Circularity Zeeland

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Circularity Zeeland

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Management Summary

The construction industry is responsible for around 50% of the raw materials extraction from nature and also 50% of the waste generated in the world. In the linear economy, most of the industries are exploiting resources from the Earth, and not giving back anything but waste which do not contribute in the regeneration of our systems. Therefore, the construction industry requires to have a transition towards a circular economy where no more resources are taken from natural streams and no more waste is generated. To be able to achieve this, innovative approaches need to be taken. Furthermore, following the need of adoption of the UN Sustainable Development Goals, the Dutch government has started a plan to trigger the change to circular solutions.

One innovative approach towards the transition to the circular economy is the development of new procurement models that enable the change from a linear perspective to a circular and sustainable perspective. The objective of this project was to design a comprehensive and practical Circular Procurement Framework and Tool which considers the circularity principles as core element to pursue the transition. By doing this, organizations will be able to incorporate this new practices into their procurement processes which will foster the development of sustainable solutions in the construction sector creating a positive change in the industry.

During the development of this project, it was identified the need of having clear definitions to understand and create feasible ambitions in the circularity approach. Moreover, it was necessary to review what are the main barriers in the adoption of this new model in order to create channels to help the different stakeholders from the industry to adapt to the change. This was performed in order to create a clear definition that encompasses the ambitions of the Province of Zeeland that is feasible to follow in their future construction projects by overcoming possible barriers that hinder the transition. For the progression of the project, the following definition of Circular Economy in the Built Environment was used: a restorative and regenerative economic model, which aims to provide solutions to sustainability related problems by maintaining the highest possible value and utility to all the components and materials that construct the system where they belong. This is achieved by a stronger control of finite raw materials exploitation and by optimizing and reducing the production of construction and demolition waste which can be undertaken if its lifespan is prolonged and its value is kept within the built environment system or another system following the R's strategies. All of this needs to be considered with the premise that the development of the system will not harm but will preserve the sustainability pillars (society, environment and finances).

As part of the barriers, the main identified were the lack of clear definitions, lack of evaluation standards, low availability of circular goods and services and poor knowledge of suppliers. This meant that with the creation of a framework that aims to fulfill the aforementioned definition, suppliers will be able to create streams for the development of knowledge that will foster the development of new business models that provide circular goods and services. The procurement phase of a project is seen as an opportunity to create knowledge between all the stakeholders of a construction project in order to think of new possibilities to provide solutions that are more sustainable following the circularity principles in the sector of construction.

Furthermore, an analysis of six existing building circularity measurement frameworks was performed. These frameworks were Platform CB'23, Madaster, Alba Concepts, W/E Adviseurs, BREEAM Circular Building and OneClickLCA. This was to understand the current practices taken for the evaluation of building circularity in the Netherlands with the different approaches to its measurement. It was possible to find a link between the definition of circularity used and the approach they followed. The need to perform this was firstly to understand manners in which it is already measured but also to create a way in which they can be adapted for procurement practices with the creation of a Circular Procurement Framework and Tool that combined the different approaches. It was identified a lack of transparency in the results of the different frameworks and a lack of traceability to understand certain results. This resulted in the idea of creating a framework that has open results from different categories to create awareness on the designers of the project on which ways to perform better with the perspective of circularity and use of biobased.

Lastly, the designed Circular Procurement Framework and Tool was tested in a case proposed by the Province of Zeeland. This case was the Veldstation Seaftinghe which is a bird watch facility built in the Seaftinghe natural region of the province. Since the solution to this project was designed to have a good circularity performance, it was needed to create five new scenarios to be able to replicate the procurement process in which several designs

are evaluated. This resulted in a useful approach to understand the performance of the Circular Procurement Framework and Tool in an interesting case.

The Circular Procurement Framework and Tool was designed to provide flexibility and adaptation considering the diverse needs of the Province of Zeeland. It can help the province to set certain bars of the expected circularity performance of new projects in a first stage of the real use of the framework. It gives the importance to the collaboration between parties promoting transparency enabling a learning process throughout the process. Once the involved stakeholders generate knowledge, these bars can be risen to have each time more sustainable, circular-biobased solutions for construction projects within the built environment of the Province of Zeeland.

The result of this project demonstrates feasibility and potential of the integration of circularity principles in the procurement process for projects within the Built Environment of the Province of Zeeland. Therefore, this project contributes in the implementation of the circular economy in the construction sector from an early phase of the projects helping the stakeholders in the learning process towards the adoption of more sustainable solutions.

At the end of this project, the report provides with valuable information regarding the limitations of the designed framework and opportunities to further develop it. This project expects to be a booster in the modification of the construction industry to create opportunities during the transition to the circular-biobased construction practices.

Management Samenvatting

De bouwsector is verantwoordelijk voor ongeveer 50% van de winning van ruwe grondstoffen uit de natuur en ook voor 50% van het wereldwijd gegenereerde afval. In de lineaire economie putten de meeste industrieën grondstoffen uit de aarde zonder iets anders dan afval terug te geven, wat niet bijdraagt aan het herstel van onze systemen. Daarom moet de bouwsector een overgang maken naar een circulaire economie waarbij geen grondstoffen meer uit natuurlijke bronnen worden gehaald en geen afval meer wordt gegenereerd. Om dit te kunnen bereiken, moeten er innovatieve benaderingen worden gevolgd. Bovendien is de Nederlandse regering gestart met een plan om de overgang naar circulaire oplossingen te stimuleren, als reactie op de behoefte om de Duurzame Ontwikkelingsdoelen van de Verenigde Naties te omarmen.

Een innovatieve benadering om de overgang naar de circulaire economie te bevorderen, is de ontwikkeling van nieuwe inkoopmodellen die de verandering van een lineair perspectief naar een circulair en duurzaam perspectief mogelijk maken. Het doel van dit project was om een allesomvattend en praktisch Circulair Procurement Framework and Tool te ontwerpen, waarin circulariteitsprincipes als kernelement worden beschouwd om de overgang te bevorderen. Door dit te doen, kunnen organisaties deze nieuwe werkwijzen integreren in hun inkoopprocessen, wat de ontwikkeling van duurzame oplossingen in de bouwsector stimuleert en een positieve verandering teweegbrengt in de industrie.

Tijdens de ontwikkeling van dit project werd vastgesteld dat er behoefte was aan duidelijke definities om het circulariteitsprincipe te begrijpen en haalbare ambities te creëren. Bovendien was het noodzakelijk om de belangrijkste belemmeringen bij de acceptatie van dit nieuwe model te onderzoeken om kanalen te creëren die verschillende belanghebbenden in de sector helpen zich aan de verandering aan te passen. Dit werd gedaan om een duidelijke definitie te creëren die de ambities van de Provincie Zeeland omvat en haalbaar is voor toekomstige bouwprojecten, waarbij mogelijke belemmeringen voor de overgang worden overwonnen. Voor de voortgang van het project werd de volgende definitie van een Circulaire Economie in de Gebouwde Omgeving gebruikt: een herstellend en regeneratief economisch model dat tot doel heeft oplossingen te bieden voor duurzaamheidsproblemen door de hoogst mogelijke waarde en nut te behouden voor alle componenten en materialen die het systeem vormen waar ze deel van uitmaken. Dit wordt bereikt door een betere controle van de exploitatie van eindige grondstoffen en door optimalisatie en vermindering van de productie van bouw- en sloopafval, wat mogelijk is als de levensduur ervan wordt verlengd en de waarde binnen het gebouwde omgevingssysteem of een ander systeem wordt behouden volgens de R-strategieën. Dit alles moet worden beschouwd met de premisse dat de ontwikkeling van het systeem de duurzaamheidspijlers (maatschappij, milieu en financiën) niet schaadt, maar behoudt.

Als onderdeel van de belemmeringen werden de belangrijkste punten geïdentificeerd als het ontbreken van duidelijke definities, het ontbreken van evaluatiestandaarden, een lage beschikbaarheid van circulaire goederen en diensten en een gebrek aan kennis bij leveranciers. Dit betekende dat met de creatie van een framework dat beoogt de eerder genoemde definitie te vervullen, leveranciers stromen kunnen creëren voor de ontwikkeling van kennis die de ontwikkeling van nieuwe bedrijfsmodellen stimuleert die circulaire goederen en diensten leveren. De inkoopfase van een project wordt gezien als een kans om kennis tussen alle belanghebbenden van een bouwproject te creëren, om zo nieuwe mogelijkheden te bedenken voor duurzamere oplossingen volgens de circulariteitsprincipes in de bouwsector.

Bovendien is er een analyse uitgevoerd van zes bestaande meet frameworks voor circulair bouwen. Deze frameworks waren Platform CB'23, Madaster, Alba Concepts, W/E Adviseurs, BREEAM Circular Building en OneClickLCA. Dit werd gedaan om inzicht te krijgen in de huidige praktijken voor de beoordeling van circulariteit in de bouwsector in Nederland, met verschillende benaderingen voor de meting ervan. Er kon een verband worden gevonden tussen de gebruikte definitie van circulariteit en de benadering die ze volgden. Het uitvoeren van deze analyse had als doel om te begrijpen hoe circulariteit momenteel wordt gemeten, maar ook om een manier te creëren waarop ze kunnen worden aangepast aan inkooppraktijken met de creatie van een Circular Procurement Framework and Tool die de verschillende benaderingen combineert. Er werd een gebrek aan transparantie in de resultaten van de verschillende frameworks geïdentificeerd en een gebrek aan traceerbaarheid om bepaalde resultaten te begrijpen. Dit leidde tot het idee om een framework te creëren dat open resultaten heeft van verschillende categorieën, om bewustwording te creëren bij de ontwerpers van het project over manieren om beter te presteren op het gebied van circulariteit en het gebruik van biobased materialen.

Ten slotte werd het ontworpen Circular Procurement Framework and Tool getest in een casus voorgesteld door de Provincie Zeeland. Deze casus betrof het Veldstation Seaftinghe, een vogelobservatiefaciliteit gebouwd in het natuurlijke gebied Seaftinghe van de provincie. Aangezien de oplossing voor dit project was ontworpen om een goede circulariteit te hebben, moesten er vijf nieuwe scenario's worden gecreëerd om het inkoopproces te repliceren waarin verschillende ontwerpen worden geëvalueerd. Dit resulteerde in een nuttige benadering om de prestaties van het Circular Procurement Framework and Tool te begrijpen in een interessante casus.

Het Circular Procurement Framework and Tool is ontworpen om flexibiliteit en aanpassing te bieden aan de diverse behoeften van de Provincie Zeeland. Het kan de provincie helpen om bepaalde normen vast te stellen voor de verwachte circulariteitsprestaties van nieuwe projecten in een eerste fase van het werkelijke gebruik van het framework. Het benadrukt het belang van samenwerking tussen partijen en bevordert transparantie, waardoor een leerproces gedurende het hele proces mogelijk wordt. Zodra de betrokken belanghebbenden kennis genereren, kunnen deze normen worden verhoogd om steeds duurzamere, circulaire-biobased oplossingen te hebben voor bouwprojecten binnen de gebouwde omgeving van de Provincie Zeeland.

Het resultaat van dit project toont de haalbaarheid en het potentieel van de integratie van circulariteitsprincipes in het inkoopproces voor projecten binnen de gebouwde omgeving van de Provincie Zeeland. Daarom draagt dit project bij aan de implementatie van de circulaire economie in de bouwsector vanaf een vroeg stadium van de projecten, waarbij belanghebbenden worden ondersteund in het leerproces naar de adoptie van duurzamere oplossingen.

Aan het einde van dit project biedt het rapport waardevolle informatie over de beperkingen van het ontworpen framework en kansen om het verder te ontwikkelen. Dit project verwacht een stimulans te zijn voor de verandering van de bouwsector, om kansen te creëren tijdens de overgang naar circulair-biobased bouwpraktijken.

Abstract

Keywords: Circular economy, circular procurement, sustainable construction, construction industry adaptation

Abstract: The construction industry is responsible for most of the waste generated in the world. Such industry requires to have a transition towards a circular economy which requires innovative approaches. An innovative approach towards this transition is the adaptation of a procurement model that enables the change between the linear perspective to a circular perspective. This project aimed to design a comprehensive and practical Circular Procurement Framework and Tool which embraces the circularity principles enabling organizations to incorporate them into their procurement processes, therefore, fostering the development of sustainable solutions in the construction sector. This project had several approaches, first a systematic literature review was conducted in order to understand definitions and barriers towards the adaptation of the circular model. Second, a review of existing building circularity measurement practices to understand the different approaches to its measurement and the possibilities to adapt them into procurement practices. And lastly the development of a Circular Procurement Framework and Tool that was tested in the case of the Veldstation Seaftinghe which is a project of the Province of Zeeland. The Circular Procurement Framework and Tool was designed to provide flexibility and adaptation considering the diverse needs of the Province of Zeeland. It gives the importance to the collaboration between parties promoting transparency enabling a learning process throughout the process. The result of this project demonstrates feasibility and potential of the integration of circularity principles in the procurement process for projects within the Built Environment of the Province of Zeeland. Therefore, this project contributes in the implementation of the circular economy in the construction sector from an early phase of the projects helping the stakeholders in the learning process towards the adoption of more sustainable solutions.

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1 Introduction

The current relationship between human kind and the planet Earth is facing an important change. Probably not a voluntary change but a necessary one, as we as a society are against the clock to be able to save our planet. But to be able to understand this, it is important to understand the reason why human kind has acted like this in the past – or maybe is still acting – and has been destroying our ecosystems in order to be able to change the present and future.

Human kind has always needed to make use of natural resources in order to survive. However, in ancient times, the consumption of resources was naturally balanced. This was because humans could only consume what was available in nature at that time and also because human population was not as big as it is nowadays. It was until the beginning of the industrial revolution and the idea of capitalism, when societies started to exploit natural resources in a rate that the Earth was no longer able to naturally balance the re-production of resources. Then, societies started emerging economically and in population. The term of Linear Economy comes from this old idea and is the current model that many societies are using.

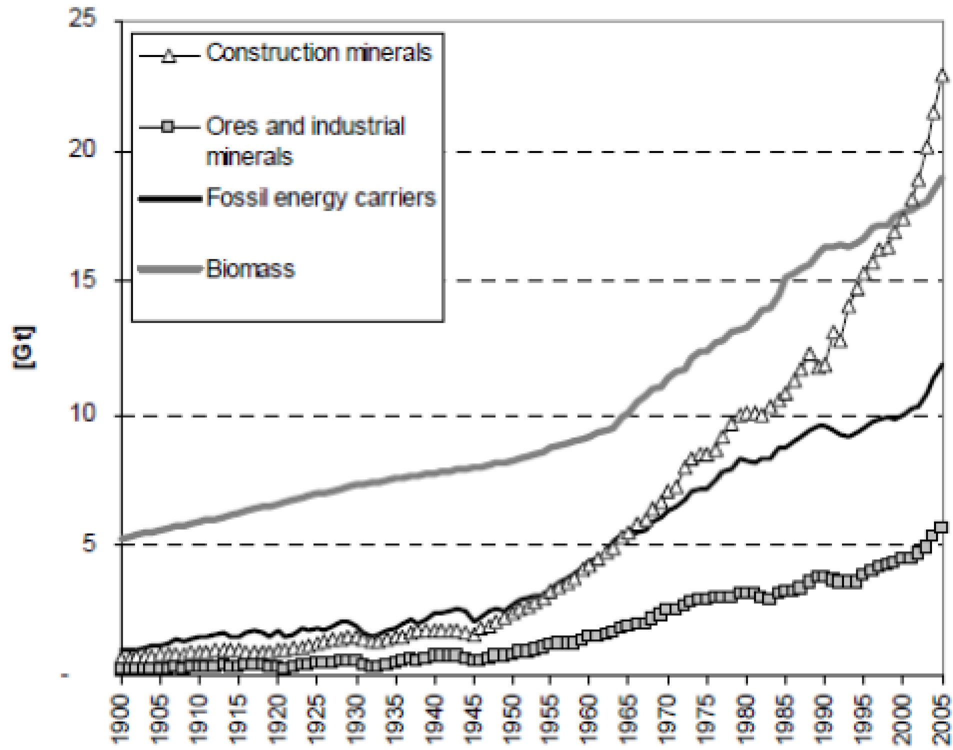

Figure 1 - Total materials use in Giga tons per year (European Environmental Agency, 2011) (Krausmann, et. al., 2009)

By Linear Economy it is understood that resources are extracted from nature, then they are transformed into materials, manufactured products and buildings or infrastructure for a planned or unplanned life cycle. When this lifecycle reaches its end, then the material, product, building or infrastructure, together with all the materials that conformed it goes to waste, is demolished and landfilled or in the best case it is incinerated to generate energy. Therefore, the natural resources were used for one single use. This is explained in the left side of Figure 2. And to narrow down the problem, specially the construction industry is responsible for 50% of all natural resources extraction, and produces around 50% of the total amount of waste generated all over the world (Akanbi et al., 2018) (Esa et al., 2017). Furthermore, another indicator that proves the failure in this Linear model, is the historic use of materials (Figure 1), which indicate that the development is no longer sustainable.

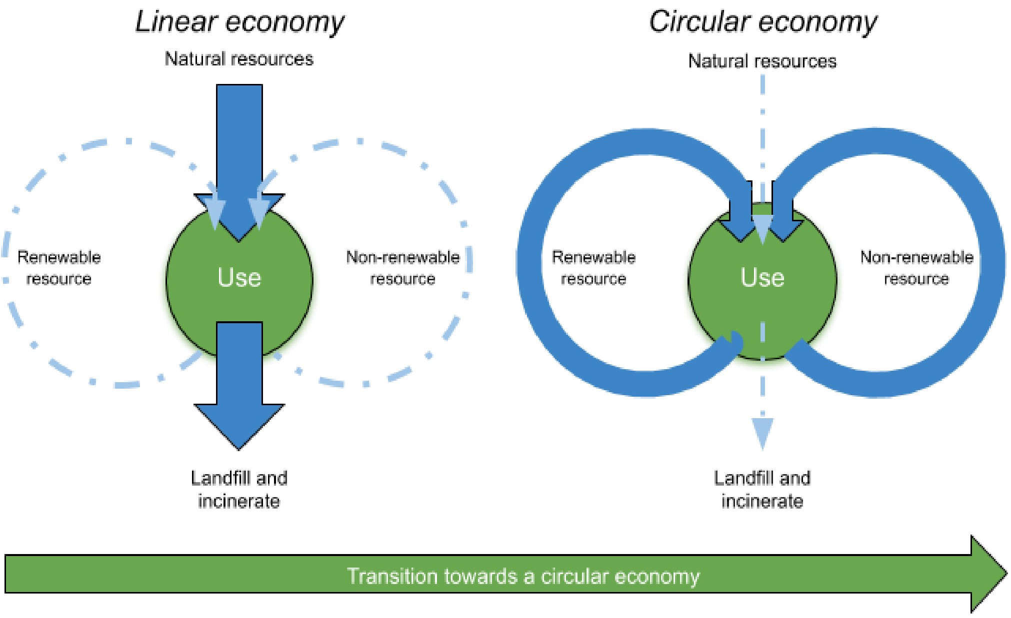

Figure 2 - Transition from Linear to Circular Economy (Potting et al., 2017)

On the other hand, it is understood as Circular Economy as an antonym to the Linear Economy (Murray, et. al., 2017) that aims to a more sustainable model that intents to close the loops by the reuse and recycling of materials. Therefore, this model does not contemplate entirely the production of waste but the repurpose of it with the extension of its lifespan. To explain it better, resources are taken from the existing system, processed into products or buildings, used throughout its life cycle and then its components are planned to be reused or recycled ideally to reduce the production of waste (Akanbi et al., 2018) and to start a new life cycle in a new loop. The Circular Economy model is shown on the right part of Figure 2.

1.1 Circular Economy in the Dutch context.

Due to the aforementioned, it is key factor to make a transition from Linear Economy to Circular economy as soon as possible. Therefore, Dutch territory aims to support national wide with the transition to become 50% circular by the year 2030 and fully circular by 2050. This ambition requires a lot of research to be done, but there are many efforts being put to be able to achieve this goal. For instance, the Dutch Planning Office for the Living Environment (Planbureau voor de Leefomgeving) (2019), made public a plan for the targets to achieve by 2030 with the operationalization and concretization of the 50% Circular Economy goal. Moreover, the Government-wide (Rijksbrede, 2019) launched its program to reach a national Circular Economy by 2050 in which they emphasise the challenge of resource usage in the 21st century in accordance to a reduction in the emissions which entail a need for knowledge and innovation. Furthermore, in a shorter term, the Execution Program for Circular Economy 2021-2023 was published in which Circular Procurement is a relevant topic (Rijksoverheid, 2021).

Since the Dutch government has visualized this need of change towards the Circular Economy, many provinces and regions from the Netherlands are trying to put their efforts in order to achieve it as soon as possible in all the different stages of the projects. Consequently, the Province of Zeeland, in order to attain to the national requirements, is also trying to accelerate it. The current ambition of the Province is to make this transition from the procurement and governance perspective of the built environment as the Transition agenda for Circular Buildings mention (Transitie-agenda, 2018). To achieve this, the province has been involved in the development of the region with a circular perspective, for instance, their participation in the Interreg Circular Biobased Construction Industry project, where partnered with other Dutch, Belgian and English universities and institutes makes the province a frontrunner province in the Netherlands in terms of transition to circularity. In this project they are working in two living labs. One in Lueven with the creation of a prototype for circular urban innovation of housing, and the second by Emergis in Kloetinge, the Netherlands, where the exploration of circular renovation and new construction is took place. Moreover, they are reflecting in current legislation and regulations which may impact in the development of circular solutions.

1.2 Problem Statement

While the province of Zeeland is a frontrunner, and there are many ongoing initiatives and well-defined ambitious targets to meet, the province still faces several challenges. A critical challenge relates to the integration of circularity targets in procurement processes. There currently is no clearly defined and operationalized way of assessing the level of circularity of a project in the built environment sector for decision making purposes.

Although there are many tools which aim to measure building circularity performance and their approach vary in the measurement strategies, there is no clear consensus on a standard measurement strategy for it. Moreover, these tools were not specifically developed as a decision-making tool for procurement purposes. This relates to the fact that they are able to provide a general overview of the performance of a project, but they are not able to give final score that allows a comparison for different alternatives. Furthermore, these tools were not explicitly developed for the design stage of a project, but they can be used in the different stages to understand the circularity performance of a building. Among the multiple indicators used by these frameworks, there are indicators that are not yet ready for its operationalization due to a lack of a clear definition. For instance, the value retention of a project components is not clearly defined and therefore, the measurement strategy is not properly developed either.

1.3 Aims and objectives

The aim of this project was to develop a Circular Assessment Tool for Procurement purposes that will help the province to achieve the national circularity goal. This tool is an essential part of adapting the current Procurement process of the Province of Zeeland to a Circular Procurement Process. With this, they can ensure that the environmental impact of future projects that they will develop will be lowered. The importance of the involvement on the early stage of a project is of high relevance, and the need of a future proof framework that allows a Circular Tendering Process is a big step that needs to be taken for a better and more sustainable development of projects.

In order to meet this aim, a list of objectives was developed:

Objective 1: Review existing literature to formulate the definition of 'circular economy' and indicators used to measure it in the context of the built environment, and to identify barriers to its adoption

Objective 2: Interview stakeholders and refer to former interviews from the Province of Zeeland to define requirements for their circular procurement process.

Objective 3: Review and compare best practices existing circularity assessment frameworks and tools with their indicators to determine whether they meet the requirements

Objective 4: Integrate indicators of existing circularity assessment frameworks and tools to develop a circular assessment tool for procurement purposes

Objective 5: Test Circular Procurement Tool to evaluate its performance and applicability to the Province of Zeeland

By addressing these objectives, the design of the tool will be tailored to the use that the Province of Zeeland envisions. Moreover, it will ensure that all the aspects that englobe the transition to a Circular Procurement Process are covered and therefore, the framework will be useful in different applications for all the different types of projects for the Built Environment.

2 Design process

2.1 Design process of Systematic Literature Review for definitions

To cover Objective 1 of this project, a Systematic Literature Review was performed following an adaptation of the scheme proposed by Okoli (2015), which is shown in Figure 3.

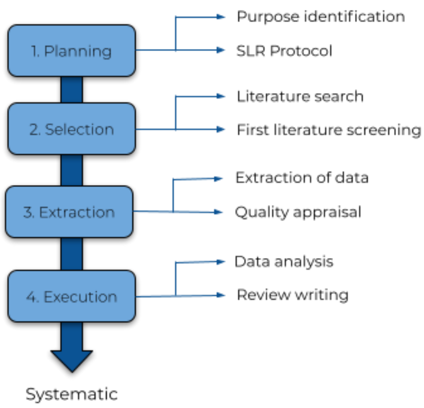

Figure 3 - Systematic Literature Review scheme (Okoli, 2015)

A Systematic Literature Review is a systematic method used for the identification, evaluation, synthesizing and analysis of existing academic and scientific work produced by researchers, scholars, and practitioners(Ahmad et al., 2019).

As for the first step (Planning), the aforementioned purpose of the Systematic Literature Review was set, and a review protocol was developed. Such protocol consisted in several steps regarding the strategy of searching the proper literature. This protocol was developed to be used in online scientific databases such as Scopus and it is based in the work of different authors such as Ahmad (2019) and (de Pascale et al., 2021). First of all, different search strings were developed to be able to acquire a reasonable amount of documents that could realistically be analyzed.

2.1.1 Search strategies

With different combinations of the keywords, it was possible to modify the amount of scientific papers that resulted from each searching loop. This step leaded to an analysis of every string which aided in the reconfiguration of the strings until a result of 315 scientific papers was achieved. This meant a reasonable amount of documents to be analyzed compared to the initial result of 1611 documents. The search strings and the results can be seen in Table 1.

Table 1 - Search strings used

# of attempt	Search string	Results
1	TITLE-ABS-KEY (“circular procurement” OR “built environment” OR “circular economy” OR “Value retention” OR “contract” OR “value cocreation” OR “organization” OR “temporal structure” OR “governance” OR “tender”) AND TITLE-ABS-KEY (“qualitative” OR “quantitative” OR “sensitivity analysis” OR “case study” OR “multi criteria”) AND TITLE-ABS-KEY (“construction” OR “construction industry” OR “built environment” OR “Dutch” OR “Netherlands” OR “infrastructure”) AND (LIMIT-TO (DOCTYPE , “ar”)) AND (LIMIT-TO (SUBJAREA , “ENVI”) OR LIMIT-TO (SUBJAREA , “ENGI”) OR LIMIT-TO (SUBJAREA , “SOCI”)) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , “English”))	1611
2	TITLE-ABS-KEY (“circular procurement” OR “built environment” OR “circular economy” OR “Value retention” OR “contract” OR “value cocreation” OR “organization” OR “temporal structure” OR “governance” OR “tender” OR “procurement”) AND TITLE-ABS-KEY (“qualitative” OR “quantitative” OR “sensitivity analysis” OR “case study” OR “multi criteria”) AND TITLE-ABS-KEY (“construction” OR “construction industry” OR “built environment” OR “Dutch” OR “Netherlands” OR “infrastructure”) AND (LIMIT-TO (DOCTYPE , “ar”)) AND (LIMIT-TO (SUBJAREA , “ENVI”) OR LIMIT-TO (SUBJAREA , “ENGI”) OR LIMIT-TO (SUBJAREA , “SOCI”)) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , “English”))	1657

3	TITLE-ABS-KEY ("circular procurement" OR "built environment" OR "circular economy" OR "Value retention" OR "contract" OR "value cocreation" OR "organization" OR "temporal structure" OR "governance" OR "tender" OR "procurement" AND NOT "waste") AND TITLE-ABS-KEY ("qualitative" OR "quantitative" OR "sensitivity analysis" OR "case study" OR "multi criteria") AND TITLE-ABS-KEY ("construction" OR "construction industry" OR "built environment" OR "Dutch" OR "Netherlands" OR "infrastructure") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , "English"))	1582
4	TITLE-ABS-KEY ("circular procurement" OR "built environment" OR "circular economy" OR "Value retention" OR "contract" OR "value cocreation" OR "organization" OR "temporal structure" OR "governance" OR "tender") AND TITLE-ABS-KEY ("qualitative" OR "quantitative" OR "case study" OR "multi criteria") AND TITLE-ABS-KEY ("construction" OR "construction industry" OR "built environment" OR "Dutch" OR "Netherlands" OR "infrastructure") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "DECI")) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , "English"))	1626
5	TITLE-ABS-KEY ("circular procurement" OR "built environment" OR "circular economy" OR "Value retention" OR "contract" OR "value cocreation" OR "organization" OR "temporal structure" OR "governance" OR "tender") AND TITLE-ABS-KEY ("qualitative" OR "quantitative" OR "case study" OR "multi criteria") AND TITLE-ABS-KEY ("construction" OR "construction industry" OR "built environment" OR "Dutch" OR "Netherlands" OR "infrastructure") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "DECI")) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , "English"))	1556
6	TITLE-ABS-KEY ("circular procurement" OR "built environment" OR "circular economy" OR "Value retention" OR "value cocreation" OR "organization" OR "temporal structure" OR "governance" OR "tender" OR "indicator") AND TITLE-ABS-KEY ("qualitative" OR "quantitative" OR "case study" OR "multi criteria") AND TITLE-ABS-KEY ("construction" OR "construction industry" OR "built environment" OR "Dutch" OR "Netherlands" OR "infrastructure") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "DECI")) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , "English"))	2016
7	TITLE-ABS-KEY ("circular procurement" OR "built environment" OR "circular economy" OR "Value retention" OR "value cocreation" OR "governance" OR "tender" OR "indicator") AND TITLE-ABS-KEY ("qualitative" OR "quantitative" OR "case study" OR "multi criteria") AND TITLE-ABS-KEY ("construction" OR "construction industry" OR "built environment" OR "Dutch" OR "Netherlands" OR "infrastructure") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "DECI")) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , "English"))	1399
8	TITLE-ABS-KEY ("circular procurement" OR "built environment" OR "circular economy" OR "tender" OR "indicator") AND TITLE-ABS-KEY ("qualitative" OR "quantitative" OR "case study" OR "multi criteria") AND TITLE-ABS-KEY ("construction" OR "construction industry" OR "built environment" OR "Dutch" OR "Netherlands" OR "infrastructure") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "DECI")) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , "English"))	1053
9	TITLE-ABS-KEY ("circular procurement" OR "built environment" OR "circular economy" OR "tender" OR "indicator") AND TITLE-ABS-KEY ("qualitative" OR "case study" OR "multi criteria") AND TITLE-ABS-KEY ("construction" OR "construction industry" OR "built environment" OR "Dutch" OR "Netherlands" OR "infrastructure") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "DECI")) AND (LIMIT-TO (ACCESSTYPE(OA))) AND (LIMIT-TO (LANGUAGE , "English"))	883
10	TITLE-ABS-KEY (circular AND economy AND procurement AND construction)	12
11	TITLE-ABS-KEY (circular*) AND TITLE-ABS-KEY (tender* OR procur* OR bid*) AND TITLE-ABS-KEY (constr* OR build* OR built* OR infra*)	315

Subsequently, the second step that Okoli (2015) suggests in the Systematic Literature Review scheme presented in Figure 3, consist of the 'screening' and selection of the papers. Therefore, a title review from the result of 315 papers was conducted, to identify the papers that are most aligned with the aim of the review, being to formulate: *"the definition of 'circular economy' and indicators used to measure it in the context of the built environment, and to identify barriers to its adoption"*. This step reduced drastically the number of papers to 26 which were directly related to the aim of the systematic literature review. Once the 26 papers were gathered, the next filter was to review the abstract to make a decision of the entirely related papers to the aim of the review. This resulted in 18 papers with high priority, 2 with not very high priority, and 6 with low priority.Table 2 shows the selection of the aforementioned papers with its prioritization according to title and abstract.

For the first step of the extraction of data (Figure 3) a keyword analysis was performed in order to be able to prioritize the order for the data extraction of each paper. To do this, the papers were introduced into an Excel tool which scanned how many times each keyword was used within each one of the selected papers. The objective of this process was related to the idea that if the keywords are more used in one document, meant that this document has a higher relation to the topic which englobed those keywords. This process gave a time priority to each paper to be deeply analyzed.

Table 2 - Selected papers for Systematic Literature Review

Ref.	Author	Title	Year
1	Luciano A., Cutaia L., Cioffi F., Sinibaldi C.	Demolition and construction recycling unified management: the DECORUM platform for improvement of resource efficiency in the construction sector	2020
2	Karhu J., Linkola L.	Circular Economy in the Built Environment in Finland - A case example of collaboration	2019
3	Ali A.K.	Mapping a Resource-Based Design Workflow to Activate a Circular Economy in Building Design and Construction	2019
4	Kelly M., Burke K., Gottsche J	Exploring material circularity opportunities for a construction-SME on small-scale projects in Ireland	2019
5	Bin Mohd Noor M.Z.	FlexZhouse: New business model for affordable housing in Malaysia	2017
6	Soto T., Escrig T., Serrano-Lanzarote B., Desantes N.M.(Soto et al., 2020)	An approach to environmental criteria in public procurement for the renovation of buildings in Spain	2020
7	Lăzăroiu G., Ionescu L., Uţă C., Hurloiu I., Andronie M., Dijmarescu I(Lăzăroiu et al., 2020).	Environmentally responsible behavior and sustainability policy adoption in green public procurement	2020
8	Zaidi S.A.H., Mirza F.M., Hou F., Ashraf R.U.	Addressing the sustainable development through sustainable procurement: What factors resist the implementation of sustainable procurement in Pakistan?	2019
9	Campbell-Johnston K., Cate J.T., Elfering-Petrovic M., Gupta J.	City level circular transitions: Barriers and limits in Amsterdam, Utrecht and The Hague	2019
10	Cramer J.	Key drivers for high-grade recycling under constrained conditions	2018
11	Manley K., Chen L.	Collaborative learning model of infrastructure construction: A capability perspective	2015
12	Mantalovas K., Di Mino G., Del Barco Carrion A.J., Keijzer E., Kalman B., Parry T., Presti D.L.	European national road authorities and circular economy: An insight into their approaches	2020
13	Satori M., Amaranti R., Srirejeki Y.	Sustainability of waste bank and contribution of waste management	2020
14	Uvarova I., Atstaja D., Korpa V., Avena L., Erdmanis M.	End-of-life tyre recycling: Going beyond to new circular business models in Latvia	2020
15	Tsolakis N., Zissis D., Srai J.S.	Supply network configuration archetypes for the circular exploitation of solid waste	2020
16	Migliore M., Talamo C., Paganin G.	Circular Economy and Sustainable Procurement: The Role of the Attestation of Conformity	2020
17	Bao Z., Lu W., Chi B., Yuan H., Hao J.	Procurement innovation for a circular economy of construction and demolition waste: Lessons learnt from Suzhou, China	2019
18	Kondo R., Kinoshita Y., Yamada T.	Green procurement decisions with carbon leakage by global suppliers and order quantities under different carbon tax	2019
19	Alhola K., Ryding S.O., Salmenperä H., Busch N.J.	Exploiting the Potential of Public Procurement: Opportunities for Circular Economy	2019
20	Paluš H., Slašťanová N.	Requirements for green public procurement of wood-based products in the EU	2019
21	Campioli A., Dalla Valle A., Ganassali S., Giorgi S.	Designing the life cycle of materials: New trends in environmental perspective [Progettare il ciclo di vita della materia: Nuove tendenze in prospettiva ambientale]	2018
22	Esa M.R., Halog A., Rigamonti L.	Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy	2017
23	Ravindra R., Fatemi-Nayeri H.	Managing Challenges and Mitigating Risks in Design, Construction, and Product Conformity of the Shared Path Bridge over Epping Road at Marsfield	2016
24	Shi C., Zhang G.	The ecological construction of scenic spots	2013
25	Mohamad Ramly Z., Shen G.Q.	Value management in Malaysia: Past, present and future	2012
26	Kim K.S., Dickey J.	Role of urban governance in the process of bus system reform in Seoul	2006
27	Hill J.W., Lumb C.	The design and construction of Belper sewage-treatment works	1979
28	Gablinger M., Yechiel A., Shevah Y.	Optimization of costs for procurement and transportation of pipes	2014
29	Lewis C., King M.	Designing the world’s largest dome: the National Stadium roof of Singapore Sports Hub	2014

As second step for the extraction of data, a list of concepts were established to analyze if and how the papers addressed them. This was done to be able to have a clear structure of what was necessary to retrieve from the literature. These concepts are presented in Table 3.

Table 3 - Analysed criteria

Research related	Circular Economy Related	Procurement related	Case study related
Research subject	Definition of Circular Economy	Definition of procurement	Location
Aim of the research	Circular Economy indicators used	Barriers	Function
Methodology	Measurement methodology of the indicators	Indicators used for procurement	Type of project
Data collection	Lifecycle stage studied	Procurement phase analyzed	Type of contract
Data source	R's strategies covered		Ambition level
Proposed solutions	Analyzed materials		Performance of indicators
Main conclusions			Public or Private

Once the papers were selected, and the criteria to analyze the papers was established, it was then possible to start the data extraction from the literature. This helped to have the information gathered in a clearly structured disposition for the following step which was the data analysis with the comparison of the different approaches of the literature, being the fourth and last stage of the systematic literature review process.

2.2 Design process of interview with stakeholders.

As part of Objective 2, an interview with respective stakeholders of the procurement process was needed. The purpose of such interview was to understand the current practices in the procurement process in order to know if the designed new Circular Procurement Framework and Tool needed to have certain conditions to be useful for them.

This interviews consisted in two different parts. In the first part, the people in charge of the procurement process at the Province of Zeeland were interviewed. The questions asked were the following:

1. What is the current procurement process?
2. How do you experience the current procurement process?
3. To what extent do you guide contractors to achieve certain solution?
4. What is the need for a Circular Procurement Framework and Tool?
5. How could you integrate a Circular Procurement Framework into your current process?

For the second part, a contractor who has already experienced a procurement process with the Province of Zeeland, was interviewed. The purpose of this was to understand their perspective and how they could adapt to a Circular Procurement Framework. The questions asked to them were the following:

1. What is the current procurement process?
2. How do you experience the current procurement process?
3. Do you think that the current procurement process guides you to achieve a desired solution by the client?
4. What do you think of the integration of a Circular Procurement Framework into the procurement process?
5. What benefits could you gain from having a Circular Procurement Framework?
6. How could a Circular Procurement Framework improve the current process?
7. Do you think that the implementation of a Circular Procurement Framework could help with the integration of more systemic circular solutions? How?

For this second part, the architecture firm RO&AD Architecten was selected. This firm has had experience with the Province of Zeeland with the design and construction of circular solutions for the built environment. They are a firm which designs at building and system level, with the mindset that a building is always part of an ecosystem. Their approach to sustainable solutions is integral by thinking in the social, economic, cultural and ecological aspects in their designs. This gives a good perspective and can be taken as a model to replicate in further procurement processes for this type of solutions that the Province of Zeeland is aiming for.

The interview was semi-structured, meaning that open dialogue and follow-up questions in between the questions were possible. No particular analysis method was adopted to analyze the outcomes of the interviews. During the interview, the main take-aways to the questions were repeated by the interviewer for confirmation by the interviewee. Subsequently, after the interviews, the outcomes were interpreted and summarized by the interviewer.

2.3 Design process of analysis of existing frameworks for Circular Buildings

In order to develop a Circular Procurement Framework and Tool, it was necessary to analyse existing frameworks which consider the assessment of Circular Buildings. To cover Objective 3 of the project, this task was performed. Figure 4 shows the followed steps for this analysis.

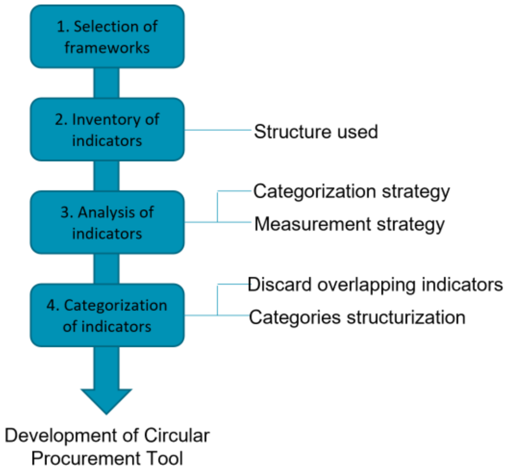

Figure 4 - Analysis of existing Circular Buildings assessment frameworks scheme

2.3.1 Selection of frameworks

To start with this process, a selection of existing frameworks needed to be done. There are multiple frameworks currently available that aim to assess the level of circularity of buildings. However, there are several of them which can be taken as a model to consider for the further development and procurement integration for this project. The first requirement to consider for selecting certain frameworks was its source. It had to be developed by a source which has certain reputation in the assessment of sustainable solutions for the built environment. The second requirement was to ensure that it was aiming for a European context in terms of ambitions. And finally, the third requirement was its applicability to procurement purposes.

One important aspect was to understand the approach that these frameworks have to circularity. What is their understanding of the term Circular Economy and what type of circular solutions they support the most.

The six chosen frameworks during this step are shown in Table 4.

Table 4 - Selected Building Circularity Assessment frameworks

Selected Building Circularity Assessment frameworks
Alba Concepts
BREEAM Circular Building
Madaster
OneClick LCA
Platform CB'23
W/E Adviseurs

2.3.2 Inventory of indicators from each framework

Once the frameworks were selected and its approach was understood, it was necessary to make an inventory of all the indicators that each one of these frameworks used. This inventory of indicators helped in the understanding of the structure that was used to be able to assess the level of circularity and how these indicators could end up in a final score. To achieve this, a tree diagram of all the different frameworks was developed. Such diagrams represent the whole overview of each of the frameworks. These diagrams can be seen in section 5 of this report.

2.3.3 Categorization of indicators

The aim of having a general categorization of indicators is firstly, to be able to compare and contrast the various frameworks, and secondly, to be able to integrate in one single framework the different approaches of the analysed frameworks and indicators.

Two ways to achieve this were tested. On one hand, to cluster the different indicators in new categories trying to generalize with common elements. And on the other hand, the categorization method of one of the frameworks may be used as a standard categorization strategy, and then to adhere the indicators of the remaining frameworks in order to adapt them in such categorization method. However, in this way, some indicators may not be adhered in which case new categories may be added.

Ultimately, one categorisation method was chosen, and the inventory of indicators was subsequently 'mapped' to this new categorisation in order to be able to conduct the comparative analysis of the frameworks.

2.3.4 Analysis of indicators

The inventory of the indicators of the different frameworks was subsequently used in a comparative analysis of the frameworks. The first step was to discern the categorization strategies and the extent to which they are aligned. The second step was to identify the similarities and differences between the indicators used in the frameworks. The third step was to zoom in on the similar, or overlapping, indicators, and analyse the potential differences in their application / operationalization. For the analysis of the measurement strategy of the indicators, each one of the different frameworks was deeply studied to learn the logic behind the calculation of them. This helped to differentiate the overlapping indicators which would therefore lead to a selection of them.

The overall aim is to gain knowledge of the measurement strategy of each indicator and its relevance for the development of a Circular Procurement Framework.

For every category of indicators, an overview of the comparative analysis of the frameworks was created, and conclusions were drawn.

2.4 Design process of development of Circular Procurement Tool

For the Objective 4 of this project, the Circular Procurement Tool was developed. In order to perform this, the following was done.

Based on the finding and selection of the different categories that were worked during Objective 3, a set of indicators that aligned to these categories were selected and assigned to the category that aims to measure the related aspect of the indicators. As the indicators were analysed per framework in the previous step, there was a clear understanding of them. Therefore, it was possible to assign them to the proper category.

Since there were different categorization strategies, but only one was selected (considering as a baseline the categorization exposed by Platform CB'23), the selected indicators were adhered to that categorization strategy. This meant that there was an final alignment of all the different indicators per framework in a single tool that was covering the desired aspects for a Circular Procurement based on the previous objectives with a vision of how the indicators have been already operationalized by the current practices of the measurement of circular buildings. This helped to translate the ambitions from the Province of Zeeland to measurable criteria.

Nonetheless, in the cases where there were junctions and connections between similar indicators from different frameworks, the criteria to select one over the other was the level of operationalization of the indicator in certain framework. For instance, if indicator 'x' appeared to be part of framework A and B in a similar way, the measurement strategy of that indicator was chosen based on the level of detail in the calculation strategy of framework A and B. In case framework A had the indicator more operationalized, then, that measurement strategy was selected.

This approach was performed for all the different categories of the Circular Procurement Tool. Then, the operationalization of the indicators was performed. This meant, that every indicator had to be calculated by developing a tool that could automatically give a score to all the indicators based on some required input information.

Finally the scoring system of each category was performed in order to be able to give a final overview of the Circular Procurement Framework. This allows the users of the tool to be able to have a decision making criteria available to select the best project during a procurement process.

2.5 Testing the Circular Procurement Tool

To finalize with covering the overall objectives of this project, a test of the Circular Procurement Tool was developed for Objective 5.

For this objective, it was required to have a case in which the tool could be tested. The goal of the case study was to be able to provide a prove that the Circular Procurement Tool is a useful tool for decision making purposes. In order to have a suitable case, the Province of Zeeland was asked to give several options in order to be able to select an option that could cope with the needs that the use of the tool entailed. This meant that there was enough information for the use of the project or that the architects could provide the information that was lacking.

Preferably, the case had to have different scenarios in which a comparison of the different scenarios could be performed in order to give an overview of the difference of the circularity performance in the tool of the scenarios. Since the idea the procurement practices is to be able to make decisions based on certain criteria that is compared between different designs. In order to have a successful test, these criteria had to be true.

3 Definitions

This section explains the result of the analysis which was previously explained in section Design process of Systematic Literature Review for definitions2.1 which was considered as an outcome for the Whitepaper of Rules and Regulations on the CBCI project. It contains three subsections where first, the definitions will be shown, then the overall identified barriers of circular procurement, and it will end with the presentation of certain indicators used in the academy for the assessment of circular economy and its application to circular procurement. Although there is a different approach in practice from this last point, it is relevant to make this remark in order to understand real practices.

The term Circular Economy is a well spread term which has not yet gotten a general consensus. This means that the definition to Circular Economy is context dependent. In general matters, Circular Economy is the economic model that in difference with the Linear Economy (take-make-use-dispose) aims to avoid the generation of waste and to use the resources more efficiently. However, within the literature many different type of definitions can be found. Such definitions can be related to sustainability and its three pillars (environmental, social and financial), they can also be related to economic processes, related to systems, as part of social value creation, and also to more technical aspects with relation to R's strategies or waste management approach. Moreover, different contexts are also found within the definitions. However, for the purpose of the white paper, the context taken will be the built environment context.

But not only is important to understand the concept of Circular Economy. It is also relevant to understand that it is a measurable concept. However, multiple measurement methodologies have been developed on the multiple contexts where Circular Economy has been applied until now. Nonetheless, there is still a lack of consensus for a single measurement methodology for the concept. Thus, at this stage of the transition from a Linear Economy to a Circular Economy, it is of high value to be able to assess it based on the specific ambition of application of the term. This will enable in the future the standardization of its measurement in a more global scale despite the different contexts and applications.

As it is shown in Table 3 one of the important aspects analyzed in this systematic literature review are the definitions. An remark that was seen through the review, is that the definition varies in a case dependent approach. This means that every definition is different according to the use of the concept that is given in each different case. However, for the development of a new framework it is important to have a clear overall definition which can be based in multiple approaches from previous experiences. To be able to do this, correlations between the most relevant and complete definitions were identified and then it was also identified a complementation between one another.

3.1 What is circular economy in the context of the built environment?

As it was previously mentioned, the same term can be explained in different contexts. Since this report aims to provide solutions within the context of the built environment, it is important to focus in that same context.

Within the context of the built environment, different concepts appear when it comes to Circular Economy. Such concepts are listed below:

Regeneration of natural systems	Optimization of resources
Reduction in the use of raw materials	Treatment for construction and demolition waste
Reduction of waste production	Highest utility with highest value
Prolongation of lifespan	Recyclability
Solution to atmospheric related problems	Implementation of sustainable development objectives
Increase of social value	Control of finite stocks
Application of R's strategies	Waste management
Preservation of sustainability pillars	Preservation of economic value

From the above listed concepts, there are important words such as 'value', 'sustainability', 'raw materials', 'finite stocks', 'construction waste', 'demolition waste' and important verbs such as 'regeneration', 'reduction', 'prolongation', 'application', 'preservation', 'optimization', 'implementation', 'control' and 'management'. This words can help us to generate the needed consensus to be able to derive an overarching definition to Circular Economy in the context of the built environment.

Despite of this, most literature consider as a baseline the definition given by Ellen Macarthur Foundation which is the following:

“Economy that is restorative and regenerative by design, and which aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles”

It is possible to see that this definition aligns to the concepts mentioned before with the terms ‘regeneration’ and ‘value’. However, the concepts dive deeper into other relevant terminologies which are tightly linked to the built environment and with the lifecycle of the elements that conform it. Putting a wider emphasis in the resources exploitation and waste generation. Moreover, the terminologies aim to preserve or increase value in a sustainability context. Nonetheless, the concepts not only aim to explain the meaning of Circular Economy, but they also try to provide solutions to it. For instance, ‘reduction of use of raw materials’, ‘application of R’s strategies’, and ‘recyclability’.

Going deeper into relevant definitions of Circular Economy in the Built Environment it is possible to find Karthu and Linkola (2019) who mention that it involves Rethinking the economic process, designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. It has a focus on the reduction of raw material consumption, the design of products for easy disassembly and reuse, prolonging the product lifespan through maintenance and repair, and using second use materials. For them, Circular Economy creates economic, social, and environmental value for the contribution of climate mitigation. Furthermore, for Soto et al. (2020), Circular Economy aims to prevent waste generation by promoting reuse, repair, and recycling of construction and demolition materials. It considers the building sector’s relevance in material cycles, climate change resilience, and the local economy. Circular economy also has an emphasis on the treatment of construction and demolition waste and resource optimization.

On the context of green public procurement, Lăzăroiu et. al. (2020) suggest that Circular Economy is a way of separation the economic growth from environmental consequences. This involves a low-use of carbon and production mechanisms, the implementation of sustainable development objectives, and the appraisal of materials within a closed-looped system. For this, Circular Economy aims to avoid the utilization of natural resources while reducing pollution, resource limitations with the objective of fostering innovative business models. Therefore, the potentializing of new business models is a core element to consider to help growing markets to develop. Zaidi et al. (2019) also focus on sustainable procurement with a more broad perspective. For them Circular Economy is a part of the sustainability pillars (environment, economy, and society). It involves recyclability of products, avoiding pollution, climate change, resource depletion, and ethical sourcing. Aiming to address atmospheric-related problems and promote sustainable procurement.

Since Cramer is one of the main promotors of the R’s strategies, in her document (2018) she mentions circular economy to be “the economy as a circular system being a prerequisite for maintenance of the sustainability of human life on Earth. Principle 1. Preserve and enhance natural capital by controlling finite stocks and balancing renewable source flows. Principle 2. Optimize resource yields by circulating products, components and materials at the highest utility at all times in both technical and biological cycles. Principle 3. Foster system effectiveness by revealing and designing out negative externalities.”.

One of the most known definitions to Circular Economy is the one from the recognized Ellen MacArthur Foundation. Different authors use it as their definition for their research. For instance, Mantalovas, et. al. (2020) uses that same definition. It is the following: “Economy that is restorative and regenerative by design, and which aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles”. Based in this definition, these authors gave their own definition as well which is the fact of adopting systemic thinking and cascade approach, end-products, components and even materials can be repurposed, reutilized, recycled or have their service life extended while keeping their highest value.

From the waste perspective, Bao et. al. (2019), aim to provide useful references to develop a Circular Economy focusing in construction and demolition waste management. Therefore, their definition to circularity focuses into that point of view as well from three different lines of thinking. First, with the Ellen MacArthur Foundation as mentioned before, but with the waste management context. The authors mention that the aim of Circular Economy is to decrease the consumption of raw resources, to reduce the emission of pollution, to minimize the generation of construction and demolition waste which will lead to eliminating environmental impacts with the added value of providing social benefits. This is intertwined with the R principles; however they only mention three R's (reduce, reuse and recycle). Furthermore, the importance of the consideration of the R's, enables the possibility for the extraction of the maximum value of resources and minimization of waste and pollution, which is a good alternative for the conventional linear economy model.

Finally, Esa et. al. (2017) also mention their definition with the construction and demolition waste perspective. For them, Circular Economy is an approach for waste minimization throughout the whole construction cycle. This approach that manages with a sustainability mindset the resources with the purpose of minimizing waste based on the aspect of regeneration. An aligned practice with sustainability in the social, economic and environmental aspects.

With this information, it can be concluded that Circular Economy in the built environment is a restorative and regenerative economic model, which aims to provide solutions to sustainability related problems by maintaining the highest possible value and utility to all the components and materials that construct the system where they belong. This is achieved by a stronger control of finite raw materials exploitation and by optimizing and reducing the production of construction and demolition waste which can be undertaken if its lifespan is prolonged and its value is kept within the built environment system or another system following the R's strategies. All of this needs to be considered with the premise that the development of the system will not harm but will preserve the sustainability pillars (society, environment and finances).

3.2 Barriers

Literature explains different type of barriers that draw a difficult transition towards circularity practices in general. These barriers have been identified as internal or external barriers which need to be considered and overcome in order to facilitate the change into a circular process. This part of the report explains such barriers.

Six different aspects have been identified as internal barriers (Zaidi et al., 2019):

1. *Absence of clear definitions*

   This is one of the major barriers and is a causing aspect for lack of understanding. As it was explained in the Definitions part of this report, the importance of having a clear definition of Circular Economy and its components is of high relevance to have a clear overview of what needs to be considered for the achievement of a concept.

2. *Lack of evaluation standards*

   The fact that there are no clear defined standards that help in the process of sustainable procurement is a relevant barrier. Since the understanding among stakeholders in this regard is lacking, and the information and standards are essential to understand the costs and benefits of sustainable procurement, the transition finds a blocking factor.

3. *Lack of understanding of costs/benefits*

   As it was mentioned in point two, due to the lack of evaluation standards and information, stakeholders are unable to find what are the costs and benefits of adopting a sustainable procurement. Therefore, there is no willingness to make the transition.

4. *Shortage of professional staff*

   Staff training regarding rules and regulations is a very important aspect of sustainable procurement. The shortage of such training results into lack of awareness of the procurement team. The correct training should be one of the first steps into the implementation of sustainable procurement.

5. *Low budget spent for training*

One of the most important reasons of why staff is not trained for the transition to sustainable procurement is the lack of financial support for this purpose. Most of the funds are allocated for market prices. However, it is known that economic support and rewards are needed for sustainable procurement in the public sector.

6. *Lack of management commitment*

Identified as one of the major obstacles for the transition to sustainable procurement, the lack of management commitment in the design of organizational processes may result in the delay in the transition to sustainable public procurement. The adoption of green innovative practices such as technologies, waste management systems, SMART construction and energy efficiency should come from the management staff and this will mean a step into the transition to green procurement. However, that is not the current picture of most management staff.

Three external barriers have been identified (Zaidi et al., 2019):

1. *Government legislations*

Due to the need of the transition to green public procurement, government legislation is the most relevant enabler of the transition in the public sector. If government legislations made mandatory some of the green practices, the industry would have a big stimulus to pursue it. Nonetheless, government legislations should not only push the transition, but they should also encourage it by incentivizing sustainable solutions. These incentives could be translated into a tax reduction framework or subsidies in sustainable goods for those entities that adopt principles related to sustainable procurement.

2. *Knowledge of suppliers*

When higher level stakeholders have the pressure into the transition to sustainable practices, then such pressure is transferred to lower level stakeholders such as suppliers. It is also through suppliers where a high resistance into the transition to green public procurement is found. There are several reasons to this. First, the poor practices suppliers have in terms of the acquisition of sustainable goods. Second the lack of resources that this type of stakeholders have. And finally, the sensitive nature of their information which depends of third parties from where they acquire such goods.

3. *Availability of circular goods and services*

Since the need of adoption of circular and sustainable goods and services is not very old, the availability of such type of products is not yet very high. This results into low availability with high demand that causes a big impact into the pricing of the materials and solutions. Due to the lack of availability of green products in the market, the sustainable public procurement cannot be implemented in some cases.

Table 5 - Barriers identified by different authorsTable 5 shows different barriers identified by other authors.

Table 5 - Barriers identified by different authors

Soto et al. (2020)	Cramer (2018)	Bao et al. (2019)
Lack of knowledge and definition for tender papers	Economic and business	Contract types
Absence of practical information for designing	Regulatory and legal	
Development of GPP criteria in relation to innovative solutions required	Social: Market prices Information failures Innovation market imperfections Technological externalities	
Lack of resources: Knowledge Training	Financial	

Motivation	
Funding	
	Structural
	Operational
	Attitudinal
	Technological

It is possible to conclude that the barriers that the adoption of sustainable procurement faces are very context dependent. On one hand, there might be geographical and socio economical aspects that might not face such barriers in a very high level. Nonetheless, the development of a Circular Procurement Framework and Tool can help overcome these barriers and see it as an opportunity to create a market change within the construction sector.

3.3 Indicators

Indicators are key elements which can be measured to explain the performance of certain objective that wants to be achieved. Therefore, Circular Economy Indicators (CEI) are measurable factors which determine the level of circularity of a component, material, process or project. In the perspective of the Built Environment, CEI aim to explain the performance of a construction project in regard to the impact that the implementation of Circular Economy has on it. Some of these indicators have a strong relationship with the R's strategies covered. Nonetheless, also the indicators can be related to other sustainable assessment methods such as the results of an LCA.

The papers analyzed, which consider the implementation of indicators, have mainly three approaches to which the authors mention several indicators. The first approach is about materials and waste flows, the second approach is about the entire lifecycle's design and the third approach is in relation to the R's strategies as mentioned before. Table 6 shows the CEI found in the analyzed literature.

Table 6 - CEI found in analysed literature

Materials and waste flows	Lifecycle	R's strategies
Products and waste management	Passive energy saving measures	Reusability
Sustainable sources	Proactive measures for energy efficiency	Recyclability
Scarcity	Water saving	Lifespan extension
Efficiency of resources	Passive measure (architectural design)	Use of standardization and prefabrication industrialized elements
	Active measures (building performance)	Maintenance and rehabilitation strategies
	LCA	
	Product life cycle	
	Carbon footprint	
	Toxicity	
	Conservation of natural habitat	

Apart from the CEI, in two papers, the authors (Soto et al. (2020) and Mantalovas et al. (2020)) also propose indicators used for procurement purposes.

Soto et al. (2020)	Mantalovas et al. (2020)
Energy efficiency and LCC	Resource efficient construction
Energy equipment proposed	Recycled content
CO2 emissions	Excavated materials
Electrical efficiency	Soil and wastes management
Thermal and light comfort	Water and habitat conservation
Building integration in urban landscape	Maintenance and rehabilitation strategies
Maintainability	Durability
Reuse of materials from the building itself (cradle-to-cradle)	
Material recover	

Some of these indicators were considered for the development of the Circular Procurement Framework and Tool. Nonetheless, the core indicators were taken from the analyzed existing frameworks that measure Building Circularity. This will be further explained in chapter 6.

4 Requirements for Circular Procurement

4.1 Province of Zeeland

As explained in section section 2.2 the first stage of the interview with the stakeholders was taken directly with the major stakeholder who is the Province of Zeeland. The answer to the asked questions are the following:

1. What is the current procurement process?
   - Need of a project
   - Development of project requirements
   - Market consultation for project feasibility
   - Invitation to tender to selected architects
   - Selection of best option if there are competitors

2. How do you experience the current procurement process?

They try to invite firms who are able to develop solutions that go in accordance with the ambitions of the province. However, they think that they are not providing the necessary requirements for the architects to work based in certain type of solution that the province wants

3. To what extent do you guide contractors to achieve certain solution?

They leave the opportunity to the architects to achieve their best solution since the province chooses the firms that might be able to give the certain type of solutions that the province aims for.

4. What is the need for a Circular Procurement Framework and Tool?

To be able to assess solutions in a more accurate manner.

To be able to guide the architects into the type of solutions that the province is aiming for.

To ensure that the procurement of construction projects aligns with the transitie-agenda.

To be able to have a more sustainable built environment in Zeeland

5. How could you integrate a Circular Procurement Framework to your current process?

By being able to set a bar for architects to work on solutions that provide a minimum standard for circularity and use of biobased materials. This could guide the architects to understand the objectives for circular buildings.

4.2 RO&AD Architecten

1. What is the current procurement process?
   - They receive a call from the province
   - They evaluate the need of the project
   - They provide a first draft of design to the province for verification and feedback.
   - They tender with the first draft to potential building contractors
   - They modify based on feedback and input from selected building contractor to ensure the feasibility of the design
   - They provide second draft of design to the province for final tender selection
   - They are awarded the project
2. How do you experience the current procurement process?
   This is a process that relies very much in communication and trust. They think that it is not really a process that will help to ensure certain quality for the circularity performance, since they are providing circular solutions based in their own experience of previous projects.
3. Do you think that the current procurement process guides you to achieve a desired solution by the client?

No, the province only mentions the desire of having a circular biobased solution and based in the architects expertise they provide a solution that best tries to achieve that desire. However, since price is still the decision making criteria, the final solution is influenced by that.

4. What do you think of the integration of a Circular Procurement Framework to the procurement process?
   They think it could be very helpful for the development of a project by being able to understand the ambitions and circularity criteria that would determine the awarded design.
   They also think that they could also use the Circular Procurement Framework to do their own tender for the potential contractors. This would improve the solution to be more circular and biobased.
5. What benefits could you gain from having a Circular Procurement Framework?
   Having a better understanding of the ambitions of the client.
   Using it as a guide for designing not only based in their experience.
   Improving their own tender process for the building contractor
6. How could a Circular Procurement Framework could improve the current process?
   By knowing in advance the requirements for a Circular Procurement Process. This means by understanding the important elements that they need to include in the tender documents that could help to know the weak points of their design to be able to improve it.
7. Do you think that the implementation of a Circular Procurement Framework could help with the integration of more systemic circular solutions? How?
   Yes, because they are providing solutions based in their experience which is not necessarily a systemic solution. If they are able to know in advance what elements are included in a Circular Procurement Framework they could be able to think in all the different aspects and therefore, provide a more circular solution.

5 Analysis of existing frameworks for Circular Buildings

As a result of the high attention that the Circular Economy has gained within the Built Environment, numerous frameworks and assessment tools have been developed to be able to evaluate and measure the level of circularity of buildings. The objective of these frameworks is to provide a structured approach for assessing the circularity performance considering aspects such as use of materials, design, waste management and resource optimization.

This section of the report focuses on the analysis of six of the most used frameworks in the Netherlands that have been developed: Alba Concepts, BREEAM, W/E Adviseurs, Platform CB'23, Madaster and OneClickLCA. Since each of these frameworks provides a different approach considering different criteria, indicators and methodologies, the analysis of them was essential to understand these approaches and perspectives on building circularity measurement. Each of the framework differs within its priorities depending on their understanding of circularity and their objectives. By analysing these frameworks, it is possible to gain insight into the diverse strategies and considerations employed in order to be able to gather the most relevant information for the development of the Circular Procurement Framework and Tool.

Moreover, the analysis helped to identify the strengths and limitations of each framework, by understanding their criteria, indicators, and methodologies. This helped to gain knowledge of the applicability for the development of a comprehensible decision making framework. This analysis provided with valuable information to adopt and develop the assessment tool taking into consideration best practices, gaps, and opportunities for improvement. This knowledge helped into the creation of a more robust tool for the promotion of circularity in the built environment.

This chapter describes the analysis of the different components of the six chosen frameworks which asses the circularity of buildings. On the first part, the different frameworks are presented with their own different approaches. On the second part, a comparison on the findings of the different frameworks is presented.

5.1 Platform CB'23

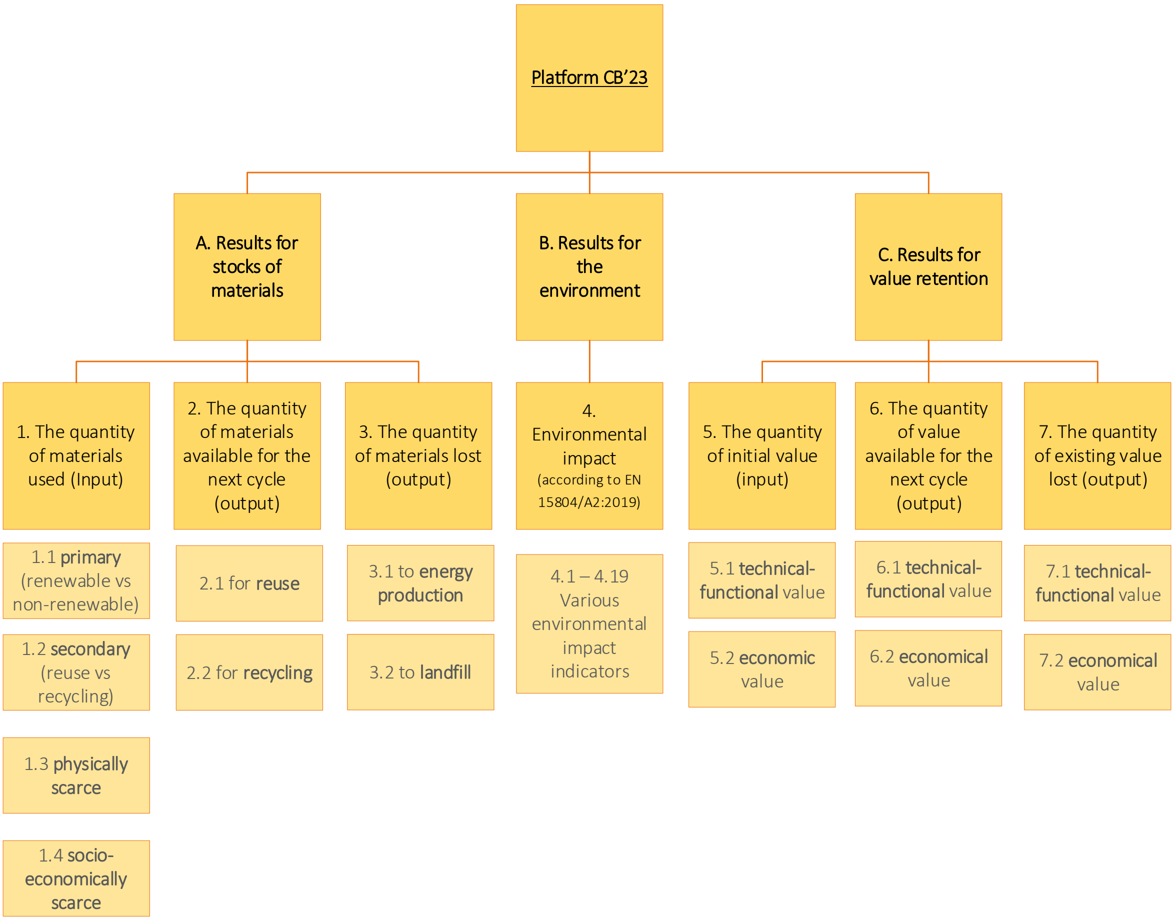

Figure 5 - Platform CB'23 Framework overview

The proposed framework developed by Platform CB'23 consists of three general categories which consist of several measurable indicators that aim to assess the level of circularity. These three main categories are the following:

A. Results for stocks of materials
B. Results for the environment
C. Results for value retention

From the overview of these three main categories, it is possible to see three main important aspects that need to be considered for a circularity approach (input, output, LCA and value retention). Therefore, this is the categorization strategy that will be followed for the development of the Circular Procurement Framework and Tool.

5.1.1 Input

The first category of the general overview of CB'23 (A. Results for stocks of materials) is tightly related to the input of the assessed project. The process for the evaluation of this category consists in the evaluation of the quantity of materials used.

It is differentiated between 1. Primary materials, 2. Secondary materials, 3. Physically scarce materials and 4. Socio-economically scarce materials.

1. Primary materials

In terms of the primary materials, Platform CB'23 makes a clear distinction between the use of the different types of materials based in their source. Therefore, two sub-indicators are present in this topic.

1.1. Renewable materials
1.2. Non-renewable materials

The assessment method for these two materials consists in the ratio of use among all the different materials used for the development of a construction solution.

2. Secondary materials

Similar is the case for the *Secondary materials*, a distinction between two types of secondary materials is done by the Platform CB'23.

2.1. Reused materials: used for the same function.
2.2. Recycled materials: used as resource for new materials.

As the assessment of the *Primary materials*, the ratio among the use of all the other different types of materials is used for the assessment of this aspect.

3. Physically scarce materials

Platform CB'23 define Physically scarce materials as follows: "scarcity based on available raw material stocks and the risk of depletion". Scarce: limited availability, based on the size of the stock of a raw material or material, the extractability and security of supply in geopolitical or social changes. Moreover, they define as non-scarce "more than enough available, based on the size of the stock of a raw material or material, the extractability and security of supply in geopolitical or social changes".

The materials definition method for the *Physically scarce materials* is by making use of the ADP indicator parameter from an LCA; which will indicate weather the component is physically scarce or not.

4. Socio-economically scarce materials

On the other hand, Platform CB'23 defines *Socio-economically scarce materials* as follows: "scarcity based on economic importance and security of supply". And the definition method to assess whether a material is socio-economically scares is by making use of the European Critical Raw Materials list presented in the following table (Table 7).

Table 7 - 2020 Critical Raw Materials list

2020 Critical Raw Materials		
Antimony	Hafnium	Phosphorus
Baryte	Heavy Rare Earth Elements	Scandium
Beryllium	Light Rare Earth Elements	Silicon metal
Bismuth	Indium	Tantalum
Borate	Magnesium	Tungsten
Cobalt	Natural graphite	Vanadium
Coking coal	Natural rubber	Bauxite
Fluorspar	Niobium	Lithium
Gallium	Platinum Group Metals	Titanium
Germanium	Phosphate rock	Strontium

5.1.2 Output

CB'23 also considers the output of the materials in the system in its first category (A. Result for stocks of materials). However, it differentiates in two different sub-categories, which are explained next.

5.1.2.1 Quantity of materials available for the next cycle

The idea behind the availability of materials for the next life cycle is the extent in which these materials may be recovered for extending its functionality into a new project. The separation of this category is simple; whether the material is suitable for reuse or for recycling after its current lifecycle. Therefore, its calculation method is similar to the one used for input materials. It consists in knowing the ratio of materials that will be suitable either for reuse or recycling compared to the total weight of materials.

$$Reuse = \frac{Weight\ of\ materials\ suitable\ for\ reuse\ at\ the\ end\ of\ the\ life\ cycle}{Total\ weight\ of\ materials} \times 100$$

$$Recycle = \frac{Weight\ of\ materials\ suitable\ for\ recycling\ at\ the\ end\ of\ the\ life\ cycle}{Total\ weight\ of\ materials} \times 100$$

5.1.2.2 Quantity of materials lost

Although in an optimal circular design the amount of material lost should not exist, the truth is that there will be some amount of materials that will not be suitable for an extension of its life. Therefore, there will be a reduced amount of material lost in the best situation. These loses are categorized in two by CB'23. These materials may end their life either incinerated for energy production or simply lost in a landfill. The calculation method is the same, it is a ratio between the weight of lost materials over the total weight of materials of the project.

$$Materials\ lost\ for\ energy\ production = \frac{Weight\ of\ materials\ used\ for\ energy\ production}{Total\ weight\ of\ materials} \times 100$$

$$Materials\ lost\ to\ landfill = \frac{Weight\ of\ materials\ sent\ to\ landfill}{Total\ weight\ of\ materials} \times 100$$

It is important to remember that this considerations should be done for the end of life of the project or the end of life of the components of the project that might need replacement throughout the life cycle of the building.

5.1.3 Value retention

Platform CB'23 is the framework which emphasises the most about value creation and value retention. These two concepts are considered as key elements for circular construction in this framework. It is relevant that before the design phase, value retention is considered in terms of use, management and end of the useful life of the project in order to be able to establish cooperation with the supply chain for the handling of the materials. This is a way into the circular transition to relevant stakeholders.

The importance of value retention and creation lays in the need to be able to use existing components by retaining value and to have a long-term vision for such components which involves the value creation. This with the idea of only replacing elements that are no longer useful and maintaining in the cycle most of the materials which are already in the system. Therefore, value retention means that the elements conforming a building can be preserved with its highest possible quality for as long as possible, not compromising the optimum use of the building. However, multiple cycles of the elements may compromise the value retention. FIGURE shows the value creation and value retention in successive cycles.

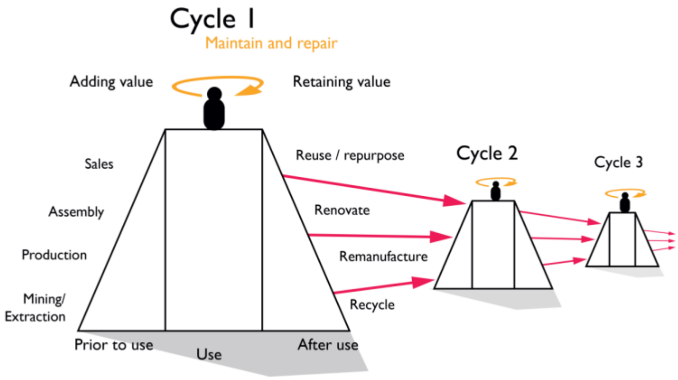

Figure 6 - Value creation and value retention in successive cycles (CB'23, 2020)

Platform CB'23 differentiates value into *Techno-functional value* and *Economic value.* Moreover, it differentiates the value in the different stages of the lifecycle of the project:

- Initial value (input)
- Value available for the next cycle (output)
- Lost value (output)

The difference between the Techno-functional value and the Economic value in the different stages is stated in Table 8.

Table 8 - Techno-functional value and Economic value differentiation throughout the lifecycle

Indicator	Description
Initial value (input)	
5.2.3.1 Techno-functional value	Degree to which the element functions in its current state
5.2.3.2 Economic value	Degree to which the element has economic value in its current function
Value available for the next cycle (output)	
5.2.3.3 Techno-functional value	Degree to which the element can be used in a new or subsequent function
5.2.3.4 Economic value	Degree to which the element represents economic value for a subsequent function
Lost value (output)	
5.2.3.5 Techno-functional value	Degree to which the Techno-functional value decreased during the lifecycle of the element
5.2.3.6 Economic value	Degree to which the Economic value decreased during the lifecycle of the element

5.1.3.1 Initial Techno-functional value

The quantity of the initial Techno-functional value (TFW_i) has to be determined for every element of the building and this initial value has to be 100% as it is the reference baseline for the following indicators.

$$TFWi = 100\%$$

5.1.3.2 Initial Economic value

To calculate the Initial Economic value (EW_i), it is necessary to first be able to calculate the Total Cost of Ownership (TCO) which is the total costs that are taken throughout the service life of a building. The total cost of an object consist of costs incurred in the different life cycle phases. From the production phase, construction phase, use phase and demolition and processing phase. From these costs it is possible to determine a residual cost which are the benefits beyond the system boundary of the element.

For the EW_i, it is necessary to consider the direct and indirect costs from the construction phase mainly. These costs will be set as the 100% of the initial economic value of the building. This process needs to be taken to every element of the building.

$$EWi = 100\%$$

5.1.3.3 Techno-functional value available for next cycle

Platform CB'23 is still developing the measurement strategy for the Techno-functional value (TFW). However, they state, that as the TFW_i, this has to be determined for every element of the building at the proper lifecycle stage.

5.1.3.4 Economic value available for next cycle

In order to determine the Economic value available for the next cycle (EW_b), it is necessary to know the other costs mentioned in 5.1.3.2.

$$EWb = \frac{B_D}{K_A + K_B + K_C} * 100\%$$

Where:

EW_b = Economic value available for next cycle
B_D = Benefits from reuse, reclamation and recycling
K_A = Costs taken during Production and Construction phase
K_B = Cost taken during Use phase
K_C = Cost taken during Demolition and Processing phase

5.1.3.5 Lost Techno-functional value

The Lost Techno-functional value (VTF) is calculated as follows:

$$VTF = TFWi - TFW$$

Once again, this has to be done for every element of the building and a final score can be added up for the whole building.

5.1.3.6 Lost Economic value

The Lost Economic value (EW_v) is determined for every element of the building as follows:

$$EW_v = EW_i - EW_b$$

Where:

EW_v = Quantity of economic value lost (%)
EW_i = Quantity of initial economic value (%)
EW_b = Quantity of economic value available for next cycle (%)

5.2 Madaster

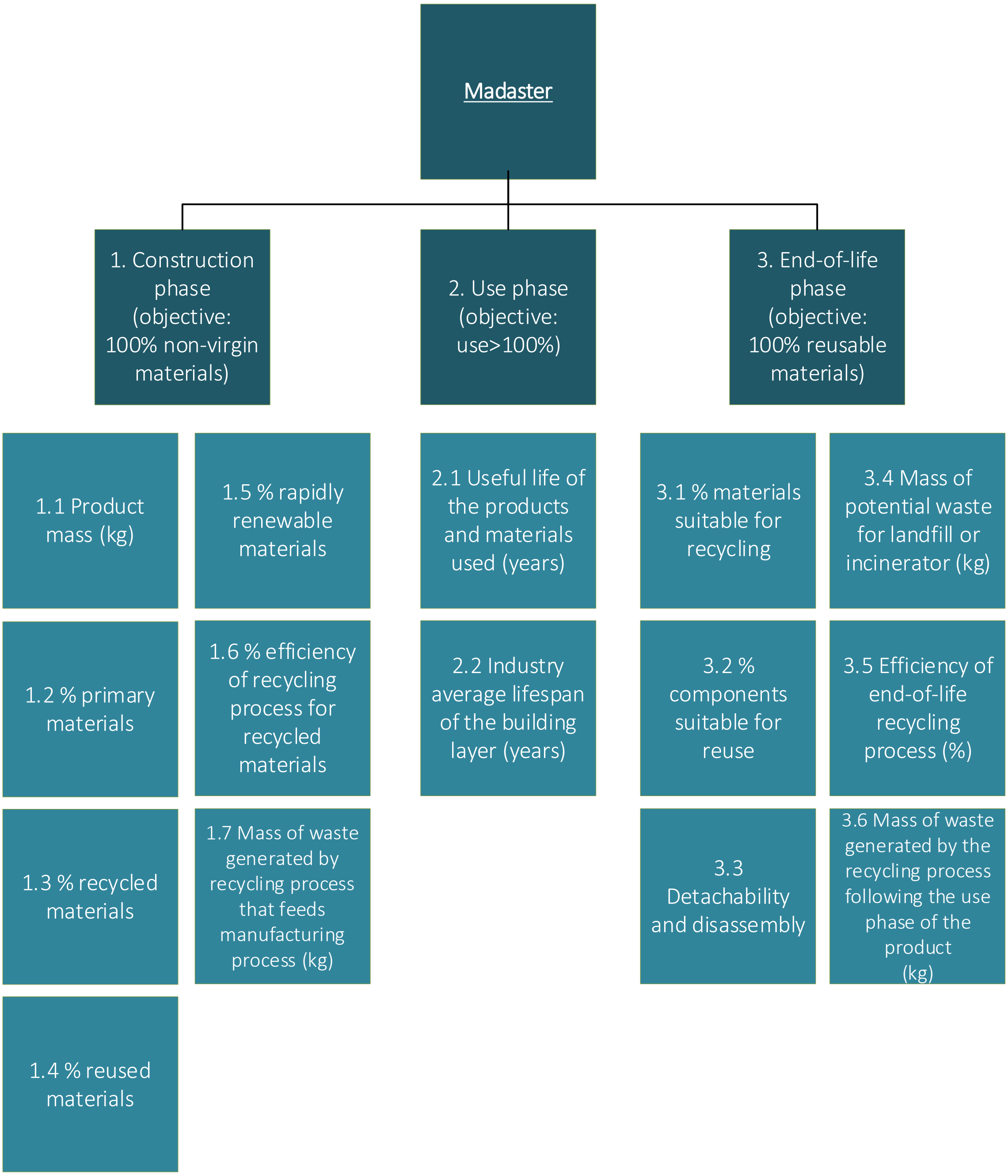

Figure 7 - Madaster Framework overview

Madaster has a very clear structure aligned with the project's life-cycle which also aligns with the structure of the aforementioned framework (Platform CB'23). This can be seen in the following categories that they use.

1. Construction phase
2. Use phase
3. End-of-life phase

5.2.1 Input

The Construction phase indicators used in the Madaster framework considers what is the input for the project. Aiming to have a construction project with 100% non-virgin materials. The indicators used to assess this are the following:

1.1. Product mass (kg).
1.2. Virgin materials used to manufacture a product (% mass).
1.3. Recycled materials used to manufacture a product (% mass).
1.4. Reused materials used to manufacture a product (% mass).
1.5. Rapidly renewable materials used to manufacture a product (% mass).
1.6. Efficiency of the recycling process resulting in the recycled materials (%).
Mass of waste generated by the recycling process that feeds the manufacturing process (kg).

5.2.1.1 Scoring system

The system that Madaster uses to evaluate the final score of the Construction Phase Circularity Indicator is:

$$CI_{Construction} = F_R + F_{RR} + F_U$$

Where:

F_R = Fraction of recycled material as a percentage of the product mass

F_{RR} = Fraction of rapidly renewable materials as a percentage of the product mass

F_U = Fraction of reused products and components as a percentage of the product mass

But also the product mass (kg), the efficiency of recycling process preceding the construction phase (%) and the mass of the generated waste during the recycling process (kg) to show as a differentiator in case there is a similar score of the $CI_{Construction}$.

5.2.2 Output

Madaster's third category 3. End-of-life phase considers the output of the project. For this, six different indicators are considered:

3.1 Materials suitable for recycling (%).
3.2 Components suitable for reuse (%).
3.3 Detachability
3.4 Mass of potential waste for landfill or incineration (kg).
3.5 Efficiency of end-of-life recycling process (%)
3.6 Mass of waste generated by the recycling process following the use phase of the product (kg)

5.2.2.1 Scoring system

$$CI_{End\ of\ life} = C_R(E_C) + C_U$$

Where:

C_R = Fraction of materials that can be potentially recycled at the end of its useful life (as % of the product mass)

E_C = Efficiency of the recycling process in the end-of-life phase (%)

C_U = Fraction of components and/or products that can be potentially reused at the end of its useful life (as % of the product mass)

5.3 Alba Concepts

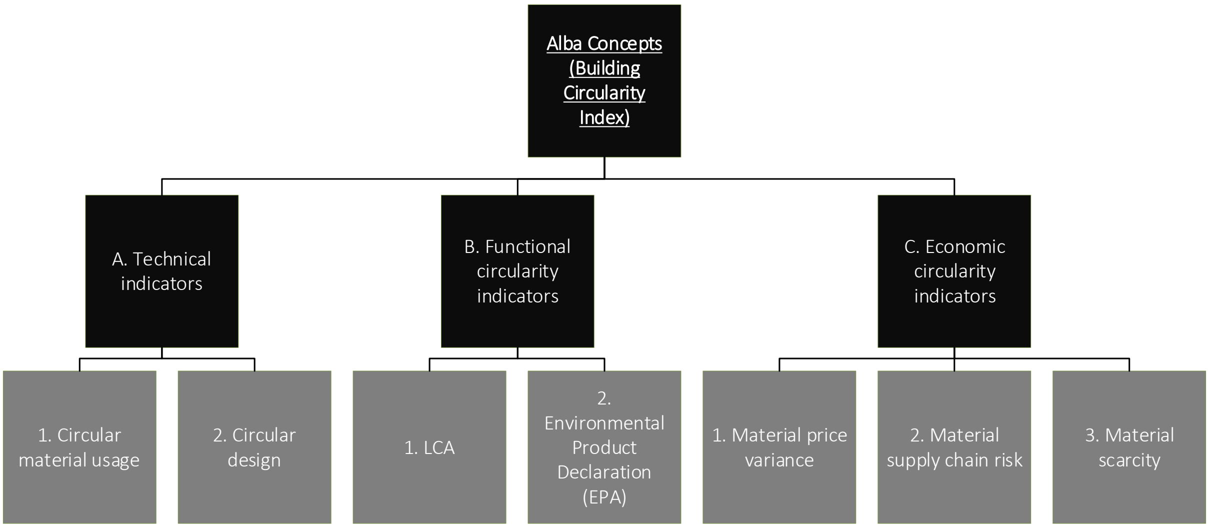

Figure 8 - Alba Concepts Framework overview

In the case of Alba Concepts, the structuring of their Building Circularity Indicator is structured as follows:

1. Technical indicators
2. Functional Circularity Indicators
3. Economic Circularity indicators

5.3.1 Input

Aspect number 1. Technical indicators are the responsible for the input of the assessment. This indicators are separated in two, which are 1.1. Circular material usage and 1.2. Circular design.

Similarly to the previous frameworks analysed, the 1.1. Circular material usage contemplates the mass ratio of the different sources of materials compared from the total amount of materials used. These sub-indicators are the following:

- % by mass of renewable materials
- % by mass of virgin materials
- % by mass of reused materials
- % by mass of recycled materials

On the other hand, 1.2. Circular design contemplates two sub-indicators

- Disassembly potential
- Building circular product levels

5.3.1.1 Disassembly potential scoring system

The scoring system used for the disassembly potential depends on two main factors. 1. Type of connection used and 2. Accessibility to the connection. Table 9 describes the scoring system depending on these two aspects, and Table 10 describes the detail for the scoring system of the type of connection used.

Table 9 - Disassembly potential scoring system

Disassembly potential factors	Types	Score
Type of connection	Accessory external connection or connection system	1.0
	Direct connection with additional fixing devices	0.8
	Direct integral connection with inserts (pin)	0.6

	Filled soft chemical connection	0.2
	Filled hard chemical connection	0.1
	Direct chemical connection	0.1
Accessibility to connection	Accessible	1.0
	Accessible with an additional operation which causes no damage	0.8
	Accessible with an additional operation which is reparable damage	0.6
	Accessible with an additional operation which causes damage not accessible	0.4
	Not accessible – total damage of elements	0.1

Table 10 - Type of connection scoring system

Disassembly type	Score
Accessory external connection or connection system	
Accessible	1.0
Accessible with additional operation which causes no damage	0.9
Accessible with additional operation which is reparable damage	0.8
Accessible with additional operation which causes damage	0.7
Not-accessible – total damage of elements	0.55
Direct connection with additional fixing devices	
Accessible	0.9
Accessible with additional operation which causes no damage	0.8
Accessible with additional operation which is reparable damage	0.7
Accessible with additional operation which causes damage	0.6
Not-accessible – total damage of elements	0.45
Direct integral connection with inserts (pin)	
Accessible	0.8
Accessible with additional operation which causes no damage	0.7
Accessible with additional operation which is reparable damage	0.6
Accessible with additional operation which causes damage	0.5
Not-accessible – total damage of elements	0.35
Filled soft chemical connection	
Accessible	0.6
Accessible with additional operation which causes no damage	0.5
Accessible with additional operation which is reparable damage	0.4
Accessible with additional operation which causes damage	0.3
Not-accessible – total damage of elements	0.15
Filled hard chemical connection	
Accessible	0.55
Accessible with additional operation which causes no damage	0.45
Accessible with additional operation which is reparable damage	0.35
Accessible with additional operation which causes damage	0.25
Not-accessible – total damage of elements	0.1
Direct chemical connection	
Accessible	0.55
Accessible with additional operation which causes no damage	0.45
Accessible with additional operation which is reparable damage	0.35
Accessible with additional operation which causes damage	0.25
Not-accessible – total damage of elements	0.1

Taking these tables into consideration, it means that the maximum total score for the Disassembly potential is 2 with a perfect score of 1 in the *Type of connection* plus a perfect score of 1 in the *Accessibility to the connection*.

5.3.2 Output

Similarly to the input category, the output category aims to know the extent in which the materials are suitable for a next life cycle. The aspects taken into consideration are the following:

% by mass of reusable materials
% by mass of recyclable materials
% by mass of materials sent to landfill
% by mass of materials sent to incineration

5.4 W/E Adviseurs

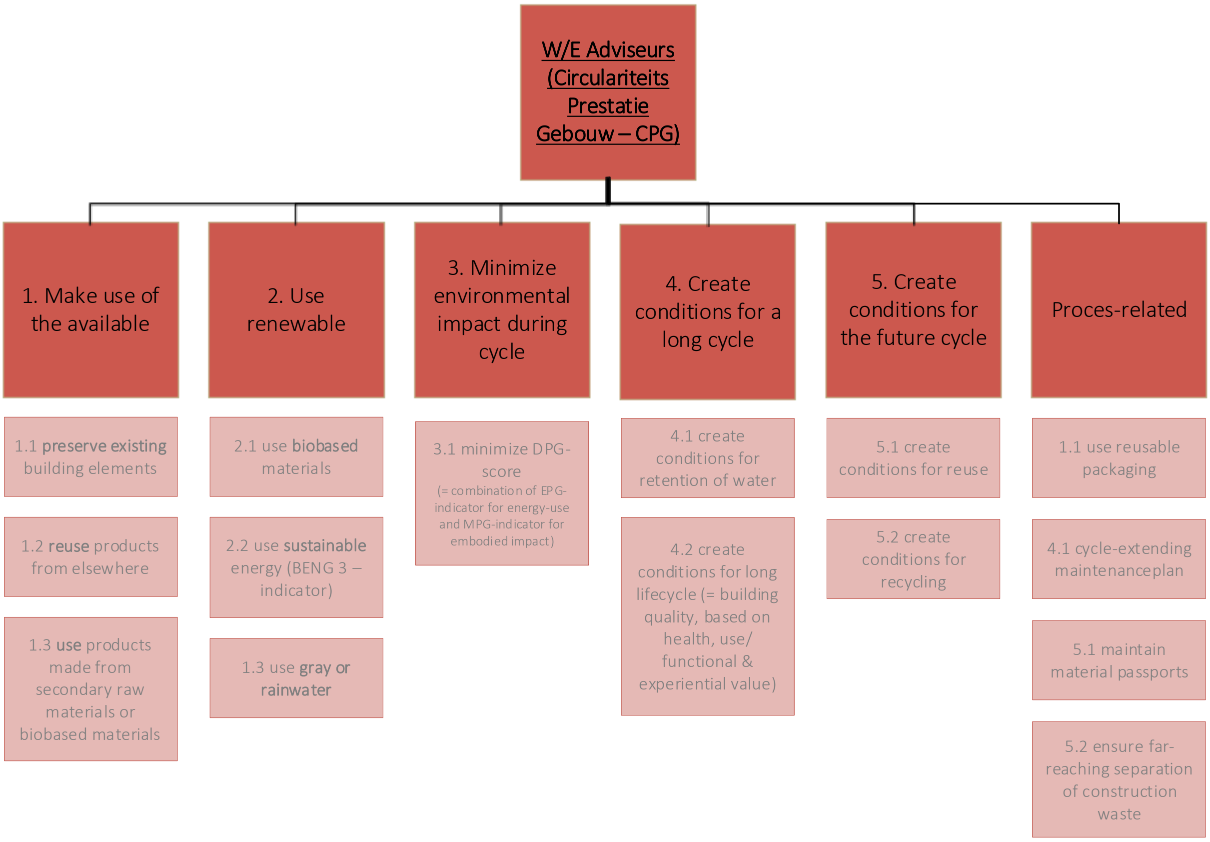

Figure 9 - W/E Adviseurs Framework overview

W/E Adviseurs structures the Circulariteits Prestatie Gebow in six different components with its sub-indicators. These components are the following:

1. Make use of the available
2. Use renewable
3. Minimize environmental impact during cycle
4. Create conditions for a long cycle
5. Create conditions for the future cycle
6. Process

5.4.1 Input

As part for the input in W/E Adviseurs categories number 1. Make use of the available and 2. Use renewable are the main aspects that determine an assessment of this.

The sub-indicators which assess the category number 1 are:

1.1 Preserve existing building elements
1.2 Reuse products from elsewhere
1.3 Use products made from secondary materials or biobased materials

Moreover, the sub-indicators to assess category 2 are:

2.1 Use biobased materials
2.2. Use sustainable energy
2.3 Use gray or rainwater

The evaluation of these aspects is similar to the aforementioned frameworks where the ratio of the type of material on the total amount of materials is calculated. The following formula explains it:

$$Make\ use\ of\ the\ available = \frac{Preserved\ existing\ elements(kg) + Reused\ products(kg) + Secondary\ Raw\ or\ biobased\ products(kg)}{Total\ weight\ (kg)}$$

On the other hand for 2. Use renewable there are three scores. First the use of biobased materials as follows:

$$Biobased\ materials = \frac{Biobased\ materials\ (kg)}{Total\ weight(kg)}$$

The second indicator is the use of sustainable energy which follows the BENG-3 indicator that is calculated as follows:

$$Use\ of\ sustainable\ energy = \frac{Amount\ of\ renewable\ energy}{Total\ primary\ fossil\ energy\ consumption}$$

And finally the use of gray or rainwater calculated as follows:

$$Use\ gray\ or\ rainwater = \frac{Used\ gray\ or\ rainwater}{Total\ amount\ of\ water\ used}$$

5.4.2 Value retention

W/E Adviseurs mainly focus in the value retention from the design perspective. This falls into their category number 5. Create conditions for the future cycle. In this category, the aim for a value retention is with the creation of conditions for reuse and the creation of conditions for recycling of the elements of the building. This two indicators are measured qualitatively and not quantitatively.

This measurement is done by asking whether the elements are designed with a suitability for recovering the elements and processing them either for reuse or recycling processes. This is to avoid construction waste and to ensure that the elements are correctly separated to ensure a new life cycle for them.

Therefore, the value retention is calculated by the output materials which are suitable for these two purposes, being the ratio of materials the result for value retention.

5.5 OneClick LCA

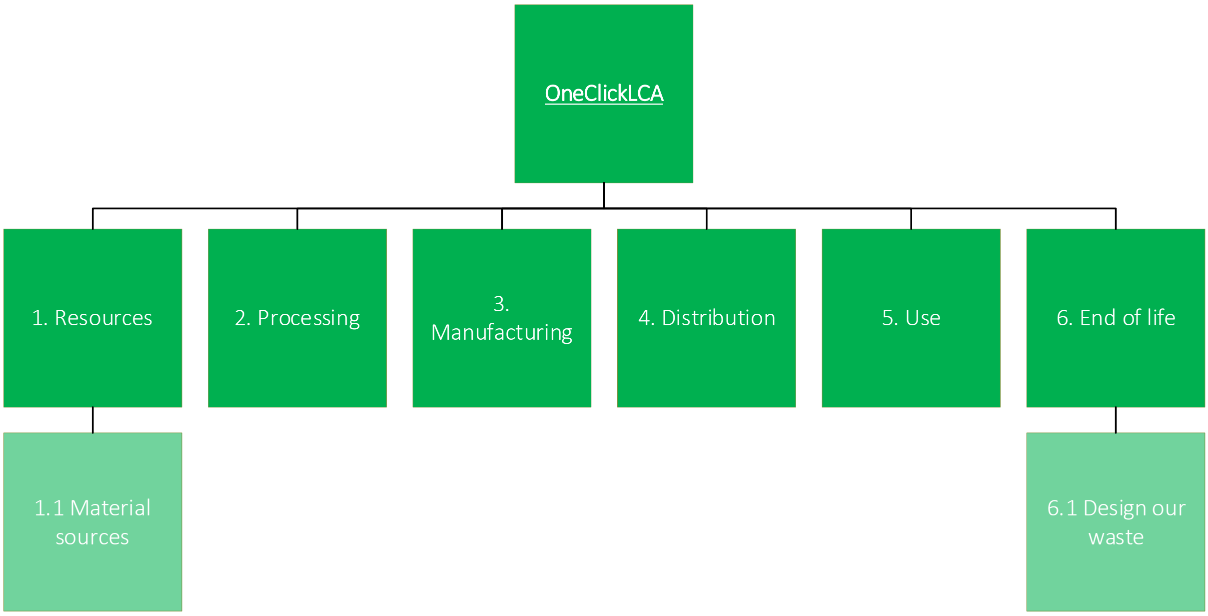

Figure 10 - OneClickLCA Framework overview

OneClick LCA has categorized its framework into six different categories which are tightly related to the project's life-cycle. However the Building Circularity Index only focuses on the category 1. Resources and category 6. End of life.

5.5.1 Input

Tabel 1 - LCA scope and system boundaries

The 1. Resources category is part of the product stage of the LCA. This means that it is where the input of the project is carried on as part A of an LCA. Table 11 shows the entire scope of OneClick LCA.

For A1 Raw material supply, it is taken into consideration the mass of raw materials used over the total mass of materials used. Moreover, A2 Transport include the emissions which result from the transportation of such raw materials to the construction site and finally A3 Manufacturing considers the production materials and fuels used by machines, and also the waste management generated in the production processes.

As part of the input, OneClick LCA also has an analysis of material scope. This is an analysis that shows the elements that were included in the elaboration of the LCA. The analysis helps to know the scope and level of detail of the performed LCA. An example of this analysis of material scope is shown in Table 11.

Table 11 - OneClickLCA material scope and boundaries

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

However, for the Building Circularity Index it is possible to select not only raw materials but also recyclable, renewable or reused materials. For the calculation of this input category, it is necessary to know the ratio of these types of materials used (as the previous frameworks explained). This information does not influence the LCA results but it is used to compute the building circularity.

5.5.2 Output

OneClickLCA uses part of their *End-of-life stage* category and *Benefits and loads beyond the system boundary* category to calculate the output of its framework. They assign an end-of-life process to the materials used which depend on the material type and its use. For the *Deconstruction and demolition* they opt to promote the use of disassembly practices with non-destructiveness of the materials and to promote designs of elements that are adaptable for modifications in the future or at the end of its life.

Moreover, on the category *Benefits and loads beyond the system boundary* they measure the balance of material recovery for a future cycle after the end of the current cycle. Therefore, the result of the Building Circularity Index provides a ratio of the materials that were used for the project which can be virgin, renewable, recycled or reused, and the ratio of the materials that have the potential for a future cycle. Table 12 shows the final overview of what this framework evaluates.

Table 12 - OneClickLCA Building Circularity Index results

Materials Recovered (input)	Materials Returned (output)
% of Virgin materials used	% of Materials used as material
% of Renewable materials used	% of Recycling
% of Recycled materials used	% of Downcycling
% of Reused materials used	% of materials used for energy
	% Disposal

5.6 BREEAM Circular Buildings

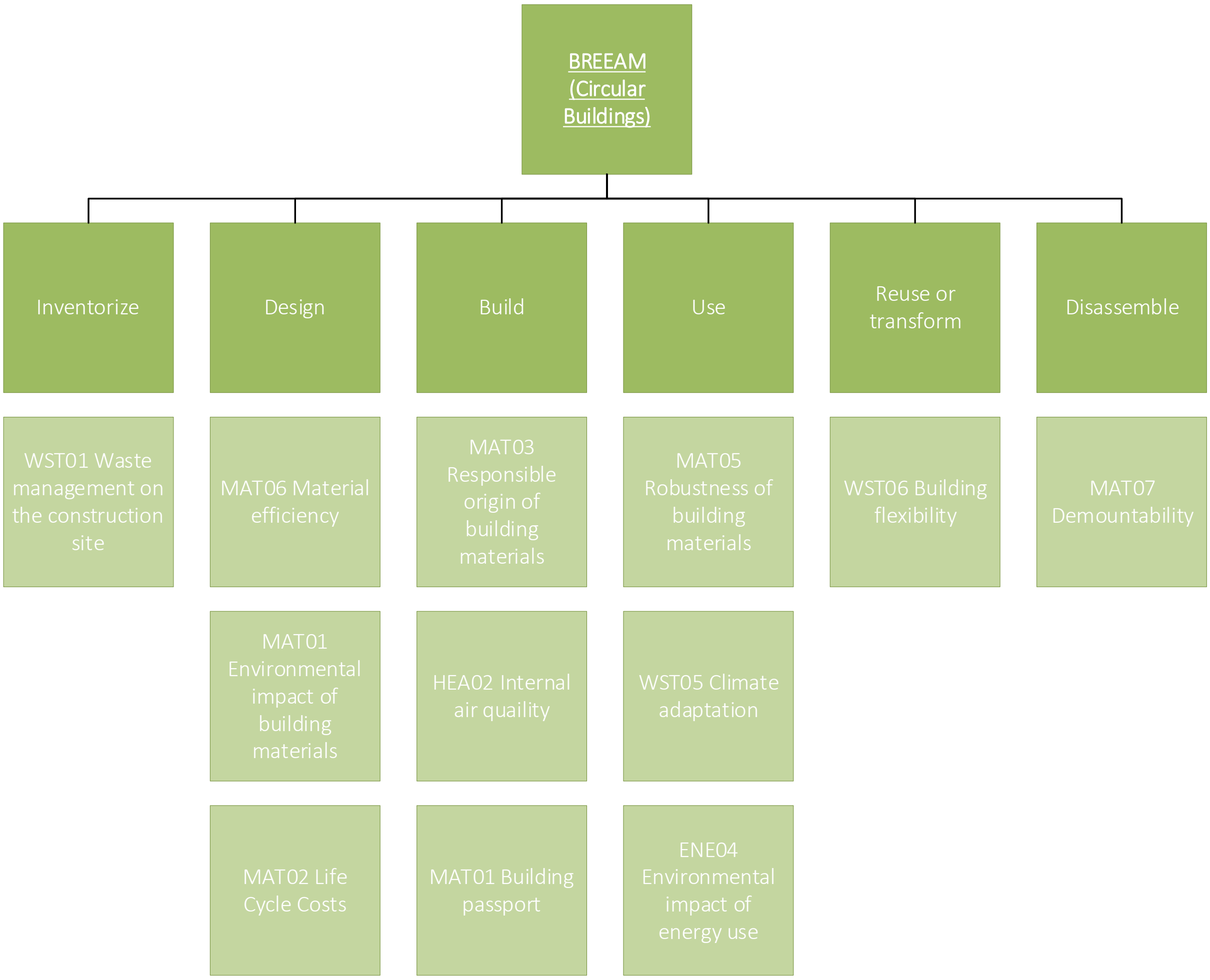

Figure 11 - BREEAM (Circular Buildings) Framework overview

BREEAM Circular Buildings framework is structured in seven overarching categories with their own sub-categories which have measurable and under-development indicators. These overarching categories are the following:

1. Material Cycle
2. Energy Cycle
3. Water Cycle
4. Biodiversity and ecology
5. Human culture & society
6. Health & Wellbeing
7. Multiple forms of values

However, within the categories, there is a differentiation between the different lifecycle stages of a project. Therefore, a similar approach as CB'23 can be given to this framework.

5.6.1 Input

As part of the input, BREEAM considers a set of indicators that help in the evaluation of this aspect. In the Material Cycle part of the framework they aim to evaluate the optimization of material use with the purpose of maximizing the reutilisation of components as well as the use of Circular materials.

5.6.2 Output

Two aspects are considered for the output by BREEAM for circular buildings. On one hand, the Building Flexibility and on the other hand its Demountability.

5.6.3 Value retention

In its Building Circularity framework, BREEAM considers an LCC analysis which helps to have an initial value and an expected end of life value of the building. To achieve this, the BREEAM indicator MAN 02 is followed (Life cycle costs and service life planning). It is suggested that during the procurement phase, the lowest TCO can be chosen to be the best option to build. Such TCO is the initial Economic value of the building.

The assessment criteria of MAN 02 consists in three parts that sum up a total of 4 points for a perfect score. These three parts are:

- Elemental life cycle costs (2 points)
- Component level life cycle cost (1 point)
- Capital costs reporting (1 point)

5.6.3.1 Elemental life cycle costs

The Elemental life cycle costs consist of three concepts:

5.6.3.1.1 Use of the Standardised method of the cycle costing for construction procurement (1 point)

This is a procurement document based in the ISO 15686-5:2008 where the contractor will show the costs of the elements of the building. This will basically be the TCO of the building which is the initial Economic Value.

5.6.3.1.2 Elemental LCC Plan (0.5 point)

This plan provides the future replacement costs, maintenance costs and operation cost estimates for a period of time set by the client. This period of time can be for example 20, 30 or 50 years. This has to give a detailed planning of such costs that will add up to a final Economic Value.

5.6.3.1.3 Example of LCC Plan (0.5 point)

This is an extension of the LCC Plan where examples are shown on how to carry on the replacements, maintenance and operation to have a reduced life cycle cost. This part of the LCC plan will not add to the final Economic value but it is necessary to fulfil the requirements of BREEAM to have an improved score from the 2 possible points of the Elemental life cycle costs.

5.6.3.2 Component level life cycle cost

These costs consist of two concepts:

5.6.3.2.1 Component level LCC (0.5 point)

This costs involve deeper level elements of the building such as the envelope (cladding, windows and roofing), services (heat source, cooling source and controls), finishes (walls, floors and ceilings) and external spaces. The presence of this analysis will give 0.5 points.

5.6.3.2.2 Example of component level (0.5)

This is an extension of the Component level LCC where examples are provided to the specifications mentioned in order to have a design with a minimized critical value.

5.6.3.3 Capital costs reporting

To earn this final point it is necessary to report the capital cost of the building in euros per square meter (€/m^2).

5.7 Framework analysis summary

This section contains a summary of the framework analysis to create a clear overview of the singularities and common shares of them. Table 13 shows how the different frameworks aim to cover the category of *input*. The common ground from all the frameworks is that all of them evaluate the percentages of input materials from secondary and renewable sources. Furthermore, to create that evaluation it is necessary to know the mass of the materials used to create a percentage from the total mass.

CB'23 has two unique aspects. The first one is that they evaluate the production of renewable materials. Considering an important aspect to know whether the materials were sustainable produced or not. The second aspect is that they evaluate the material scarcity from two perspectives: physically scarcity and socio-economically scarcity.

Finally, W/E Adviseurs are relevant for evaluating the energy use of the building as well as the gray water and rain water usage.

Table 13 - Input coverage of the different frameworks

Aspect		Framework	BREEAM	CB'23	Madaster	Alba Concepts	W/E Adviseurs	OneClick
Total Mass				1	1			
Secondary	From Reuse		1	1	1	1	1	1
	From Recycling		1	1	1	1	1	1
		Efficiency recycling			1			
		Waste Recycling			1			
Primary	Renewable		1	1	1	1	1	1
		Sustainably produced		1				
		Non-sustainable produced		1				
	Non-renewable		1	1	1	1	1	1
Physically Scarce	Non-scarce		1	1				
	Scarce		1	1				
Socio-economically Scarce	Non-scarce			1				
	Scarce			1				
Energy-use of the building							1	
Gray water/rainwater							1	

Regarding the output, Table 14 show the coverage of the elements in the different frameworks. It is possible to see that most frameworks consider three aspects as the most important. These aspects are *Materials available for next cycle, Detachability and demountability* and *Materials to waste and landfill.* However, some of the singularities are that Madaster considers the *Efficiency of the end-of-life recycling process,* OneClickLCA the *Downcycling* and BREEAM the *Building flexibility.*

Table 14 - Output coverage of the different frameworks

Aspect	Framework	BREEAM	CB'23	Madaster	Alba Concepts	W/E Adviseurs	OneClick
Materials available for next cycle			1	1	1		1
Materials lost			1				
Detachability and demountability		1		1	1		1
Materials to waste and landfill			1	1	1		1
Efficiency of the end-of-life recycling process				1			

Mass of materials for incineration			1	1		
Downcycling						1
Building flexibility	1					

Finally, Table 15 shows the Value retention. Only three of the frameworks consider this to be an important aspect for building circularity. These frameworks are BREEAM, CB'23 and W/E Adviseurs. However, CB'23 is the framework who puts a big emphasis on this aspect which can be seen by the broad coverage it gives to the value retention in its framework.

Table 15 - Value retention coverage of the different frameworks

Aspect	Framework	BREEAM	CB'23	Madaster	Alba Concepts	W/E Adviseurs	OneClick
Input Techno-functional value			1				
Input Economic value		1	1				
Output techno-functional value			1			1	
Output Economic value			1			1	
Lost Techno-functional value			1				
Lost Economic value			1				
TCO		1	1				
Production and construction costs		1	1				
Use phase costs		1	1				
Demolition and procesing phase costs			1				

6 Proposed framework for Circular Procurement Tool.

Once the existing frameworks were analysed, it was necessary to make a selection of the indicators from such frameworks that will conform the Circular Procurement Tool that was designed. To perform this, an analysis of the different indicators and the overlapping indicators was developed to have a fundamental selection of them. Moreover, the indicators were selected and categorized to structure the Circular Procurement Tool with the traceability to the source of the chosen indicators to its original framework to be able to strategically measure them in order to have a final score on the tool. This process is explained next.

6.1 Indicators categorization and selection

After the analysis of the six different existing frameworks, a selection of the indicators had to be done in order to design a framework which enables a procurement process. To be able to perform this, the structure of the categorization of indicators of Platform CB'23 was selected. This due to the fact that it widely covers the entire lifecycle of a project, being able to have it as a base to link the different indicators used in the other frameworks. These main categories and structure are shown in Figure 12.

However, following this structure would neglect several indicators which are of high relevance for the circularity principles. These indicators had to be added to the framework in a final category called "Other".

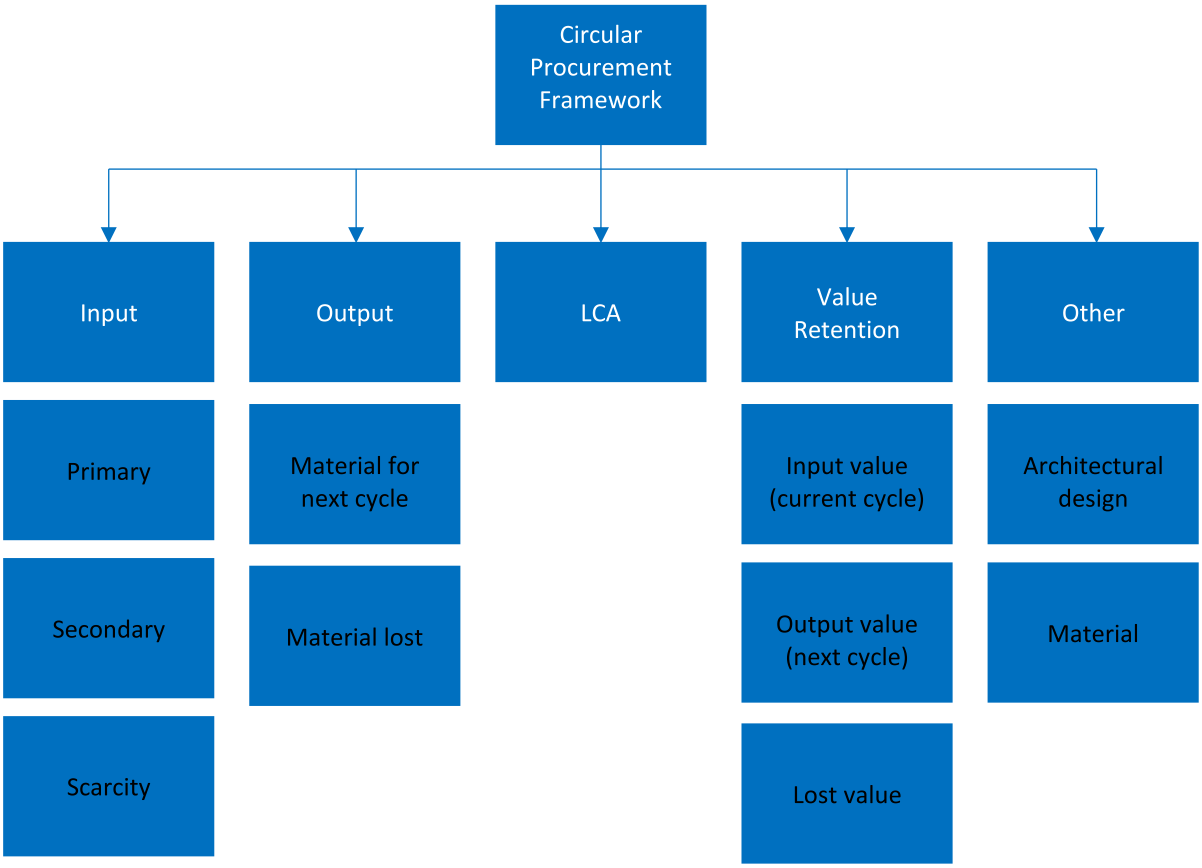

Figure 12 - Circular Procurement Framework

6.2 Indicators measured

6.2.1 Input

1.1. Primary					
Renewable			*Non-renewable*		
1.1.1. Renewable components	100,00	(%)	1.1.4. (Primary input) non-renewable	0,00	(%)
1.1.2. Maximize use of renewable materials					
1.1.3. Use of Biobased	100,00	(%)			

1.2. Secondary					
Reuse			*Recycle*		
1.2.1. Refurbishment	0,00	(%)	1.2.6. % recycled materials	0,00	(%)
1.2.2. Local & reuse	0,00	(%)			
Local	100,00	(%)			
Reused	0,00	(%)			
1.2.3. % reused materials	0,00	(%)			
1.2.4. Preserve existing building elements	0,00	(%)			

1.3. Scarcity					
Physically			*Socio-economic*		
1.3.1. Building not made from circular materials	0,00	(%)	1.3.4. (Input) socio-economically scarce	0,00	(%)
1.3.2. Documentation of use of critical materials	Yes	OK!			
1.3.3. (Input) Physically scarce	0,00	(%)			

Figure 13 – Input

As shown in Figure 13, the category *Input* assesses two main aspects, one is the source of the material considered for the design, and the other is the scarcity of the materials used.

For the primary materials used, there are two types of classified materials which are the renewable and the non-renewable. The framework and tool considers the ratio of used of these types of materials as explained in chapter 5. The same logic goes to the secondary materials, where the importance relies in the use of reused or recycled materials considering the ratio of use of these materials as the core element to assess the design. On the other hand, for the scarcity, the importance relies on the presence of the used materials on the list of scarce materials presented in Table 7 - 2020 Critical Raw Materials list.

6.2.2 Output

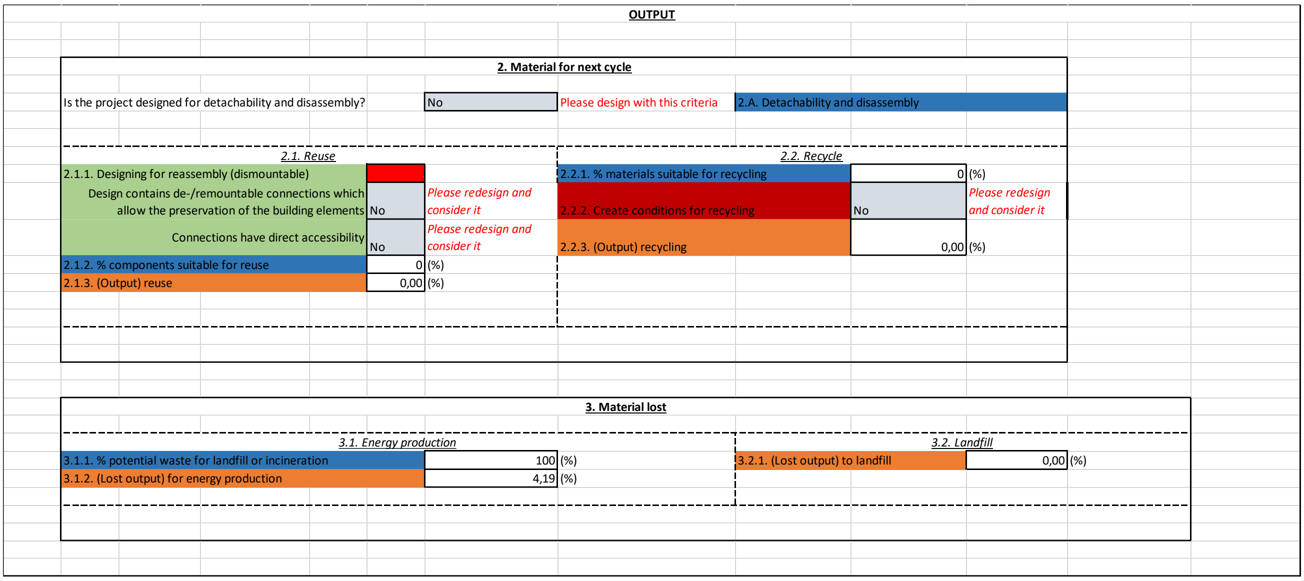

Figure 14 – Output

The category *Output* has three main aspects that are assessed. First, the design for detachability and disassembly with the evaluation of the easiness to perform such activities at the end-of-life of the design that is being evaluated. This should ensure that the Table 9 is followed for the evaluation of this aspect. Furthermore, for the second aspect the elements need to be assessed weather they have any suitability for their use in a next life-cycle. It is important to evaluate if the design contemplates a next use to the elements that are being used after they reach their end-of-life. A ratio of the materials for reuse or recycle is performed by knowing the amount of materials that are designed for a next life-cycle. Finally, for those materials that do not have a suitability for a next life-cycle are materials lost. These lost materials may have to different destination. They can either be used for energy production and in the worst case they will be taken to landfill. To evaluate this, the ratio of lost materials will be calculated.

6.2.3 LCA

LCA's are widely used for the analysis of construction projects as well. As they are tightly linked to the development of circular designs, it is also suggested to use them as part of this framework. No new methodology is developed for the LCA development in this framework. Therefore, a regular LCA needs to be performed and assessed. The required elements that need to be assessed are the same as suggested by Platform CB'23. These elements are presented in Table 16 which are in accordance to the indicators measured by Platform CB'23. For the comparison of the designs with these indicators, the lowest scores score better.

Table 16 - LCA elements

	LCA
1	Eutrophication terrestrial kg PO4-eq
2	Eutrophication aquatic freshwater kg PO4-eq
3	Eutrophication aquatic marine kg PO4-eq
4	Human toxicity carcinogenic
5	Human toxicity non-carcinogenic
6	Eco-toxicity (freshwater)
7	GWP total kg CO2-eq
8	GWP fossil fuels kg CO2-eq
9	GWP biogenic material kg CO2-eq

10	GWP land use & land use change kg CO2-eq
11	Ozone depletion kg CFC-11-eq
12	Acidification mol H+e
13	Photochemical ozone formation kg NMVOCe
14	Abiotic depletion minerals & metals kg Sbe
15	Abiotic depletion of fossil resources MJ
16	Particulate matter emissions
17	Ionising radiation

6.2.4 *Value Retention*

VALUE RETENTION				
5. Input value (current cycle)				
5.1. Technical/Functional			*5.2. Economic*	
5.1.1. Refurbishment (1.1.2.)	€ 11.427,88		5.2.1. (Input value) economic value (5.2.)	€ 81.373,83
5.1.2. Design for flexibility (1.2.)	Yes	*OK!*		
5.1.4. Material passports (4.1.1. - 4.1.2.)	Yes	*OK!*		
5.1.5. Ensure long-term aesthetics (V1.)	Yes	*OK!*		
5.1.6. (Input value) technical-functional value (5.1.)	100%			
6. Output value (next cycle)				
6.1. Technical/Functional			*6.2. Economic*	
			6.2.1. (Output value (next cycle)) economic value (6.2.)	€ 7.397,62
6.1.2. Recycling and reuse potential (2.4.2.)	Yes	*OK!*		
6.1.3. Guarantee future performance of elements (2.4.3.)	Yes	*OK!*		
6.1.4. Feasibility study to prove reuse potential (2.4.4.)	Yes	*OK!*		
6.1.5. Demolition specificaitons and disassembly guidelines (4.1.3.)	Yes	*OK!*		
6.1.7. (Output value (next cycle)) technical-functional value	€ 155,09			
7. Lost value				
7.1. Technical/Functional			*7.2. Economic*	
7.1.1. (Output lost value) technical-functional value (7.1.)	€ -7.242,53		7.2.1. (Output lost value) economical value (7.2.)	€ -73.976,21

Figure 15 - Value Retention

There are two types of *Value Retention* evaluated in with the Circular Procurement Framework and Tool. First of all, the *input value retention* which is the value that is brought to the new designed system which is the one being evaluated. This value can be either Techno-functional or Economic. The *input techno-functional value* is the value that is being taken from the physical use of the elements that are second handed. Whereas the *input economic value* is the cost of ownership considering the circularity of the elements for the use in the design. On the other hand, the *output value* also considers the *techno-functional* and *economic value*. This is measured by the potential elements that may have a new life-cycle after the end-of-life in the design being evaluated. For the *economic output value* the costs of depreciation need to be taken into account. Finally, the lost value is the expected variation between the *input value* versus the *output value.*

6.2.5 *Other*

8. OTHER					
8.1. Architectural design			*8.2. Material*		
8.1.2. Shared amenities and services (HS2.)	Yes	*OK!*	8.2.1. Environmental Product Declaration (EPD)	33,23168075	(%)
8.1.3. Design strenghthens local biodiversity (BE3.)	Yes	*OK!*	8.2.2. Material passport mantained during use cycle (M4.1.1.)	Yes	*OK!*
8.3. Knowledge development and sharing					
8.4.1. Knowledge development and sharing (HV	Yes	*OK!*			
8.4.2. Knowledge development and sharing (W	Yes	*OK!*			
8.4.3. Knowledge development and sharing (BE	Yes	*OK!*			
8.4.4. Knowledge development and sharing (HS	Yes	*OK!*			
8.4.5. Knowledge development and sharing (V2	Yes	*OK!*			

Figure 16 – Other

Finally the category *Other* is a qualitative category that assesses three aspects. First, the *architectural design* ensuring the use of circular principles that support the shearing economy and the protection of local biodiversity. Second, the ratio of materials that own an Environmental Product Declarations and the assurance of maintaining the variation of the materials within the life-span of the design with the proper documents that state the use of those materials. These documents include EPD's and Material Passports. Finally, to ensure the knowledge development and sharing with the learning cocreation throughout the ideation, design, life-span and end-of-life of the project. This knowledge needs to be regarding health and wellbeing, health and safety, waste management and the built environment.

6.3 Differentiation to other frameworks

Despite of the fact that this framework and tool is an adaption from other frameworks, the difference between this and the analysed frameworks is that this framework not only aims for the assessment of the circularity level of a building. This framework aims further, to be used as decision-making tool for the selection of the best solution to be developed. Furthermore, the transparency of this framework supports the creation of knowledge throughout the procurement process by allowing the participants of the tender to learn about their weaknesses in their designs. This can ensure a creation of better circular designs and also the knowledge generation for the contractors who are being part of the process.

Furthermore, this framework tries to unify the most relevant indicators used for the measurement of circular buildings with a scoring methodology that allows decision-making. This happens since some of the used indicators are not yet fully operational in all of the frameworks.

7 Circular Procurement Framework testing

As it was mentioned in section 3 in the Design process for testing. This tool was tested in a case scenario. Such case scenario was chosen by the province of Zeeland due to the availability of information that they had in the case. This case was the Veldstation Seaftinghe.

7.1 Case: Veldstation Seaftinghe

As it was mentioned in section 3 in the Design process for testing. This tool was tested in a case scenario. Such case scenario was chosen by the province of Zeeland due to the availability of information that they had in the case. This case was the Veldstation Seaftinghe.

The Veldstation Seaftinghe is known to be a birdwatch tower. Which is built in Seaftinghe region in the province of Zeeland. This project was designed and built following all the possible circularity principles. Therefore all the materials were thought to be of second hand and the design was carefully considering the surrounding area which is a natural preserved area. This station was designed and built by RO&AD Architecten who were also taken into consideration in the development o this project. In order to develop the tests there was an interview with both the province and the architects in order to obtain all the required information from the design, to be able to have it as an input data for the testing of the framework.

Once the original data was acquired, there was the need to modify and adapt the information to be able to use it with the framework. These modifications consisted basically in the transformation of the data to weights and volumes which is the way that the Circular Procurement tool works. With this transformed information the first test was done. Since this was a project that was originally thought and designed to have all the potential circular solutions, the first results were not satisfactory to show what the tool is able to provide in real practice. This is because the results of this first test showed an optimal scenario and it is not comparing any different solutions. Therefore some modifications were necessary in the testing approach.

At this point is where the iteration for framework validation came into consideration. For this iteration as explained also in the design process, several scenarios with different designs of the Veldstation Seaftinghe were developed. These scenarios consisted in multiple variations of the same design. This means that for the sake of the project, different solutions on the different aspects of the Circular Procurement Framework were provided. Table 17 shows the six different scenarios that were built for the development of this test. These scenarios consisted in a variation of the expected results of the five categories of the Circular Procurement Framework.

This approach of different type of designs is more relatable to understand in a way that a procurement process work. This is due to the fact that a procurement process will most likely need to compare different scenarios to decide which scenario is the most suitable scenario to be built.

Table 17 - Testing scenarios Veldstation Seaftinghe

Scenario	Input	Output	Value retention	Economic lost value	Other
1	Biobased	Energy production	Low	High (bad)	High
2	Reused	Landfill	Low	High (bad)	High
3	Traditional (steel-concrete)	Demountable	Best	Low (good)	Mid
4	Biobased	Demountable	High	Low (good)	High
5	50% Circular-biobased 50% Raw	Demountable	High	Low (good)	Low
6	Traditional (steel-concrete	Traditional (demolish)	Poor	High (bad)	Low

7.2 Testing approach

Despite of the fact that the Veldstation Seaftinghe is not a very big project in terms of volumes, it consists of a great variety of elements that conform the project as a whole. Due to the fact of time constrains during this project, it was not possible to examine every element of the design for the purpose of testing the procurement framework. In order to have a more manageable approach for this test, some elements of the complete design were neglected. The reason for this was to reduce the amount of components that were considered for the analysis. Moreover, to align with the common practices of procuring the heaviest financial elements in a building, only the roof, structure and foundation of the original design were contemplated. Therefore, the six different scenarios examined these three main elements of the project. Figure 17 shows the 3D overview of these examined elements.

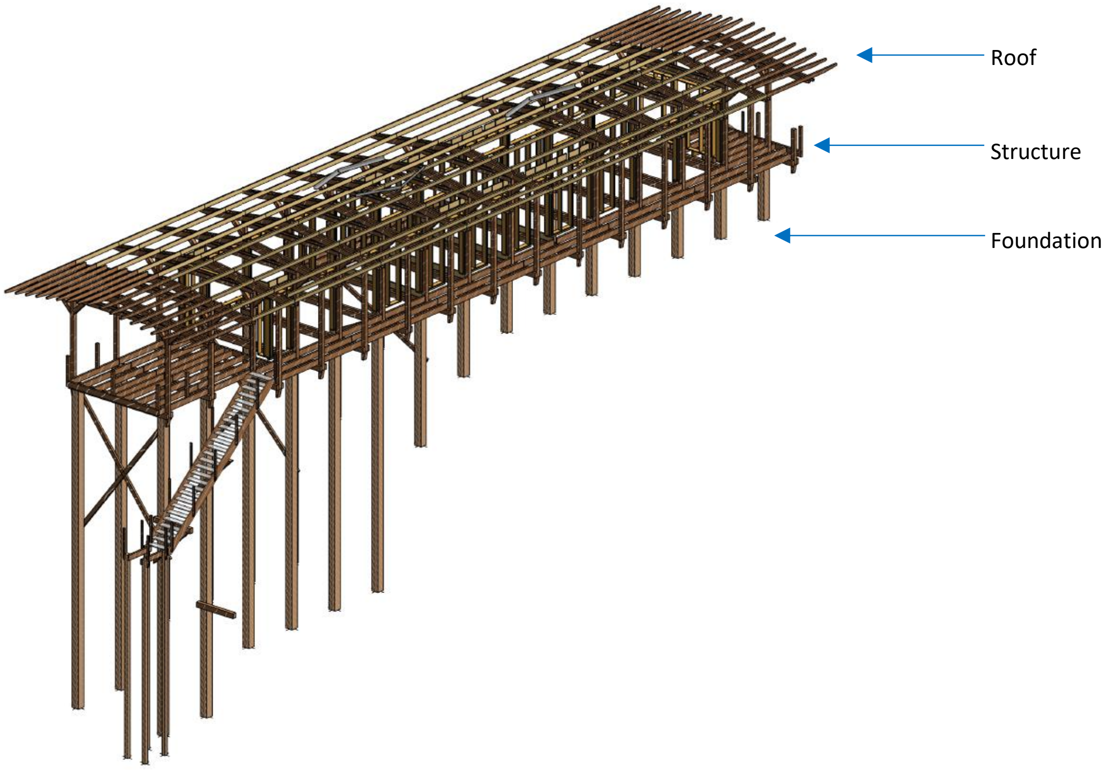

Figure 17 - Original Veldstation Seaftinghe 3D overview of roof, structure and foundation.

Once the selection of the elements that were going to be tested was done, the following step was to develop the complete bill of materials of the selected elements. The project's website contained this information, however, it was necessary to validate this information with the technical drawings that were provided by the Province of Zeeland together with RO&AD Architecten. This bill of materials is part of the input data for the Circular Procurement Tool that was developed for this project. Furthermore, the information regarding the expected output and unitary costs were added in order to be fully capable of running the Circular Procurement Tool. This was the base scenario which helped to understand the way that the other five scenarios had to be developed.

The following step was to develop the comparative designs mentioned in Table 17 which would help in the test for the comparison of different solutions to the same project as a way to emulate a procurement process in which multiple designs compete for one project. For some of the designs, the input information was similar to the base scenario. In such cases, minimum modifications were performed. However, a bigger challenge was to develop those scenarios that contemplated a completely different input information. For these designs, a complete different scenario had to be built. Nonetheless, these scenarios also contemplated only the three elements of the original scenario – roof, structure and foundation.

As the six different scenarios were built and the same information of each scenario was available, it was possible to input the data from the six different scenarios into the Circular Procurement Tool. After inserting the data into the tool, the results of the tool were graphed in order to have a visual interface of them. The six different results were compiled in one single graph to have a visual overview of the six different scenarios for decision making purposes.

7.3 Test results

This section explains the results of the use of the Circular Procurement Framework and Tool in the different scenarios. Based on the design there was an expected result to obtain with the Circular Procurement Tool. Therefore, it was necessary to prove that the expected outcomes will appear during the application of the tool with the introduced information.

Table 18 - 'Input' results

Scenario	Input	Score
1	Biobased	100%
2	Reused	100%
3	Traditional (steel-concrete)	0%
4	Biobased	100%
5	50% Circular-biobased 50% Raw	42,74%
6	Traditional (steel-concrete)	0%

As it can be seen in Table 18, the expected outcomes of the results were positive and aligned to the design considering a circular-biobased perspective. The reward of considering a circular-biobased design is a higher score on the system. The case of scenario five is not exactly the expected 50-50% due to the fact that the materials could not be equally spread with the design. Therefore, there was a higher amount of use of raw materials which gave a result of 42,74%.

Furthermore, Table 19 shows that a similar phenomenon happened in the second category (Output). The use of a design that creates waste of that do not consider a useful end-of-life of the building components will be negatively evaluated with the tool. Therefore, a building that consists of detachable and demountable elements will score higher using the tool, which enhances the use of circular solutions in the building sector.

Table 19 - 'Output' results

Scenario	Output	Score
1	Energy production	0%
2	Landfill	0%
3	Demountable	100%
4	Demountable	100%
5	Demountable	100%
6	Traditional	20%

As for the *Value Retention* concerns (Table 20), the outcome of the results also aligned to the expected outcome of the evaluated design. Despite of the fact that this category still requires an improvement on its calculation due to the further development of the indicators, it is possible to see the difference in the results for current procurement practices.

Table 20 - 'Value retention' results

Scenario	Value Retention	Score
1	Low	5%
2	Low	10%
3	Best	90%
4	High	85%

5	High	83%
6	Poor	0%

Finally, for the final category (Other), the results are shown in Table 21. It is possible also to see that the results align to the expected outcome, which means that the use of this category is also operable at the current stage of the framework. This means that the circularity criteria for this last category is useful for the decision making of certain design.

Table 21 - 'Other' results

Scenario	Other	Score
1	High	90%
2	High	90%
3	Mid	50%
4	High	90%
5	Low	30%
6	Low	20%

In order to have a more visual perspective of the results, the aforementioned results were graphed. Figure 18 shows the different results per category which gives a way to visually compare the results of the different designs.

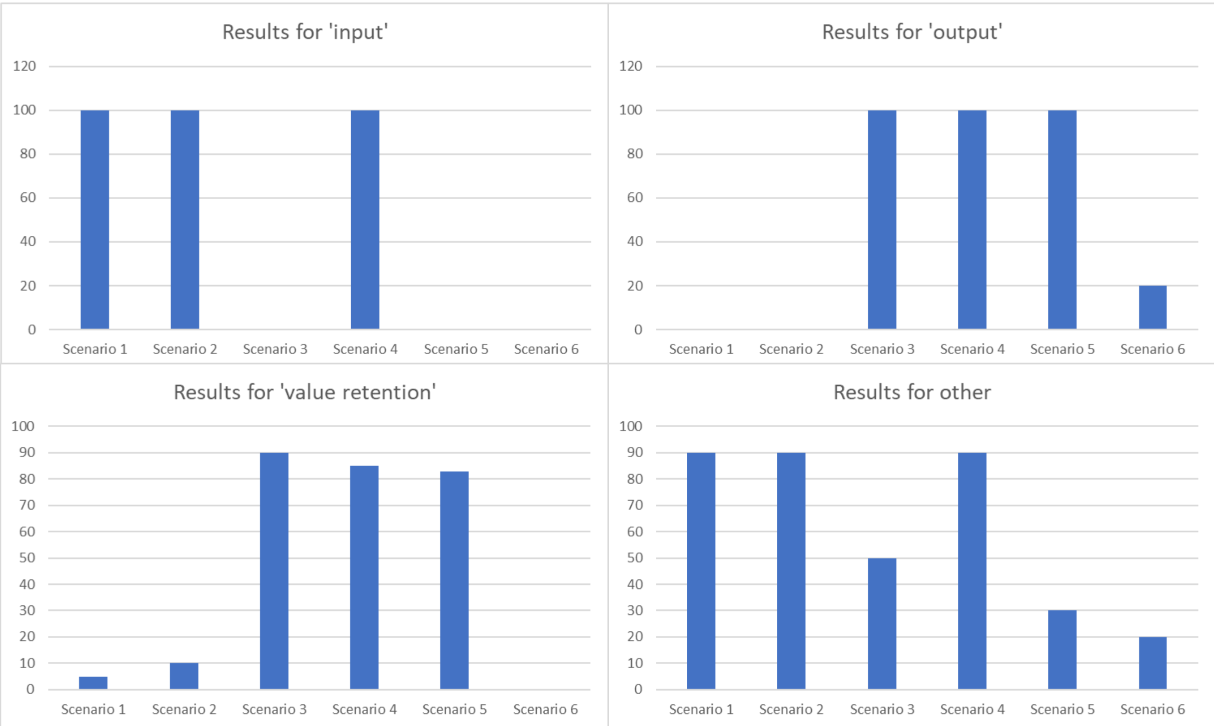

Figure 18 - Test results per category

The users of the framework (Province of Zeeland in this case) could start by setting certain bar to the different categories. This means that the design developers should follow certain design criteria to fulfil the minimum requirements that the Province considers to be good for the continuation of the project. For instance, the Province could say that they expect that the result for *Value retention* should not be lower than 85%; therefore, only scenarios three (90%) and four (85%) could go to the next round with their current design. Nonetheless, the other designs could still develop further in their designs to cope with such hypothetical requirement.

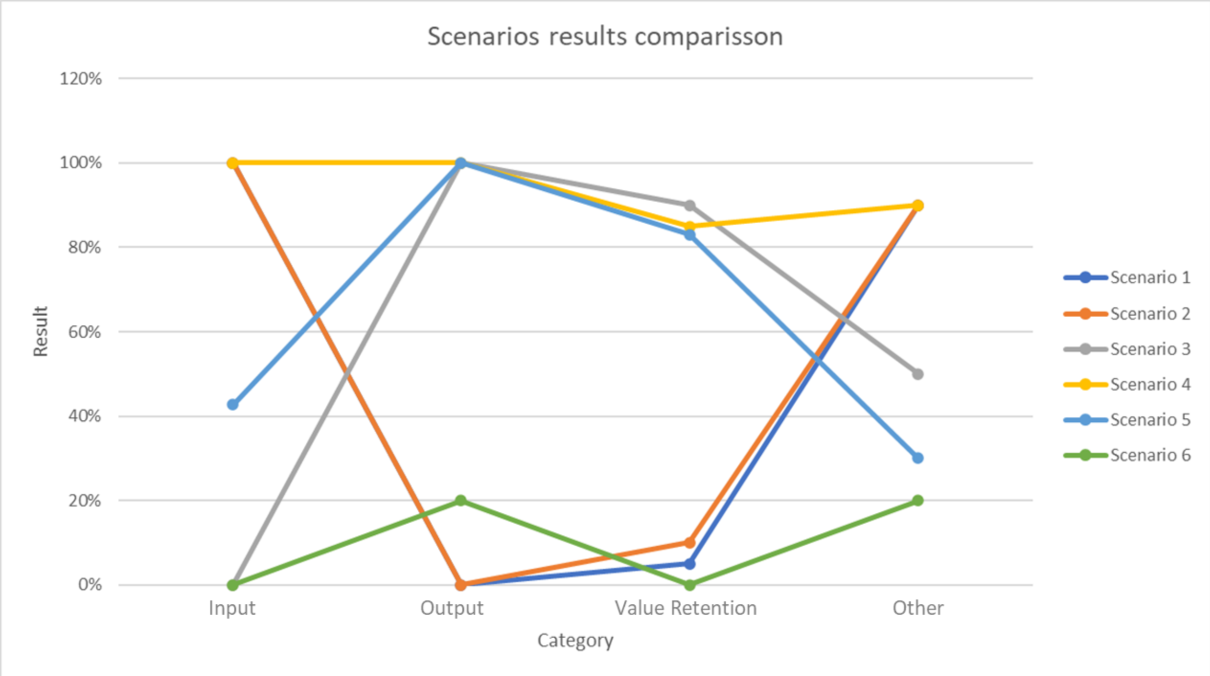

Figure 19 - Test results overview

In order to be able to have an overall comparison of the different results of the designs, the results are graphed together as shown in Figure 19. This can help in the decision making process of the Province of Zeeland by having a clear overview of the overall circular-biobased performance of the design. In case the province believes that the best approach to follow a procurement process is to set a minimum requirement of 80% in the overall performance of the building, they could know that the best option for this case is to continue with scenario four. This is because this scenario has all categories higher than 80%. However, it is up to the users of the framework to decide which are the bare minimums that a design should have in order to be awarded as a good design. Nonetheless, designers can still learn from this process to understand which elements of their design needs improvement to have a better performance.

8 Conclusion

The aim of this report was to explain the work performed in the past two years. It has emphasized the development of several tasks that were planned to fulfil the five core objectives of this project. This section will show the main conclusions to each one of those five objectives.

- The justification of the need of the development of a Circular Procurement Framework and Tool.
- A clarification of the definitions of Circular Economy in the Built Environment.
- The development of a useful Circular Procurement Framework based in the different existing circularity measurement approaches in the building sector in the Netherlands.
- An overview of the structure of the proposed Circular Procurement Tool.
- An explanation of the different indicators that conform the Circular Procurement Tool
- A first approach of the use of the Circular Procurement Tool in the Veldstation Seaftinghe case.

All of the abovementioned was performed by the creation of a link between the PDEng. Trainee, and all the relevant stakeholders of the project.

Objective 1: *Review existing literature to formulate the definition of 'circular economy' and indicators used to measure it in the context of the built environment, and to identify barriers to its adoption*

The agreement of a relevant definition of the term 'circular economy' in the different industries is a core activity to perform in the development of circular solutions. Although there are overarching definitions of such term, there are still context related arguments that modify the understanding of the general definitions. After reviewing different definitions from existing literature and having direct meetings with the people from the Province of Zeeland, a consensual definition based in the ambitions of the province and the literature reviewed was developed. This definition is presented next.

Circular Economy in the *built environment* is a <u>restorative and regenerative economic model</u>, which aims to provide <u>solutions to sustainability related problems</u> by maintaining the highest possible <u>value</u> and <u>utility</u> to all the components and materials that construct the system where they belong. This is achieved by a stronger <u>control of finite raw materials exploitation</u> and by <u>optimizing and reducing</u> the production of construction and demolition <u>waste</u> which can be undertaken if its lifespan is prolonged, and its value is kept within the built environment system or another system following the R's strategies. All of this needs to be considered with the premise that the development of the system will not harm but will preserve the sustainability pillars (society, environment and finances).

Moreover, there was a finding of a list of barriers that are – in literature – the main reasons of the difficulty of the adoption of circular solutions in the built environment system. From this list, the four main barriers that were relatable for the Province of Zeeland are:

- Absence of clear definition of Circular Economy
- Lack of circularity evaluation standards
- Low availability of goods and services
- Poor knowledge of suppliers

Therefore, the justification for this project was to explore possibilities to overcome the aforementioned barriers which would enable the transition to the application of innovative circular solutions within the built environment of the Province of Zeeland. Which means that with the development of this project would aim to overcome the first two barriers which are systemic for the Province which would cause a pulled change in the second two barriers. This means that with the development of a clear definition that considers the ambitions of the Province of Zeeland in the transition to avoid linear solutions, and with the development of a clear evaluation standard that could be used for procurement purposes, there will be a growth in the availability of goods and services which will increase the knowledge of suppliers. This will enable the transition to circular solutions with the innovation of suppliers that fulfil the transition agenda followed by the Province of Zeeland.

Objective 2: *Interview stakeholders from the Province of Zeeland to define requirements for their circular procurement process.*

For the second objective interviews where performed for both understanding the current practices in the procurement process and also to identify the requirements that those stakeholders set for the development of a Circular Procurement Framework and Tool. The most important aspect identified was the transparency of the framework. It is needed for the clear understanding of the measurement indicators to improve the knowledge generation of all relevant stakeholders in the procurement process. Guaranteeing a transparent framework and tool will help small and medium enterprises to understand their weaknesses when it comes to designing circular solutions for the built environment. This can ensure the survival of lower level stakeholders into the transition to a circular economic model by allowing them to adapt based in the knowledge generated throughout the procurement processes.

To ensure the aforementioned, it is necessary to have a tight communication strategy between the Province of Zeeland and the small and medium contractors. Setting the wanted ambitions by the Province in a clear list of requirements is fundamental for achieving the transition. A proper Circular Procurement Framework can be the link that tightens the communication of the ambitions and requirements for the sake of the development of circular solutions in the built environment.

It is important to mention that based on these requirements setting from the perspective of the Province of Zeeland, one of the most important aspects was to ensure the growth of the use of biobased solutions; therefore, this aspect was considered as a fundamental element for the development of the Circular Procurement Framework.

Objective 3: *Review and compare best practices existing circularity assessment frameworks and tools with their indicators to determine whether they meet the requirements*

The aim of the third objective was to undergo some of the most used circularity assessment frameworks in the Netherlands to understand their differences in the approaches of their measurement strategies. This analysis helped to understand the differences and similarities of the frameworks. However, one finding from the perspective of the needed requirements settled by the different stakeholders in objective two, was the lack of transparency and operability of the six analysed frameworks. The use of these frameworks require of acquired abilities for their users, and results are not explicitly showing the strengths and weaknesses of the analysed designs. Moreover, the use of these frameworks have the unique property of assessing the level of circularity of a building; however, they are not explicitly used for procurement purposes. Therefore, an adaptation of such frameworks was needed for the operability of a Circular Procurement Framework and Tool.

The multiple existing circularity assessment frameworks use certain indicators for their measurements. In some cases there are overlapping indicators in the different frameworks and there are other cases that some of the frameworks may use some indicators that the others do not. The reason for this is based on the variation of the definition of the term Circular Economy in each one of the frameworks. For that reason, and sympathizing with objective one, it was needed to agree on a particular definition that aligned to the ambitions of the Province of Zeeland in order to integrate the required indicators to the designed tool being taken from the different analysed frameworks. To be able to have an integration of the indicators from the different frameworks, it was necessary to study the different approaches of the overlapping and non-overlapping indicators to properly build a measurable framework with the selected indicators. Therefore, a categoric analysis of each indicator was performed.

Objective 4: *Integrate indicators of existing circularity assessment frameworks and tools to develop a circular assessment tool for procurement purposes*

The core objective of the project was objective four. The output of this project was agreed to be a Circular Procurement Framework and Tool that could be operable by the purchasing department of the Province of Zeeland for the future procurement practices for the built environment sector. This was a follow-up objective from objective three. Having already analysed the six different building circularity assessment tools, understanding the difference in their approaches and the use of the different indicators that they measure was the first step into the development of the Circular Assessment tool for procurement purposes.

This resulted in a first version of a tool that with the proper and continuous development with the sake of learning and improving it, can become a powerful tool that can help achieve the transition to circularity providing room for innovation in the construction sector. It can work as a guideline to help unexperienced contractors in terms of circularity to gain knowledge and cocreate solutions together with the Province of Zeeland.

Objective 5: *Test Circular Procurement Tool to evaluate its performance and applicability to the Province of Zeeland*

Having used the case of the Veldstation Seaftinghe was an interesting approach for the first use of the Circular Procurement Tool. Although, the design was done based in previous experience and not with a set of guidelines to develop it given by the Province of Zeeland, the score was very satisfactory. Knowing that this was the first approach to use the tool, still required to assume aspects that were not perfect. However, in the case of using it as an aid for the development of a new design, may be valuable for the architects to understand circularity from a new point of view which is based in the best practices of the measurement of circular buildings. Since this was the first time that this procurement process is performed, it could be seen that the market is still not ready for the fully performance of the Circular Procurement Tool. All the parties from the procurement process need to be aware of the necessary information for the tool in order to have a successful tender process. In order to achieve this, communication between the purchasing department of the Province of Zeeland and the involved parties needs to consider the emission and reception of this information. Nonetheless, with the knowledge of the tool from both parties, the tool can be very powerful for designers and decision-makers.

9 Discussion

The Circular Economy is still a very debatable solution towards more sustainable solutions at any sector. Starting from the perspective that there is still no real consensus on the definition of the term Circular Economy, it is still an approach to sustainability that requires a lot of growth and effort in its development. In the construction sector, the approach to circularity is still less developed than in other industries. It is rewarding to know that there are efforts put by high level actors from different countries, and that in Europe there are higher instances that support the transition to avoid the linear economy and that specifically there is a focus being put in the construction sector. Yet, the system still requires a lot of change to cope the transition.

Bearing in mind that the main objective of this project was to develop a Circular Procurement Framework and Tool that is operable in the short term by the Province of Zeeland, it is a worthy step for the transition to circular solutions in the construction sector. It is valuable to have a procurement process that enables small and medium enterprises to cope with the aforementioned transition. The lack of transparency in the current procurement process will not enable such companies to learn from the practices in order to subsist against the big companies who have the resources for knowledge generation. However, for a true transition of the construction sector, having a Circular Procurement Framework and Tool is not the only solution. There is still a need for the development of new business models that consider the circularity principles. It is true that with this project, the different stakeholders in the construction industry are more exposed to the necessary considerations for achieving the transition. Still, suitable business models are required within the whole supply chain.

It can be argued that the current availability of Circularity Assessment Tools is enough for their use for procurement practices. However, it is relevant to state that the development of this project was to improve the knowledge generation and to simplify the procurement process with the perspective of circularity.

It is also relevant to mention that this tool was developed since the first instance for its explicit use in the promotion of the use of biobased materials. This means, that the framework and tool will reward better to the use of biobased materials over any other circular solution. Withal, the tool may be adapted for further development with the increasing level of importance of other materials based in the creation of new circular business models in the Province of Zeeland. This can be performed by prioritizing the resource availability within certain time-frame in the surrounding areas of the different projects that may be designed.

Further research and development on this project can be performed. First of all, further research on the operationalization and scoring of the indicators is needed. Even though the framework is currently already operable, some of the indicators are still under development by the different analysed frameworks. Therefore, an adaption of those updated indicators need to be considered when further developing and using the Circular Procurement Framework and Tool. In addition, a better integration of the framework with an LCA is suggested. Knowing that LCA's are already a tool to measure circularity, having it as a category in the framework may suggest that there are aspects being double counted. That is the reason why only several scores from an LCA are considered for this framework. However, if it is possible to fully integrate the two methods, a better result could be achieved.

Also, having a more visual interface of the tool as well as more user friendliness with an improved user experience, may result in an improved learning process of the users of the tool. This goes from the suggestion of using certain materials, teaching them the reasons of the use of those materials and a visual variation of the results could help both users and the Province of Zeeland to develop the required business models in the construction sector that improves the availability of circular goods, services and solutions to accomplish in the shortest term the ambition to reach the desired Dutch and European circularity levels.

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