Master Thesis

What is the most sustainable measurement method for #HoudbareHuisvesting?

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Preface

Dear Reader,

The reason for writing this report is the completion of the Business Administration program at the University of Twente. My master thesis was conducted at Kleissen Bouwmanagement en Advies to investigate what methods there are to make circularity measurable. With this research, I have found a good combination of knowledge gained from my previous study, this study, and my interest in the construction sector. I would therefore like to thank Kleissen for allowing me to carry out this research.

Specifically, I would like to thank Eugenie Knaap at Kleissen for the guidance I received from her. Despite the few moments of contact, I was always able to talk to her extensively. She thoroughly helped me determine the scope of the study. Especially in the initial phase of the research which gave me the opportunity to translate Kleissen's expectations into feasible objectives and action points.

From the University of Twente, I would like to thank Kjartan Sigurdsson for the guidance I received. The direct and extensive feedback combined with the friendly, positive, and fun meetings has given me a clear red line that I have tried to reflect on in this report. Without his help, I probably would not have succeeded in bringing the study to the same outcome.

Finally, I would like to thank everyone who has supported me in carrying out this research in the past six months. Both colleagues at Kleissen, interviewees, friends, and family.

Sam Soeteman

Oldenzaal, 25 October 2021

Abstract

As a major consumer of raw materials, the construction sector is increasingly affected by the climate change that is taking place in the world. Sustainability and circularity are therefore receiving more attention. The objective of this research is to assess the various measurement methods that are available to make circularity measurable for Kleissen Bouwmanagement en Advies. Based on the research objective and the problem identification this study answers the following research question:

What is the most suitable measurement method to make sustainability measurable for Kleissen and its stakeholders?

Kleissen is a company that specialises in construction management and consultancy. With the label #HoudbareHuisvesting (Literal translation: #SustainableHousing), introduced in 2017, Kleissen wants to emphasise that they believe in ecological, social, and dynamic housing. However, it is clear which goals and interests' stakeholders have but not how Kleissen can measure these. This problem leads to difficulties in comparing sustainable and circular solutions and implementing circularity in their projects. To get a better understanding of the problem, the literature was consulted and the current situation described.

The literature research starts with the overarching concept of sustainability, in which ecological, social, and economic issues are addressed. These three aspects are also called the Triple Bottom Line (planet, people, and profit). The aspect circularity mainly relates to the planet aspect, as circularity in the construction industry aims to keep the materials as long as possible in a closed loop. This results in the reduction of new resources. To measure circularity in the construction sector, the Dutch government prescribed the Milieu Prestatie Gebouw (MPG) and sets requirements for a minimum level to be achieved.

After the literature review, previous research, interviews and brainstorm sessions gave insight into the stakeholders' wishes. Previous research has revealed the main areas of stakeholder interest in terms of circularity. In addition to the stakeholders' wishes, Kleissen's requirements were also identified through interviews and a brainstorming session. When these requirements and wishes are combined, a distinction can be made between practical requirements and functional requirements. Practical requirements refer to price, ease of use, structure, how specific, reliability and future-proof. Functional requirements relate to MPG, detachability and material processing.

Findings from the study showed that the MPG cannot be considered a comprehensive way of measuring circularity. The MPG is too concerned with the environmental impact of a particular product. As a result, other important aspects, such as detachability, residual value, and CO2 emissions, are not sufficiently included. Measuring methods with a broader scope, sustainability, measure more aspects than just circularity. These methods therefore give the user more information about the building. However, the methods are also capable of calculating a circularity score, although they ultimately rely on the MPG for this purpose. There are, however, other measuring methods that do focus specifically on making circularity in the construction industry measurable. Although these methods (CPG, BCI and Circulariteitsindex) also use the MPG as a basis, they all have additional aspects that make them unique. The Building Circularity Index (BCI), for example, focuses specifically on construction in a detachable form, while the Circulariteitsindex looks at a broader scope than the MPG.

This study recommends running a pilot project with the CirculariteitsPrestatie Gebouw (CPG) (via GPR Gebouw). In addition, further advice is given on how to better implement circularity within Kleissen. Moreover, the conclusion chapter also advises on how the construction sector in general can develop circular construction.

Table of content

List of Figures

List of Tables

List of Abbreviations

BENG:	Bijna EnergieNeutrale Gebouwen (Nearly Energy Neutral Buildings)
BRE:	Building Research Establishment
BREEAM:	Building Research Establishment Environmental Assessment Method
CPG:	CirculariteitsPrestatie Gebouw (Circularity Performance of Buildings)
CSR:	Corporate Social Responsibility
DGBC:	Dutch Green Building Council
EET:	Energy-efficient technologies
EPC:	Energie Prestatie Coëfficiënt (Energy Performance Coefficient)
EPD:	European environmental Product Declarations
DPG:	DuurzaamheidsPrestatie Gebouwen (Sustainability Performance of Buildings) (DPG = MPG + BENG)
GRI:	Global Reporting Initiative
LCA:	Life Cycle Analysis
LEED:	Leadership in Energy and Environmental Design
MPG:	MilieuPrestatie Gebouwen (Building's Environmental Performance)
NMD:	Nationale Milieu Database (National Environmental Database)
SBK:	Stichting Bouwkwaliteit (Foundation for Building Quality)
TBL:	Triple Bottom Line (people, planet, profit)
USGBC:	United States Green Building Council
WELL:	International WELL Building Institute (IWBI)
WGBC:	World Green Building Council

1. Introduction

Climate change is more actual than ever before, and it is no coincidence that the famous 'World Economic Forum' was about 'Stakeholders for a Cohesive and Sustainable World' in 2020 (Sandford & Chadwick, 2020). With a rising global temperature, rising sea levels, the disappearance of nature due to the deforestation of rainforests and the increasing world population, the world's pressure is considerable. These are reasons corporate social responsibility (CSR) and sustainability are emerging worldwide (Jamali & Karam, 2018). Sarkar and Searcy (2016) and Dyllick and Hockerts (2002) argue that CSR and sustainability focus both on the responsibility and voluntariness of companies to behave ethically in the activities they undertake. In both instances, the emphasis is on the pressure put on businesses to act accordingly towards society, the economy, and the business environment. Therefore that at present, more than ever before, companies are expected to conduct business in a responsible manner (Pryce, 2002). These three performance points are reflected in the 'triple bottom line' (Elkington, 1997; Fisk, 2010). In short, as the world's pressure increases, companies seem to feel more compelled to show interest in CSR and sustainability.

Developments around CSR and sustainability have not gone unnoticed in the construction sector, where this thesis emphasises. The construction sector is increasingly adopting pressure from society, regulations and legislation that forces companies to implement CSR and sustainability strategies (Awaysheh & Klassen 2010), because of the recognized effect buildings' construction has on the natural environment (Gorecki, 2019). Opportunities to minimise buildings' impact on nature are becoming increasingly scarce as the construction process progresses (Blauwhof, Spiering, & Verbaan, 2013). Thus, sustainable solutions must be chosen early in the process along with consideration to the design, construction materials, construction methods and parties involved (Sharp & Zaidman, 2010).

Additionally, Tang and Zhou (2012) explain that the global demand for natural goods has increased due to increasing economic developments globally. However, the supply of these goods (oil, metals, wood) is continuously decreasing, while the supply of waste is continuously growing. As opposed to this current linear economy, the circular economy is introduced (Corona et al., 2019) which can be characterized as an economic system that replaced the end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes (Kirchherr, Reike, and Hekkert 2017). Although much information is already known about sustainable solutions in buildings, measuring sustainability is often seen as an abstract concept. Even though the client's wishes regarding sustainability are known, it is often challenging to provide concrete material. Seuring and Müller (2008) mention that for a focal company (Kleissen in this case) to 'produce' sustainable products, it should consider three important aspects of contacting suppliers. These three are increased communication, communication of criteria to suppliers, and supplier development.

As recognized by Awaysheh and Klassen (2010) and Gorecki (2019) construction companies adopt strategies towards sustainable solutions. However, although sustainable products' communication and development in construction companies have been increased, it remains a challenge to communicate criteria of measuring and comparing different sustainable products/possibilities with each other. The differences between traditional solutions and sustainable solutions are challenging to measure, and therefore, difficult to measure and compare the added value of these sustainable products in buildings. As a result, it remains a reason to continue opting for the traditional solution. After all, these are proven, financially attractive and meet the (comfort) requirements.

The objective of this study is to look at ways of making sustainability and circularity more measurable and will be carried out at Kleissen Bouwmanagement en Advies in Hengelo, the Netherlands. Kleissen is a company that specialises in construction management and consultancy. With a team of about 20 employees, they have expertise in construction-, process-, and contract-management, construction costs, and supervision. In addition, they also focus on various advisory roles. With the label #HoudbareHuisvesting (Literal translation: #SustainableHousing), introduced in 2017, Kleissen wants to emphasise that they believe in ecological, social, and dynamic housing. The

vision is to make housing future proof. Kleissen focuses on the fields of education, housing, care, sports, corporate housing and retail, government, culture, and leisure (Kleissen, 2021). By comparing different existing measurement methods to wishes, goals and requirements of Kleissen and its stakeholders, sustainability and circularity can be better addressed.

This research contributes to the literature as research on sustainability and circular economy, which is often limited to various suitable sustainable materials, effects, and influences of sustainability on stakeholders, and multiple reasons for choosing sustainable. Moreover, it is not clear what methods there are and how they are built up. This makes it, for example, difficult for construction companies to substantiate the added value of their sustainable contribution. As a result of no straightforward method that is used, it is hard to compare sustainable solutions. This research answers the following research question: **"What is the most suitable measurement method to make sustainability measurable for Kleissen and its stakeholders?"**. Thus, this research aims to fill this gap by comparing the available methods on a set of requirements. To answer this question, three subquestions are formulated:

Question 1: What is the current sustainable and circular situation of Kleissen?

Question 2: What are the requirements of Kleissen and its stakeholders when measuring circularity?

Question 3: What are the relevant and future proof measurement methods to measure circularity for Kleissen and its stakeholders?

The thesis intends to respond to this gap and address the shortcomings. Firstly, the research framework will be developed drawing on sustainability and circular economic activities in the construction sector. This chapter will also provide literature on various sustainability and circularity measurement methods. Secondly, the research starts with background information about Kleissen; where does the research take place, what has already been researched, which steps still need to be taken. This is followed by a description of the research objective, elaborating the research questions and definition of the scope. Thirdly, the research methodology is worked out. In this part, the research expands on why a single case study combined with interviews is chosen. Fourthly, the findings of the study are provided per sub-question. It will examine what information is received from the single case study, including the interviews. Fifthly is the discussion in which the findings from the sub-questions are linked to the theory. Finally, the conclusions, limitations and recommendations will be discussed, and the research questions answered. This chapter will report the main findings, answer the research question/s, and provide recommendations and future research.

2. Literature review

The reason for this study is the increasing interest in sustainability and circularity. These concepts have already been briefly explained in the Introduction section. In the theoretical sections, sustainability and circularity in the construction sector and how both can be measured are further discussed.

2.1. Sustainability

2.1.1. Defining sustainability

Sustainability is often seen as a broad concept. It is driven by multiple actors, such as local, regional, national and international parties and covers multiple topics, such as ecological, social, and economic issues (Chakrabarti, Henneberg, & Ivens, 2020). According to the Oxford English Dictionary sustainability is defined as "the degree to which a process or enterprise is able to be maintained or continued while avoiding the long-term depletion of natural resources", as cited in Chakrabarti et al. (2020, p. 529). However, not all literature seems to agree that the depletion of natural resources is the 'only' target of sustainability. Dyllick and Hockerts' (2002, p. 131) definition of corporate sustainability as "meeting the needs of a firm's direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities etc), without compromising its ability to meet the needs of future stakeholders as well" mentions the importance of considering the stakeholders around the company.

However, to meet the needs of the stakeholders, the company must maintain and grow its economic, social and environmental capital base (Dyllick & Hockerts, 2002). This aligns with Kleindorfer, Singhal, and Van Wassenhove (2005) that combine both definitions. According to them, companies must not only focus on the economic issues to ensure long-term success; they must also include the future of people, both internal and external, and the planet's future. As a result, Kleindorfer et al. (2005) see a growing trend in interest in sustainability.

2.1.2. Defining CSR

The interest in CSR accelerated rapidly in the last decade according to Loosemore and Lim (2018), mainly due to shifts in key earth systems trends, such as greenhouse gases and socio-economic trends (Sarkar & Searcy, 2016). As a result, multiple definitions of CSR have been produced. The World Business Council gives an extensively cited definition for Sustainable Development: "The continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large" as cited in Loosemore and Lim (2018, p. 67). Marrewijk (2017) highlights that the continuing commitment of businesses should be considered in both present and future generations.

Sarkar and Searcy (2016) emphasize that companies must consider their actions' impact on stakeholders in society. It, therefore, overlaps with Dyllick and Hockerts' (2002) definition of corporate sustainability that companies must take account of their actions on their stakeholders. Additionally, Sarkar and Searcy (2016) argue that firms must assume their economic responsibility and contribute to global sustainability.

Combination of sustainability and CSR

The literature often uses CSR and sustainability interchangeably. The definitions of both terms boil down to the fact that companies should not only focus on making profit, but also on the people and nature they are affecting. This applies not only to the current generation but also to future ones. It is important to consider the companies' actions on the stakeholders. Because sustainability recurs in Kleissen's label #HoudbareHuisvesting and the previous research also used this concept, the term sustainability will be used in the rest of the research.

2.1.3. Triple Bottom Line

As definitions mentioned above clarify, the term sustainability often corresponds to the Triple Bottom Line (TBL) principle. The anchor point of TBL are people, planet and profit (Bernardová et al., 2020; Dyllick and Hockerts, 2002; Elkington, 1997; Fisk, 2010; Kleindorfer, Singhal, & Van Wassenhove, 2005). Sustainability can be achieved at the intersection of the three principles (Chakrabarti et al., 2020; Fisk, 2010), or at least that the other aspects stay the same when one is optimized (Chakrabarti et al., 2020). As the main aim of sustainability is to affect all present and future relationships with stakeholders, it is important to consider all aspects (Dyllick & Hockerts, 2002; Fisk, 2010; Küçükbay & Sürücü, 2019). Although the measure of business success used to be economic value creation as owners, investors and leaders are mostly interested in future profits, business success's main drivers are changing. Fisk (2010) mention that social and environmental issues are becoming the biggest drivers of economic value in business. Although these two concepts are still in the early adoption phase they "will fundamentally redefine the future" (Fisk, 2010). The three aspects are therefore elaborated below.

The first aspect, people, emphasises ensuring a 'fair' society which means that companies should add value to communities in which they operate (Dyllick & Hockerts, 2002). This can be done in two ways, through human capital and societal capital. The first one concerns mainly aspects such as promotion of skills, motivation, and loyalty (of partners and employees). The second one, societal capital mainly includes the quality of public services. Examples are education, infrastructure, and culture supportive entrepreneurship (Dyllick & Hockerts, 2002). However, Gladwin et al. (1995) warn that for a company it is almost impossible to meet the expectations of all stakeholders simultaneously when trying to create a socially sustainable enterprise.

The second aspect, planet, is focusing on the natural environment on which the company depends. This part focuses on the fact that the earth has no infinite amount of supply, and cannot deliver endlessly. Dyllick and Hockerts (2002) distinguish between two types of natural capital: renewable resources (such as wood, meat, and wheat) and non-renewable resources (such as oil and iron). Both types of resources cannot be used infinitely by humans, and therefore a company that wants to apply sustainability will have to consider this aspect. Dyllick and Hockerts (2002) warn that natural resources should only be consumed at a rate that is below natural reproduction. It is also important that the caused emissions are compensated and that the company does not engage in activities that degrade the ecosystem.

The third aspect, profit, emphasizes sustainably managing economic capital. If a company wants to be successful over a long period, it should consider multiple financial aspects. According to Dyllick and Hockerts (2002), firms manages several types of economic capital: financial capital (equity, debt, etc.), tangible capital (machines, inventory, etc.) and intangible capital (reputation, goodwill, know-how, etc.). Financial sustainability is more than just the ability to overcome potential (financial) risks. It is also the capacity to make decisions that do not compromise future generations. The main aim is to have information available about the coming financial years, instead of focusing on current figures (Bolívar, 2017).

Figure 1 gives, an overview of the three aspects of TBL. The corresponding subcategories contain performance factors that can be used as guidelines.

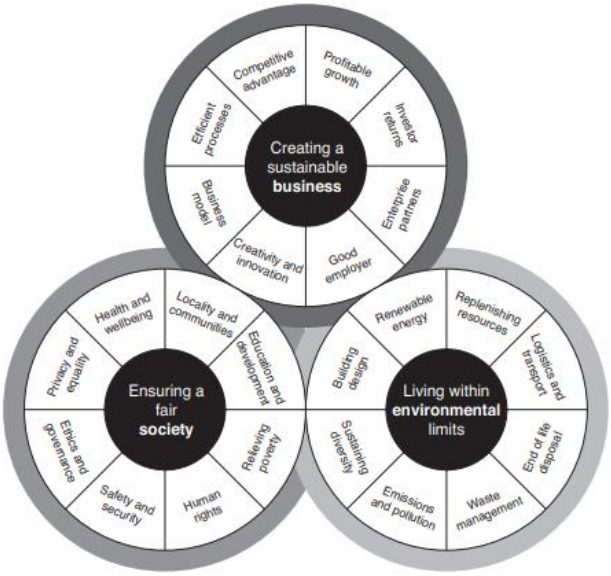


Figure 1 People, Planet and Profit (Fisk, 2010).

2.2. Sustainability in the construction sector

Sustainability is an increasingly important topic in the construction sector. The sector is responsible for 40% of the energy consumption worldwide to build, operate and demolish buildings (Iqbal et al., 2021). Energy-efficient and innovative technology could contribute to the environment and the energy consumption of buildings. For example, in the construction phase of projects, energy-efficient technologies (EET) could save energy, reduce potential associated costs, lower environmental impact, and create new types of jobs. In the use phase of a building, EETs can reduce energy consumption in various ways. Concrete examples are solar panels, smart design features and developments of new materials (Iqbal et al., 2021). Balaras et al. (2007) even mention that EETs contribute to the national economy and local environmental protection.

However, Balasubramanian and Chanchaichujit (2020) observe that not all companies are eager to keep up with the latest sustainability developments. According to Häkkinen and Belloni (2011), this is not because of technology; it is because, as also acknowledged by Iqbal et al. (2021), technology is in full development. The cause lies mainly in organisational and procedural difficulties in adopting it. New technologies are hampered because changes in working are expected, which in turn entail risks and unforeseen costs. Clients are often concerned about the use of unfamiliar techniques, lack of previous experience, additional testing and inspecting in construction and a lack of performance information (Häkkinen & Belloni, 2011). Further barriers are mentioned by Pitt et al. (2009):

- Affordability (financial unattractiveness of a sustainable solution)
- Building regulations (regulations that apply to a specific construction measure)
- Lack of client awareness (possible customer unawareness of sustainable solutions)
- Lack of business case understanding (understanding about the project)
- Lack of client demand (limited demand for sustainable solutions)
- Lack of proven alternative technologies (no available alternative technology)
- Lack of one labelling/measurement standard (no uniform measurement method for sustainability)
- Planning policy (sustainability measures do not fit with the intended schedule).

Loosemore and Phua (as cited in Loosemore & Lim, 2018) expand on the fact that clients are often unaware of construction companies sustainability strategies, as they find it hard to link the construction company's sustainability strategy towards their building project outcome. The building users are even less concerned with the construction companies' sustainability strategy, as they often

have no idea which company built the property. Let alone the fact that they should know about the construction company's sustainability strategy.

Pitt et al. (2009) mention possible drivers of sustainability:

- Client awareness (increasing customer commitment to sustainable solutions)
- Building regulations (rules that improve sustainability standards)
- Client demand (increasing demand for sustainable solutions)
- Financial incentives (financial stimuli to choose a sustainable option attractive)
- Investment (investments in sustainable solutions)
- Labelling/measurement (labelling can help promote sustainability, such as energy efficiency rating)
- Planning policy (direction of future wishes and goals regarding sustainability)
- Taxed/levies (financial stimuli to choose a sustainable option attractive).

Concrete examples of possible reasons for these mentioned drivers are introduced by Iqbal et al. (2021). The main additional drivers are new possible employment opportunities through economic development, following international changing standards and developments regarding sustainability, saving raw materials, and lowering costs, creating competitive advantage, and reducing carbon emissions. Considering the TBL principle, the most emphasis is laid on the profit and planet aspects. The only aspect that directly benefits the people is the health protection and clean environment for local citizens that is realized through a reduction in carbon emission. See additional benefits in Figure 2.

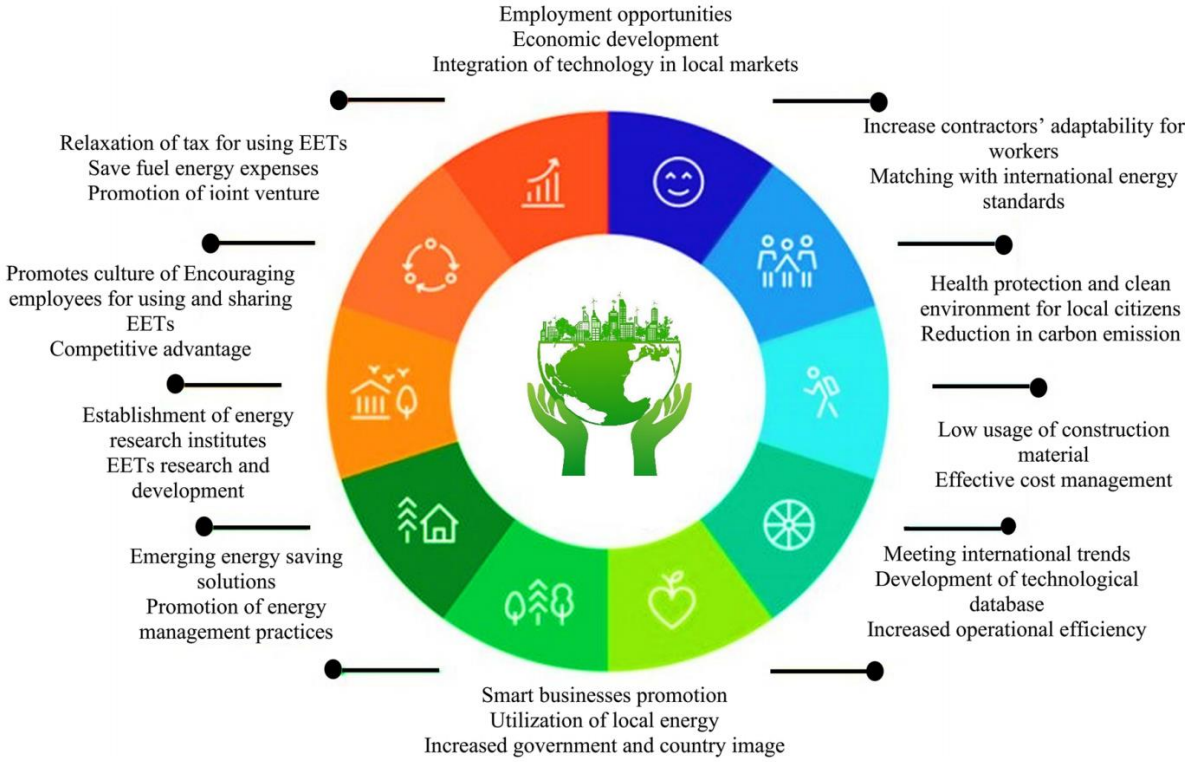


Figure 2 Benefits of energy-efficient technologies (Iqbal et al., 2021).

2.3. Circularity

Definition and conceptualization of circularity

The circular economy can be characterised as a combination of reducing, reusing and recycling activities (Kirchherr, Reike, & Hekkert, 2017). Kirchherr et al. (2017) defines a circular economy as:

> An economic system that replaces the end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations (p. 229).

Geissdoerfer et al. (2017) add to the circular economy that it is a regenerative system that minimizes the consumption of raw materials, waste, emissions, and energy. This is done by slowing down, closing and reducing the material and energy loop. Stahel (2016) makes the distinction between two types of circular-economy business models. The first one is the group that extends the product's service through reparation, remanufacturing, upgrades, and retrofits. In this case, the used product returns directly to the use phase. The second group are those who turn old goods into as-new resources by recycling the materials. The original product will be dismantled with this process, leading to the reuse of the remaining usable parts in other products. In this way, the demand for newly extracted raw materials is reduced. See Figure 3 for an overview of the closing loop of the circular economy.

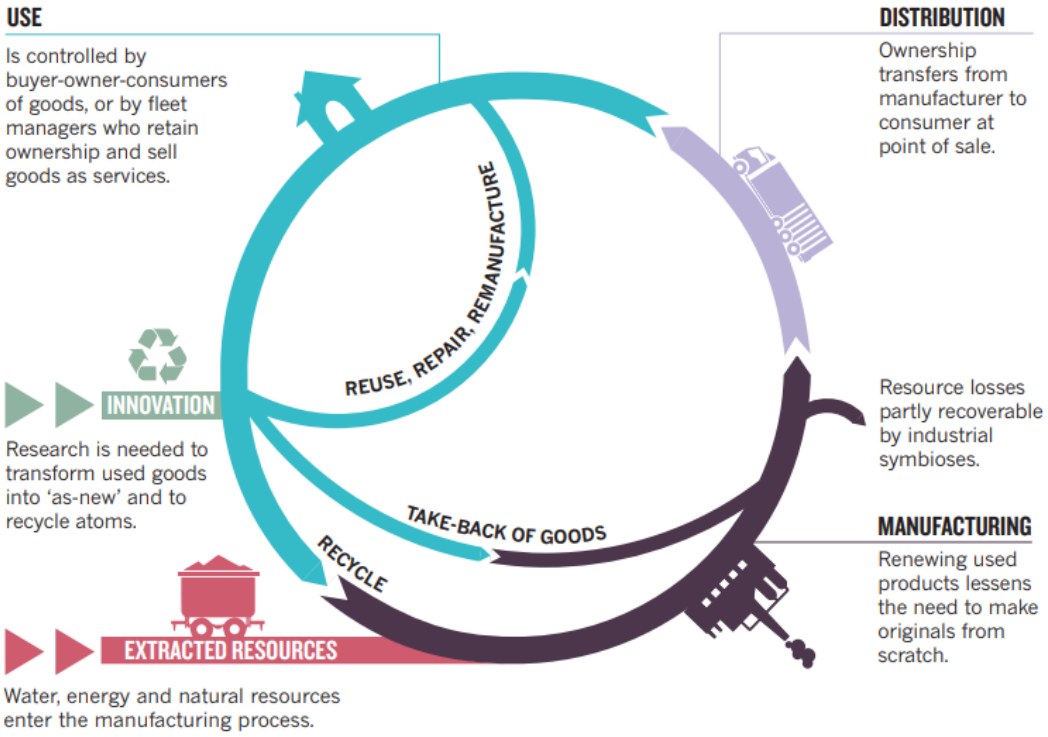


Figure 3 Closing loop Circular Economy (Stahel, 2016).

2.4. Circularity in the construction sector

The construction sector is responsible for the highest production of waste (Van Dijk, Tenpierik, & Van Den Dobbelsteen, 2014) and 40% of global energy consumption (Iqbal et al., 2021). A circular economy focused on the construction industry is defined by Benachio, Freitas, and Tavares (2020) as: "The use of practices, in all stages of the life cycle of a building, to keep the materials as long as possible in a closed-loop, to reduce the use of new natural resources in a construction project". The life cycle of the building is divided into four steps: (1) project design, (2) material manufacture, (3) construction operation and (4) end of life (Benachio et al., 2020). Although the ultimate aim of a circular economy is to reuse, repair or remanufacture products (Stahel, 2016), it is often impossible to reuse materials in the construction sector (Osobajo et al., 2020). Buildings are often demolished when they reach the end of their life cycle.

However, Gorecki (2019) mention that circularity does not always mean reusing an entire building. It may also be that parts of the building can be reused (think of a new function for an existing building) or reusing separate building parts (think of reusing wide slab floors). Additionally, current trends in the construction sector show that a circular economy can be a facilitator of a (more) sustainable sector (Osobajo et al., 2020). This is also recognised by Benachio et al. (2020) and Eberhardt, Birgisdottir, and Birkved (2019) who mention that awareness about a circular economy in the construction sector is good. Although they warn that these concepts are introduced slowly, as most of the stakeholders do not understand how they can practically apply the concept. Eberhardt et al. (2019) warn that a lack of knowledge on implementing a circular economy is a problem. The main reason for this is the complexity of the supply chain and the short-term goals of companies that do not align with circularity.

It also does not help that there has been limited research of circular economy principles in the built environment. This is acknowledged by Adams et al. (2017) who state that most research is limited to the end of life phase of a product to manage waste generation. Despite this has led to an improvement in the management of construction and demolition waste, the main effect remains limited to 'just' recycling and downcycling. Theory considering the whole life cycle of a buildings' circularity level seems relatively undiscovered (Adams et al., 2017).

Layers of Brand

To make circularity in construction more visible, it is possible to look at different building levels. Stuart Brand's "Six S's", as mentioned in Mallory-Hill (2004), divides a building into six layers, all of which have different properties and lifespans. The following six layers are distinguished (from inside to outside):

- Stuff (furnishings and equipment, 1 day - 1 month)
- Space-plan (floor plan, 3 - 30 years)
- Services (HVAC, lighting, acoustics, 7 - 15 years)
- Skin (envelope, 20 years)
- Structure (skeleton, 30 - 300 years)
- Site (form and orientation - eternal).

Even though each layer of the building has different characteristics, they are all interconnected. For example, floor covering (space-plan) is glued to the floor (structure) and power supplies (services) are integrated into the wall (both structure and skin). By promoting circularity, one must carefully examine the materials chosen in each layer, but it will also be necessary to explore how these layers are interconnected.

10R Model

At the end of a layer's life, it is desirable to find a possible solution to reuse this material, i.e. it must be easy to remove and reuse it in the best possible way. The connection of different layers is essential here. When all the layers are glued, bonded, or poured, the materials become inseparable, making reuse practically impossible. One way of gaining insight into the degree of recycling is to use the 10R model. This 10R distinguishes between 10 steps (Re-fuse, Re-think, Re-duce, Re-use, Re-pair, Re-furbish, Re-manufacture, Re-purpose, Re-cycle and Re-cover) (Potting et al., 2017) that can be divided into three levels (Reike, Vermeulen, & Witjes, 2018):

- Shortest loops: R0-R3 (Re-fuse, Re-think, Re-duce, Re-use)
- Medium Long Loops: R4-R6 (Re-pair, Re-furbish, Re-manufacture)
- Long Loops: R7-R9 (Re-purpose, Re-cycle, Re-cover).

The shortest loop should closely connect to the consumer and is often related to extending the product's life span, such as the reuse of a parquet floor in another house. The medium loop is indirectly related to the consumer to ensure that a particular product is given a second life, be it through repair, refurbishment or reuse in another product. The most extended loop most closely resembles waste

management activities, as it looks primarily at recycling and reclaiming the raw material. This loop is the most distant from the consumer and the least desirable as it requires the most effort to be reused appropriately (Reike et al., 2018).

2.5. Sustainability and circularity goals in the construction sector

To examine the sustainability objectives set for the construction sector, a distinction is made between two types of actors; rules and objectives set by the Dutch government and objectives and wishes expressed by important stakeholders.

Dutch government sustainability goals

The Dutch government has set targets in the area of sustainability. Many of these goals are extended to the goals set by the European Union which are detailed in Appendix 1. For example, concrete targets have been set for the years 2020, 2030, and 2050. These targets are summarised in Table 1.

Table 1 Summary targets European Union (European Commission, n.d.).

Summary European Union targets	2020	2030	2050
Cut in greenhouse gas emission (from 1980 levels)	20%	55%	100%
EU energy from renewables	20%	32%	
Improvement in energy efficiency	20%	32,5%	

Specific targets set by the Netherlands are in addition to the European targets. For example, the Netherlands aims to be CO-2 neutral by 2050 and to make its energy supply almost entirely sustainable. A starting point in this respect is that the country should not be fully dependent on energy from other countries. As a result, the target is to generate 70% of all electricity and at least 27% of all energy (electricity, gas and heat) sustainably by 2030 (Rijksoverheid, n.d.). The Netherlands will take the following steps to achieve this:

- Using energy more efficiently
- From electricity from coal to electricity from sun and wind
- From heat from natural gas to sustainable heat, such as geothermal heat, residual heat and green hydrogen
- Involving residents by allowing them to think about or become co-owners of local energy projects
- Fitting energy projects into the environment and landscape in a smart way.

Much of the sustainable energy is currently generated by wind turbines on land and sea, and solar panels on roofs and in parks. In the future, the ''Small-scale initiatives'' identified by the EU will be further developed to also contribute to the generation of sustainable energy. Examples are geothermal heat, waste heat and green hydrogen (Rijksoverheid, n.d.). However, sustainable building is more than just saving energy. In the development of buildings, people and the environment come first. It is therefore important that:

- The use of sustainable materials that take the environment and the health of the occupants and users into account
- A healthy indoor environment, for example through good ventilation. This prevents moisture, mould, and the accumulation of harmful substances
- Pleasant and liveable homes, buildings, neighbourhoods and cities
- Sustainable demolition, so that materials released during demolition can be reused (recycling);
- Responsible water use
- Preventing the depletion of raw construction materials.

The Dutch government states that sustainable construction is by no means always more expensive (Rijksoverheid, n.d.). If only the land and building costs are considered, this is often the case. However,

when the costs of maintenance, energy and water are included, savings are often feasible. Various schemes have been set up to further stimulate sustainable building both by the national government, the province, and the municipality. Additional measures that have been taken to accelerate the process of sustainability include no longer installing a gas grid in new housing estates. The government wants to replace the obligation to connect gas with a right to heat. As a result, energy performance requirements have been tightened up (Rijksoverheid, n.d.).

BENG

These requirements are translated into the BENG and are mainly aimed at improving the energy performance of buildings. Where previously the EPC was always used to map this out, in the Netherlands the BENG (Bijna EnergieNeutrale Gebouwen - Nearly Energy Neutral Buildings) has recently been introduced (Rockwool, n.d.). For all new buildings, both residential and non-residential, permit applications must meet the BENG requirements. These requirements are based in part on the European Energy Agreement for Sustainable Growth (Rijksdienst voor Ondernemend Nederland, 2021a; Rockwool, n.d.). The energy performance of buildings is determined by three individual requirements, all of which must be met:

1. The maximum energy demand in kWh per m2 usable area per year (kWh/m2.yr)
2. The maximum primary fossil energy use, also in kWh per m2 usable area per year (kWh/m2.yr)
3. The minimum renewable energy share in percent (%).

There are different minimum/maximum values for each type of building that must be complied with. The BENG requirements are therefore different for each building type (Rijksdienst voor Ondernemend Nederland, 2021a). In addition to the BENG requirements, a limit value for TOjuli has been included for newly built houses. TOjuli is an indicative figure that provides insight into the risk of exceeding the temperature limit (Rijksdienst voor Ondernemend Nederland, 2021b; Rockwool, n.d.). Since houses are increasingly well insulated, they retain more heat. In the summertime, this can cause problems when high indoor temperatures can lead to health risks and discomfort. As a result, a limit value of 1.20 has been imposed as of 1 January 2021. BENG and TOjuli requirements are assessed using NTA 8800 (Rijksdienst voor Ondernemend Nederland, 2021b).

Not only for new buildings measures have been taken to stimulate/enforce sustainability. As the EU already pointed out, 75% of the existing buildings were built before energy performance standards existed. Renovation is often more sustainable and less damaging to the environment than demolition followed by new construction. Therefore, extending the life span of a building is an important means of sustainable construction. Thus, renovating houses saves waste and increases energy efficiency (Rijksoverheid, n.d.). As a result, requirements are set for rebuilding and renovating homes. These requirements are elaborated in the building decree (Bouwbesluit in Dutch). For example, requirements have been set for rebuilding, renewing or replacing insulation layers, dormers, major renovations and rebuilding with adjustments to technical installations (Rijksdienst voor Ondernemend Nederland, 2020).

MPG

In addition to the BENG, the MPG calculation is mandatory for every application for an environmental permit. It indicates the environmental impact of materials used in a building. An MPG calculation must be made for new office buildings (larger than 100m2) and newly built houses. The MPG calculation can be seen as an important measure for the circularity of a building. The aim is to have the lowest possible MPG score, although there are maximum limit values that must be met in any case. For office buildings, this is 1.0, while for newly built houses it is 0.8 (from as of 1 July 2021, before that it is 1.0). In addition to being a mandatory part of an environmental permit, the MPG can also be used as an objective tool in the design process of a building. The client can even choose to include a specific MPG score in a Programme of Requirements (Rijksdienst voor Ondernemend Nederland, 2021c).

The MPG ensures that the environmental impact of a building can be calculated, promoting circularity. The basis of this is that an environmental load of a single material is calculated to calculate the score of the entire building. The calculation of the environmental impact for a single building is done using an LCA. This LCA results in 11 indicators for the environmental impact of a product. Not only does the choice of material impact the score, but the impact of the product during its entire life cycle is calculated. For example, the production costs (think of transport costs) and maintenance costs (painting, replacing materials, renewing installations, etc.) also count. The final score is an average of all 11 indicators and creates the 'shadow cost per unit of the product', which is measured in, for example, kg, m3, m2 or the like. It is the cost that must be made to undo the damage to the environment caused by using materials. To arrive at the final figure all the total costs of a building are added up and divided by the life span and building area. When the environmental burden of a product is known, it appears in the NMD managed by SBK (Rijksdienst voor Ondernemend Nederland, 2021c).

As mentioned, the European Union and the Dutch government have strict goals and requirements concerning the energy performance of buildings (translated into the BENG). The MPG calculation, however, focuses on material use and its effects on environmental impact. Given the relatively strict requirements of the BENG, the MPG can be seen as an increasingly important measure of sustainability. This is mainly because the targets and requirements around material consumption have not yet been developed as far as the targets and requirements around energy performance/BENG. Moreover, it is the case that the calculations of the BENG may conflict with the calculation of the MPG. For example, the use of solar panels reduces the BENG because it produces its own energy, but the use of solar panels increases the MPG because it contributes negatively to the environmental burden (Rijksdienst voor Ondernemend Nederland, 2021c).

Kleissens' stakeholders

Besides governmental goals are goals set by Kleissens' stakeholders who were defined in earlier research by J. van Galen (2020). These stakeholders are architects, contractors, and clients (where clients are divided into work fields: residential, educational and care). Each of these stakeholders has different wishes regarding construction, which results in various wishes that Kleissen must consider. However, these wishes do not immediately result in sustainable goals and the implementation of circular construction. The most important aspects can be found in Table 2.

Table 2 Most important aspects stakeholder Kleissen (Galen, 2020).

Most important aspects, adapted from Galen (2020)	Architects	Contractors	Clients
Aspect 1: The building fits the end-user	Yes	Yes	Yes
Aspect 2: The building fits in its environment as well as possible	Yes		
Aspect 3: The building is future-proof	Yes	Yes	Yes
Aspect 4: Efficient cooperation with all parties		Yes	
Aspect 6: The building is as energy-efficient as possible, where required energy is locally and	Yes	Yes	Yes

sustainably generated			
Aspect 7: As many circular materials as possible are implemented	Yes		
Aspect 11: Not exceeding the total budget of the project when realizing the building			Yes
Aspect 12: The task budget of the construction project should not be exceeded		Yes	
Aspect 13: The building needs minimal maintenance			Yes

Of the three types of stakeholders, interviews conducted by Galen (2020) have shown that architects have the most experience with circular construction. For them, circular construction means the reuse of materials. When designing a building, architects are most interested in the clients' wishes. If a client has no desire for sustainable construction, the architect will therefore not readily emphasise this. Like the architects, the contractors mention the reuse of materials as a definition of circular construction. Their experience is that this sometimes happens by recycling materials on the building site. Of the five most important aspects for constructors, three are the same as for architects. For the contractors, the clients' wishes are also an important aspect. From the architects and contractors' interest, it can be concluded that sustainability should be a requirement of the client, making it a goal for these two parties.

Lastly, the interviews conducted by Galen (2020) showed that the clients in residential construction are familiar with circular construction. According to this group, circular construction means using natural (fossil) resources as little as possible. The second target group, educational institutions, has little or no experience with the concept of sustainable construction, but they are aware of its usefulness. They define the concept as selecting and reusing the right materials. This target group is interested in the concept but is often bound by financial restrictions. The third target group also has little experience with circular construction. They interpret circular construction as the reuse of materials. For the clients, the interests lie mainly in the users' wishes and the future-proofing of the building. In addition, the energy-efficient design, minimal maintenance and not exceeding the budget are important points. This shows that sustainability is important to this group.

2.6. Measuring sustainability

Sustainability is still often seen as a vague concept because measuring it is difficult. Seuring and Müller (2008) explain that communication of sustainable criteria should always be considered when selecting suppliers. Furthermore, to choose suppliers, the focal company must evaluate suppliers on the different criteria. Therefore, Panayiotou et al. (2009) report that if the exact contribution of sustainability is to be mapped out, measuring it is necessary.

After all, when sustainability can be made measurable, stakeholders can be informed and motivated more clearly, concrete goals can be set, and the impact of sustainability is clearer. However, there is no straightforward way to measure sustainability. Although different sources (Bernardová et al., 2020; Kocmanová & Šimberová, 2014; Korhonen, 2003; Küçükbay & Sürücü, 2019; Panayiotou et al., 2009) agree that the TBL should be part of the calculation, the interpretation of how this should be done is not always the same. Therefore, the three aspects of TBL are operationalised.

Operationalize people

Panayiotou et al. (2009) warn that, when considering the social aspects of the TBL, they are often difficult to measure and quantify. Furthermore, Gladwin et al. (1995) recognised that companies are almost always unable to meet all stakeholders' expectations simultaneously regarding social issues. As a result, Porter and Kramer (2006) emphasise that choices regarding addressing social issues need to be made. According to the article, social issues are divided into three categories:

1. Generic social issues: social issues that are important to society but are not significantly affected by the activities of the company. They also do not influence the long-term competitiveness of the company.
2. Value chain social impacts: social issues that are significantly affected by the activities of the company.
3. Social dimensions of competitive context: social issues in the external environment that significantly affect the competitiveness of underlying drivers in the places where the company operates.

When companies divide social issues across these categories, they can create a sustainable agenda in which they can rank social issues based on importance. Advised is to choose for social issues that are closely tied to the company. Therefore, it gives the company the leverage to use its resources and capabilities and make a greater impact. This, it is important to find the link between business activities and the society in which the company operates to find suitable improvement opportunities. The way on how to address these social issues can be derived from best practices, as companies do not have to reinvent the wheel (Porter & Kramer, 2006).

Operationalize planet

When considering the planet aspect of the TBL, Hart (1997) mentions that to achieve sustainability, the environmental burden should be stabilized or reduced. This can be done through a decreasing world population, lower consumption or changing the technology used to create wealth. In short, only the third option can be seen as a viable one. As a result, three stages of environmental strategy are described:

1. Stage one - Pollution Prevention: the first stage is to make the transaction from pollution control towards pollution prevention. Control means cleaning up waste after creation. Prevention means minimizing or eliminating waste before it is created.
2. Stage two - Product Stewardship: the second stage goes a bit further in minimizing waste. It does not only focus on pollution from manufacturing but also all environmental impacts associated within the full life cycle of a product.
3. Stage three - Clean Technology: the third stage focuses on developing new and clean technologies, as existing technology is most of the time not environmentally sustainable.

As mentioned in stage two, a life cycle analysis can measure the environmental impact of materials and assess the impact of material from the initial extraction and processing of raw materials to final disposal (Ayres, 1995). It includes material production, manufacturing, use, retirement or disposal (Rodriguez et al., 2002). The life cycle analysis is divided into four components (Ayres, 1995; Ortiz, Castells, & Sonnemann, 2009; You & Wang, 2019):

1. Scoping: in the first step, the goal and scope definition in LCA are set, using criteria that specify which units are included and excluded from the project system. Another step is to define the unit that defines the boundary of the analysis.
2. Inventory analysis: the second step is the quantification of energy and raw material requirements for the product life cycle, as well as its emissions to air, water, and land. For a building system, this phase includes calculating both the material and energy input and output.
3. Impact assessment: the third step evaluates environmental impacts and estimates the resources used in the system. This step consists of three steps: (1) selection of impact categories (e.g., CO2), (2) assignment of inventory analysis results and (3) modelling category indicators. An optional step is to normalize the results, to compare all impact categories as they now will have the same scale.
4. Improvement assessment: the fourth step is to evaluate the results. This stage identifies issues, evaluates findings, reach a conclusion, and formulate recommendations.

Operationalize profit

Bolívar (2017) mention several possible indicators for measuring financial sustainability. Spending, revenues, and debt are always mentioned. For example, the amount of short- and long-term debt would be examined. The income statement is therefore an important component (Bolívar, 2017; Navarro-Galera et al., 2016). However, data must be publicly accessible. Assessing in this way is not possible without accessible data. Nonetheless, the indicators to measure profit will differ per situation. For example, a private individual who wants to take out a mortgage for 30 years will look at the development of the interest rate and the repayment, while a buyer of raw materials will look at the differences between invoices in lower unit prices when his sales increase.

Preconditions for measuring methods

Bernardová et al. (2020) state that, having investigated different methods of measuring sustainability in different scientific sources, there is no consensus about the method of determining the weights and index construction. However, they do refer to the source Mansourianfar and Haghshenas (2018) that the subcategories of a measurement method must comply with at least:

- Relevance to sustainability: represent the three main aspects of sustainable transportation
- Understandable and useable: easily understood by the general public
- Transparent in content and structure: users should be able to identify how the final value is calculated
- Predictability: model future policy impacts and indicators values can be forecasted for the future
- Comparative: should allow for comparisons to be made among governing alternatives
- Appropriate to scale: should be measured at the appropriate spatial and temporal scales
- Technically measurable: should be reproducible and quantifiable
- Feasible: data must be reliable, available at a reasonable cost
- Independent: should be independent of each other (p. 153).

Panayiotou et al. (2009) mention that when measuring sustainability, it does not matter if the inputs are qualitative (e.g., energy consumption levels) or of quantitative nature (level of satisfaction of customers). It is most important that the targets align with the organisational culture and corporate vision and contribute to different departments. As a result of involving workers across different departments, Fisk's (2010) concludes that workers expectations towards sustainability are developing can better be met.

2.7. Measuring sustainability in the construction sector

The abovementioned sustainability goals set out by the European Union and the Dutch government are, as described, primarily aimed at reducing energy consumption. However, sustainability in construction is not solely focused on the 'energy' side, in which the BENG is being used. It is therefore interesting to find out whether there are measuring methods that take both aspects into account.

Measurement methods

Some methods that measure sustainability more extensively and/or more specifically are described by Pitt et al. (2009), see Table 3 for an overview. Especially Building Research Establishment Environmental Assessment Method (BREEAM) is a widely used method in the Dutch building sector. Other methods, not included in the table below, are International WELL Building Institute (WELL) and Leadership in Energy and Environmental Design (LEED). These will be elaborated on below.

Table 3 Building construction measurement systems (Pitt et al., 2009).

Measure	Description
Eco-quantum	Assesses the lifecycle of whole units of construction; for example, glazing systems/structural walls.

Lifecycle assessment	Evaluates performance of the building through its life. It considers the individual elements, which when used together will affect the overall benefits.
Environmental management systems	Developed under ISO 14001, and provide guidelines on good principles and practice. Briggs and Nestel believe it provides a ''Market driven framework for balancing environmental protection with socio-economic needs that embodies the principles of sustainable development'' (cited in Zhang et al., 2000).
BREEAM	Developed for office buildings by the BRE and compares and scores different design strategies for possible pollution and local impact. Some consider the BREEAM assessment techniques to be heavy ''feature'' orientated – for example providing showers for cyclists although it does some CO_2 and energy analysis (Curwell & Cooper, 1998).
EcoHomes	Is the BREEAM standard for dwellings, which rates the environmental qualities of new and renovated houses. It balances the issues of climate change, resource use and the impact on wildlife with the need for quality of life considerations (BRE).
Eco-labels	Used for specific product items, for example, light bulbs, paints, etc. and are based on EU standards (regulation 880/92 March 1992). These use lifecycle analysis on pre-production, production, distribution, utilisation and disposal of the product (Keeping & Shiers, 1996).
Eco-points	A method of ranking and scoring of different environmental impacts. Different issues are weighted using the points so allowing comparisons to be drawn.
Embodies impact study	A way of measuring the impact of manufacturing construction materials, including quarrying and transport, the construction process, including transport to site and the demotion and disposal of materials at end of life of the building (Anderson & Mills, 2002).

BREEAM

BREEAM is a certification method for buildings. This certification method is available for new construction, existing buildings, infrastructure and master planning (large scale development plants) (Dutch Green Building Council, n.d.). BREEAM is active in more than 80 countries. Originally developed by the Building Research Establishment (BRE), but made fit for the Dutch market by the Dutch Green Building Council (DGBC, member of the World Green Building Council (World Green Building Council, n.d.)). The BREEAM model distinguishes between Energy, Health and Wellbeing, Innovation, Land Use, Materials, Management, Pollution, Transport, Waste and Water.

Under the materials component, the MPG is an important part (see 0 for an explanation of the MPG) of the score (BREEAM NL, 2021; Rijksdienst voor Ondernemend Nederland, 2021c). "With the BREEAM-NL Toolbox you can map out the sustainability of your project in a clear and concise way. Calculate the score of your new building project, existing building or area development and see where your sustainability ambitions lie" (Dutch Green Building Council, n.d.). The different categories that are assessed within BREEAM are not all included to an equal extent. The distribution of the weighting factors is based on the TBL principle where a balance is found between the aspects (BREEAM NL, n.d.). When BREEAM is chosen, the assessment and certification will be carried out by a third party (Dutch Green Building Council, n.d.). The assessment will therefore not be carried out by the client/contractor itself. The advantage of this is that the assessment is reliable, but the disadvantage may be that the client/operator is not in control.

WELL

International WELL Building Institute (IWBI) is a global company that provides a seal of approval that measures and monitors health in buildings. WELL aims to make buildings healthier, resulting in a better living environment for users. This could lead to higher productivity and lower absences due to illness (Dutch Green Building Council, n.d.). To achieve this WELL provides a roadmap "For creating and certifying spaces that advance human health and well-being". WELL's assessment is made up of 10 core concepts that promote physical and mental health (Air, Water, Nourishment, Light, Movement, Thermal Comfort, Sound, Materials, Mind, and Community (WELL, 2021)). Each core concept is further elaborated in detail in subcategories, each with its own goals. For example, the Air component already has four preconditions and 10 possible optimisations (WELL, 2021).

In total, there are 24 preconditions requirements and 97 optimisations available (WELL, 2021). In a perfect situation, a score of 100 can be achieved. The assessment of the standards for design interventions, operational protocols and company-wide practices are verified by an external party. WELL is widely applicable: from a single office to entire organisations (WELL, n.d.). Because WELL focuses on the promotion of health in buildings, this method does not initially seem suitable for measuring circularity.

LEED

LEED is an assessment method for determining the sustainability performance of buildings. LEED is developed by the U.S. Green Building Council (USGBC, member of the World Green Building Council (World Green Building Council, n.d.)). LEED makes it possible to certify new buildings, renovations, existing buildings and areas. Each of the certificates works with its own concepts and weightings. The assessment of the various certificates are expressed in the terms Certified, Silver, Gold and Platinum (Duurzaamheidscertificering, n.d.). LEED divides its activities into 8 parts, of which three are most relevant for this research: (1) Building Design and Construction (for new construction or major renovations, includes new construction and core & shell), (2) Interior Design and Construction (for complete interior fit-out project, includes commercial interiors and retail & hospitality), and (3) Building Operations and Maintenance (for existing buildings that are undergoing improvement work or little to no construction, includes: existing building such as schools, retail, hospitality, data centres and warehouses & distribution centres (LEED, n.d.).

Looking at the checklist of Building Design and Construction, it can be seen that the projects are evaluated on 8 parts (Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation, and Regional Priority). Each sub-category has a checklist in which an X number of points can be achieved. The number of points that can be scored is different for each subsector. For example, Schools can score 13 points for Materials and Resources, while Healthcare can score 19 points for the same item. The total score remains at 110 points through the different sector categories. The more points, the better the certificate label (Paladino Consulting LLC, 2019).

Similarities and differenced BREEAM, WELL, and LEED

When the above three methods are compared with each other, it can be seen that all three are aimed at improving sustainability. BREEAM, WELL and LEED all emphasise the importance of healthy buildings. All three also aim to improve the quality and health of the built environment. However, the methods differ mainly in their scope. Of the three methods, BREEAM focuses most on the building process. WELL and LEED focuses more on the well-being of the users. In Figure 4, the overlap between BREEAM and WELL and their scopes are clearly shown.

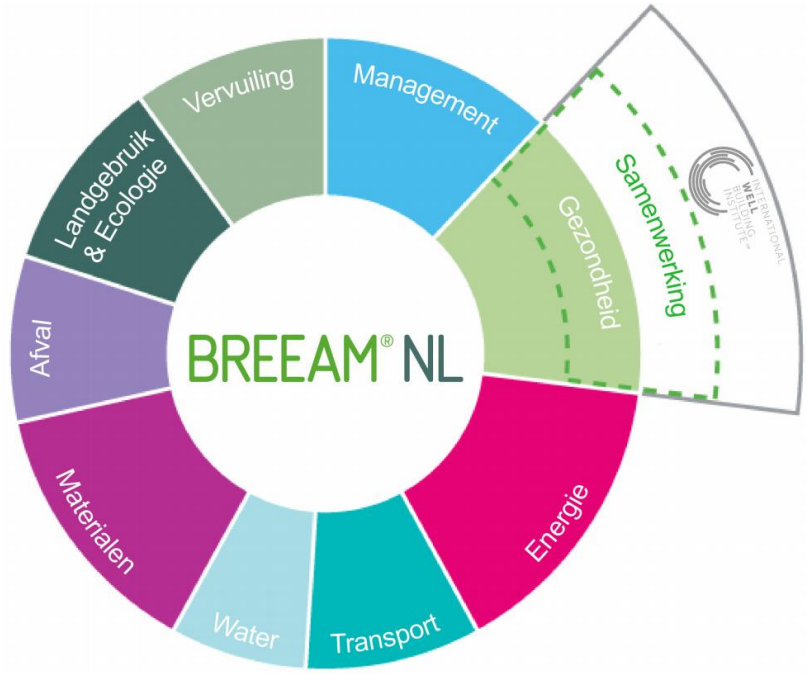


Figure 4 Scope BREEAM and WELL (Metz & Gabriëls, 2018).

Figure 5 shows that WELL focuses specifically and comprehensively on the health of the user while BREEAM focuses more explicitly on a broader aspect of sustainability in which health is a component. The overlap between BREEAM and WELL is therefore mainly in the promotion of health for the end-user. For example, the requirements concerning the building and installations, such as air quality, light and acoustics, are found in both methods. WELL furthermore addresses other health aspects such as nutrition and mental health. BREEAM, however, emphasises more on the energy consumption, ecological impact and waste flow of a building. BREEAM and WELL show that they can be complementary (Metz & Gabriëls, 2018).

LEED can be seen as an alternative for BREEAM. Although LEED was developed by a member of the World Green Building Council, just like the party behind the Dutch version of BREEAM (World Green Building Council, n.d.), both methods seem to be completely independent of each other. LEED-certified buildings are buildings designed to improve the performance of the subjects: "Energy savings, water efficiency, CO2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts" (Boston University, n.d.). It is therefore very similar to BREEAM, which has similar goals. The methods would technically correspond to 70-80% of each other.

However, the major difference between the two methods lies in the assessment method. With LEED, the project team (often with the help of a LEED Accredited Professional) is involved in the design and construction of the building. The team is responsible for the registration of the project, taking into account the requirements of the LEED standard and preparing the necessary documentation. Eventually, they will have to send the documentation to USGBC where the examination will take place (GBRI, 2020). With BREEAM, the process is different. There is an 'assessor' who assesses the project individually. This assessment is very formal and takes place twice. The first time is during the design phase of the project and the second time is around completion. The final report will be assessed on a sample basis by the DGBC and is periodically reviewed by the parent organisation BRE. After all, checks have been made, the assessor will issue the certificate (Dutch Green Building Council, n.d.; GBRI, 2020). It appears however that BREEAM is preferred in the Netherlands as the Dutch Green Building Council has adapted BREEAM for the Dutch market, instead of LEED.

2.8. Measuring circularity in the construction sector

Companies, governments and educational institutions have developed different methods to measure circularity, such as GPR Materiaal, One Click LCA and DuboCalc (Nationale Milieu Database n.d.). Ideally, a measurement method would give a uniform score (for example, between 1 and 100) in which a product/building scores in the area of circularity. However, most methods do not address the full scope of circularity, they usually aim at measuring the extent to which a product closes its 'resource loop'. This is mainly because the circular value of a product is often based on the life cycle analysis (LCA). As described in paragraph 2.5, the MPG is an aggregation of all LCAs of the materials used in a building. The MPG is therefore used by most measurement methods to measure circularity.

However, by using the LCA as the main input, the measurement method is limited mainly to the environmental impact (the planet aspect of the TBL principle), as they do not consider the overarching concept of circularity and sustainability. Therefore, the complete TBL principle is often skipped or forgotten. Another aspect that does not help is the fact that there is an overabundance of indicators to measure the three principles of the TBL (Corona et al., 2019). In short, it is not easy to link circular measurement methods to the overarching concept of sustainability.

Measurement methods allowed by the government

The government has not approved all assessment methods for calculating the environmental performance of buildings. Since all parties involved in the building process (e.g., investors, clients, architects, construction companies and users) have different interpretations of circular buildings, only a select number of methods have been approved by the government. The Foundation for Building Quality (SBK – Stichting Bouwkwaliteit) manages the determination of approved calculation instruments (Rijksoverheid, n.d.).

SBK is the governing organisation for managing and maintaining the determination method under which the National Environmental Database (NMD – Nationale Milieudatabase) falls. It is responsible for keeping the data supplied by industries and companies in the NMD up to date (Nationale Milieu Database, 2020c). An instrument must be approved by SBK to be used for the legally required calculation of a building's environmental performance (MPG – MilieuPrestatie Gebouwen). The foundation updates its assessment method based on practical experience, newly acquired insights, changes in products and material's processing and new or amended European standards. At the moment, there are five approved calculation tools; four for residential and non-residential buildings and one for infrastructure (Rijksoverheid, n.d.). However, the website referred to only considers four approved calculations for their latest determination method (3.0): GPR Materiaal, MPG Toetshulp and One Click LCA for residential and non-residential and DuboCalc for infrastructure (Nationale Milieu Database, n.d.). In this report, all mentioned methods of both sources are considered, with the ones of the latest approved methods as visible on Nationale Milieu Database (n.d.) underlined in **Bold**.

Measurement methods:

Residential and non-residential buildings:

- GPR Gebouw and **GPR Materiaal**: GPR Materiaal measures the sustainability of residential and non-residential buildings. The tool makes circular building measurable for developers. As a result, the effect of increasing sustainability on the return on investment can be made visible. The method also ensures that the aspect of sustainability can be included in tendering processes. It takes approximately two hours to enter new projects into the software. Existing buildings can be completed in between four and eight hours.
  GPR Gebouw is slightly more extensive than GPR Materiaal. Whereas GPR Materiaal calculates the environmental impact through material use via the MPG, GPR Gebouw calculated the broader concept of sustainability (W/E adviseurs, n.d.).

In GPR Gebouw, sustainability is assessed based on five themes: energy, environment, health, quality of use and future value. See Figure 4 for an overview in which also the TBL principle can be seen (W/E adviseurs, n.d.). GPR software relies upon the calculation of the sustainability score on input from Madaster. Madaster already functions as an online library in which materials and buildings are documented. Madaster provides information about the quality of materials, the financial value and the monetary value of the product (W/E, adviseurs n.d.).

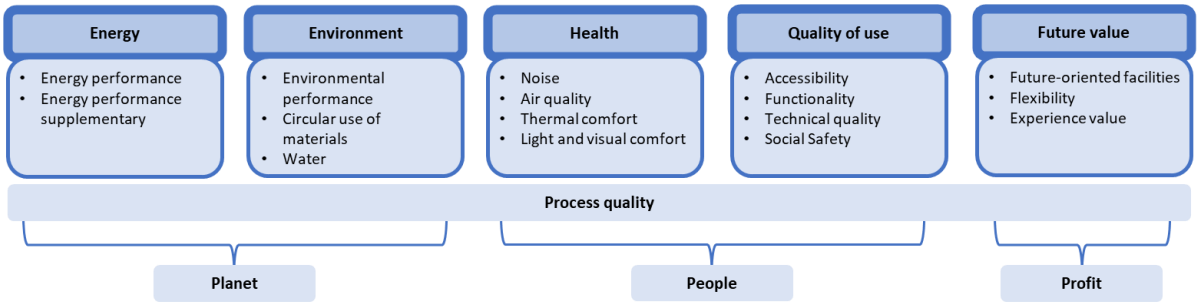


Figure 5 GPR Software: Sustainability in 5 themes (W/E adviseurs, n.d.).

- **MPG Toetshulp**: This method helps to provide early insight into the environmental performance of a building. It can display the performance in real-time because the module is linked to drawing programs (BIM models). The MPG Toetshulp tests the materials that it extracts from the BIM model against material properties from the NMD. It is therefore not necessary to transfer data; the MPG performance can be seen directly from the modelling programme (Bimpact, 2020).
- MPGCalc: The MPGCalc is a free software programme that offers the possibility to make an MPG calculation. In contrast to, for instance, MPG Toetshulp, the programme is not linked live to a drawing programme. It is therefore necessary to fill in the data manually. As MPGCalc is not approved in the latest determination method of the SBK, the method cannot be used for applications for environmental permits. The website describes that in the short term the software will not be adapted to the new calculation rules from the determination method (DGMR Software B.V., n.d.).
- MRPI MPG software: MRPI MPG software is a free software programme that works in the same way as MPGCalc. The materials and quantities must be entered manually to arrive at an MPG score. Like MPGCalc, this method does not meet the latest requirements of the NMD. The website does not indicate whether an update is in development (MRPI, n.d.).
- **One Click LCA:** One Click LCA is a tool for making MPG calculations. This tool has been developed to serve as an important input for BREEAM, LEED and other certification methods (One Click LCA, n.d.). DGBC (the party responsible for the Dutch version of BREEAM) has integrated One Click LCA into BREEAM to be able to make the MPG calculation in a good and efficient way. The tool is integrated into the latest method of the NMD. It can link the tool to for example Excel, BIM or Revit files to determine the MPG (Dutch Green Building Council, n.d.). This basic method can be expanded with additional tools. For example, there is an addition that makes it possible to translate the life cycle assessment into life cycle costing to make the trade-off between cost optimisation and carbon emission (One Click LCA, n.d.). Another function offered by One Click LCA is that it makes it possible to measure circularity. In this way, different scenarios can be considered to arrive at the most circular option (One Click LCA, n.d.).

Infrastructure:

- **DuboCalc:** DuboCalc is a calculation tool used in the civil engineering sector. DuboCalc calculates the environmental impact (MPG) of a material, a building or a construction method and is linked to the latest approved methods of the NMD (DuboCalc, n.d.). The method was developed by Rijkswaterstaat (the executive agency of the Ministry of Infrastructure and the

Environment in the Netherlands) and is used as a quality criterion in tenders according to the best-value-for-money method. The lower the score, the more sustainable the project. A low score often also makes a positive contribution to CO2 reduction and achieving Rijkswaterstaat's goal of a circular economy by 2030 (DuboCalc, n.d.; Rijkswaterstaat, n.d.).

3. Case company

This chapter provides background information on how the study arose. In addition to the gap in the literature, Kleissen identified an area of research that is elaborated on below. In this chapter, the research scope is also elaborated.

3.1. Problem description

Previous research

In 2020, a preliminary study was carried out for this research. This study investigated the possibilities of setting sustainable/circular goals that correspond to Kleissen's stakeholders' interests. This is because the label #SustainableHousing was not structurally applied in projects: "Only occasionally and unorganised" (Galen, 2020). The previous research by Galen (2020), was used as the main input to find out the motivations of Kleissen's stakeholders to implement circularity.

This research stated that the main objective of sustainable and circular construction is to protect material sources. To expand on this, three sub-objectives are recognized; re-use materials when managing a construction project, design for disassembly when managing a construction project, and use circular material when managing a construction project. To achieve these objectives, stakeholders must be motivated to choose sustainable and circular construction. The research divided architects, contractors, and clients into three types of stakeholders. With the clients, the research made the distinction between residential, educational, and healthcare. Although some differences can be seen within the types of stakeholders and groups, overall, the five most important interests are:

- Aspect 1: The building fits the end-user
- Aspect 3: The building is future proof
- Aspect 6: The building is as energy efficient as possible, where required energy is locally and sustainably generated
- Aspect 13: The building needs minimal maintenance
- Aspect 4: Efficient cooperation with all parties

To implement sustainable and circular construction, it is advised to formulate sustainable and circular objectives that meet the corresponding interests between the stakeholders. In this way, stakeholders feel motivated to construct sustainable/circular. As a result, the main- and subobjectives of sustainable/circular construction are more likely to be achieved. However, to achieve this, the report advises Kleissen to change the working method. Changing the working method and formulating sustainable/circular objectives serve as ''The foundation of a more structural circular construction implementation'' (Galen, 2020).

Problem description: future steps necessary to take

Where previous research has mapped the interests of stakeholders and laid a foundation for the structural application of sustainable and circular construction, this research goes further. Kleissen is now aware of the interests of stakeholders but has difficulty making them measurable. To apply #HoudbareHuisvesting structurally, an unambiguous measuring method must be used among the stakeholders. Galen (2020) concluded that:

> Sustainable construction is one of the criteria that, most of the time, count in the assessment of the registrations of the parties during a tender. However, in none of Kleissen's construction projects' tender guidelines, specific circular construction criteria have been requested. Parties are asked for their ambition or interpretation of sustainable construction. Since the tender guidelines and project plan do not contain specific requirements, the external party is even after the agreement free to give its interpretation of sustainable construction. In the worst case, this could mean that the party decides not to give substance to sustainable construction after the agreement (pp. 24-25).

From this citation, the problem description dealt with in this study has already been described in concrete terms. To clarify this, here is an example of a common problem:

> When Kleissen must assess different construction companies for their tender, the different aspects of these tenders must be evaluated. Construction companies are not often assessed on the lowest price. Several aspects can be considered: price, planning, dealing with the environment, sustainability. Price can be assessed on value, planning can be assessed on duration, but for sustainability, there is yet no unambiguous way of assessing this. As a result, the various sustainability options proposed by the different construction companies cannot be unequivocally assessed against each other. As a result, the choice for 'best' tenderer in this respect can lead to a lack of understanding. After all, every construction company can interpret sustainability differently.

A solution to this problem is that Kleissen clarifies during the tender process which measuring method they will use to assess sustainability. Via this way, the assessment will be objectively, and stakeholders are aware of what to expect. However, this seems easier than it is. Kleissen does not yet see that companies in the construction industry consistently use a certain method of measuring sustainability. Sustainable solutions are not structurally applied, partly because there is no clear method for assessing sustainability.

3.2. Research objective

As a result of the above problem description, this research aims to investigate the most appropriate measurement methods for Kleissen and its stakeholders. It is important to see how these methods are built up; what do they calculate, what do they not calculate, how does the report look like that comes out of the calculation, is the method prepared to quickly add future developments to the database. It is important to investigate whether the methods meet the requirements of Kleissen and its stakeholders. The accessibility of the method must be considered. If architects and/or construction companies must purchase expensive and long-term licences to 'measure' their offerings, it will not be a workable method. After all, the method must be usable for Kleissen and its stakeholders.

3.3. Research questions

From the above information, the main research question was formulated. To answer this question, three subquestions were formulated, with their corresponding subsections. Figure 6 shows a schematic representation of all related topics. The following subquestions have been developed:

> Question 1: What is the current sustainable and circular situation of Kleissen?
>
> Question 2: What are the requirements of Kleissen and its stakeholders when measuring circularity?
>
> Question 3: What are the relevant and future proof measurement methods to measure circularity for Kleissen and its stakeholders?

To conclude the main research question, several sub-questions must first be answered. The first of these is sub-question 1, which examines the current situation. This question analyses the literature around (mainly) sustainability. In addition, Kleissen's current sustainability and circularity activities will be examined. The second sub-question looks at the requirements Kleissen and their stakeholders have about measuring sustainability in line with the literature around measurement methods for sustainability. The final sub-question compares the possible measurement methods with the requirements set by Kleissen and its stakeholders (sub-question 2). This comparison is made through an internal brainstorming session and external interviews with sustainability experts in the construction sector. The result will be a decision on which measurement method best suits Kleissen. See Figure 6 for visualisation.

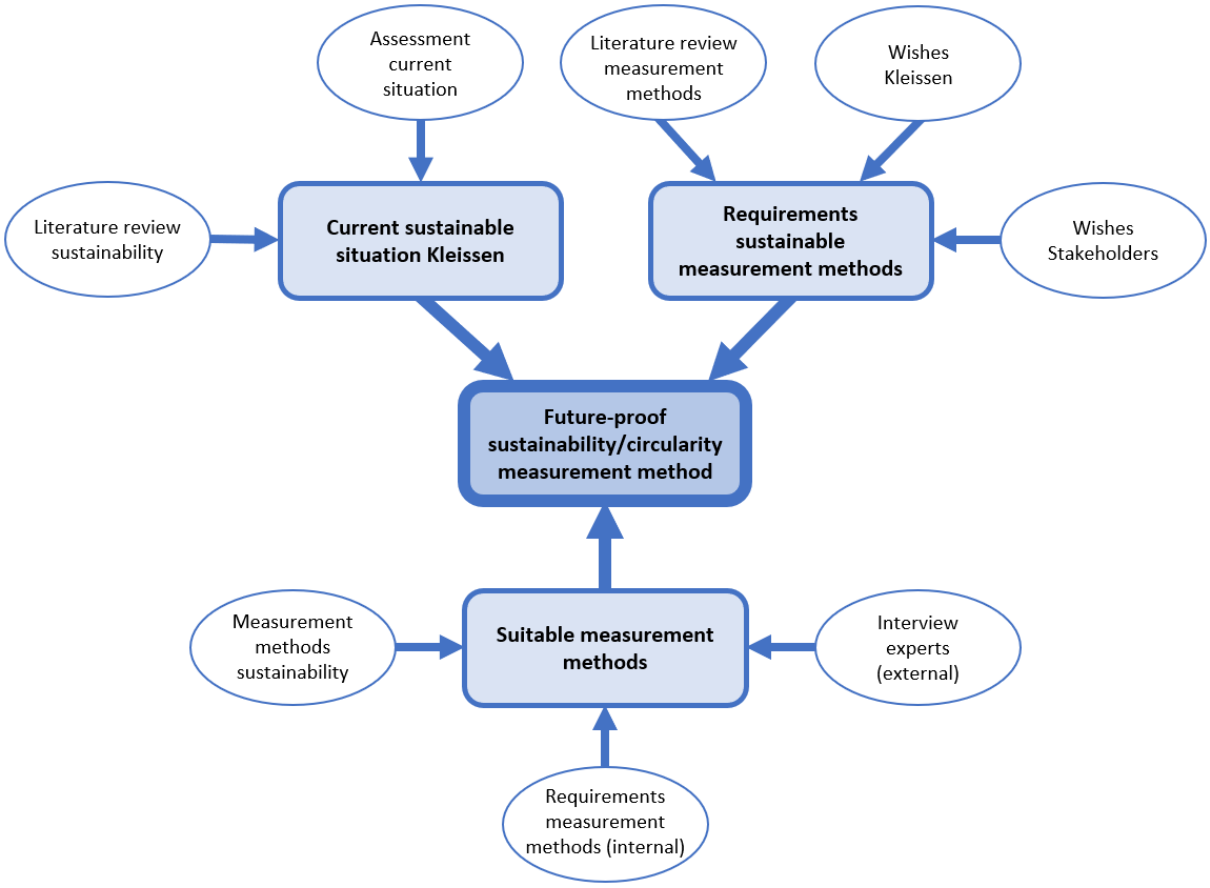


Figure 6 Research topics.

3.4. Research scope

To ensure that the final research question can be answered, the research scope within which the research is carried out is explained. It also gives a good idea of the environment in which the research is situated. For Kleissen, the chosen model to calculate sustainability must be widely applicable. Therefore, it is important to know the interests of the most prominent stakeholders are; Kleissen itself, its clients, construction companies and architects. Because the types of customers/clients residential, educational, and healthcare were investigated in previous research, these groups will also be distinguished in this study. `

Since Kleissen mainly works on Dutch soil, it is important to consider methods approved by SBK (Stichting Bouwkwaliteit: foundation for building quality) to be used for the legally required MPG calculation. However, Kleissen has indicated that it does not only focus on the methods approved by SBK. Therefore, multiple measurement methods will be considered. However, the measuring methods that this research will look at will mainly focus on the 'material side'. As the literature has shown, sustainability in the construction sector often distinguishes between the aspects of energy and material use. For the energy aspect, the Dutch government has set up BENG to establish minimum requirements. Still, the government has not set any firm requirements for the materials used (choice of materials, circularity, dismantlability, etc.). Because there is potentially more sustainability in the area of material use, the study focuses mainly on measurement methods that stand out in this respect. See Figure 7 for visualisation.

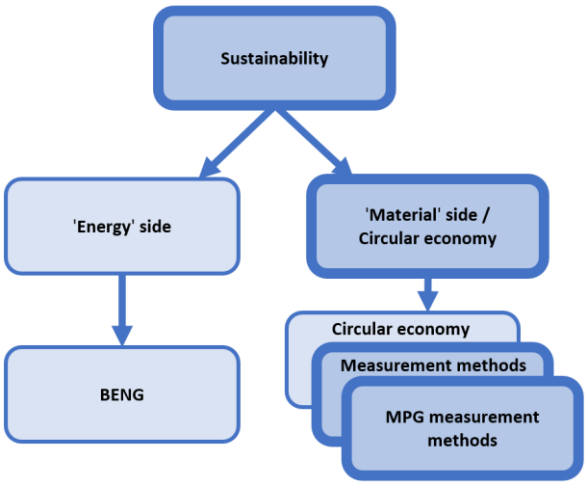


Figure 7 Research scope.

A further specification of the research scope focuses on the building process. To help the customer choose and set sustainability targets, it is helpful that Kleissen is involved in the early stages of the construction process. Via this way, Kleissen can help the client make the best (sustainable) choices. After all, the main objective of this research is to look for a suitable measuring instrument to compare different sustainable solutions that can come from different construction companies. Therefore important for Kleissen to be involved in the construction process before the price and contract are determined. In this way, Kleissen can act as a mediator between the client and the contractors. See Figure 8 for a visualisation.

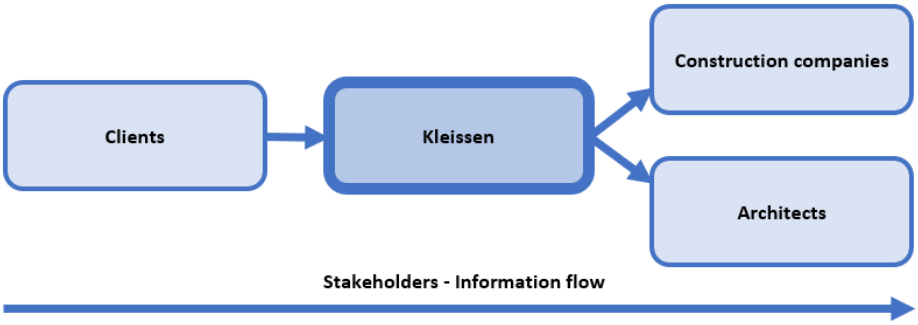


Figure 8 Stakeholders and information flow.

The final scope of the study is the industry. As mentioned above, the GPR measurement methods focus on residential and non-residential buildings or infrastructure projects. Because Kleissen is active in the first specialisation, measuring methods for circularity in infrastructure (such as DuboCalc) will not be included in this research.

4. Research methodology

The methodological chapter elaborates on the research method. It substantiates the type of research carried out, how the data is collected and how this data is analysed.

4.1. Qualitative research

A qualitative research strategy was chosen as a suitable measurement method for this research to gain insight into important issues (Baarda, 2014). To answer the questions put forth for this single case study, qualitative inductive research has been deemed as the most appropriate choice. Creswell and Poth (2018) argue that qualitative studies connect well with subjects that have not been studied much before. According to Creswell and Creswell (2018), examples of typical qualitative data collection include observations, interviews, documents (journals, personal documents, memos, blogs, biographies) and digital audio-visual materials. The strategy of the research is partly determined by the design of the sub-questions. Each sub-question requires a particular research approach to arrive at the correct answer. Therefore, how an answer is obtained for each sub-question will be described below. It will also be mentioned why that specific method was chosen.

Research question 1: What is the current sustainable and circular situation of Kleissen?

For the first research question, it is important to examine the literature around sustainability and circularity. For this purpose, this research looks at sustainability and circularity activities in general and particular in the construction sector. By studying the literature, an indicative picture can be created. Furthermore, it is important to understand Kleissen's current situation. The organisation will be examined by carrying a single case study (see Paragraph 4.2). This will include the role of Kleissen within the construction process, the label #HoudbareHuisting and the different types of stakeholders.

Research question 2: What are the requirements of Kleissen and its stakeholder when measuring circularity?

The second research question looks at the requirements of Kleissen and its stakeholders in the field of sustainability and, more specifically, circularity. This sub-question also uses the Kleissen case study for input. Using this case study, the research determines the wishes of Kleissen and its stakeholders. For Kleissen's requirements, a brainstorming session with Kleissen's circular working group will be held. For the interests of stakeholders, the previous research by Galen (2020) will also be used for input.

Research question 3: What are the relevant and future proof measurement methods to measure circularity for Kleissen and its stakeholders?

The third research question is closely related to the overall idea for doing this research: the final answer to the main research question. To answer this question, possible measuring methods will be examined. To find out which measuring instrument is best suited for Kleissen and its stakeholders, interviews will be held. This will take place both internally, within Kleissen, and externally. With the information gained from sub-questions one and two, information is gained in the different measurement methods by conducting interviews with external respondents. The specific details of the methods are then discussed with the respondents.

4.2. Single Case Study

The first research method that is used in this thesis is a case study. To get more information about Kleissen, this method will help to gather information. Case study research researches a particular phenomenon through an in-depth narrow-scoped study (Steenhuis & Bruijn, 2006). Creswell and Poth (2018) define case studies as:

> A qualitative approach in which the investigator explores a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audiovisual

material, and documents and reports), and reports a case description and case themes. The unit of analysis in the case study might be multiple cases (a multisite study) or a single case (a within-site study) (p. 153).

Because this research is focused on Kleissen, a single case study is chosen. Single case studies aim to understand the dynamics present within a single firm (Eisenhardt, 1989). This single case study provides qualitative data giving a rich description of local contexts that can derive useful explanations (Miles and Huberman, 1984). According to Yin (2018), a case study is a perfect choice when the goal is to explain 'how' and 'why' questions as they elaborate on the description of the topic. As a result, information will be obtained for the first two sub-questions. Creswell and Poth (2018) state that interviews are one of the most used sources of data in qualitative case studies. Therefore, E. Knaap (Project manager of the label #HoudbareHuisvesting) was interviewed (06-05-2021) to gain more information about Kleissen. A second data collection method is used as an in-depth study of previous research (see paragraph 0). Core themes that this case study has its focus on are:

- Their label for sustainable construction #HoudbareHuisvesting.
- Kleissen's workflow and its task within the construction process.
- Kleissen's stakeholders and their drivers towards sustainable and circular construction.
- Kleissen's vision towards sustainability and what Kleissen expectations towards the future of sustainable and circular construction.
- The outcome of the research.

4.3. Interviews

The second research method aims at answering the third research question. To answer this question, interviews will be performed with external experts in the field of sustainability. The study aims to discuss and evaluate with experts the possible measurement methods of sustainability. Verhoeven (2018) distinguishes three types of interviews: unstructured, semi-structured, and structured interviews. Because Kleissen is not well enough known in the field of sustainability/circularity measurement, a semi-structured interview was chosen. This 'middle way' means that the interviewer has a questionnaire with both open and closed questions. However, this option also offers the possibility to respond to the situation per interview by asking different questions; after all, every expert is different and has differing knowledge (Bryman & Bell, 2011; Verhoeven, 2018).

The questions asked to the experts were drawn up after the literature research and the case study had been completed. In this way, the most specific questions can be asked as preliminary research gives the researcher a better orientation to the subject and asks more specific questions (Verhoeven, 2018). The interview questions were written together with Kleissen's circular working group employees and can be found in Appendix 2.

Specification measurement methods

Because this research has examined numerous measurement methods in the literature review, a shortlist will be made before the interviews with the experts take place. This shortlist will also be made together with Kleissen's circular working group. The shortlist filters out the measurement methods that can be considered irrelevant without the input of external experts. It allows focussing more precisely on the remaining measurement methods in the interviews.

4.3.1. Preparations

Semi-structured interviews questions

The interviews are conducted in a semi-structured format. The interview questions that have been drafted will follow the red line through the interview, although it is possible to deviate from this, as described by Bryman and Bell (2011):

> Questions may not follow on exactly in the way outlined on the schedule. Questions that are not included in the guide may be asked as the interviewer picks up on things said by interviewees. But, by and large, all the questions will be asked and a similar wording will be used from interviewee to interviewee (p. 467).

The questions were not always asked in the same order. The questions were asked in such a way that the conversation could always proceed smoothly. The researcher did not just ask questions prepared in advance to tap into the knowledge that the respondent had (Bryman & Bell, 2015). The interviews always started the same way, with a short introduction followed by questions about the MPG. From this section, the second, more substantive part of the interview began. This second, more substantive part, focused on the specific knowledge the respondent in question had about a measurement methodology. Figure 9 shows an overview of the steps taken to arrive at the interview questions. Feedback was received from both E. Knaap and Kleissen's circular working group.

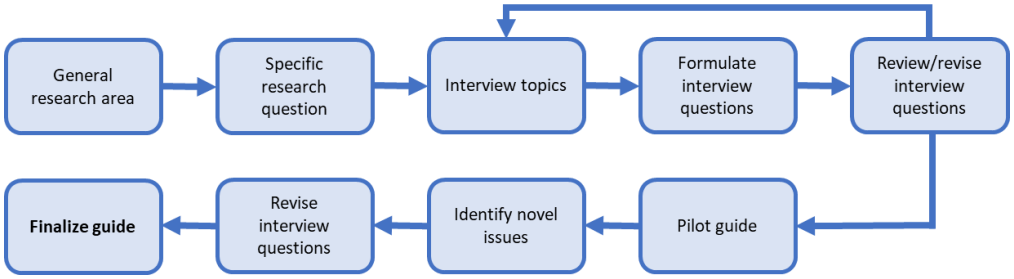


Figure 9 Formulating questions for an interview guide (Bryman & Bell, 2011).

In addition to the interviews, further information was found through the internet, email contact with respondents and contact persons of the companies that developed the specific measurement method and test licenses of various measurement methods. By combining and comparing different sources (triangulation), validity was increased (Bryman & Bell, 2011; Yin, 2018).

Sampling

Eight interviews were held who all were gathered using nonprobability sampling (techniques in which samples are selected in some way not suggested by probability theory). The exact sampling method used is a combination of convenience sampling and purposive sampling. Convenience in the sense that the researcher relies on the available sources that Kleissen has. The first interviews that were conducted came from Kleissen's own database/existing connections. Purposive sampling in the sense that the researcher relies on assumptions that the interviewee brings a certain amount of knowledge and is therefore valuable for the research (Babbie, 2014; Bryman & Bell, 2011; Creswell & Poth, 2018).

New participants were added to the study if further information occurred. When data saturation were reached, and the scarcity of new relevant information increases, the search for new participants is stopped (Creswell & Creswell, 2018; Creswell & Poth, 2018). A total of two mail rounds were held to find respondents. After the second mail round, it became clear that sufficient information had been gathered and saturation was reached.

Ethics

Before the interviews took place, respondents were contacted by email where the research was briefly described and the purpose of the interview was explained. In the request for participation it was mentioned why the person is suitable for the study, and what is expected from the person (what questions will be asked, how long will the interview take, where will the interview take place, etc.). In addition, the person in question will have the opportunity to ask additional questions before the interview should there be any ambiguities. At the same time, it was stated that participation in the study is voluntary and that the respondent could withdraw at any time, before, during or after the interview. Participation in the study will be anonymous unless the interviewee agrees otherwise.

According to the interviewee's wishes, the interview was done online or face-to-face (regarding Covid-19). Permission to record the interview was asked in advance so that a summary could more easily be made afterwards. This summary is available to the interviewee, who can correct any misconceptions made. All interviews done via Microsoft Teams were transcribed. Of the interview done via telephone, a summary was made.

4.3.2. Data collection - interviews

The interviews conducted have a semi-structured, one-on-one format. The questions posed to the participant were developed in cooperation with Kleissen's circular working group. The researcher came up with a first draft, after which these were improved and finalized in a brainstorming session with Kleissen's circular working group (29-04-2021). Candidates were given the option of conducting the interview face-to-face or via Microsoft Teams. All respondents chose the second option apart from Respondent E (who asked to do the interview through the telephone) and were completed in May and June of 2021. All interviews were conducted in Dutch. See Table 4 for a final list of all persons interviewed, including the type of company, size, the position of the interviewed participant, date of interview and location. The size of the company is based on guidelines formed by the European Commission: Micro-sized (<10 staff headcount), Small-sized (<50 staff headcount) and Medium-sized (<250 staff headcount) (European Commission, n.d.). Companies bigger than 250 headcounts are labelled as Big in this research.

Table 4 List of participants interviews.

Resp.	Type of company	Company Size	Position	Date	Duration	Location
A	Building consultant	Small	Consultant	05-05-2021	37 min	Teams
B	Building cooperative	Medium	Advisor (1x), Project Leader (2x)	06-05-2021	32 min	Teams
C	Building consultant	Micro	Project Leader / Director	12-05-2021	41 min	Teams
D	Consulting and engineering	Medium	Partner / Consultant	25-05-2021	58 min	Teams
E	Software consultant	Micro	Director	31-05-2021	60 min	Telephone
F	Consulting and engineering	Medium	Mediator / Specialist	03-06-2021	59 min	Teams
G	Construction company	Big*	Advisor Energy and Sustainability	25-05-2021	43 min	Teams
H	Consulting, management and development	Small	Consultant	28-05-2021	36 min	Teams

Internal validity

Logically, not every person has sufficient knowledge to be able to add new insights to the research. Therefore, the research specifically filtered respondents through nonprobability sampling. The respondents had to be active within the construction sector and have a position that dealt with the contents of the study. Many of the respondents turned out to have a consultancy role in the field of sustainability and circularity within the construction sector. The eight companies interviewed were working daily with the various measurement methods covered in the study. A combination of small, medium-sized and large companies gave a good picture of how different types of companies dealt with the circularity conundrum. By thinking carefully about the respondents to be selected, the effect of irrelevant (i.e. unwanted) variables was reduced.

4.3.3. Coding and themes

Data generated from the interviews were coded using Gioia, Corley, and Hamilton (2013) theory. In this way, in-vivo codes were translated into initial concepts (first-order concepts), and overarching themes (second-order themes) into aggregated dimensions. With first-order concepts, the literal statements of the interviewee (in-vivo codes) are roughly summarised in global categories. In second-order themes, these global categories are carefully grouped into a theoretical realm. It is the bridging of concepts to an overarching dimension that the interview attempts to explore. This overarching dimension is also called the Aggregate Dimension (Gioia et al., 2013). The interviews were transcribed to recognise the overarching themes and codes (Bryman & Bell, 2011). A part of the coding scheme can be found in Appendix 3.

5. Findings

This chapter describes the findings. It will summarize the information received from the case study and the interviews.

5.1. Findings research question 1

Research question 1: What is the current sustainable and circular situation of Kleissen?

The first sub-question focuses on the current situation at Kleissen sustainability. First, existing available documents were examined; the main input is Kleissen's vision document on circularity (Appendix 4), Kleissen's vision document #HoudbareHuisvesting (Appendix 5) and previous research. The circular vision document gives a comprehensive picture of Kleissen's view on circularity. This vision document describes various concepts, such as circularity, materials passport, cradle-to-cradle, bio-based-materials, primary raw materials and Life Cycle Analysis (LCA). The document also indicates looking at a variant of the 'Levels of Circularity' model as described by Potting et al. (2017) and Reike, Vermeulen, and Witjes (2018).

Kleissen distinguishes the following Re-principles (translated from Appendix 4):

Table 5 Re-principles Kleissen.

Re-fuse	Refuse/prevent the use of raw materials.
Re-think	Rethink/think differently, so that products are used more intensively by, for example, sharing it or using multifunctional products.
Re-duce	Reduce the use of raw materials.
Re-design	Redesign with an eye to circularity.
Re-use	1 to 1 reuse. Demolish products in a circular way and reuse them again. Second hand.
Re-pair	After small-scale maintenance and/or repair, products can be reinstated.
Re-furbish	Refurbish a product and then it can be reused as a second hand.
Re-manufacture	Reuse of raw materials after major processing to come back to the same product.
Re-purpose	Reusing products but for a different purpose. Products that no longer meet the requirements of what they were made for can still fulfil another goal.
Re-cycle (downcycle and upcycle)	In recycling, products and materials are separated into separate raw materials. New products are made from these raw materials, often with large processing. When this comes at the expense of the quality (regardless of the energy needed for this procedure) we talk about downcycling. When the end product has a higher value than recycling, we talk about upcycling.
Re-cover	Regaining energy.

In contrast to Potting et al. (2017), Kleissen adds the step of Re-design and that focus on the Level of Circularity model specifically on the building sector. During the interview with E. Knaap (06-05-2021), it became clear that Re-design emphasizes that the design of a building should specifically consider the end of its life span. This is because the design determines the extent to which the building is circular. In addition, at that point, it can be examined at which step of the above 'ladder' certain materials can be placed at the end of the building's life. Materials that are on a higher step should have a better circular score. In summary, Kleissen's vision of a circular construction (process) is (translated from Appendix 4):

> Circular construction means that we consciously think about housing questions (re-fuse; perhaps no need for new housing). We also look at what we already have (re-use; the existing buildings) what materials we have (how can we re-use them) what other materials we are going to add and how we are going to add them.

This vision document gives an idea of Kleissen's goal but does not say to what extent it is currently implementing circularity. The previous research, carried out by Galen (2020), described several concrete learning points. The most relevant for this study are briefly described below:

- Apply circularity objectives in the tender requests for architects and contractors: when asking for, for example, different construction companies, set concrete (assessment) objectives/guidelines to steer towards circularity
- During the construction project, check and manage the achievement of the circularity objectives: when the stakeholders are established, make sure that at each stage of the construction process in the transition document a part is assigned to the drawn up circular goals. In this way, it can be checked whether the circular ambition of the customer is achieved.

During the interview with E. Knaap, it became clear that one recommendation had not yet been implemented in Kleissen's standard working methods. The first action point is the main basis for this research and therefore cannot yet have been implemented. For the second action point, E. Knaap indicated that the advice had been implemented in the transition document. This second action point is solved by dedicating a paragraph to circularity in each phase transition document. However, with this recommendation being implemented, it is still difficult to secure circularity during the various phases of the construction process. Interviews with experts will show whether different measuring methods during different phases of the design process can steer towards circularity.

In addition to the vision document on circularity, Kleissen has also drawn up a vision document on #SustainableHousing. In this document, Kleissen makes a distinction between three streams: ecological sustainability (Ecologische Duurzaamheid), social sustainability (Sociale Duurzaamheid) and dynamic sustainability (Dynamische Duurzaamheid), as shown in Figure 10. Broadly speaking, these three pillars can be traced back to the TBL principle.

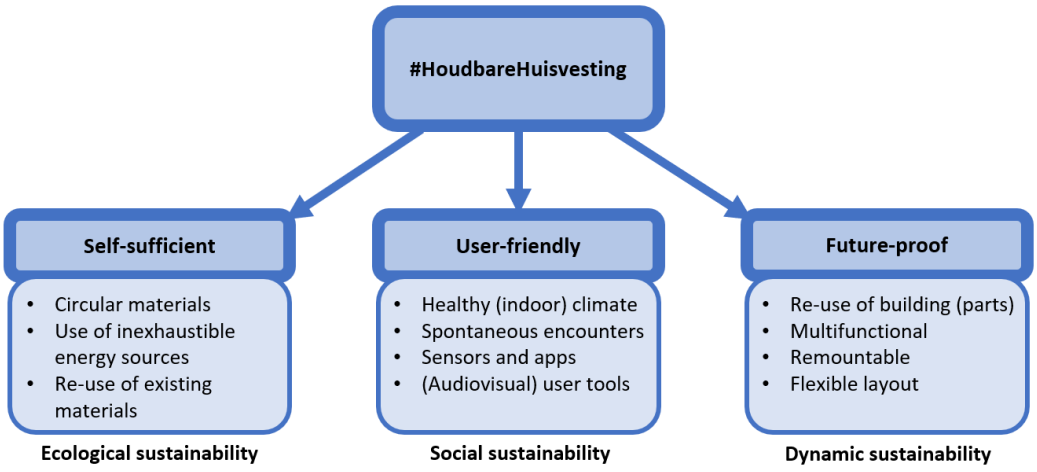


Figure 10 #HoudbareHuisvesting.

- Ecological sustainability deals with self-sufficient housing. It strives for housing that is not a burden on the earth but is part of the circular economy. Ecological sustainability is mainly linked to the planet aspect. Both ecological sustainability and the planet focus on the natural environment in which the company is located. It focuses on renewable resources and the need to promote circularity. Concrete measurement points that can be derived from the vision document are reducing Life Cycle Costs and promoting materials with a low CO-2 impact.
- Social sustainability aims at user-friendliness. The goal is to create housing that supports and stimulates the user to get the best out of themselves, which corresponds to the people aspect. Kleissen focuses on a healthy (indoor) climate, sensors and apps and user resources. It does not seem to steer specifically on circularity, as it not specifically mentions characteristics that come back in the theory of circularity.

- Dynamic sustainability focuses mainly on the future-proofing of housing. It strives to preserve the value of the raw materials used to be reused at a minimal loss of value (within the circular economy). Kleissen's vision on dynamic sustainability seems to correspond with two aspects of the TBL principle. Namely planet and profit. In the interview with E. Knaap, this proved to be accurate. According to her, dynamic sustainability mainly affects the future-proofing of a building. Materials must be easy to reuse. This is not only good for the planet but also financial sustainability (profit). A demountable building will be worth more at the end of its life than a building that cannot be disassembled. In this way, building components can remain in a smaller circular 'loop' and have less impact on the planet. For profit, this naturally provides an advantage in a higher residual value of a building. She gives the example that banks are prepared to reduce the interest on a mortgage if a building owner can demonstrate that the building can be properly disassembled at the end of its lifecycle. After all, a reusable building to a large(r) degree has a higher residual value than a 'traditional' building.

In general, #HoudbareHuisvesting corresponds to the TBL principle. When the link between the TBL principle and legislation on sustainable construction is made, a distinction can be made in sustainability on the 'Material' side and sustainability on the 'Energy' side. Although both aspects are mainly linked to the aspect planet, this research has the scope entirely on the 'Material' side. The material side is strongly linked to circularity.

Laws and regulations surrounding the material side mainly link to the MPG. The MPG aims to create a sustainable construction economy by promoting circularity. The material side and the MPG are in theory linked to the planet aspect and the profit aspect as described above by Bolívar (2017) and Hart (1997). The link between circularity and the people aspect is only briefly described in theory, as circularity strives for 'social equity'. Consulted sources emphasise the aim of circularity to create a system that minimizes the consumption of materials. This should be done by slowing down, closing and reducing the material and energy loop (Geissdoerfer, 2017). Therefore, measuring circularity primarily focuses on the planet aspect of the TBL principle (Corona, 2019).

From the label #HoudbareHuisvesting point of view, no concrete measuring points can be obtained that link people/social sustainability to circularity/MPG. A cautious conclusion can be that circularity in construction has the strongest connection with the aspect planet, an average connection with profit and a none too weak connection with people, see Figure 11, an overview and insight. Interviews with experts checked whether this model is also seen in practice. Sub-question 3 goes into this in more detail and tests the model.

In summary, Kleissen's vision of circularity focuses mainly on the elaboration of core concepts that surround the definition of circularity. How Kleissen translates this in concrete terms is not as concrete as to how sustainability is translated. This is done through the label #HoudbareHuisvesting and offers concrete examples that can be linked to the TBL principle.

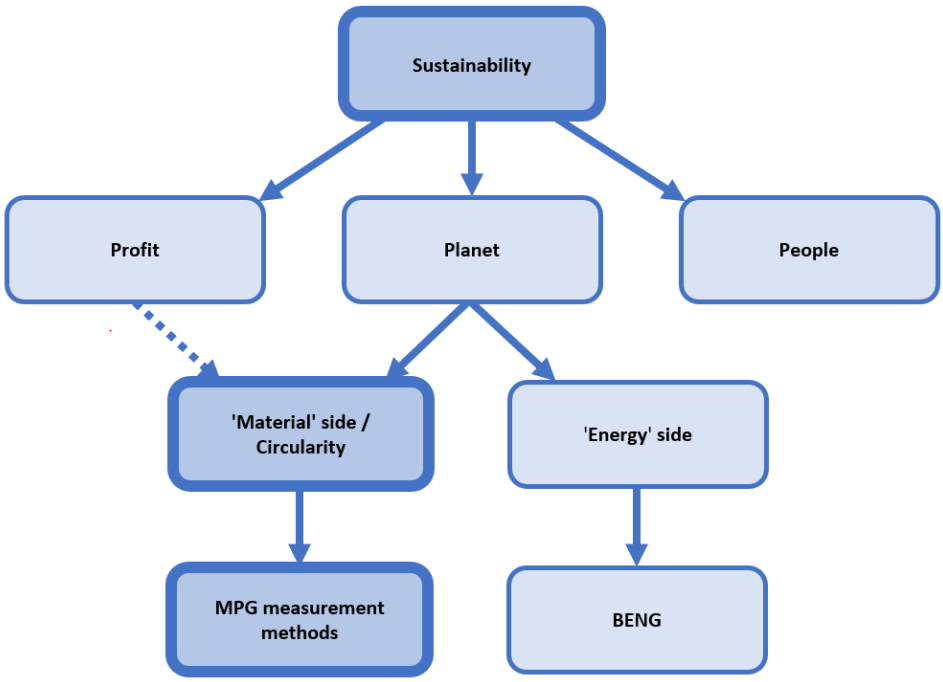


Figure 11 Overview sub-question 1, the current situation.

5.2. Findings research question 2

Research question 2: What are the requirements of Kleissen and its stakeholder when measuring circularity?

The second sub-question answered by this research focuses on Kleissen's and its stakeholders' requirements for measuring circularity. The motivations of stakeholders are an important input for Kleissen to choose for a particular measurement method. The previous research distinguished between the stakeholders: architects, construction companies and customers. Customers are subdivided into residential, educational and care services. A summary of the results of this previous study is already provided in section 3.1. Problem description. However, these results can also be elaborated per target group. For this survey, the results of the customers are of interest:

Table 6 Most important aspects for clients.

Presence in top 5 most important aspects for the client:	Residential	Educational	Health Care
Aspect 1: The building fits the end-user	Yes	Yes	Yes
Aspect 2: The building fits in its environment as well as possible	-	-	Yes
Aspect 3: The building is future-proof	Yes	Yes	Yes
Aspect 6: The building is as energy-efficient as possible, where required energy is locally and sustainably generated	Yes	Yes	Yes
Aspect 9: Focus on the detachability of the building	Yes	-	-
Aspect 11: Not exceeding the total budget of the project when realizing the building	-	-	Yes
Aspect 12: The task budget of the construction project should not be exceeded	-	Yes	-
Aspect 13: The building needs minimal maintenance	Yes	Yes	-

If the link is made from these aspects to the measurement of circularity, then Aspect 1, 2, 6, 11 and 12 are not possible or relevant. Aspect 1 and 2 are not specifically aimed at circularity because they have more to do with the layout of the building and less with the choice of materials. Aspect 1 is the only aspect that, as it considers the wishes of the end-user, has a connection with the people aspect. Aspect 6 focuses mainly on the 'energy' side and is therefore not relevant to the scope of this

study and Aspects 11 and 12 focus on the financial side of the building process. Although it is relevant to assess the financial consequences of a circular measure, it is not a core competence that a measurement method should have. After all, these consequences would be straightforward to compare in a calculation.

Aspects 3, 9, and 13 are relevant to include in the choice of a measurement method. Aspect 3, which looks at the future durability of a building, could be measured by the residual value of used materials. Aspect 9, which looks at the detachability of a building, can be measured by looking at detachability. How are building components attached; dry connection, wet connection, etc. Aspect 13 looks at the amount of maintenance a building has. Interviews with experts should show whether different measurement methods take this aspect into account.

A brainstorming session with Kleissen's working group on circularity (29-04-2021) gave a good idea of which aspects the measuring methods should be assessed for. During this brainstorming session, the assessment components were discussed. From the interview with E. Knaap, Galen's (2020) previous research and Kleissen's available vision documents, functions emerged that are particularly important for the measurement methods. The brainstorming session focused on practical issues surrounding the measurement methods. The following components came to light:

- Price: what are the costs of using the software?
- Ease of use: how long does it take to fill in the method? Which persons can use the method? Is it necessary to take a training course? Can different calculations/options be easily compared? Can other parties investigate the calculation?
- Structure: which elements does the measurement method consist of? How many gradations are there?
- How specific: to which building elements can the method be applied (element level, product level)?
- Reliability: Is the method always the same when completed by someone else?
- Future-proof: Does the method keep up with market developments?

Combined with the answers to sub-question 1, it can be stated that the following assessment aspects are of particular importance for the assessment of measurement methods to measure circularity:

Functions that the measurement method must fulfil in terms of content:

- MPG: given that legislation and regulations adhere to the MPG guidelines for measuring sustainability/circularity, it is wise to check whether the measuring method to be compared complies with the MPG. Given the fact that the MPG is relatively new, it can be expected that not every method includes this in its method. It is also interesting to look at how the MPG is calculated.
- Detachability: theoretically, the MPG focuses on the environmental impact of a specific product. It is also interesting to see whether the measurement method takes account of the detachability of building components, as clients from the previous research thought this was an important aspect. Disassembly refers to the ease with which building components can be disassembled. For example, bolting a wall to the floor instead of glueing it.
- Material processing: It is interesting to find out whether the measurement method and/or MPG takes account of the processing involved in the product. A simple example is a comparison between a wooden window frame and an aluminium window frame. In theory, a wooden window frame seems more sustainable, as wood is a more renewable material than aluminium. However, does the measurement method also consider annual maintenance and residual value? A wooden window frame needs to be painted every few years, while an aluminium window frame does not need to be (re-)painted. At the end of the life span; is a wooden or an aluminium window frame easier to re-use?

Assessment: In addition to content matters, practical matters should also be considered to compare the measurement methods:

- Price: what are the costs of the measurement method? Does a licence holder have to pay a certain amount each month, does the licence holder pay per project or is the method free to use?
- Ease of use: can the measurement method be completed by anyone with a certain level of knowledge of construction, or does this person need to have a certificate? What about the link with other programmes: can the measurement method be linked to a BIM model, or does everything have to be converted manually? How much time does it take to complete a project, is it possible to compare different options with each other and to what extent is the outcome visible? Is there only a total score, or is there an overview for each building component?
- SBK/NMD: Legislation and regulations have indicated that an MPG calculation is approved if it is calculated by a measuring instrument validated by the SBK/NMD.

In summary, to assess measuring methods to measure circularity, a distinction is made between two aspects. The first aspect, the functional requirements, looks at which minimum technical requirements the method must meet. It looks at the MPG, detachability and the processing of materials. The second aspect, the practical requirements, looks at the price, the ease of use and whether the method complies with laws and regulations.

5.3. Findings research question 3

Research question 3: What are the relevant and future proof measurement methods to measure circularity for Kleissen and its stakeholders?

Below is a summarised version of the information obtained mainly from the interviews to answer research question 3. A full elaboration can be found in Appendix 6. This appendix contains quotes given by the respondents. Comparisons between the various methods are made on the basis of these quotes. Appendix 6 shows how the various respondents agree or disagree with each other's views. The reliability of the research was increased by comparing the various outcomes of the interviews with each other.

MPG

Even before the study was carried out, Kleissen indicated that they did not expect the MPG as a comprehensive way of measuring a circular building economy. The interviews showed that all respondents agreed with this. Various arguments were mentioned, the main ones being:

- The MPG does not go far enough
- The database is too small
- The MPG does not include CO-2 emissions

Most respondents also stated that the MPG focuses only on the environmental impact of the building and takes limited account of, for example, the detachability. However, another respondent stated that a new update of the MPG ensures that detachability is included in the MPG calculation, but that there are still some specifics attached to this. The new update does, however, make it possible to use an MPG to score better on a particular design strategy, such as detachable or biobased construction, because a distinction is made between four phases. Thus, the MPG should be able to measure the effect of a particular design strategy, although it does appear to be difficult to design in a specific way using the MPG.

MPG measurement methods

There are three main ways in which circularity can be measured. One of these is using the MPG. The MPG is the only one of the three main types that are required by legislation. It must be submitted

when applying for permits. The MPG has three validated methods: GPR Materiaal, One Click LCA and MPG Toetshulp. Unvalidated measurement methods, the MPG Calc and the MRPI MPG Software appeared to be unknown among the respondents. The three validated measurement methods appeared to be more familiar to the respondents.

The major difference between the three methods is that the MPG Toetshulp is the only one linked to a BIM model. Therefore, the MPG Toetshulp requires different knowledge than GPR Materiaal and One Click LCA. Because the MPG Toetshulp is linked to a BIM model, the MPG calculation can be seen without extra effort at any moment of the design process. For the other two methods, information about the building must be taken over manually, thus taking more time. Respondents do, however, believe that all three methods are easy to use. GPR Materiaal and MPG Toetshulp clearly show how the various building components score. In terms of price, GPR Materiaal seems to be the most advantageous option, as revealed by the interviews, price quotes and the internet.

Sustainability measurement methods

The second main type that is distinguished is measurement methods for measuring sustainability in its entirety. From literature research, BREEAM, LEED and WELL appeared to be suitable methods. Additionally, interviews mentioned GPR Gebouw to be a suitable method for further research. However, the methods LEED and WELL are not used or known on a large scale by respondents in the Netherlands. BREEAM and GPR Gebouw appeared to be more suitable methods to map the sustainability of a building. These methods are more suitable because they are familiar to the respondents, they also fit the scope of the study. To a large extend, LEED is the same as BREEAM and therefore does not distinguish itself in terms of familiarity and unique measurement method, but WELL is unique in what it measures. Still, as the literature review showed, it is limited to the health aspect. Therefore, the link with circular building is not directly present.

BREEAM and GPR Gebouw consist of several chapters in which sustainability is broadly viewed. Each method devotes a chapter to circular aspects. BREEAM deals with the chapter on Materials and GPR Gebouw with the chapter on Environment. Both chapters fall back, to measure circularity, on the MPG mentioned above. In the case of BREEAM, you are not tied to a method if it is validated by the NMD. The MPG for GPR Gebouw is derived from the calculation made for GPR Materiaal. In the near future, it is expected that GPR Gebouw will be linked to GPR Materiaal. Some respondents see GPR Gebouw as a simpler, faster and cheaper version of BREEAM.

Circularity measurement methods

The third main type to be distinguished is measurement methods specifically developed to measure circularity. Three methods emerged from the interviews: CPG, BCI and Circulariteitsindex. The CPG is nothing more than a conversion sheet that relies on input from GPR Gebouw. It is free to download and available for use by anyone with a GPR Gebouw license. It translates the vision of W/E Adviseurs on circularity from GPR Gebouw to the CPG. When a user wants to use other criteria to measure circularity, he can easily adjust the ratios in Excel. According to the interviews, the CPG looks at circularity from multiple perspectives. Respondents also mentioned ease of use and price as strong points of the method.

The BCI is a tool that measures circularity by combining the MPG with a detachability index. To calculate the MPG, BCI uses a method not validated by the NMD but does provide a good guideline. The method is distinguished by how it calculates detachability. To calculate the detachability index, Alba Concepts distinguishes 4 components: (1) type of connection, (2) accessibility of the connection, (3) form closure and (4) crossings. The method often first makes a traditional calculation of the building to make 'improvements' more transparent. It is not necessary to undergo training to work with the method, although the interviews have shown that some knowledge of calculating an MPG is useful.

The cost to register a building is 500 euros for one building. With one building, you can make three scenarios. With validation, if desired, costing another 300 euros.

The Circulariteitsindex is the last tool that emerged from the interviews to measure circularity. The tool is less well known than the previous two. Unlike the MPG, this tool considers all the components that make up a building. However, the tool relies on three databases, so respondent's data quality is more extensive but lower. By using Stewart Brands' building components, the Circularity Index produces a very comprehensive score overview. The disadvantage of the tool is that it is not yet widely used and currently only pilot projects are being done with it.

The results of the information obtained mainly by the respondents are summarised in Tables 7, 8 and 9. In these tables, indications make it more feasible to compare the different measurement methods with each other. A detailed explanation of these results can be found in Appendix 6.

Table 7 Comparison measurement method (Part I).

Measurement method	**GPR Materiaal**	**One Click LCA**	**MPG Toetshulp**	**MPG Calc**	**MRPI MPG Software**
Scope	MPG	MPG	MPG	MPG	MPG
Database	NMD 3.0	NMD 3.0	NMD 3.0	NMD 2.3	NMD 2.3
Certified	Yes	Yes	Yes	No	No
Known with participants	++	+/-	+/-	+/-	--
Phases of design stage	+	+	++	+	+
Knowledge required	++	++	++	++	++
Ease of use	++	++	++	++	++
How specifically	++	Unknown	++	Unknown	Unknown
Price	++	+	+	++	++
Detachability	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable

Table 8 Comparison measurement method (Part II).

Measurement method	**BREEAM**	**GPR Gebouw**	**WELL**	**LEED**
Scope	Sustainability	Sustainability	Sustainability	Sustainability
Database	NMD 3.0	GPR Materiaal	Unknown	Unknown
Certified	Not applicable	Not applicable	Not applicable	Not applicable
Known with participants	++	++	--	--
Phases of design stage	+	+	Not applicable	Not applicable
Knowledge required	+	+	Not applicable	Not applicable
Ease of use	+/-	+	Not applicable	Not applicable
How specifically	++	+	Not applicable	Not applicable
Price	-	+	Not applicable	Not applicable
Detachability	+	-	Not applicable	Not applicable

Table 9 Comparison measurement method (Part III).

Measurement method	**CPG**	**BCI**	**Circulariteitsindex**
Scope	Circularity	Circularity	Circularity
Database	GPR Gebouw	NIBE*	NMD, NIBE, Own
Certified	Not applicable	Not applicable	Not applicable
Known with participants	++	++	+/-
Phases of design stage	+	+	+
Knowledge required	+	+	+
Ease of use	+	+	+
How specifically	+	-	Unknown
Price	-	++	+

As can be seen from the tables above, there are some differences in the various measurement methods. By dividing the measuring methods into three different scopes, it is clear what the measuring methods focus on. However, how the measuring methods implement this scope is almost always different. Each method, therefore, has stronger and weaker aspects. There is no best method, one method fits better in one situation while another method fits better in another situation.

6. Discussion

This chapter discusses the findings from the previous chapter and compares them with the literature found in the second chapter.

6.1. Discussion research question 1

Research question 1: What is the current sustainable and circular situation of Kleissen?

The findings of the first sub-question revealed Kleissen's current sustainable and circular situation. An interview, a brainstorming session and available files/documents consulted showed that Kleissen is familiar with many of the themes described in the literature, such as the 10R model described by Potting et al. (2017), LCA by You and Wang (2019) and the TBL principle described by, for example, Dyllick and Hockerts (2002). These themes are mentioned in Kleissen's vision document for circularity and sustainability.

Kleissen sees circularity primarily as an issue of dealing with what is already there (in existing buildings) and what new materials are needed, and how these are subsequently applied. This reflects the 10R model, in which Kleissen view materials reused as much and as widely as possible. There is no further specification of how Kleissen wants to do this in concrete terms, unlike, what the Layers of Brand could make clear (Mallory-Hill, 2004).

Kleissen has searched deeper into elaborating its vision on the broader aspect of sustainability. This is done via the label #HoudbareHuisvesting where Kleissen distinguishes three pillars that roughly corresponds to the TBL principle (Bernardová et al., 2020; Dyllick & Hockerts, 2002; Elkington, 1997; Fisk, 2010; Kleindorfer et al., 2005)[1]. The ecological sustainability aspect mainly corresponds to the aspect planet, the social sustainability aspect mainly corresponds to the aspect people, and the dynamic sustainability aspect mainly corresponds to the aspects planet and profit. However, regulations and measurement methods of sustainability and circularity mainly aim at the planet aspect. However, regulations and measurement methods of sustainability and circularity mainly aim at the planet aspect.

Theory surrounding measuring sustainability and circularity comes up with two streams. First, BENG looks at the energy consumption of buildings in the Netherlands (Rijksdienst voor Ondernemend Nederland, 2021a). The second is the MPG, which mainly looks at buildings' material use and its impact on the environment (Rijksdienst voor Ondernemend Nederland, 2021c). Both methods are linked to making the planet aspect measurable. However, of these two methods, only the MPG is connected to measuring circularity. It aims to stabilise or reduce the environmental burden by setting requirements for the maximum environmental impact a building may have on its surroundings (Rijksdienst voor Ondernemend Nederland, 2021c). In addition, Hart (1997) states that the environmental burden must be stabilised or reduced. Furthermore, Ayres (1995) and Rodriguez (2002), state that a strategy to measure planet is through life cycle analysis to map the impact of a material, from raw material extraction to end of life, acknowledge the aim of the MPG. The MPG, as described in the theoretical chapter, ''Ensures that the environmental impact of a building can be calculated, promoting circularity'' (Rijksdienst voor Ondernemend Nederland, 2021c).

Interviews with the respondents revealed the ultimate relationship between the aspects from the TBL and the MPG. This will be elaborated further in paragraph 6.3 below.

[1] The previous chapter, in answering part of question 1, already made the link between Kleissen's vision of circularity and sustainability and the theory surrounding this chapter. This was necessary in order to be better prepared for the external interviews that were conducted during sub question three.

6.2. Discussion research question 2

Research question 2: What are the requirements of Kleissen and its stakeholder when measuring circularity?

The findings from the second sub-question provided insight into the requirements of Kleissen and its stakeholders. Kleissen's stakeholders, specifically Kleissen's clients, have named eight aspects that they consider most important for circular construction however only three relate to the scope of the research for measuring circularity. In addition, Kleissen itself has also set requirements for measuring circularity. These requirements are bundled into functional requirements.

The outcome of the research regarding the functional requirements corresponds minimally to the theory. Only one of the five described functional requirements drawn up by Kleissen and her stakeholders matches with Mansourianfar and Haghshenas (2018). Only the aspect that a measurement method must take the future value of a product into account corresponds to Mansourianfar and Haghshenas (2018) who state that products must have a clear added sustainable value to be successful. The other requirements, robust and strong enough to have a long lifespan, demountable, include MPG and taking processing into account, do not correspond to any of the aspects mentioned by Mansourianfar and Haghshenas (2018). An explanation can be given to the fact that these functional requirements are aimed at a specific scope that only fulfils a small part of the scope served by Mansourianfar and Haghshenas (2018), which is to look at measurement methods in the sustainability sector in general.

In addition to these functional requirements, Kleissen has indicated several practical requirements that a method should satisfy. These requirements are divided into price, ease of use and compliance with laws and regulations. In contrast to the functional requirements, these requirements can be linked to the theory of Mansourianfar and Haghshenas (2018). The theory states that measurement methods should be understandable and usable by the general public (ease of use), predictable in considering future policy impacts (comply with laws and regulations) and feasible through reliability and affordability (ease of use + price). It is more logical that these aspects are more in line with Mansourianfar and Haghshenas (2018) because these practical requirements are hardly linked to the scope of this research (circular measurement methods within the construction sector). Furthermore, these practical requirements can also be relevant for other measurement methods that fall within the scope of measurements methods for sustainability.

6.3. Discussion research question 3

Research question 3: What are the relevant and future proof measurement methods to measure circularity for Kleissen and its stakeholders?

The findings for the third sub-question provide insight into the different types of measurement methods that have been compared in this study. Broadly speaking, the measurement methods can be divided into three categories: MPG, sustainability and circularity. Logically, these three categories all have a different scope.

The MPG focuses mainly on the Netherlands' objective of promoting circularity in the construction industry (Rijksdienst voor Ondernemend Nederland, 2021c). The MPG aims to calculate and minimise the environmental impact of a building. However, this does not imply that it can be fully linked to the use of reusable (demountable) materials, as described by Stahel (2016). According to respondents, the MPG would be overly linked to the measurement of the environmental impact. Additionally, it does not include CO-2 emission measures clearly in the calculation and does not assess circularity from a larger perspective. As a result, detachability, among other things, would not be sufficiently included. A solution would be to use an extension to the MPG that could supplement its 'flaws'. However, according to Mansourianfar and Haghshenas (2018), it is not desirable to make

usability more difficult due to the extra work involved in the second method and by making it more difficult to compare different options.

Sustainability measurement methods have a broader scope, focusing on the entire TBL principle, as described by Elkington (1997) and Fisk (2010), among others. The relevant measurement methods that fall under this scope, BREEAM and GPR Gebouw, takes into account the three aspects of TBL. The total score of both methods is an average of the social, economic and environmental aspects (people, planet and profit). The methods each also provide insight into how one specific part of the TBL aspect scores. As a result, the methods correspond to some of the requirements of measuring sustainability prescribed by Mansourianfar and Haghshenas (2018), such as transparency, comparative predictability and technically measurable.

The third scope of measurement methods focuses on the specific measurement of circularity. However, in agreement with what Benachio et al. (2020) and Eberhardt et al. (2019) write: applying circularity in the construction sector is difficult. Construction companies often do not know how to apply circularity practically. This also translates into the big difference between the three measurement methods that are within this scope. How the methods measure circularity differs. This can lead to doubts about whether the measuring methods use the same definition of circularity or whether they each rely on their own definition. Therefore, the outcome of the study seems to correspond to what the theory describes.

7. Conclusion

This study examined various methods of making circularity measurable. To this end, eight respondents were interviewed with whom the various measurement methods were examined. The interviews did not show that the legally required MPG can be seen as a comprehensive way of making circularity measurable. Nevertheless, the interviews provided a great deal of insight into the MPG and the measurement methods associated with the MPG. Other ways of measuring circularity were also discussed. Following on from the literature review, the research examined measuring methods for measuring sustainability. It was investigated whether these measuring methods could also calculate circularity. Finally, the interviews revealed that, even though the literature search did not yield any specific measurement methods, there are measurement methods aimed at measuring the broader concept of circularity.

However, before discussing the various measurement methods with the respondents, this study examined the current situation regarding Kleissen Bouwmanagement en Advies's approach to sustainability and circularity. It also examined what is important for Kleissen and its stakeholders to include in comparing the various measuring methods.

With all data collected, both through an internal case study and interviews with external experts, the sub-questions can be answered:

Sub-question 1: What is the current sustainable and circular situation of Kleissen?

In terms of sustainability, Kleissen has a comprehensive explanation. Through the label #HoudbareHuisvesting, Kleissen knows how to link the TBL principle with the aspects people, planet, and profit and concrete examples. To measure sustainability, the construction industry often looks at the MPG and the BENG. The MPG measures circularity and focuses on the 'material' side of the building. The BENG focuses on the 'energy' side of the building and measures the energy consumption of the building.

In terms of circularity, Kleissen has elaborated several concepts on how it considers circularity. Kleissen's vision in this area is primarily aimed at reusing existing materials as much as possible. If new materials are to be used, Kleissen takes a careful look at where new material comes from and how it can be applied.

Sub-question 2: What are the requirements of Kleissen and its stakeholders when measuring circularity?

Kleissen's vision, on stakeholders essentially, looks at the functional and practical requirements. Functional requirements on which the measuring methods should be assessed are whether it can make a validated MPG calculation, whether it addresses the detachability of a building, and how the method deals with the processing of materials during the lifetime of the material.

Practical requirements on which the methods are assessed come down to price, ease of use and compliance with legislation and regulations. User-friendliness includes the required knowledge, training, linkage to other methods, filling in and results.

Sub-question 3: What are the relevant and future proof measurement methods to measure circularity for Kleissen and its stakeholders?

The interviews showed that measuring circularity can be done in three ways; through the MPG, the umbrella concept of sustainability, and specific circularity measurement methods.

According to respondents, the MPG proved not to be completely perfect for measuring circularity in its entirety. Nevertheless, these measurement methods have been compared with each other since the MPG is required by law. The measuring methods GPR Materiaal, One Click LCA and MPG Toetshulp appeared to be the only relevant ones to measure the MPG. The methods are similar in most respects,

although there are some differences. The MPG Toetshulp is the only method that is linked to a BIM model, which makes it possible to make an MPG calculation without any effort. However, the advantage of the GPR Materiaal measuring method is that it is financially interesting and can be linked to methods that measure sustainability and circularity.

According to the interviews, 'BREEAM' and 'GPR Gebouw' are particularly relevant for measuring sustainability. These methods devote a specific chapter to calculating aspects related to circularity. The calculation of these aspects appears to limit themselves to the MPG. GPR Gebouw links this section to GPR Materiaal, while BREEAM also focuses on one of the three validated measurement methods mentioned above. As a result, the methods do not differ from methods that focus entirely on calculating the MPG when it comes to circularity. When comparing both methods it can be concluded that GPR Gebouw is in most aspects the lighter version of BREEAM. However, the possibility of GPR Gebouw to balance the MPG with the BENG is a big advantage when looking at sustainability as it can compare the material side with the energy side.

In addition to the MPG and sustainability, there are also specific measurement methods that measure circularity. The interviews revealed that the CPG, BCI and Circulariteitsindex are relevant methods to investigate further. All three methods are similar in terms of ease of use, translated into the amount of knowledge required and how long it takes to complete the method. The advantage of the 'CPG' is that it is developed by the same party as 'GPR Materiaal' and 'GPR Gebouw'. This means that all aspects, MPG, sustainability and circularity can be measured by the same organisation. In addition, this method is not financially unattractive. The CPG gave the best results from the interviews, the literature research and the test licenses. This is because the CPG is the only method that highlights circularity from different points of view. The method is also relatively accessible and clear.

On the other hand, the BCI is a bit more expensive, as the price is calculated per project and validation has to be done by the developing party. However, the distinguishing feature of this method is that it emphasises detachability, whereas the CPG measures several aspects of circularity. The BCI measures detachability appears to be relatively well developed and can be well substantiated.

The third method to measure circularity, Circulariteitsindex, is probably the most extensive of the three methods, as it assesses the building on various components and aspects. However, the method does have the disadvantage that the quality of the data is the lowest. It uses different databases and is currently only used in pilot projects.

By answering the three subquestions, it is possible to answer the main question: **"What is the most suitable measurement method to make sustainability measurable for Kleissen and its stakeholders?"**. The research resulted in four propositions for Kleissen to measure sustainability.

P1: Since Kleissen has indicated that it wants to focus on the 'material' side, or circularity, within the broader concept of sustainability, as shown in paragraph 3.4, it is recommended to disregard measurement methods around the MPG. The same applies to measurement methods concerning sustainability because these are also strongly dependent on the MPG calculation.

P2: Start up a pilot project with GPR Gebouw to subsequently make a CPG calculation.

P3: Expand vision document on circularity that has been approved by Kleissen and with which its stakeholders agree, in this way it is possible to validate better whether the measuring method suits Kleissen and its stakeholder.

P4: Further explore the vision of W/E Adviseurs to find the overlap between the CPG and Kleissen. That way, it can be seen whether the ratios need to be adjusted to fit Kleissen's vision.

7.1. Limitations and future research

The main limitation is the scant research on circularity in the construction sector. Scientific research is even harder to find when it comes to making circularity in the construction sector measurable. In addition to the fact that there has only been a small amount of research into measuring circularity in the construction sector, it would also be wise to conduct this same study more broadly in the future. As this study focuses on Kleissen specifically and uses a single case study approach, it might not be reliable to extrapolate the research results to the entire (Dutch) construction sector. The next research could focus on a pilot study in which several (Dutch) construction companies test, through a multiple case study, different measurement methods that emerged in this research. In this way, a reliable picture can be created of the construction sector' needs for a widely supported uniform measuring method of circularity. Furthermore, the interviews revealed that not everyone has the same opinion about the meaning of the concept of circularity. Because the concept's meaning is not uniform, it is difficult for construction market parties to develop suitable measurement methods. The measuring methods that currently exist were developed by pioneers who work with their own definition of circularity.

Future research should conduct more research into circularity in the construction sector. This should start with finding a general definition. When there is an unambiguous definition of circularity in the construction sector, construction companies have a basis from which they can draw up a strategy and possibly their own adapted definition. This definition would give construction companies guidance to look at circularity with the same scope as other stakeholders in the construction sector. Additionally, with a definition and clear guidelines, laws and regulations can be made more specific and stakeholders in the construction sector who develop measurement methods can create a better measurement method that all construction parties' support. When more parties apply circularity and there is a uniform definition, it will be easier to apply circularity on a larger scale.

Appendices

Appendix 1: European Union sustainability goals

The European Union has set an extensive number of targets. For example, concrete targets have been set for 2020, 2030 and 2050. Below is a summary of the most important points for achieving the climate, energy and environmental objectives (European Commission, n.d.).

Table 10 Summary targets European Union (European Commission, n.d.)

Summary European Union targets	2020	2030	2050
Cut in greenhouse gas emission (from 1980 levels)	20%	55%	100%
EU energy from renewables	20%	32%	
Improvement in energy efficiency	20%	32,5%	

The European Union has drawn up its environmental action programme in several parts. For the construction sector, the following action points, which have been drawn up to be achieved by 2020, are important: climate and energy targets, energy strategy and action plan for the circular economy.

The climate and energy targets for the year 2020 are shown in Table 9. To achieve a 20% reduction in greenhouse gas emissions, the EU has set binding annual targets for each country. The latest figures show a 24% reduction in 2019, which means that the target has been met. Besides reducing greenhouse gas emissions, a 20% reduction in the use of renewable energy must also be achieved. To achieve this, action plans have been drawn up for each country (European Commission, n.d.). The action plan for the Netherlands includes requirements on energy performance for newly built homes and utility buildings, as well as for major renovations. In short, this means that the total building-related energy consumption may not exceed the standard energy consumption. The standardised energy consumption is dependent on the user function, the total loss area, and the total user surface of the building (European Commission, n.d.).

The requirement is set in the form of a dimensionless number: the EPC (Energie Prestatie Coëfficiënt – Energy Performance Coefficient). The EPC says something about how economical a building is, i.e. the more economical a building is, the lower the EPC value will be. The EPC standard is set based on the energy efficiency of a typical house built-in 1990. A house with the same energy efficiency will have an EPC value of 1.0. In recent years, the legal maximum EPC value has been lowered further and further (Klimaatexpert.com, n.d.). How a construction company goes about meeting the requirements of the EPC is up to them. Different options are available: limit energy loss, use renewable energy. (Rijksoverheid, 2009). The third action point, environmental action, is considered with the improvement in energy efficiency.

Several amendments have been drawn up regarding the construction sector. For example, in 2020, an amendment has been drafted setting out an action plan that regulates, finances and measures building renovation to double the number of renovations by 2030. A second amendment is to make all new buildings nearly zero-energy buildings by 31 December 2020. In addition, energy performance certificates must be issued when a building is sold or rented out and maintenance schedules must be drawn up for heating and cooling systems. The Dutch government must draw up a list of national measures to improve the energy efficiency of buildings (European Commission, n.d.). The following paragraph goes further into targets set up by the Dutch government.

For 2030, the European Union has drawn up several stricter measures. While all three components in Table 9 above must achieve a 20% reduction by 2020, the goal for 2030 is much higher. The original planning called for a 40% reduction in greenhouse gas emissions by 2030. However, calculations have shown that if all the energy and climate plans are effectively implemented, a 45% reduction will be achieved by 2030. As a result, the target of 55% reduction compared to 1990 has been set. Further tightening is not yet mentioned, as the proposal is due in June 2021 (European Commission, n.d.). For the year 2050, the European Union has drawn up a long-term vision. Achieving a complete reduction

in greenhouse gas emissions requires a deeper understanding of possible options and how they transform the various sectors. This includes technologies that can remove CO-2. To complete the 2050 target, the EU will have to "Rely on a combination of drivers in deploying all options to achieve this ambitious vision" (European Commission, 2019).

For the construction sector, the main emphasis is on the renovation of existing buildings, as 75% of these buildings were built before energy performance standards existed. Besides renovating the buildings, additional measures will have to be taken (European Commission, 2019): "Additional efforts include switching to sustainable renewables for heating, efficient products and appliances such as heat pumps, smart building/appliance management systems and better insulation materials" (p. 9). To achieve this, emphasis will have to be placed on a competitive industry and circular economy. Recycling goods such as glass, steel and plastic will reduce consumption and CO-2 emissions. As a result, the EU will gain a competitive advantage and jobs can be created. However, if companies want to be part of a sustainable and circular economy, they will have to modernise their machinery. Thus, it is important to invest in digitisation and automation because CO-2 emissions cannot be reduced completely. Small-scale initiatives to contribute positively to this objective will have to be developed in the coming years to perform on a large scale (European Commission, 2019).

Appendix 2: Interview questions guide external experts

Version: 04-05-2021

Introduction

- In what role are you involved in the construction process?

Sustainability guidelines

- This research focuses on the 'material' side/Circular Economy/MPG (Environmental Performance Building).
- When looking at a circular economy, is the MPG comprehensive to measure this? Or is circular material use broader than what is calculated in the MPG?
- If something is missing, what does the MPG not measure when it comes to circularity?
- Are you familiar with the guidelines of the MPG ('material' side)? How strictly are these directives complied with in practice?

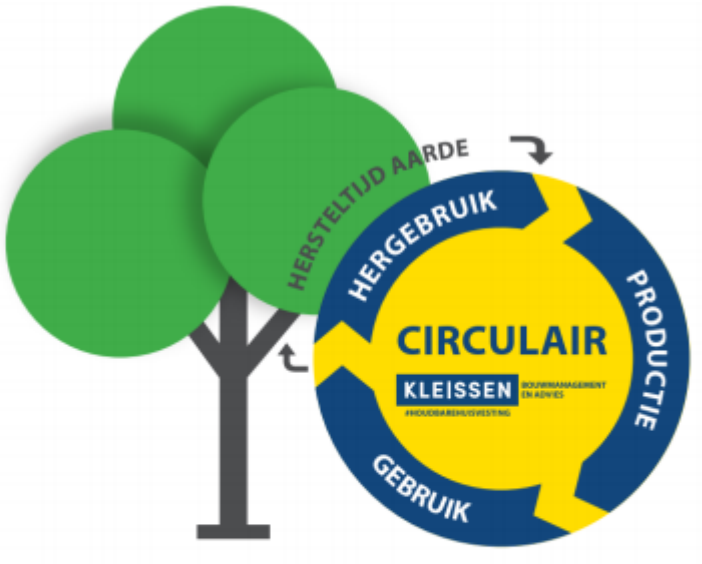
Measurement methods sustainability

- Are you familiar with methods to measure sustainability in material use (in construction)?
- If so, can you explain something about the methods, concerning the 'material side'/circular economy?
- Which methods for measuring circularity (in a general sense) do you know?
- If this method addresses circularity overarching:
    - What aspects does it consist of? What does it measure? Is the MPG one of the parts?
    - How does this method deal with possible shortcomings of the MPG?
- Ask for each measurement method:
    - How does the measurement method work (how specific? Different degrees?)
    - How much work is it to use the measurement method (Is it easy to compare different options with each other)?
    - For whom can the method be used?
    - Is there a need for training (e.g., obtaining a certificate), if so, which one?
    - Is the method easy to fill in for users (e.g. using BIM, Revit, Excel); how long does it take to fill-in?
    - What are the costs associated with using the measurement method (licenses)?
    - When different parties use the method, will the 'outcome' always be the same (is the method reliable and valid)?
    - In which phases of the design process (SO, VO, DO, etc.) can the method be used (can already be controlled on the MPG in earlier design phases, so that the change impact in later design phases can be reduced)?
    - When a party works with the measurement method, is it easy for external parties to watch (so that, for example, an advisor company can steer on consistency during the process)?
- What is good about method X (compared to method Y)?
- What is less good about method X (compared to method Y)?
- If you had to choose a measuring method for Kleissen to measure the 'material side'/the degree of circularity, which measuring method would you choose? (Or at least; which factors would be important to you when comparing different measuring methods)?

		Company	A	B	C	D	E	F	G	H
Aggregate Dimension	**Second-Order Themes**	**First-Order Concepts**	**In-Vivo Codes (Fragment number)**							
Introduction / background										
Background	Role/function									
		Project leader		B.0						
		Advisor/consultant/mediator		B.0	C.0	D.0		F.0	G.0	H.0
		Expert	A.0							
		Owner/Director			C.0	D.0	E.0			
Sustainability guidelines										
Meaning circularity	Concept circularity	The concept Circularity is not year clear and uniform				D.1*	E.3, E.5		G.3	
Totality MPG	MPG all-inclusive for circular construction?	Yes								
		Not sure					E.6			
		No, limited database	A.5	B.2				F.4, F.8		
		No, not taking CO-2 absorption into account	A.7, A.8	B.2						H.4
		No, not taking detachability into account		B.1, B.7	C.2	', D.13, D.17		F.2, F.7		H.1, H.2
		No, not taking existing buildings/materials into account			C.1, C.2, C.3					
		No, it is limited to only the materialimpact				D.2*		F.2	G.1, G.6	H.1
		No, MPG should be used to calculate the effect of different circular strategies			D.3, D.8, D.12, D.13, D.17					
		No, it does not include all materials that are in a building						F.4		
		No, it only gives a moment snapshot						F.2, F.7		
	What is important for the MPG (to add)?	Nothing								
		The MPG itself nothing, but something beside it			D.5, D.7, D.8, D.14				G.1, G.2	H.2
		Calculate sustainability as completely as possible	A.38	B.9	C.9					
		User-friendliness	A.38							
		Be up to date with the NMD	A.39							
		Distance from resource extraction to construction site		B.9						
		Promoting to keep the materials as pure as possible			C.5					
		Consider the financial aspect			C.7, C.12				G.1	
		Eliminate waste (1: reuse, 2: for new materials: only get the sustainable)			C.8					
		Design your building in a circular way				D.8				H.5*
Guidelines MPG	Known with MPG	Yes	A.6			D.1	E.0	F.1		H.7
		Limited			C.4					
		No								
	Compliance regulatory in practise	Yes		B.6		D.26*				
		Not always/almost never	A.9							
		No								
In dept MPG		Respondent went in debt about the different stages/modules in the MPG			D.14, D.15, D.1		E.6	F.7		
Measurement methods	Known with specific measurement method	No								
		Yes, with GPR Gebouw	A.1	X		D.10	E.7	F.16	G.4	H.9
		Yes, with GPR Bouwbesluit / Materiaal	A.1			D.19	E.7		G.4	
		Yes, with MPG Toetshulp				D.19	E.1	F.18		
		Yes, with MPG Calc								
		Yes, with MRPI MPG software				x				
		Yes, with One Click LCA				D.19				
		Yes, with BREEAM	x	X	X	D.3			X	
		Yes, with LEED								
		Yes, with WELL								
		Yes, with BCI (Alba Concept)		B.3		D.8	E.3	F.12	G.4	H.1
		Yes, with CPG (W/E adviseurs)		B.3		D.9		F.16	G.4	
		Yes, with Circulariteitsindex						F.10		

Appendix 4: Vision document Kleissen Circularity

KLEISSEN BOUWMANAGEMENT EN ADVIES
#HOUDBAREHUISVESTING



De aarde is een gesloten systeem, er komen niet meer fossiele grondstoffen bij, dus we moeten er bewust mee omgaan om de aarde niet uit te putten. Wij moeten onze verantwoordelijkheid nemen om deze aarde ook geschikt te houden voor de generaties na ons. We moeten kritisch naar de behoefte kijken en naar de middelen en materialen die we ter beschikking hebben.
De aarde is zelf herstellend, maar alleen wanneer wij de bronnen minder aantasten dan het tempo waarin ze kunnen worden hersteld door de aarde.

Begrip	**Definitie**
Circulair	Is letterlijk in een kring rondgaan. Kenmerkt een manier van omgaan met (grond)stoffen op de aarde zodat de belasting van de aarde in balans is met het tempo waarin de aarde zichzelf hersteld.
Grondstoffenpaspoort / materialenpaspoort	Een overzicht van alle grondstoffen/ materialen die beschikbaar zijn. Een -paspoort van een gebouw geeft bijvoorbeeld aan hoeveel van welke grondstoffen er in het pand zijn verwerkt. Op deze manier kan worden bepaald hoe deze grondstoffen kunnen worden heringezet na gebruik. Daarbij is het belangrijk dat niet alleen hoeveelheden per materiaal zijn vermeld, maar ook de manier waarop het is verwerkt (gemonteerd). Met een -paspoort kan ook de (rest) waarde van een pand worden bepaald.
Madaster	Het materialen kadaster. Een online platform waarin materialen/ grondstofpaspoorten worden verzameld en bewaard.
Cradle-to-cradle	Afval = Voedsel. Bij cradle-to-cradle worden gebruikte producten hergebruikt als nieuw product of als een grondstof van een nieuw product.
Bio-based-materials	Dit zijn materialen gemaakt van natuurlijke / organische grondstoffen. De gebruikte materialen groeien tijdens de levensduur van het product terug waardoor de aarde niet wordt uitgeput.
Primaire grondstoffen	Minerale, fossiele en metalen grondstoffen zijn voorbeelden van primaire grondstoffen. Ze worden gewonnen uit de aarde en gebruikt als grondstof voor andere producten.
Life Cycle Analysis (LCA)	Wetenschappelijke methode om de milieu-impact van een product te bepalen. Alle processen die het milieu kunnen beïnvloeden worden meegenomen. Van grondstofwinning tot het moment dat de producten aan het einde van hun levensduur zijn. Bij de berekening worden diverse elementen meegenomen zoals het gebruik van energie, transport en zelfs eventuele sloopprocessen.

KLEISSEN BOUWMANAGEMENT EN ADVIES
#HOUDBAREHUISVESTING

Circulaire Re-principes
In volgorde vanaf de beste aanpak naar de minst toegevoegde waarde:

Re-fuse	Weigeren/voorkomen van gebruik van grondstoffen *Bijv. eigen boodschappentas meenemen i.p.v. plastic zakjes aanpakken.*
Re-think	Heroverwegen/anders denken, waardoor producten intensiever worden gebruikt door het bijvoorbeeld te delen of multifunctionele producten in te zetten. *Bijv. het realiseren van werkplekken voor multifunctioneel gebruik.*
Re-duce	Verminderen van het gebruik van grondstoffen *Bijv. voorkomen dat meer geproduceerd wordt dan gevraagd en er zo afval ontstaat.*
Re-design	Herontwerp met oog op circulariteit. *Bijv. champignons kweken op koffiedik (afval na koffiezetten).*
Re-use	1 op 1 hergebruik. Producten circulair slopen en opnieuw gebruiken. 2de hands. *Bijv. een wc-pot.*
Re-pair	Na kleinschalig onderhoud en/of reparatie kunnen producten worden heringezet. *Bijv. plafondplaat voorzien van nieuwe verflaag.*
Re-furbish	Een product opknappen waarna het opnieuw gebruikt kan worden als 2de hands. *Bijv. een telefoon.*
Re-manufacture	Hergebruik van grondstoffen na grote bewerking om weer tot hetzelfde product te komen. *Bijv. dakbedekking. Afgeschreven dakbedekking verwijderen, shredderen, en in productieproces van "nieuwe" dakbedekking toevoegen.*
Re-purpose	Producten hergebruiken maar met een ander doel. Producten die niet meer aan de eisen voldoen van waarvoor ze zijn gemaakt kunnen nog wel een ander doel vervullen. *Bijv. oude isolator gebruiken als lampenkap.*
Re-cycle (downcycle en upcycle)	Bij recycling worden producten en materialen gescheiden tot aparte grondstoffen. Van deze grondstoffen worden, vaak met een grote bewerking, weer nieuwe producten gemaakt. Wanneer dit ten koste gaat van de kwaliteit (los van de energie die nodig is voor deze ingreep) dan spreken we over downcycling. Wanneer het eindproduct een hogere waarde heeft dan voor de reclycling spreken we over upcycling.
Re-cover	Het terugwinnen van energie. *Bijv. afval verbranden en de vrijgekomen warmte benutten.*

Visie Kleissen op circulaire bouw(proces):
Circulair bouwen houdt in dat we bewust nadenken over huisvestingsvragen (re-fuse; misschien geen behoefte aan nieuwe huisvesting). Ook kijken we naar wat we al hebben (re-use; de bestaande gebouwen) welke materialen we hebben (hoe kunnen we die opnieuw inzetten) welke andere materialen we gaan toevoegen en op welke manier we die toevoegen.

Appendix 5: Vision document Kleissen #HoudbareHuisvesting

KLEISSEN BOUWMANAGEMENT EN ADVIES

#HOUDBAREHUISVESTING

Begrip	Definitie
Zelfvoorzienende huisvesting	Huisvesting die minder aanspraak maakt op grondstoffen en energie. De grondstoffen die wel worden gebruikt zullen gedurende de gebruiksfase door de aarde worden hersteld (terug groeien). De energie die nodig is wordt verkregen zonder negatief effect op de aarde (geen fossiele brandstoffen en geen schadelijke uitstoot).
Gebruikersvriendelijke huisvesting	Huisvesting waarin een gebruiker blij wordt en zich prettig voelt. Een plek die aansluit bij de wensen en behoefte van de gebruiker. Zowel de behoefte van vandaag als in flexibiliteit aanpasbaar, aan de ontwikkelende behoefte.
Toekomstbestendige huisvesting	Huisvesting die flexibel en modulair is waardoor het aanpasbaar is in functies en omvang. Door materialen zo toe te passen dat ze zonder verlies aan waarde weer uit elkaar kunnen worden gehaald en in aanmerking komen voor hergebruik.
Ecologische duurzaamheid	Het streven naar huisvesting die geen belasting is voor de aarde, maar onderdeel is binnen de circulaire economie. *Voorbeeld: een pand energiezuiniger maken middels grondstoffen die hernieuwbaar zijn binnen de gebruiksperiode*
Sociale duurzaamheid	Het streven naar huisvesting die de gebruiker ondersteunt en stimuleert het beste uit zichzelf te halen. *Voorbeeld: een indeling van huisvesting/inrichting waardoor samenwerkingen en verbindingen tussen verschillende stakeholders als vanzelf ontstaan.*
Dynamische duurzaamheid	Het streven naar het behouden van waarde van de ingezette grondstoffen zodat ze zonder verlies aan waarde (elders) opnieuw kunnen worden ingezet (binnen de circulaire economie). *Voorbeeld: een oude behouden fabriekshal inrichten als flexibele en prettige werkomgeving met een geheel andere functie en doelgroep.*
#houdbarehuisvesting	(Bestaande) Huisvesting duurzamer maken. Met de toekomstige generaties in gedachten een bewuste bijdrage leveren aan de circulaire economie door te focussen op ecologische, sociale en dynamische duurzaamheid.

Appendix 6: Elaboration findings research question 3

Research question 3: What are the relevant and future proof measurement methods to measure circularity for Kleissen and its stakeholders?

The third sub-question compares the various methods of measuring circularity based on the criteria formulated in sub-question 2. As a basis for this, interviewed respondents were asked about measurement methods relating to the MPG. For the study not to focus too much on the MPG, it is chosen to also involve research methods with a broader scope in the interviews. As stated in the theoretical chapter, these methods include BREEAM, LEED and WELL.

During the interviews, after an initial introduction, the content part often started with the question of whether the respondent thought that the MPG could be seen as all-encompassing for a circular (building) economy. None of the respondents agreed with this statement. Several factors were mentioned as reasons. Respondents A, B and F agreed that the databases of measurement methods validated by the NMD to calculate the MPG are limited. By no means all materials used during the building process would be included in the NMD, as respondent A pointed out:

> I don't really think the MPG is too in-depth. It is too superficial. The database is not very extensive in terms of circular and sustainable materials. There is relatively little choice of materials. For example, if we are given a very beautiful sustainable building and we have to draw up an MPG for it, it hardly corresponds to reality. We often choose materials that look similar, but not the ones actually used. So I don't think the MPG is all-encompassing for a circular economy.

Another argument used to justify why the MPG is not comprehensive is the fact that CO-2 emissions are not sufficiently included in the calculation. Respondent B mentioned that products that can store CO-2, such as wood, are not sufficiently included. According to respondent H, so-called bio-based materials do not always have a lower MPG score compared with other materials. This is often due to the end scenario of the material that the MPG takes into account.

> Bio-based products score poorly in the MPG calculation because the waste scenario for wood is through incineration. If you then look at the environmental impact, you have [...] steel compared to wood. You burn wood at the end of its life, according to the MPG, and you recycle steel. So steel scores better than wood. But that's rather odd, only because there's now a burning scenario attached to wood, it scores poorly. Whereas wood does not necessarily have to be burnt at the end of the series. (Respondent H)

The next argument that is often used is that the MPG does not sufficiently take into account detachability. According to Respondent C, the problem is that detachable construction is not a standard: "If we want to secure materials for reuse, we should build that way. Not everything should be glued together, stacked, glued [...]. If you have built-in a detachable way, then those materials can also be recovered in their full potential". Respondent B even mentioned that the MPG can be contradictory to circular construction: "An MPG does not say everything about circularity. It is sometimes contradictory to circularity. For example, it does not include detachability, while that is part of circularity". Respondent F agrees;

> The detachability indeed, how do you put them in your building so that you can also take them out again. The only thing your environmental performance (MPG) says is: in that one building you have materials. Of those materials, we can measure the origin of the raw materials and the production processes. It is a snapshot and it does say something about the product inside, but not about how you get it in and out. And yet, in the larger scale of circularity, that is a very important step.

However, not every respondent agreed. Respondent D indicated that the MPG did take the detachability of building elements into account. Recent developments would have improved this. The

respondent did indicate that the MPG can only measure the environmental impact of a detachable product. If a client wants to design specifically for detachability, the MPG is not a suitable tool for doing so. According to the respondent, that is not why the MPG was developed.

> A number of improvements have of course been made in recent months. Several indicators have been added which have always been considered in an LCA, [...] all those data are now added to the NMD data. This enables users and calculation tools to also use them in calculations. Genuine detachability is a design strategy because then you really have to look at the details of how to put something together so that it is actually detached, but the effect and the declaration of the effect are now included in the MPG. (Respondent D)

Respondents D, F, G and H cite the reason why the MPG cannot be seen as all-encompassing for measuring a circular building economy as being that the MPG is limited to measuring material impact. Respondent G sees that circularity should be viewed from different angles. The MPG "Does give you an insight into your material consumption and where you can improve. But it does not provide insight into circularity", and thus argues for methods that address the issue in a broader way than just the MPG. Respondent H adds: "The MPG calculates the environmental impact of material [...]. So it says something about emissions and the environmental impact expressed in euros of the product or material and ultimately at building level". Respondent D and F put forward similar arguments.

Some other factors that an individual respondent mentioned as to why the MPG cannot be seen as comprehensive are;

Respondent F indicated that an MPG calculation does not include all the materials in a building. The MPG follows the Buildings Decree and therefore does not mention everything, as an example given by Respondent F shows:

> A concrete example: from the perspective of the Buildings Decree, you strive for a safe, healthy and sustainable building. In order to provide for that in terms of safety, you have to cover your bathroom with tiles, for example, so that it is a watertight layer so that your structure remains intact... so you do fill in the tiles you need for your floor and your walls, but you do not fill in the fact that you know that a toilet will be installed and a washbasin hung there.

So the MPG does not include all the materials used in a building. Respondent F indicated that the Madaster circularity index does.

Another factor mentioned by an individual respondent is that the measurement methods do not take sufficient account of materials that are already available. It fails to include existing materials that may be reused. Respondent C, given his history in demolition, stated: "I think the existing buildings are a raw material depot, but at the moment it is not yet extractable as a raw material depot but (only) at the time when it is dismantled or demolished". This respondent did indicate, however, that it was not only the MPG that took insufficient account of this: "In my experience, this is not sufficiently included in all systems and not only in this methodology but also all the other methodologies".

Although all respondents believe that the MPG cannot be seen as all-encompassing, respondents agree that the MPG should not necessarily have this intention either. Respondent D, for example, states that the MPG should be used to measure the effect of different circular building strategies. It should not be a method of circular design: "When it really comes to measuring circularity, the concepts of modularity, adaptability, detachability, are often named to measure in the MPG. I see the MPG mainly as an effect to be able to calculate these strategies". In addition, three respondents (D, G and H) indicated that something should be added to the MPG to measure circularity. As an extension and expansion of the MPG. In the opinion of the respondents, the basis of the MPG is fine, but an extension could emphasize specific components (such as detachability). As already indicated by Respondent D, the MPG is a suitable tool for measuring the effect of a particular strategy. A supplement to the MPG would not only allow the effect to be calculated but would also make a specific strategy more

measurable. Respondent D and G are "Not in favour of adding all kinds of other aspects to it (to the MPG)" (Respondent D). The main reason for having an extension to the MPG rather than an expansion is technical. As the data quality of the SBK (from which the MPG gets its input) is very high, the extension to the MPG should also be of the same data quality, according to respondent D:

> The NMD has a fairly well-developed system for the data quality of the environmental impact information. If you want to add other information, you actually have to guarantee the same level of data quality at the very least. [...]. If you do it badly, that will only detract from the data quality you have now.

Even though the MPG is a mandatory method to submit with a permit application, in practice this was not always the case. Respondent A states: "We try to send as many good quality MPG reports as possible ourselves, but there is little or no control of this by the government or municipality. They are often approved in one go". Respondent B, however, indicates that things have become stricter recently: "A while ago, the municipalities did little with it. Now you see that there are more checks. [...]. I think it has become more of an item now". Whereas Respondent A indicated that he could still do a bit of fiddling at times, this will no longer be possible in the future once the private quality assurance act has been finalised, according to Respondent D: "Once we have the private quality assurance act, the contractor will also have to provide a guarantee for the calculation. This will make contractors take it more seriously and want to have it checked themselves".

To find out more about the MPG, some respondents were asked to delve a little deeper into its content to find out how it is structured. In recent years, the MPG has been further expanded. Respondent D stated that the MPG had recently been structured in a modular way. Figure 12 below shows this structure. The environmental performance of buildings is made up of 4 modules. Module A looks at the production phase and the construction phase of a particular material. In the production phase, the extraction of raw materials, their transport and their production into materials are taken into account. The construction phase looks again at transport and the building and installation process. Module B looks at the Use phase. In this Use phase, the aspects Use, Maintenance, Repairs, Replacements, Renewals and possibly Operational energy use and Operational water use are included. Module C covers the demolition and processing phase. It includes different scenarios such as Demolition, Transport, Waste treatment and Final waste treatment. Module D looks at what happens to the material outside the life cycle of a building. It looks at environmental costs and benefits beyond the system boundary of the building. It also looks at opportunities for reuse, recovery and recycling. Thus, Module A, B and C deal with the life cycle of the product in a building. Module D deals with additional information outside the life cycle of the building.

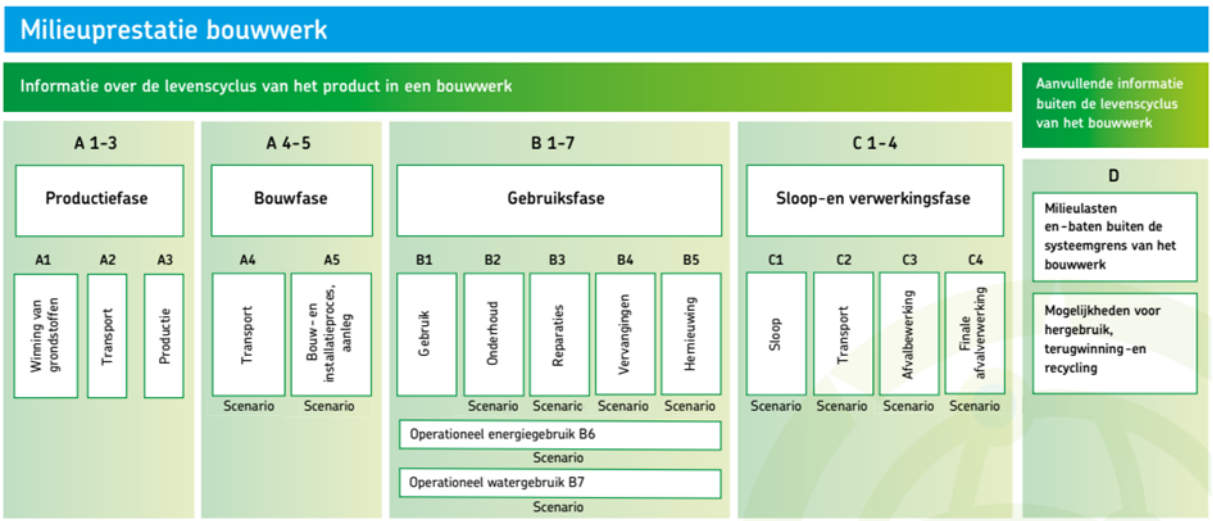


Figure 12 Modular setup MPG (Nationale Milieu Database, 2020a).

According to Respondent D, the implementation of these modules within the MPG makes it possible to measure the effect of a particular design strategy even better. It is now possible to look specifically at each module to see what the MPG score does. If, for example, the design strategy is to have a detachable design, then in the MPG calculation module D should score well. A building that is fully demountable and of which parts can be reused in another environment scores well in the latter module. Respondent D gives another example where the emphasis is on the use of bio-based materials:

> For example, if you have bio-based as a strategy, then you might want to put a little more focus on module A because bio-based materials have a somewhat lower environmental footprint than technical materials, right at the front end. So in that way you can work your way up to a more sophisticated focus with information from the NMD.

In this way, as described in Sub question 2, it would be easier to weigh up the choice of certain materials. If the focus is on more bio-based materials, one could look at materials that score well in module A. A wooden frame, for example, would be more suitable for this than an aluminium frame. However, when the focus is on minimising maintenance, repairs, replacements and renewals in the use phase (module B), an aluminium frame would probably be preferred to a wooden frame again. By breaking down the MPG into the life cycle of a building, more specific measurements can be made.

In summary, the MPG is not seen by the respondents as all-encompassing for calculating circularity. The MPG is said to be limited to the environmental impact only. CO-2 absorption, detachability and some other arguments would ensure that the MPG is not sacred. The MPG could well be used to calculate the impact of a particular design strategy, but it is not a tool that helps to advance the particular design strategy.

Comparing measuring methods MPG

As described in the theoretical chapter, there are three validated measurement methods for calculating the MPG. Two measurement methods do not comply with the latest determination method. It was decided to include these two methods in the interviews to find out whether they might become a validated method again in the future and whether they might calculate the MPG in a unique way that could be of interest to Kleissen. However, these methods, the MPG Calc and the MRPI MPG software turned out not to be known or interesting to the respondents. The MRPI MPG software was not mentioned by any respondent.

The MPG Calc was mentioned by a single respondent. This was used by Respondent A, until the switch was made to another (validated) measurement method. The reason for this was that the method did not go along with the latest version of the NMD. The respondent did indicate that MPG Calc was very easy to use: "MPG Calc is actually a matter of looking up the right materials and assigning the right values to them. It is reasonably accessible. The method is set up in such a way that it is just a matter of clicking and typing in some figures, simply put". Respondent A indicated that almost all methods, whether GPR Materiaal or MPG Calc, are basically the same, so it does not matter which method is chosen. The advantage of this method is that it is free. A disadvantage of the method, however, is that it cannot be used to make an official MPG calculation. If Kleissen wants to calculate circularity based on the MPG, this method is therefore not interesting.

The three **approved measuring methods**, in contrast to the non-approved methods, were mentioned by several respondents. All three measurement methods have many similarities. Logically, they all use the same database, namely that of the NMD. The outcome of the methods is also always the same. Because an MPG calculation is nothing more than the addition of the quantities of specific product times the environmental impact of that specific product. It will therefore not be the case that choosing method X will produce a better or worse result from the MPG compared with method Y or Z.

Because all three methods work the same, it does not matter which method you use in which phase of the design process. The earlier in the design process, the less information is available and the more assumptions you have to work with. It does not matter which of the three methods you use, the outcome is the same. However, there are some differences in the convenience of the method. For example, GPR Materiaal and One Click LCA cannot be linked to a 3D design program. This means that the user of the method has to take over all the information about the building manually and fill it into the tool. However, this does not seem to be a problem, according to Respondent A: "For an average house, we need about 2 hours". However, if a new calculation has to be made at each design stage to check whether the desired final goal has been achieved, this can still be seen as a time-consuming task. According to Respondent F, one should carefully consider the extent to which a building will be modified during the design process. When the design is known relatively soon, during the different design phases only "Small adjustments are needed".

However, when the design is not fixed from the start and many changes are made during the design phases, GPR Materiaal and One Click LCA can be perceived as cumbersome when compared to the MPG Toetshulp. The MPG Toetshulp is the only validated measurement method linked to BIM, according to respondent E. When a building is drawn in Revit, the MPG score can be calculated live. It is therefore no longer necessary to make a new MPG calculation between all the phases. Respondent D explains:

> I think the MPG Toetshulp has made a next step, because you can link your BIM model to it. The others are still separate inputs, so you make the MPG calculation on the basis of your elements budget or cost estimate. The great thing about the MPG Toetshulp is that it already does part of this automatically based on the BIM codifications.

Although how the MPG is calculated differs, according to the respondents all three methods can be calculated without extensive knowledge. About GPR Materiaal, Respondent A says that anyone can use the method. However, if you plan to make these calculations much more often, it is possible to take a course to learn all the ins and outs: "Then you get a certificate. Once a year, you get a refresher course. That is more of a meeting where you can discuss matters with other experts". So this is not compulsory. However, if the calculation is to be used for a MIA/Vamil subsidy, for example, the calculation must be made and verified by a GPR Expert and a GPR Assessor. To become one, a training course will have to be followed (W/E adviseurs, n.d.). Also, for example, during a tender, it can be indicated that the MPG calculation should be made by a GPR Expert. In this way, the developer can expect the tenderers to submit a high-quality calculation. This consideration is, however, voluntary.

Concerning One Click LCA, it is very similar to GPR Materiaal in its way of working, according to Respondent D: "In principle, it is all a little bit of layman's software. If you give someone the elementary budget for the building, they should be able to make an MPG calculation". The respondents did not mention whether One Click LCA also has experts and whether training is required. The website of One Click LCA does not provide much information on this either, but it does offer courses:

> The tool is designed to make LCAs as easy as possible so that anyone can perform an LCA. Our offers include trainings and customer support to ensure smooth onboarding and help you at any time. The tool integrates workflows to guide you through each step of the process and our customer support center is full of useful guides and videos, as well as community forums, so that you can reach out to the other users (One Click LCA, n.d.).

Also with MPG Toetshulp, there is no obligation to obtain certificates. Because the test tool is directly linked to BIM, the calculation will be made automatically by the computer. As a result, training or attending courses is not required. Logically, however, it is necessary to be able to make a BIM model. According to Respondent E, it is not possible to fill in the MPG Toetshulp by hand, as is the case with the other two methods.

When the calculation is made, all three methods produce an MPG score. When investigating which building component scores poorly, it is interesting to see how specifically the measurement methods underpin the MPG score. Respondent A mentioned that the GPR Materiaal provides an extensive report: "It is a qualitatively extensive and attractive report. The results page is focused on our client. So they can see graphs and values very nicely. Which sensitive points there are and where the sustainable points are". The MPG Toetshulp can also provide an extensive overview. Respondent E, for example, says that it is possible to see the MPG score for each building component (roof, wall, floor). The MPG Toetshulp makes it possible to assess each unit (e.g. separate flats, offices, etc. within a larger building).

The final aspect in which the methods are compared is in terms of price. According to Respondent A, who uses GPR Materiaal, the price is estimated at 300 to 400 Euros per person on an annual basis. This corresponds to a price quote that was requested in which Table 10 was sent:

Table 11 Price quote GPR Materiaal (personal communication, June 15, 2021).

GPR Materiaal	Licence	Entry fees
1 user	€398,00	None
2 – 5 users	€498,00	None
6 – 15 users	€ 798,00	None
16 or more	€ 998,00	None

Respondent D expects this price for One Click LCA to be reasonably comparable. She also mentions that her company has all the software packages in house, so they are not unnecessarily high financially:

> If I look at our own office, it is not the software packages that are under discussion every year whether we need them. So in relation to, for example, finite element software, other physical software that we have or the drawing packages themselves; it is not a big cost.

In contrast to the licence fees of +/- €400 per year, the costs of the MPG Toetshulp are slightly higher. The cost for one person comes to €130 per month, resulting in an annual fee of €1.560 (Bimpact, n.d.).

In summary, GPR Materiaal and One Click LCA are very similar, although GPR Materiaal appears to be better known among the respondents. The GPR Toetshulp distinguishes itself by being the only method to link to a BIM model. In terms of price, this method is slightly more expensive, although the costs remain relatively low.

Comparing measuring methods sustainability

In the theoretical chapter, measuring methods that do not focus solely on the MPG appeared to have the scope to measure sustainability as a whole. The methods that emerged were BREEAM, LEED and WELL. The interviews also revealed that GPR Gebouw is such a method for mapping sustainability.

The LEED and WELL methods turned out not to be known to the respondents, where nobody mentioned them. As already described in the theoretical chapter, LEED was developed by the same organisation as BREEAM. As BREEAM is the standard in the Netherlands, LEED does not seem to be a common method for the Dutch market. The same applies to WELL. In the theoretical chapter, it appeared that WELL mainly focused on the health of users within the building and not on the promotion of circularity. The interviews with the respondents also revealed that WELL is not a well-known method for making circularity measurable.

According to the interviewed respondents, BREEAM and GPR Gebouw were more familiar. At least four respondents were able to tell something about BREEAM in terms of content. Of the eight respondents, seven even knew something about GPR Gebouw. Like the theory, respondents were

aware that both methods are used to assess sustainability. When asked how BREEAM interpreted circularity, Respondent D answered:

> BREEAM is actually broader, that is sustainability, health, that is also about temperature exceedance calculations. It's about the building economy, not specifically about the circular building economy. BREEAM is the broad framework for sustainability and includes many aspects.

Respondent D says the same about GPR Gebouw: "GPR is just like BREEAM a somewhat broader assessment framework where several aspects such as environment, energy, health, sustainability, circularity come together". So it seems that both methods have a broader scope than just making circularity measurable. To make the aspect of circularity measurable, both methods have a specific chapter. In the case of BREEAM, this chapter is 'Materials' and in the case of GPR Gebouw this chapter is 'Environment'. Respondent D states that "Both GPR Gebouw and BREEAM use [...] the MPG calculation for these chapters. The GPR credit for materials and also the BREEAM credits for materials refer to the MPG". To take a closer look at this the guidelines of both methods have been reviewed.

BREEAM has described its guidelines extensively on the internet. This shows that the chapter 'Materials' is divided into five parts;

Table 12 'Materials' guidelines BREEAM (BREEAM NL, 2021)

Code	Chapter	Available points
MAT 01	Environmental impact of building materials	7, Identify, promote and document the use of materials with low environmental impact throughout the building life cycle.
MAT 03	Responsible sourcing of building materials	4, Encourage the purchase of building materials with responsible sourcing when used in the main building components.
MAT 05	Robustness of building materials	1, Optimal application of robust materials, minimisation of replacement frequency, and adequate protection of exposed building components and parts of the project site.
MAT 06	Material efficiency	1, Material efficiency measures to minimise the environmental impact of material use and waste.
MAT 07	Detachability	1, Promotion of 'detachability' of the applied building materials, building parts and components, so that they can be more easily disassembled at the end of the building life to be reused in another project.

A closer look at the five chapters shows that most of the points to be gained can be traced back to the MPG. In the first chapter, MAT 01, for example, six of the seven points can be obtained by achieving a good MPG score. The remaining points can usually be gained by reporting or documenting the materials used. In MAT 03, for example, one point can be gained by the client reporting how it will guarantee the sustainable and responsible procurement of building materials (BREEAM NL, 2021). Apart from an MPG calculation and reporting, few other measurement methods are therefore in use for assessing circularity. The MAT 07 chapter is however relevant to mention, as it specifically deals with detachability. Here too, however, no specific method can be linked. BREEAM has developed its own tool via bream.nl/help that can calculate this (Dutch Green Building Council, 2020).

GPR Gebouw describes its guidelines in less depth. It makes a distinction between five themes for mapping sustainability. Of these, the theme 'Environment' mainly addresses the measurement of circularity. This theme is divided into three parts:

Environmental performance, Circular use of materials and Water. Respondent A says that the theme Environment "Is actually the same as the MPG". In the section Circular use of materials/Environmental performance, additional, the user has to tick options: "That is made up of all

kinds of options (reuse of materials, circular materials, wood from sustainably managed forests, construction method), all of which have points attached to them".

To seek confirmation, a test license was requested. Within the test license, the following descriptions are given:

- Environmental performance: "In the subtheme Environmental Performance, the environmental impact of the building by the materials used is calculated on the basis of the "Environmental Performance of Buildings and GWW Works". For this, within GPR Gebouw® 4.2 and 4.3, the same methodology is used as in GPR Bouwbesluit/Materialen" (W/E adviseurs, n.d.).
  Several respondents (A and G) report that at the time of writing, the link between MPG Gebouw and GPR Materiaal has not yet been made. However, this should happen with an upcoming update, probably within half a year. Also, the developer of the tool, W/E Adviseurs, claims that in the next update this link will be made (W/E adviseurs, 2021).
- Circular use of materials/Environmental performance, additional: "In the subtheme Environmental performance, additional attention is paid to material characteristics of buildings that are not or not sufficiently expressed in the standardised MPG calculation (Origin of raw materials and materials) such as wood from sustainably managed forests and design-related subjects (Building methods and techniques) such as flexibility" (W/E adviseurs, n.d.).
- Water: "In the sub-theme Water, points can be gained by limiting the absolute consumption of drinking water and reducing the burden on sewers, soil and groundwater. In this sub-theme, too, the user can specify additional measures and award bonus points" (W/E adviseurs, n.d.).

GPR Gebouw thus seems to rely mainly on the GPR Materiaal measuring methodology for the assessment of the Environment component. For the subthemes Circular material use/Environmental performance, additional and Water there are tick-boxes to earn points, as shown in Figure 13 below (W/E adviseurs, n.d.):

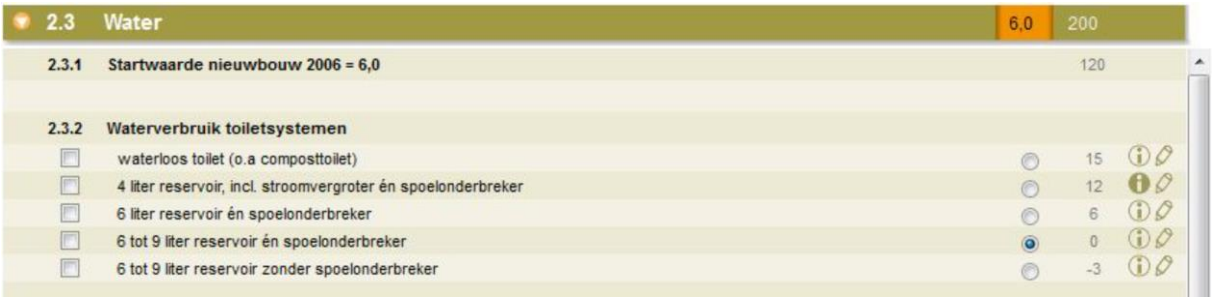


Figure 13 Example subtheme GPR Gebouw (W/E adviseurs, n.d.).

Respondent D thinks that the ticking options are very general and do not go into depth. He mentions an example:

> Like the use of secondary materials; that's very simple in there. It's just a question of: did you reuse one material, or two, or several? But it doesn't include a quantity of the use of those materials. It doesn't really go in-depth. That's what GPR should do.

Respondent F seems to refute this by saying that the use of these tick marks makes it possible to make good comparisons. She says it could be an option to substantiate the tick marks with a calculation. This would make it easier to check whether the option chosen is reliable.

Comparing BREEAM and GPR Gebouw

Both methods are designed to make sustainability measurable. They have in common that they are not designed to specifically measure circularity. However, both methods have a chapter dedicated to aspects related to circularity. As a database, both methods largely use the MPG. For GPR Gebouw this

is linked to GPR Materiaal. W/E Advisors will automatically link both methods in the next update. For BREEAM there is no specific measurement method prescribed to make an MPG calculation. They do require: "Confirmation from the National Environmental Database that the products are included in the NMD. Confirmation from the producer that the products (materials) have been added to the NMD for the project concerned". This, therefore, results in an obligation to use one of the three approved measurement methods to calculate the MPG (GPR Materiaal, One Click LCA or MPG Toetshulp) (Dutch Green Building Council, 2020).

When looking at the phases of the design process in which both methods can be used, few differences can be seen. For both models the argument mentioned by Respondent G applies:

> The more information you have, the further in the building process, the more specific the information is that you know and therefore can fill in. I work a lot in the design and development phases, so I would be the last one to say that it is impossible, but you do have to make assumptions at the front end. If you have certain ambitions, you have to try and hold on to them in the building process. Otherwise, you won't be able to realise your ambitions. So you have to keep measuring it to make sure that the number you promised in the first place is achieved. So it is possible, but then you start working with assumptions and you have to pin them down and keep monitoring and checking.

Both methods are also fairly similar in terms of the knowledge required, while there are several differences when it comes to ease of use. To use BREEAM you don't need any training or diploma. The assessment of your building can be made by anyone. However, if you want to have the building recorded, you are obliged to involve an assessor (BREEAM NL, n.d.). Respondent G also acknowledges this: "If you actually want to record it, that little number, then you enter the whole mill of assessors and measurements". Given the number of chapters involved in BREEAM, it is likely that the method cannot be completed in a few hours.

GPR Gebouw cannot be completed by everyone, according to Respondent A. Because GPR Gebouw consists of various pillars, it cannot be completed by a 'layman'. According to Respondent F, this is mainly because GPR Gebouw requires different calculations; both a BENG calculation and an MPG calculation: "The MPG calculation is easy to learn, but the BENG calculation is not. The BENG calculation can only be done by certified consultants. So it's certainly not easy to do". Respondent D sums it up: "It's not rocket science. It's a checklist of what you're going to do with your building. You have to add an MPG calculation and a BENG calculation. Other than that, you have to make choices".

So it is not necessary to have a GPR Gebouw calculation made by a GPR Gebouw Expert (as they also exist for GPR Materiaal). However, when it comes to an important calculation, Respondent F does recommend it: "Who is trained by W/E Adviseurs and knows how you can fill in a calculation and what applies to achieve certain points. That way you really guarantee the reliability of what is filled in".

Both methods have in common that they are not mandatory, whereas an MPG calculation is. Respondent G: "Nobody is going to force you to use that tool. So it really has to come from a client who wants to construct or manage a building and wants to measure it".

In terms of price, both methods are different. BREEAM is known to be an expensive method. This is mainly because the building has to be checked by an assessor. Respondent G recognises this:

> The problem with BREEAM is that it's very expensive, those assessors and everything that comes with it, the measuring afterwards and things like that... The whole method costs a lot of money to implement properly in the building process.

Because it is so expensive, it is not a realistic method for many projects. This is especially true for housing projects, which usually have a lower construction cost:

> As a result, BREEAM is very often applied to non-residential buildings and office buildings. It's an excellent measurement method there because the managers or owners of those buildings are willing to pay the money to measure in this way. But it's really far too expensive for residential buildings. That method is not affordable for homes. That's why we use GPR Gebouw much more often for houses because it is a much more affordable method. (Respondent G)

A full overview of the costs associated with BREEAM can be found at: https://www.breeam.nl/tarieven-7. A distinction is made between building type, surface area and partner/non-partner. However, BREEAM does not have to cost money; it is possible to choose not to have an assessor check the building, in which case the building will not receive a certificate. This is because the BREEAM guidance is public and freely available. Respondent G: "BREEAM consists of many chapters. For each chapter it explains exactly how many points you can achieve and what you should do next. You can just use it. That download is freely available". GPR Gebouw, on the other hand, is a cheaper tool compared to BREEAM. A price query gives the following overview in Table 12:

Table 13 Price quote GPR Gebouw (personal communication, June 15, 2021).

GPR Gebouw	Licence	Entry fees
1 building (1 year)	€367,50	None
1 building, renewal (per building, 1 year)	€175,00	None
10 buildings + introductory course 1 person	€ 1433,25	€ 250,00
20 buildings + introductory course 1 person	€ 2094,75	€ 250,00
50 buildings + introductory course 6 persons	€ 3472,88	€ 500,00
Unlimited buildings + introductory course 6 persons	€ 4134,38	€ 500,00

There is also the possibility that the method does not have to cost money, according to Respondent G:

> It also works in a way that if a municipality requires a GPR calculation to be made, then the municipality can just give you a licence as a company to actually make the GPR. It doesn't even have to cost anything for a property developer or a construction company.

Sub question 2 showed that detachability is a specific component of circularity that Kleissen's clients like to see in a building. In the MPG, detachability is included in Module D. In BREEAM and GPR Gebouw, detachability is included differently. As described above, the 'Materials' chapter is divided into five sections. One of these parts is Detachability. Within BREEAM specific attention is therefore paid to this aspect. However, with only one point to be gained, detachable design is not greatly encouraged.

GPR Gebouw does not seem to specifically address 'detachable' design. In the three parts; Environmental performance, Circular use of materials and Water no specific attention is paid to detachable designs. In this sense, detachable designs are not extra rewarded. However, as described above, the method is largely dependent on the MPG score, which is known to take detachability somewhat into account. Respondents did not link detachability and GPR Gebouw in the interviews either. However, W/E Adviseurs and DBGC (the organisation that developed BREEAM) have indicated that they are prepared to include detachability in their existing sustainability measurement methods (Nationale Milieu Database, 2020b).

Although GPR Gebouw does not specifically address dismantlability, the interviews showed that GPR Gebouw distinguishes itself in another way. As the literature review showed, MPG and BENG may be contradictory. When the MPG increases, the BENG may decrease, and vice versa. According to Respondent F, GPR Gebouw has a solution to this. GPR Gebouw would combine the BENG and MPG into one score, to achieve an ideal balance between the two. The literature study confirms this. The

DPG (DuurzaamheidsPrestatie Gebouw - Sustainability Performance Building) is used to make this comparison. In this way, an optimal result for both can be created (W/E adviseurs, 2016).

In summary, BREEAM and GPR Gebouw are the most widely used methods to measure sustainability. Basically, they both rely on the TBL. BREEAM is more cumbersome and extensive than GPR Gebouw. It also involves more costs and time, which makes it seem more suitable for commercial buildings. The advantage of GPR Gebouw is that it can balance the BENG and MPG.

Comparing measuring methods Circularity

It emerged from the interviews that specific measurement methods have been developed to measure circularity. These did not emerge from the literature review. These methods all aim to make circularity in the construction sector measurable. The methods in this regard are the following: CPG (CircularityPerformance of Building), BCI (Building Circularity Index) developed by Alba Concepts and the Circulariteitsindex (Circularity Index) developed by Madaster. These three measuring methods are compared: how do they measure circularity, which database do they use, in which phases of the design process can the method be used, what knowledge is needed and what costs are associated with the method.

How the measuring methods measure circularity is the part in which they differ the most. The CPG measures circularity based on input received from GPR Gebouw. In Figure 14 below it can be seen that the CPG takes something from almost all aspects of GPR Gebouw.

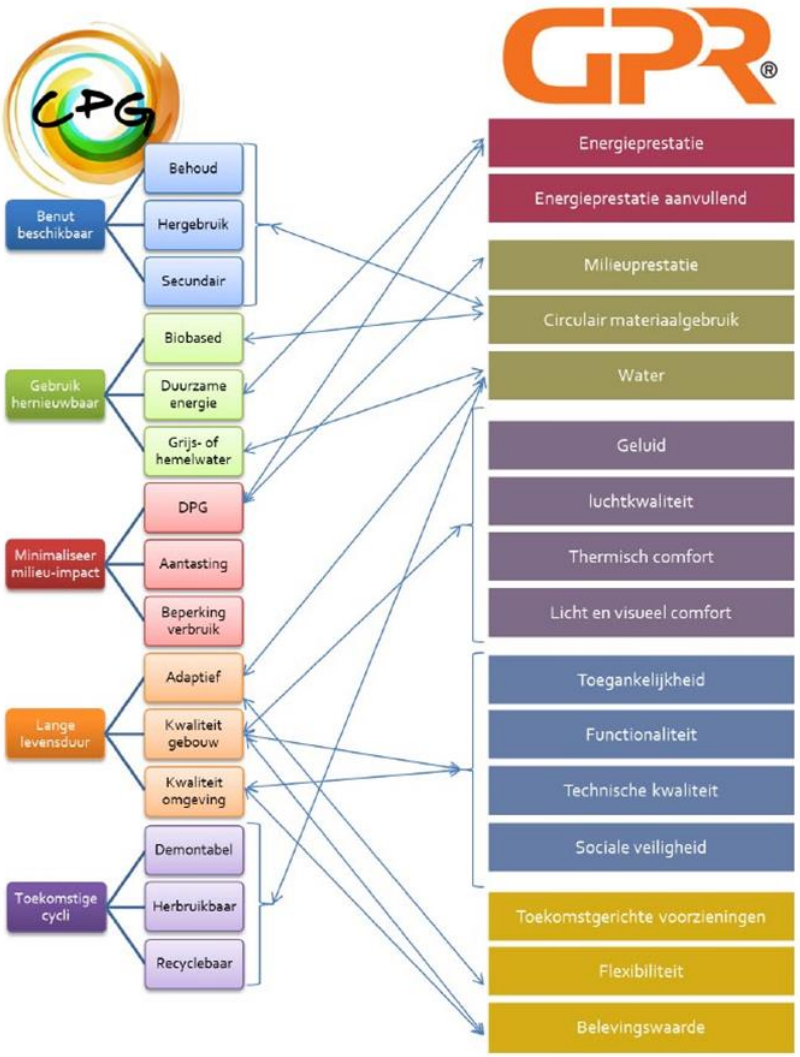


Figure 14 Connection between GPR Gebouw and CPG (W/E adviseurs, n.d.).

It shows that the CPG achieves the circularity score not only from the aspect of Environment but from all five aspects. Filling in a CPG takes minutes. This is because the CPG is nothing more than an Excel sheet in which values are taken from GPR Gebouw:

> So the CPG is just an Excel sheet where you take certain scores from your GPR calculation. So it is not a separate calculation. You only have to copy some scores, so you do have to enter the entire GPR calculation. The CPG is a kind of abstraction of the themes that are important for circularity. (Respondent A)

Respondent F states that the CPG circularity score is assessed based on W/E's own opinion. According to their website they interpret circularity as; "A building is circular if, during construction and operation, resources are kept in a closed loop without harmful emissions to air, water and soil" (W/E adviseurs n.d.). W/E Adviseurs has made the CPG make circularity measurable from the input from GPR Gebouw. For Respondent G, however, it is the most suitable tool for finding something of circularity: "I think that tool comes in the direction of what it should be. It also includes a component of secondary materials, prefabrication. In any case, it tackles circularity from different angles. The MPG is really only about environmental performance". According to Respondent G, this is mainly because W/E would be the most active in creating a total picture of circularity.

The BCI of Alba Concepts has a different approach to measure circularity. According to Respondent G, the two-month-old tool "Mainly originated from detachability". Respondents F, G and H mentioned that the method is made up of two parts. Respondent H: "The BCI is a bit of material use and detachability", as can be seen from a recording of the conversation in Figure 15:

Figure 15 BCI (personal communication, May 28, 2021).

This corresponds to several sources on the internet, which confirm the same (BCI Gebouw n.d.; Stolk n.d.). The Material Consumption element is calculated by an MPG calculation. The Detachability component is calculated by four detachability indicators which are aggregated to a Detachability Index (LI). These four factors are (1) Joint type, (2) Joint accessibility, (3) Form closure and (4) Crossings (BCI Gebouw n.d.).

For Respondent H, this method works very well. She felt that the MPG was a good basis, but that it only focused on the environmental impact: "I think that measuring MPG per se is not a bad measuring method but it does not give the whole picture of the theme of circularity". By using the BCI "As a kind of extension of the MPG, a total ambition for circularity can be expressed". To make a BCI calculation, Respondents E and H normally first make a 'traditional score' of a building. In this way, improvements in the use of materials and detachability can be better compared. The outcome of the BCI consists not only of a total score but also of an MPG value, CO-2 emissions, detachability and circularity of material, product and element (Respondent H). This can be confirmed by a requested test license of BCI. The programme clearly shows the final scores of the above-mentioned aspects.

According to Respondent F, the Circulariteitsindex developed by Madaster is a measurement method that measures much more than a traditional MPG calculation. In the Circulariteitsindex all materials in a building are included. This is not the case for an MPG calculation. Respondent F gives an example:

> The building code requires a safe, healthy and sustainable building. In order to achieve this, you have to cover your bathroom with tiles, for example, so that it is a watertight layer and your construction remains intact. You fill in the tiles you need for the floor and walls, but you

> don't fill in the fact that you know a toilet and washbasin will also be installed there. But in the Circulariteitsindex, you do enter the fact that a kitchen and bathroom fittings will be installed. In fact, standard things that end up in your home, for example.

According to Respondent F, to obtain all the information needed to draw up a Circulariteitsindex, a materials passport must first be created. This material passport lists all the materials used in the building.

The different methods extract the information from different databases. The CPG relies as described on the input it gets from GPR Gebouw. Information about the life cycle of a building comes from the section Environment. The MPG created in this section meets the requirements of the NMD and therefore also uses their database.

The BCI uses a different database. On the BCI website, they state the following: "The MKI in the BCI Building environment is an indicative MKI that is not based on the assessment method Environmental Performance of Buildings and GWW-works of the Foundation for Building Quality" (BCI Gebouw, n.d.). Respondent H states that the BCI currently relies on the NIBE database. Even though the LCA information extracted from the database is virtually the same, this MPG calculation may not be used for an environmental permit. However, she also informs us that Alba Concepts wants the BCI to become a validated calculation tool for the MPG in the future. For this, they would have to switch to the database of the NMD.

The Circulariteitsindex retrieves data from three different databases. It uses the database of the NMD, the database of NIBE and it allows users to add products themselves. The advantage of this is that the range of different products is much larger. The disadvantage is that it may not be used for an official MPG calculation either. Respondent F states that the information is not checked by a validated party, whereas the database of the NMD is. The risk here is that the reliability decreases. However, according to Respondent F, this method provides the most information when looking purely at the circularity score of a building:

> The circularity index really does include the following: what percentage of renewable materials do you use, where does it come from, can it be disassembled, do you have details of this, how does it enter the production cycle again or how is it processed, is it refurbished, manufactured, that sort of information is included again.

This can be confirmed via the Madaster website. It shows that the Circulariteitsindex distinguishes three phases: construction phase, use phase and end-of-life phase. For each phase of life, there are different aspects on which a score can be obtained. Each of these aspects then looks at each building component as elaborated by Stewart Brand. The website shows 13 aspects and 6 building components. One of these aspects looks at the detachability of the building component. In total there are 78 topics on which circularity is assessed. Both per aspect and per building component an overview score is shown. A total score is also given and determines your circularity index (Madaster, n.d.).

All three measurement methods are comparable at the phase of use. All three methods can be completed with building data available at the time of design. The earlier in the design process, the less data is available and the more inaccurate the calculation. There is little to distinguish between the various measurement methods.

All methods are fairly similar in terms of knowledge required and ease of use. The CPG requires the same knowledge as GPR Gebouw. The user will need to make a BENG and MPG calculation, among other things, to fill in the full CPG, according to Respondent F. However, it is possible to choose to fill in standard values, which makes it possible to simplify one of these steps. To fill in the BCI, it is useful to have some basic knowledge of construction, according to Respondent H: "It is easy, I did not study construction, but I have noticed that it is useful when you start working with it for the first time to

have some construction knowledge, or at least to have made an MPG calculation once". Respondent F agrees:

> I would be surprised if it's very difficult. As long as you get the right information and can link it. That's the beauty of software, of course: in principle, the difficult part of the calculation is a black box through which you can pass it.

According to Respondent H, no training is required to use the BCI. Alba Concepts does offer training on their website. In a half-day course, participants are taught the basics of the tool. The costs are 199 Euros, or 149 Euros for licence holders (BCI Gebouw, n.d.). A user's manual can also be found on the website.

At the time of writing, BCI is not yet linked to other software, according to Respondent H. The link to BIM is on the agenda for future developments. Currently, you have to manually fill in the materials used, based on NL/SfB coding. This is comparable to the MPG calculation that will eventually be added in the CPG (via GPR Gebouw and GPR Materiaal).

According to Respondent F the Circulariteitsindex is very easy to fill in: "The Materials Passport/Circulariteitsindex is certainly easy to do because it is a matter of taking a material and putting it in and linking it to the right data. So anyone can do that". So it seems to work here in the same way as the BCI. It is not clear, however, whether the Circulariteitsindex also uses NL/SfB coding, as it makes use of three databases.

In terms of costs, the three methods differ relatively much. The CPG is nothing more than a free downloadable Excel file. Since the input is taken from GPR Gebouw, it is mandatory to purchase this license. For the BCI there are more costs involved. According to Respondent H the costs are 500 Euros for one BCI calculation. Within this calculation, it is possible to calculate three different scenarios. If you want to have the calculation validated by Alba Concepts, an additional 300 Euros is charged. None of the respondents mentioned the costs of using the Circularity Index. Respondent F did mention that the Circularity Index is not yet really a thing, and only pilot projects are being run with it: "The materials passport is not yet really a thing. It is really the pilot projects that are working with it, and they are the pioneers who really want us to do something with it. So it is still very small".

In summary, the three methods of measuring circularity all differ in the method. The CPG looks at circularity from multiple perspectives, the BCI looks at circularity mainly from the perspective of detachability and the Circulariteitsindex looks wider than the MPG by including all materials in a building and assessing them per building layer. All three methods have advantages and disadvantages. The CPG is fairly global and is 'just' an Excel file from GPR Gebouw. However, ease of use, scope and price are strengths of the method. The BCI focuses heavily on detachability and relies on an alternative database. Additionally, it is only live for two months. The advantage, however, is that the BCI is designed based on scientific research and corresponds to the respondents' wishes for an extension of the MPG. The Circulariteitsindex is currently only in a pilot phase and uses three databases. This results in lower reliability but a comprehensive overview of the building performance.

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