

Interview with Rick Scholtes at NIBE.

7th of April 2015.
Rick Scholtes: RS
Marie Chevalerias: MC

MC: Tell me, what's your role with the NMD?
RS: Well, the MaterialenTool is based on GreenCalc+, and NIBE created the GreenCalc+ tool, together with DGMR, that was around 4-5 years ago. There is different kind of consultant companies that made different kind of calculations for environmental building. So we (understand all together) said, let's do all the same things, with the same calculations and the same database. So NIBE and DGMR, they wrote the database and gave in to SBK, the owner now. From that moment, we used the NMD for all the calculations. At NIBE we also have our own database that has more environmental impacts. At this moment I do a lot of LCA to put in the NMD. I am also member of the TIC (Technische Inhoudelijke Commissie)

MC: And what do you do exactly there?
RS: We advise the MBG (Milieuprestatiecommissie Bouw en GWW), it's about the content of the database and the quality of the data. And at the same time, I am also a member of VLCA, there we talk about how to make an LCA and how to get quality in the LCA. Some people, like me, are both in the VLCA and the TIC, so there is a lot of exchange and discussion. So we discuss about the subtexts in VLCA and how close it is to the subtext in TIC. But it's a bit different because the VLCA is not part of the NMD.

MC: Ok, and you said you had your own database here at NIBE, I have noticed that there is more environmental impact categories in yours, I was wondering why did you decide to have a different database?
RS: Well, we added some different impact categories because we (at NIBE) think that you need those. In the NMD you have 12 environmental impact categories, the land use for example is not one and if you don't take it into account, it's like it does not happen. And it's not true, that's why we put it in our database.

MC: And do you think it should be in the NMD?
RS: Yes.

MC: But then, would it not be a bit difficult with the European standard?
RS: Yes, it would.

MC: So, what do you think is the best: to have a database as accurate as possible according to the context or a database that allows to exchange information between European countries?
RS: I think it is always a big discussion. Now the discussion between NIBE and the NMD is about the land use, I think it's the most important now. But between the NMD and Europe, the discussion is about the Toxicity. At the beginning, they didn't want to use the Toxicities (impact categories) in Europe but maybe now they want to, I am not sure what they are doing about it now. At this moment at least it's not mandatory. And when you don't take them into account, it's like saying they are not happening even though they are having an impact on the environment. Of course you need to work on the environmental impact categories to make

them very good but in the meanwhile you still need to take them into account otherwise it's like saying they are zero which is more incorrect than using an imperfect impact category.

MC: From my experience, it seems to me that LCA is a very young field of study.
RS: Well, it's not that young anymore but yes you can still make it better.

MC: Could you tell me a bit more about how the shadow cost weighting system was decided?
RS: According to the Dutch University of Delft made some study but I am not sure how exactly they did it. But most of the LCA practitioners agree on this weighting system which was one of the most difficult step. Everyone knows there is some assumption but everyone agrees on them and agree to use this method. That's the most important, that no matter the mistakes, and all the calculations are comparable. Also, the shadow cost itself is very clear in what it says, and it's understandable by everyone even not LCA's experts.

MC: Another thing I am wondering about your database is how we can use these value since they are not the same as in the NMD.
RS: well on our website you can see the detail of the shadow cost. So you can pick only the impact categories that are included in the NMD and calculate the shadow cost from there.

MC: And why isn't your database included in the NMD? As well as the DUBOKeur product that you certify?
RS: It's true that our database is bigger that the NMD. Well, first of all, we do these LCA ourselves and they are not reviewed by a third party which makes them category 3 and the goal of SBK is to include new data that are category 1 or 2. Secondly, we like to show more environmental impact that are not in the NMD. And finally, we also want to present the environmental performance of products like finishing layers that are not necessarily taken into account in the NMD because they are the choice of the user of the building and not the designer. Also the NMD comport several stakeholders and members etc., which is a good thing but also makes things a bit slower, that's why we continue doing our label DUBOKeur. Another good thing with this label is that it doesn't only state the shadow cost of the building, it shows how good it the product in comparison with similar product.

MC: But then, what happen when a new product comes into the market?
RS: Well, that's the power of this system: every two years, we update the DUBOKeur database and new product are included and can indeed change the order of which product is the best, therefore, every manufacturer really makes the effort to improve its product and the ways it is produced and which material they use.

MC: Do you think DUBOKeur is easier to use than the NMD in order to make choice for your building?
RS: It depends at which stage of the design you are, I think DUBOKeur product are a bit like Category 2 and you use them at an early stage, when you are not sure yet about which exact product you are going to use.

MC: I am also looking into re-use of material within the circular economy and its effect on the shadow cost. But I am not completely sure how to show it. What do you think about it?
RS: I think it is quite difficult because you need to do two whole LCA and it is a lot of work. And you cannot really use the LCA from the NMD. Now we calculate the material with the

actual percentage of reuse of the material. We always take the value of what is really happening at the moment. There are some already existing scenarios in the NMD. And if maybe a company use more secondary material and can prove it, then we don't use the generic scenario for its kind of material but we do a new personalized scenario according to the reality.

MC: So it's not in the essence of LCA to calculate something based on fiction?
RS: Exactly, a company might tell us, for example, PVC could be recycled at 99% at its end of life, ok, but we want to know at this moment how much is actually recycled? If it is actually only 50% we take 50% and not 99%. You could make an LCA to predict the environmental impact of a future product but that is not how we do things now. That's also why is very good to have the same determination method, to make sure everyone make the same assumption.

MC: So in conclusion, what do you think about the NMD in general.
RS: I think it is a very good tool because it makes it the same for everyone, if there is a discussion we can discuss about it, there are so many people and discussion, it gets better and better. It's a big process but it gets better and better. I think it's a good tool to make decision, and choose what material to use.

MC: And which way do you think it will develop itself, will it expand itself to other countries or will it focus even more itself on the particularities on the Netherlands?
RS: It would be difficult to use the NMD abroad because every country has its particularity. For example the distance between production and construction site is probably smaller in the Netherlands than in Sweden. Also for the end of life scenario, probably in Sweden they do it in another way. Also the energy mix is not the same. Probably the energy mix in Sweden is better than in the Netherlands. Of course we could make a very big database with all the products from every country but it wouldn't be very useful. I think it is better to have NMD adapted to each country. But I think it is important for the product that when they do the calculation which are usable in different countries which is the case with the new EN15804 which include all phase of the EPD.

MC: yes, it must be frustrating for the producer to have to pay for several EPDs.
RS: It is very frustrating but I think it's not very difficult to make the changes so you only need to make it once, slowly it is coming together. You should check the ECO platform which regroup LCA expert from different countries so they recognize each other's LCA.

MC: Ok, I got the impression that the Netherlands is quite advance on the question of LCA, maybe you know more about that?
RS: what is indeed special about the Netherlands is the Determination method which is for entire building. In Germany for example, I think they have a very good method about how to handle calculation for products but it is not the end point, you need to bring the product together to make the building and that's the big plus from the Netherlands. And this shadow cost is quite clear to people.

Interview with Martin Bijleveld at DGMR.

30th of April 2015
Martin Bijleveld: MB
Marie Chevalerias: MC

MC: I would like to have your point of view about the Dutch method for assessing the environmental impact of building as a BREEAM expert but also maybe you have other connection to the Dutch method?
MB: Alright, I have some experience with the method, I was working at the NIBE, one of the founder of the GreenCalc software. It is, now a days, sold to the DGBC and they put the material data in the MaterialenTool. So I am familiar with how the method is working, what is laying underneath the software. That is why at DGMR, I know a lot about the MaterialenTool. I think what is difficult is that the MaterialenTool is now made by the DGBC but the ownership and all the procedure is at SBK, so it difficult to access the database, it is not directly linked to each other. Furthermore, what is difficult is that it is quite costly to do an LCA. A lot of producer say: “That’s in it for me? Well, not so much!” So they don’t do it. And also, they don’t want to share they receipt. Then the big producer company, they can put a lot of political pressure on these data.

MC: And do you think it would be easier if it was not owned by SBK?
MB: No, it’s just that the money is an issue. Someone has to do it and it cost a lot of time and money. And to get all the data. Plus, when you got a product and all the data maybe two years later the receipt change, it’s not the exact same composition…It is quite costly to keep the data up to date.

MC: But it is mandatory anyway to review the LCA, right?
MB: Yes but when you made an LCA once, you give the data and then it is not renewed after 5 years…Who is going to check? Sometimes is it the best you can get. From my own point of view at my work as a BREEAM Expert it is difficult to predict the score of the MaterialenTool, it is just a black box, we hope to get a lot of points and a very low shadow price but it is not very predictable.

MC: And do you use some king of rule of thumb, like maybe “wood is better than concrete” for example?
MB: Yeah that is my feeling, wood is a natural material there are some environmental impact by sawing and transport, and other things but not so much than that, especially if you have a certificate of the FEC and the environmental impact of where is it grown , it is also not so much. Then, my feeling is that is must score better than concrete or steel. But then I am not sure what will be the score in the calculation. Also the database is constantly renewed, so maybe your calculation will be different a year later. Of course it is due to new insight which is good and the reference point is also adjusted by the DGBC.

MC: And do you know how this reference price is determined?
MB: What they do it that they look at about 10 buildings, they have some data and they see how much they score in each database.

MC: And do you know what kind of building is taken?
MB: That I am not sure, it is the DGBC.

MC: Ok, because it would be useful to know I think. Is it a very old king of building or a recent one…?
MB: Yes, they have different kind I think, some environmental friendly, some more traditional. So the 10 building allows to make an average. And it's better than nothing.

MC: Yes, I discover that the Materialentool is not only use for BREEAM but also for the Building Act of 2012 which does not give a reference value.
MB: Exactly, you have to make a calculation and that is enough because the government don't have a reference. So, they hope they can get enough data from the last years since they collect the information from the mandatory calculation and they can get an average value of the recent building stock and set some regulation. Maybe in 5 years or so , they have enough data to analyse and they can set how much this reference price is and maybe how much percent it can be reduced every two years or so. And in the meantime of course the database needs to be improved because there is still a lot of information missing.

MC: It is quite hard to have a reliable result when the database is not complete. And do you think the manufacturer see the database as a constraint or maybe the NMD could be a way to encourage manufacturer to create better products?
MB: No, not really no. Probably you know DUBOKEUR product. This label is quite a low cost to make while if they want to be in the NMD, they have to pay for the LCA and then it has to be reviewed which is also costly. This process is maybe 5 time more expensive than the DUBOKEUR label. So then the choice is quickly made by the manufacturer, especially since the sustainability of the product is only one of the selling arguments.

MC: Talking about Dubokeur and also C2C product, in the BREEAM.NL it says that you can get innovation points. But you have to make an inventory, what do they mean by that?
MB. You also have to make a shadow cost calculation but the difficulty is that you don't have the data so you have to go to one of these company that make a Dubokeur product and with them make an LCA and get the shadow price of this new product. But when you look a C2C it is a very different way of looking at the material and life cycle analysis. It is not cradle to grave but cradle to cradle and that is the whole point. At DGMR with develop with Delta a C2C office park in Hoofddorp and C2C is there is main focus, most of the material are C2C but they are not scoring very well in the life cycle analysis because the data is not available.

MC: Because instead of inputting the actual shadow cost of the C2C product you insert a default one already in the database?
MB: Yes, also when you look at the traditional material in the database sometimes they are recycled or dumped in the landfill or whatever but it is still in the LCA and when you look at C2C it's not in accounted anymore because it can go another cycle.

MC: And that is very beneficial, right?
MB: Yeah, but also C2C material at the moment are not completely cradle-to-cradle. Maybe wood can grow again when you dispose of it. But most of the C2C products are on their way to cradle-to-cradle. So they make an inventory of the composition of the product, a list of all the ingredients and the very hazardous they try to get them out and when a company is

improving every year eventually they get a certain grade in the C2C certificate but it is not really cradle-to-cradle yet.

MC: And as a consultant do you recommend to use BREEAM or C2C?
MB: That completely depend on the client. There is not one better than the other really, especially since the C2C is not completely cradle to cradle yet. If you had to choose you could choose the best of both way.

MC: An argument that I have heard in favour of C2C is that is encourage innovation while LCA is stuck in the standard way of doing things. Do you think the NMD could also be a motor to innovation?
MB: The C2C can be implemented in the NMD of course but the innovation part comes from the C2C certificate. For the NMD the main difficulty is the cost of all the research and that the manufacturer are not willing to communicate their process.

MC: And when you do want to add a new product in the database to get an innovation point, who should be the one paying for it?
MB: It is mostly the person who is willing to go the extra miles. In our case maybe the client, since they want a very sustainable building, is willing to give more money to do the research. But maybe it is the architect that really want to use this product, they also have to find the extra money. Same thing for us at DGMR, if we advise people to do it, maybe we take some extra free hours to do some research work to do the LCA. And it a lot of work to get all the information you need to the LCA, and it is hard because some company don't want to share the information you need.

MC: Ok, and in the case of the Triodos project, I was looking into a C2C curtain wall system that correspond to the demand of the project with wood inside and aluminium outside but it is not in the NMD of course. And to get the innovation point it would be much more work than to just assume a wooden frame and some amount of aluminium in the Materialentool. So I get the impression that it is not worth the effort. And if client like Triodos don't do it I think nobody is likely to do it!
MB: No, and that is why at DGMR we are going to talk with the DGBC to see how we can improve this.

MC: And do you have idea how it could be improved?
MB: Well, maybe we can the Dubokeur product into the database. Maybe we can motivate the wood manufacturer to put more data in the database. But there is also branch association and they are keeping the data away, but for sure it is going to take some time. Also, maybe, then there is a reference shadow price in the building regulation, then the manufacturer will say: "Oh, my product could have a very low shadow price, so I should put some effort in an LCA. Like that it will be chosen by architects, etc." Because for the moment there is no pressure to be in the NMD and if their concurrent are in the NMD then they will do it also.

MC: Because now there are some product in the NMD that are from the specific manufacturer. Which one do you use in the calculation?
MB: It depend on which stage of the project is at the moment of the calculation. But also it depend if the difference in shadow cost is significant or not because if it is about the same it is probably better to keep the choice of brand open and not get fixed on only one specific

brand. For a developer it costs more if they have a specific brand and no choice to find a lower cost option. So we can make an estimation with different product options and see which one is the best is and which one is the worst.

MC: And when you do use a specific brand product in the calculation, is it checked by the BREEAM assessor if you really applied this specific brand?
MB: Yes. The assessor check this in the bills, for example. Also the BREEAM certification is made in the design stage (it last two years) and after the building is done (and then it gives you the final certificate).

MC: And as a sustainability consultant do you use any other tools to assess the environmental impact of building.
MB: GPR. When I started at DGMR almost 10 years ago there was GPR and GreenCalc. GPR was for housing and GreenCalc for utilities. They both moved toward the others. After that in 2009, GreenCalc sold it to the DGBC because they can develop it more. And GPR is still used but it cost less and mostly used for smaller building. Usually BREEAM is too expensive for a small building and also too much paperwork, while GPR is one calculation. So you use it mostly for school and housing project.

MC: And back to the MaterialenTool, could you tell me what are the advantages and inconvenient according to you?
MB: One problem is that it is a bit like a black box. I think the MaterialenTool should give more information about the product. Like for example if you have a window frame, how much material is there when you enter 1 m² in the tool? We should know how much kg /m² or the dimensions in width and length for example. Especially if you want to estimate the shadow cost of an innovative material, you cannot really select similar product if you don’t know what is in it. And maybe it would be nice to have some raw material, like 1 kg of aluminium, 1 kg of …so you could put together your own product but the difficulties then is that you don’t really take the process into account. Maybe then you could apply a percentage of uncertainties to have a reliable data.

MC: Yes, that is more or less what I did for the climate ceiling, and would that be accepted by the assessor?
MB: Well if you make a report explaining as transparently as possible how you did it and on what you base your estimations maybe he could accept it. You would have to make the best guess when you don’t know something to be always on the safe side. But especially if it brings a big reduction on the total shadow price, they will be more careful and maybe more reluctant to accept it. Also, maybe the manufacturer can help us to make a better assumptions and eventually start the process to add this product to the NMD. So the first thing would be to estimate if it is worth the effort and money.

MC: But then maybe it takes more time to get your product in the NMD than to finish the construction of the building concerned. And I guess you cannot update your result once you got the certificate, right?
MB: Yeah it can be difficult. You would have to discuss with the DGBC. Maybe if you give them a reason why it is getting longer to get the product in the NMD they could accept to delay the certification. Making the LCA could go quite fast if you have the willingness of the manufacturer and you get access to all the information you need. Then it still takes few month

of processing time for people to check and do the calculation and report…but if the hardest part of getting the information is made, then it can go fast enough to get your product in time in the NMD. If the willingness is not there, just forget about it!

MC: So the NMD could be a great tool but is nobody makes the effort to contribute to it, it completely falls apart.
MB: Yes, now we should put some political pressure to get the data in a better way. But it will happen with very small step. I think that having a reference point in the building regulation will encourage to make the database better. But it could go the other way around, if the reference point is not coming until the database get better.

MC: I was also wondering if you have building from outside the Netherlands, do you also use BREEAM.
MB: Yes sometimes we do and we use BREAAM international. But we don't have so many project abroad. Sometimes we use LEED but we are not LEED Auditors so we ask another company to do it.

MC: And did you see a big difference in the different version.
MB: Well first the material, the transport, the energy is not the same in different countries. The scarcity of water is not the same, etc.

MC: And the MAT1 section, does it work the same way?
MB: I think the international version refers to the UK version, I think.

MC: To my knowledge the Dutch are the first one to create a national database.
MB: yeah I think the Dutch database is quite unique. But it still needs to be filled, with good values and up to date… And who is going to pay for that? Should it be the manufacturer? Should it be the government, or Europe? We will see what the next few years will bring…

MC. Because for the others European countries, I think they just look at EPD s which are not necessarily easy to compare. So maybe the Dutch system could be a good example to follow?
MB: Yes, I think so too.

MC: We talked before about when you want to use reclaimed material, and you showed me this graph (See graph) and that is quite a big simplification.
MB: Yes because their environmental impact has been made already, they finished their life-cycle.

MC: But maybe you still need to transport it or cut it to the new dimension you want…And this is just neglected?
B: Sometimes yes, for some others material it is a lot of effort to modify them and the environmental impact is maybe the same as taking a new product. Most of the time we are able to make this estimation and neglect it.

MC: Because if you like to be precise you should also make an LCA as if it was a new product not in the NMD yet, right?
MB: Yes. We do have it for some the product in the NMD already like the aluminium, you can choose an aluminium that come from 80% recycled aluminium for example. So it is a new recycled product. One problem is that this kind of material use is often specific to only one project so not general enough to be in the database.

MC: But if you want to make an LCA for a product not in the NMD , isn't it better to make an LCA for the whole building instead of putting together LCA results from different product?
MB: No, I think using the NMD is still more beneficial because you don't have to search of all the data every time because it is a lot of information you need, especially for a big complex building. So then you can just select the material and most importantly make the calculation in advance. When you are designing, you can make a calculation and modify your design in function. While LCA of building are most likely made when the building is already done and you cannot do anything about it anymore.

MC: So it is a help for the designer! I think it is really interesting to be able to put numbers on different solution. And do you think we will ever be sure of these kind of results?
MB: No, there is always new insight, and process are changing, energy mix… Maybe in two years it will be different results, so we just have to make the best guess at this moment, it is not perfect but that is how it is. The world keep changing and a database today is already old tomorrow. You have to live with that. That is something I have learned to deal with over the years. You want to be perfectionist but it is not possible so you just do the best you can at the moment. Otherwise, not building is the best for the environment!

Interview with Dennis Grootenboer at RAU Architects.

21st of May 2015.
Dennis Grootenboer: DG
Marie Chevalerias: MC

MC: I understood you are like the sustainability expert could you tell me a bit about your role in the agency?
DG: I am a technical designer, it's not really an architect but it's in between. I had a long study period before working here about technical thing, how to detail it, etc…I stand next to the architect to make the design possible. In that part, I also did a course more about sustainable solution. About how to make new ideas, concept doable. So you could say that I am the sustainability man here but I am mostly working with new concepts, innovation and how to implement them.

MC: And are you using the NMD in the office?
DG: Yes, you are always looking at hard numbers, what is real and what is not real. You must make your own idea of it but you also want the hard number. So the NMD is a good start point. For sure, it is ok but then you also need to decide for yourself which direction you want to go. It's a good tool to confirm our point to the person that does not necessarily knows about environmental impact. We can say it but if this group of people also say the same thing, then it is reassuring.

MC: You mean you the client?
DG: Yes, for example.

MC: So, when you the NMD, is it always to comply with BREEAM.NL or is it also a tool on its own for you?
DG: All different way, so yes both.

MC: And before the NMD was created, that did you do concerning environmental impact of building in the agency?
DG: Well we did and always do look at new materials but we couldn't really show numbers. Then that is really hard to explain (your intuition) to others. For example take wood. It a really good material, that is logical, right? But if you are going to glue it, it is still good? And then you need to be a scientist to answer that, otherwise you cannot say it. So it was always looking for new material and scanning everything. And you get a lot of information because everybody want to give it to you since you are a sustainable architects.

MC: And that is information from the manufacturer?
DG: For example, yes. Or new projects…You also have C2C books for example

MC: I discovered the C2C but also the Dubokeur product, how do you decide which one is the best? Is it according to the project or do you have a general preference?
DG: No. How I see it, it is about what is your focus on the sustainable building you are going to make and that is a really important step. Most people don't do it, and in this case "sustainable" can mean anything really. For example if you are going to make an energy-neutral building then material is not really the issue. But more and more, what I see and what

we see if that the materials of the building is becoming the issue to address. The energy issue is almost solve, especially now with the tesla battery for homes but also more simply everybody now can have his own solar panel and almost everybody understands it. So it's not the step anymore and we try to make the next big step with materials. Since it is the big issue of the next century. So if material is your focus then you ask two questions: First, how are we going to reduce our material usage? Second, if we are going to use material, what is a good material? And a good material is not necessarily standing in a list because we have a new way of thinking. For example we think that re-using a material is better than introducing a new one. Like what we did for the Alliander project for example, we took old palettes, we cleaned it we cut them to the right dimension and it became the facade!

MC: Yes, and that you know it is good, and it sounds logical, but you don’t have the hard number on that, right?
DG: That is true and that is also the issue with “sustainability” it is a big word but you have to be careful what you put under it, it’s not just putting solar panel on the roof no, it’s a way of thinking. Concerning material it is not about the material itself, it is about how you use it. And reclaimed wood, it’s not in the NMD, and that is okay because it is indeed a database, and that is really good. Somebody got to do it but it’s not telling you anything about the way of thinking!

MC: So, as I understand it, for you it is more important to present new idea that people haven’t think about than to actually do the calculation. Am I right?
DG: Calculating is really important to understand what is good or not but it is not our goal. Because otherwise the answer is simple, making no building is better than building something. That must be very clear. If you have 1 million square meter of empty housing, it is stupid to build new housing because you don’t know how to use the 1 million already standing, assuming it is on a good location as well. So it is better to combine those, to find a way to reuse the material already on site and change them in order to renovate the building.

MC: So that is definitely a limitation of the NMD, the fact that you don’t have “re-used material”. But do you think it should actually be included in the NMD or it is just a different way of thinking and it should stay apart?
DG: No, I think, in at some point, it should be introduced. If you look at the big picture of what is sustainable, it is changing. 10 years ago, not some much attention was given to materials, the big thing was energy. At a global scale the problem is that we don’t have enough resources. So you can introduce real good new material but you still need the resources to produce them. We think, and I too that it is going to be more and more about re-use, 2nd and third life even, circular economy, cradle-to-cradle…That is also an idea

MC: So you agree that the NMD is a good tool?
DG: Yes. And for example all this innovation about 3D printing seems great but is it really good? I don’t know. What is the material made of? And can you reuse it later? I don’t know but maybe 3D printing is actually the worst thing to do. And hopefully the database can tell us whether it is good or not depending on how we use it in the project, which mean it has to be included in the NMD.

MC: And staying on the subject of the database. There is the NMD of course, but there is also the NIBE which is a little bit different since they take more impact category into account. I personally found that the data from NIBE was more clearly presented.
I was wondering which database you mostly look at as an architect. Do you check them both or do you prefer one to the other? Maybe you only look at the NMD since it's recognized by the government?
DG: Well, we use the database which is the most clear, so then it's the NIBE database since it is quicker, it is online it is really fast to look it up. But what is really strange about it is that there is so much happening about material, the same as it was before for energy, there is like this grey fog around it which makes everything confusing. That is really stupid. And I don't think it is only Dutch, it's just that many people have some interest involved in it. They want their material to be better than the other and that is not very good. The data should be clear and independent. So I think it is important that there is only one big standard that you have to respect and from the government not linked to a company. And in that case it should be good. That is the same with BREEAM or C2C and all the other labels, it is really good but the money involved in total, it's crazy. So most of the building are not going to do it, then it's mostly about PR, if you have the money to show how good you are. Maybe the other buildings are just as good but they just don't show it. And that is not good.

MC: At least, I got the impression that BREEAM.NL is the main certification scheme which makes it easier to compare building. In Sweden, I remember coming across Miljöbyggnad, LEED, and BREEAM… and they don't relate to each other so you cannot compare two building with a different label.
DG: That is true that there must be one big thing but then they have the monopoly which can also be dangerous. So that is why we don't work only with that you know in the end it's just a label. It is a lot of money and there are also a lot of things NOT in the list. New ideas, news ways of doing things, you have to create them yourself. Hopefully in 20 years once everything will have been invented, the bream will really reflect the best building that can exist. But if you do it now there are still a lot missing and you should set your standard much higher than a label. Take the fridge for example, before it was from F to A and now we are from A to A+++! Maybe in the future, once we rescale the steps the A+++ will actually correspond to a F…

MC: How would you show the sustainability of a building without a label then?
DG: Take Alliander for example, we want that 80% of the material are circular, re-used if you prefer. We are making a beautiful building but it's difficult since you must think but most importantly DO in a different way we use to. And the goal is to show that it is possible so therefore we should have the liberty of doing it, outside the box, and maybe that also means outside the NMD then.

MC: So in that sense, would you say that the BREEAM and the NMD are more a constraint than a tool?
DG: Yes, exactly. That is not a bad thing. But if you want the next step, a step further than BREEAM outstanding, where the change is, then it is going to be a strange discussion, when you say, this type of circular building should be more than outstanding, but outstanding is the best you can get…. For us in the end the goal is not the BREEAM certification and not even to have a hard number for the shadow cost, it's to make the best building possible with a low environmental impact.

MC: Another question concerning innovation and the NMD. If we look at the case of the Triodos office building, the climate ceiling that we would like to implement are not in the NMD yet. And we would like to have it in the calculation to reduce the shadow cost of the building. And to do that you need to do the LCA, make it reviewed by a third party, have it inserted in the NMD and finally use it in your calculation.
DG: This takes a lot of energy.

MC: Yes, energy, time and money. And the question is who should be paying this money. So my question is do you think it should be the architect who pays for it?
DG: No, I think it should be the NMD responsible. I think, their goal is to have the best database, as complete and correct as possible. Then they should be able to pay for that and then I think it would be much faster to have it ready, and probably it is the cheapest way as well. If I have to do it, then I will think about the time and money it cost me and I am simply not going to do it. The Client already has a lot of money to spend already, it's not really in its interest as long as the building is the best he can get.

MC: Now about the "shadow cost". When I arrived at the office, every architect seemed to know about the shadow cost of the building but it took me a lot of time to understand what was behind the term "shadow cost". And I wonder if it is confusing for the architects here as well? For example, what does the reference shadow price means…?
DG: Yes, that is a good question! I have it as well and I think it is strange that it is not explained somewhere. It is too vague. What this "standard building means"? Is it normal, bad very bad?

MC: I got the impression that very label has this side effect that nobody really knows what the meaning of it is?
DG: That is true. And that is why we use the concept of circular economy and re-use of material. You can really show it, it's very visual and it is clear for everybody.

MC: Although, I think that the shadow cost is already something easier to visualize than kg of CO_2 equivalent…
DG: Yes, that is true. And it is not necessary that everybody understand everything but when even the insiders don't understand what the reference price come from, that is not good, it should be clear!

MC: Finally I wanted to ask you about the material passport. What is it? What is the goal of making such a document?
DG: Well, when you see a building, nobody knows exactly how many materials are inside except the one in charge of building it. And you cannot compare it and just know. For example, how much ton of concrete are in the building, you don't know.

MC: But why would you like to know that exactly? Is it simply to document it or is it to help the purpose of re-using it later?
DG: The first idea is to document how much material is implemented in the building. That was the main idea. But if you want to use the circular economy you have two things to have in mind. First, you want to use as less material as possible (for the same building performance) and to be able to show it you must know how much material you have in your building. Secondly you want to know what king of material you have and not only wood or steel

because it could be there under different from, as a beam or in the concrete floor but really combination of material as products. So you can identify which things you can re-use or not. For example columns, you can find information about the strength, the resistance…Whereas the concrete slab you cannot reuse it. So you want to know all these things so you can re-use directly. To illustrate that, the car industry is a good model: If I sell my car in an auction, I will get a lot of money. If I have the big elements maybe I can get back more money or the same money. The good part, the whole seat… If I sell the small part: the screws, the rubber…I can also get money but probably less. And finally if you really melt it down and just get the material from that you will get the lowest price. It is lower but it is still money. So either you sell the whole but if you can’t, you get the money from the material which is not so much, plus you need to spend energy and money to tear it down. So it is interesting to look at the building that way. With the idea that the bigger the element you can easily re-use the better it is. Then you can see your building as a material depot or even a money depot.

MC: And don’t you think the life span of the material will be too short to endure a second or third life?
DG: Well, that is why you need to have the information about the material. The steel industry is a very good application for that. They already have all the figures about the product, whether it is an IPN 300 or an IPE 350 there is a lot of data linked to that reference number giving you information about the strength, the dimension…

MC: In general, I have got the impression that the most important step whether it is in LCA or in re-use or in the NMD is the documentation of everything as clear and detailed as possible.
DG: Yes

MC: Because even though the shadow cost is supposed to represent the building’s performance, the number might change over time while if you have a very clear and precise inventory of the materials of the building then it could be easy to do again the calculation according to the new standard, right?
DG: Yes.

MC: And do you really think that future generation will use these material passport to re-use materials?
DG: Yes or no, it’s an unknown road. What matters is that we implement it and then they will have the choice to do whatever they want with it. But they won’t if we don’t do it. That’s how I think. We should not wait and see what happens, we should just do it, everybody should do it actually otherwise it will not work as well as it could.

MC: Yes , and I have the impression that it is the same thing with the NMD, the idea is great but if not everybody contribute to complete de database it is not as efficient as it could.
DG: Yes, and when you create a database you should first accept the idea that it will always be old. There are always new products or different way of manufacturing your product, you always need to update it. 8 years ago we also thought about having our own database but it’s too much additional work for us and it would be always old. So you need a database that facilitate the entry of new information, so front runners can quickly add information, that way it would be really up to date and everybody will want to use it while now everybody is waiting for the other to do something, it’s too slow.

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