The BRU-C framework - an Urban Circularity Assessment Tool for the Brussels-Capital Region

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Abstract

The escalating climate crisis has catalysed ambitious environmental targets within the European Union's building sector. A dual focus on operational and embodied energy consumption underscores the need to overhaul the resource-intensive linear economic model. Transitioning to a circular economy paradigm is imperative, particularly within the complex urban environment. This research responds to the critical gap in frameworks that effectively integrate circular economy principles into urban planning and design. While existing methodologies often rely on extensive data and post-project evaluations, this thesis introduces the "BRU-C" framework, a pioneering approach to assessing circularity in early-stage urban projects based on design data values. By combining qualitative and quantitative analysis, BRU-C empowers urban planners to make informed decisions that promote circularity.

Centered in the Brussels-Capital Region, the research involved a rigorous examination of ten existing frameworks, culminating in the development of a tailored assessment tool. Through case studies in Brussels and Amsterdam, the "BRU-C" framework was refined, focusing on four core dimensions of circularity: Spatial Development, Materials & Resources, Environmental Quality, and People. These dimensions were further articulated through eight Design Factors and evaluated using twenty-four criteria. While constraints limited the full development of Environmental Quality and People, the framework offers a robust foundation for assessing and advancing circular practices in urban planning. This research contributes a valuable tool for urban practitioners seeking to embed circularity-inspired ambitions into their urban projects that will build the world of tomorrow. Recommendations for framework refinement and broader application are provided to guide future research and implementation.

Keywords: urban circularity, design factor, circular city, circular indicator, framework, circular economy

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Chapter 1

Introduction

1.1 Context

Contemporary cities are increasingly focused on becoming healthy, sustainable, and inclusive, with the goal of fostering robust communities where all individuals can prosper, all while adhering to the Earth's ecological constraints. Today, cities are still the largest drivers of environmental impact as they account for 75% of the world's total carbon emissions, they are home to 56% of the global population and consume 75% of the world's primary energy [1]. The percentage of the world's population living in cities is expected to reach 70% by 2050 [2]. A paradigm shift is necessary to rethink cities which are confronted with a myriad of economic, social, and environmental challenges [1].

Currently, resources are consumed at a rate equivalent to 1.5 Earths to meet daily needs and absorb resulting waste. This measure demonstrates that it takes the planet 18 months to compensate for what is used in 12 months. With these current trends, it is estimated that by 2030, the resources of two planets will be required to answer the needs. This rapid transformation of resources into waste, faster than they can be regenerated, places the planet in a state of ecological overshoot. It is an unsustainable condition that requires urgent attention. This climate urgency is driven by numerous forces. The human population has surged exponentially over the past 60 years, growing from about 2.5 billion in the 50s to 7 billion today. The current linear resource use model that treats the outputs as waste pollutes the atmosphere, water and soil with its toxins. This model of extraction, use, and disposal accelerated the exhaustion of the stock of non-renewable energy, water, and materials. Thereby, it is hastening Earth's greatest struggle: climate change [3].

Cities are also confronted with severe challenges including food security, economic competitiveness, and financial austerity. Coupled with the increase in global human population, is a rapid urbanisation. Currently, more than half of the world's population lives in cities and the United Nations predicts this number to rise to 70% by the year 2050 accompanied by the popping up of megacities that are home to between 10 and 20 million people. Both the resource scarcity and the rapid urbanisation will crucially impact the urban development in the coming decades. This is why addressing these issues is essential for cities to become more sustainable [3].

In light of the urgent climate challenges, the European Union has set ambitious objectives with the aim of reducing the environmental impact and the total energy use of the building sector [4]. The building industry is a material-intensive sector. In 2019, 100.6 B tonnes of materials was consumed in which 38.8 B tonnes was consumed by the housing sector [5]. The European Union strives to develop a sustainable, low-carbon, resource-efficient, and competitive economy. To do so, the EU launched an action plan to steer the economy towards a more circular one in 2015, called "Close The Loop". This action plan demonstrates that the implementation of circular economy will enhance the EU's competitiveness by safeguarding businesses from resource shortages and fluctuating prices, while also fostering new business opportunities and encouraging innovative, more efficient methods of production and consumption. Each EU member state will create its own action plan for the implementation of circular economy in their national legislation and goals [6].

The current linear economical model is energy and resource consuming and does not care for the environment. Furthermore, it is not a model adapted to the citizens' needs and pushes towards an irresponsible consumption of resources, only seeking for the economical profit. The Brussels-Capital Region is confronted to serious economical, social, demographic, sanitary, climatic and environmental issues, and requires a paradigm shift towards a development model which is sustainable, human-oriented, wherein economic growth is a way to achieve quality of life. Circularity is high on Brussels' agenda. The Brussels-Capital Region aspire to be a pioneer in the development of circular economy. Brussels built a road map that fights for the reduction of the environmental footprint of the economy, advocating for economic local loops and promote the richness of the local economy and responsible consumption [7].

Circular economy is defined as a continuous positive development system designed to be regenerative and always maintains the value of components at their highest [8]. It seeks to design "out" waste and replaces this "end-of-life" concept with restoration and regeneration. It allows the transition towards renewable energy and suppresses the exploitation of toxic chemicals [9]. It is also defined as an economical model of exchange and production that seeks to enhance resource efficiency and minimise environmental impact at every stage of the product's life cycle all the while improving individual well-being. It should be developed at the local scale [7].

As demonstrated, green neighbourhoods play a crucial role in addressing the environmental challenges our planet faces [3]. They can be considered as vessels for circularity and local-scaled economy. Current methods to measure circular economy at the urban level revolve around urban metabolism which have been proven to be to data-intensive and only focused on input and output flows [10]. Whereas neighbourhoods and cities can counter-attack resource scarcity while improving the quality of life and social participation, and live in harmony with the environment all the while still growing economically. More and more research is made on how to integrate circularity in cities, but still quite business focused and how to include circularity in urban planning and design is still yet to be clearly defined. In the midst of all this, the concept of "urban circularity" has arisen, and it aims to be less consuming and less wasteful while paying attention to social, economic, and environmental factors. It fosters more resource-efficient, resilient, and just behaviours and practices, considers more-than-human perspectives, aims to reduce the overall net inputs and outputs of cities while maximising the value of local materials, and interconnects the participants of the urban ecosystem [11].

There are more and more frameworks and research done in Brussels, in Europe, and worldwide. The objectives of the European Union and its capital, Brussels are clear, and they have already jumped the wagon by implementing more and more frameworks and tools such as GRO [12]. The existing frameworks are both local and international, with assessment varying from sustainability in districts to circularity in buildings. However, some can be considered quite data-intensive, and most are used to determine circularity and sustainability post-project. The purpose of this research is to contribute by elaborating a framework that would assess circular-inspired ambitions in urban plans during the early phases of the design in the Brussels-Capital Region.

1.2 Problem Statement & Research Objectives

Amid the climate crisis, and to tackle the environmental challenges, it seems fundamental to address the way we consume and the way we treat material and resources. As stated before, a paradigm shift is crucial to rethink cities that are confronted to a plethora of economic, social, and environmental issues [1].

Green neighbourhoods have increasingly been recognised as essential in addressing the environmental challenges our planet faces, serving as microcosms for circular economies and sustainable practices [3]. These neighbourhoods are seen as crucial vessels for implementing circularity and fostering local-scaled economies. However, current methods to measure circular economy at the urban level, primarily centred around urban metabolism, have significant limitations [10]. Urban metabolism is defined to be the sum of the technical and socioeconomic processes that happen in urban areas that result in growth, production of energy, and suppression of waste [13]. Smart cities have also gained momentum and are seen as vessels for sustainability in urban environments. They are considered as activators of circular economy initiatives, using digital methods to wisely manage natural resources through participatory governance. It requires to gather data through technology [14]. Similarly, urban metabolism studies tend to be data-intensive and overly focused on input and output flows, lacking a comprehensive approach that integrates social, economic, and environmental dimensions within the urban context [10].

While neighbourhoods and cities hold the potential to counteract resource scarcity, improve quality of life, enhance social participation, and achieve economic growth in harmony with the environment, the integration of circularity into urban planning and design remains underexplored and insufficiently defined. Despite a growing body of research focused on circular cities, much of it remains business-oriented, leaving a gap in how to apply circular principles effectively at the urban planning level [11]. Amidst these challenges, the concept of "urban circularity" has emerged as a promising approach. Urban circularity aims to create cities that are less resource-consuming and wasteful while fostering more resource-efficient, resilient, and just behaviours and practices. This concept considers more-than-human perspectives, seeks to minimise the net inputs and outputs of cities, and strives to maximise the value of local materials by interconnecting all participants in the urban ecosystem [11].

Transitioning to circular economic models have moved up in the political agendas [11]. The Brussels-Capital Region aims to lead the way in advancing the circular economy. Brussels has developed a road map called the Regional Program of Circular Economy (PREC) focused on reducing the environmental impact of its economy, promoting local economic cycles, and encouraging responsible consumption while highlighting the value of the local economy [7].

In Brussels, as in other parts of Europe, there has been a growing emphasis on developing frameworks and tools to promote circularity at both local and international levels. The European Union and Brussels-Capital Region have demonstrated a strong commitment to these goals, implementing frameworks like GRO to advance circular practices [12]. There are other pioneering international frameworks such as BREEAM Communities and LEED for Neighbourhoods that assesses sustainability in districts [15][3]. In Brussels, Be Sustainable developed a framework to guide urban planners in developing more sustainable districts and GRO is commonly used to assess sustainability and circular ambitions in buildings [16][12]. This demonstrates that Brussels is hands in the circularity framework development plan. However, many existing frameworks are either data-intensive or remain too general. Most of them are primarily used to assess circularity and sustainability after project completion, rather than during the crucial early design phases.

This research aims to address this gap by developing a framework specifically designed to assess circular-inspired ambitions in urban plans during the early stages of the design process in the Brussels-Capital Region. This framework will contribute to the ongoing efforts to embed circularity into urban planning, ensuring that these principles are considered from the outset and are integrated throughout the development process. The elaboration of the framework will focus on the early-design phases of the urban development projects in Brussels, and will assess the circular ambitions of each project, before, during, and after its design. The objective is to create a easy-to-use design-based tool which requires only open-access data readily available that will guide urban planners and designers in the decision-making process of the urban project. Given that the cities' objective is to obtain circularity, promote local economy all the while assuring quality of life and protecting the remaining resources this planet has to give, the way to do so is to implement circularity-inspired ambitions in the constantly evolving neighbourhoods. This is why developing a tool which assesses and guides circular ambitions in urban plans and designs during early-design phases is beneficial.

1.3 Research Questions

As stated in the previous section, the purpose of this master thesis is to develop a design-based framework that analyses and assesses the implementation of circular economy principles in the early design phases of urban planning within the Brussels-Capital Region. By investigating current circular initiatives and their impact on the local circular economy market, the research aims to identify key circular design factors and develop a methodology to evaluate their implementation potential. Focusing on early-stage design, the framework seeks to be less data-intensive than existing assessment methods while providing a quantitative circularity score. Hence, the main research question is:

How can a tool be developed to assess the circularity potential of urban projects within the Brussels-Capital Region, supporting urban planners and stakeholders to integrate circular principles into the early stages of development of a project?

Some guiding sub-questions are:

- How can a set of design factors be selected to quantity and qualify urban circularity in an urban development project?
- How can a tool be developed to quantify and qualify urban circularity in order to assist urban designers in early-phase design?
- How can the urban circularity of a development project in the Brussels-City Region be evaluated?

1.4 Methodology

The end-goal of this research is to develop a tool that could be used by architects-urbanists, urban planners, to assess, evaluate and improve the implementation of circularity-inspired ambitions in masterplans and in urban plans. To do so, the research is divided into several phases. After executing a literature search on existing works concerning urban circularity, circular definitions, a selection of 10 existing tools related to circularity and sustainability were made. An in-depth analysis of these tools was made with the objective of putting forward the forces and weaknesses of each tool. This analysis will help direct and create the base the urban circularity tool. Parallelly, the literature search on circular definitions will help define the urban circularity concept for the tool. From that defined concept, the main goals of the tools can be outlined. A preliminary framework can be designed with design factors and the correct method of assessment. A parallel work will be made, where this framework will be tested on 3 different case studies, each of them at a different locations in the city all the while defining the calculation methods of each design factors. Improvements are proposed and can be studied further.

In a nutshell, our main methodology is broken down into a literature review, the analysis of 10 existing frameworks, the development of the framework, and the parallel work between the case studies analysis and the framework simulations. These will be further detailed in the following sections.

1.4.1 Litterature review

The literature search focuses on outlining the research domain related to urban circularity definitions and existing frameworks. Overall, the literature search phase was an explorative one, to understand the concept of urban circularity to understand circular economy concepts and principles, to determine the main objectives of the Brussels-Capital Region. Because the framework had to be design-based, circular design principles were also explored, notably, design principles defined by the Vrije Universiteit Brussel. A first exploration was made to find existing frameworks, before selecting.

An array of existing tools was selected with the idea of covering different types of tools. They range from the local to the international scale and vary between sustainability and circularity assessment. In the selection, the idea was to also pick out frameworks which were qualitative or quantitative one, or both. The analysed tools are: Circular Building Design (VUB's tool), Be Sustainable's Toolbox, GRO, The Regional Program of Circular Economy (PREC), BREAAM Communities, LEED for Neighbourhood Development (LEED-ND), City Resilience Index (CRI), Urban Circularity Framework (UCAF), Ademe, Circular Urban Scan (Metabolic's tool).

BESUSTAINABLE, GRO and Circular Building Design are all Belgian tools, each respectively covering the urban scale, the building's scale, and the material and design scale. The PREC is a Brussels' governmental framework with a focus on circular economy. It is not an assessment tool, but it helps contextualise CE in Brussels. BREAAM Communities, LEED-ND, and CRI are well-known tools which possesses urban-scale sustainability or resilience assessment methods. Ademe is a French tool focusing on adapting circular economy at the urban scale. The Urban Circularity Assessment Framework and the Circular Urban Scan are also circularity assessment frameworks which were discovered during the first literature search.

As demonstrated, this panoply of tools is diverse and covers a large spectrum of existing frameworks and tools. The analysis of the different frameworks revolved around understanding the objectives of each tool, of highlighting the different criteria or questions posed and their definitions, to understand the respective method of assessment. All the analyses were synthesised to offer a global view and highlight categories of criteria. The coloured synthesis permits to visualise the scope of impact of each tool and will help underline the positive and negative aspects of each. Furthermore, when the tools provided circular definitions, these were studied with the ones found in the literature search.

1.4.2 Development of the framework

To create the base of the urban circularity tool, the definition of urban circularity and the goals of the tool had to be defined. With the in-depth literature search on circularity definitions, the definition of urban circularity was established. Four goals were defined as to what the tool was going to assess in a project to respond to the question of circularity in an urban project. These goals were defined during a brainstorming session founded on knowledge of the analysis of the different tools. Axes of interventions were defined and provide a response for those goals wherein design criteria are categorised. Each of the design criteria are defined qualitatively and quantitatively via a credit system.

As this represents an enlarged tool, for the sake of this research, the development of the design criteria and the testing of the tool were restrained to the Material and Resources and Spatial Development axes. This research therefore focuses on urbanistic and material design factors.

1.4.3 Case studies analysis and framework simulations

Once the preliminary framework was elaborated, the idea was to confront it to realistic case studies, focusing majorly on Brussels, where a lot of information on Brussels is publicly available and accessible. There was a parallel work done between the testing and the refinement of the framework. For this research, three case studies were chosen to conduct the tests with the idea of improving the tool. Two projects reside in the Brussels-Capital Region which are the Masterplan Cityforward located in the European Quarter and the PAD Defense located on the outskirts of Brussels, close to the Zaventem Airport. The third project is named Buiksloterham and is in Amsterdam, Netherlands. This third project considers itself as a sustainable and circular project. This project was developed by Metabolic and was found during the literature research phase. It is a finalised project and in-use. This project possesses a lot of information which will permit us to test how a finished project can be circular.

1.5 Structure of the thesis

This thesis will first introduce the context, the problem statement, the research questions, and the methodology. Then the thesis body will be divided into a state-of-the-art on urban circularity, an analysis on existing frameworks, followed by the elaboration of the urban circularity framework, the testing of this created framework and the discussion of its results as seen in fig.1.1.

The chapter on the state-of-the-art concerning urban circularity will breakdown the different definitions already present in the research domain that will colour the base of this research. Europe's and Brussels' ambitions concerning circular economy will be demonstrated. Some interesting research works is also laid out. This section will also quickly explore the different existing frameworks that will be studied in depth in the next chapter.

The third chapter will focus on the analysis of 10 existing frameworks. In each analysis will figure a visual synthesis of each tool done during the analysis and help procure a quick overview of each framework. A global conclusion is drawn and the most interesting elements of each framework will form the basis for the elaborated framework on urban circularity. The analysed frameworks are : GRO, Be Sustainable's Toolbox, Circular Building Design, PREC, BREEAM Communities, LEED-Neighbourhood, Circular Resilience Index (CRI), Urban Circularity Assessment Framework (UCAF), Ademe, and Circular Urban Scan.

The fourth chapter "BRU-C – An Urban Circularity Framework" will present the elaboration of the framework in the context of this research. The chapter will begin by presenting the definition of urban circularity, the drive of the entire framework. The goals of the tool are then unveiled. The overview of the final framework is shown, and each of its components are broken down and defined: axes of intervention, design factors and criteria. The correlations between the criteria are demonstrated. Because the thesis only shows the final framework, a subsection related to the evolution of the framework will explain the methodology that was employed to arrive to such a result. Finally, the toolbox of BRU-C will be explained, the components of the toolbox, which are the brochure and the Excel file, will be detailed.

The fifth chapter concerns the testing phase of this research. In this section, 3 case studies are presented: Cityforward, Buiksloterham, and PAD Defense. The urban context, and ambitions of the project will be outlined, and the different steps of the test via the Excel file of the toolbox will be skimmed through. The results of the 3 tests are then presented.

The results of these tests will be discussed and criticised in the sixth chapter "Results and Discussion". The objective of this section is to take a step back and analyse the results of the tests. Moreover, a critique of the BRU-C framework will be inspected. The different pros and cons of the elaborated framework are laid out and the different shortcomings and perspectives are unravelled.

Figure 1.1: Structure of the thesis

1.6 Work Distribution

For this master thesis, the majority of the research was done by both Chaimae and Lam. The only phase where we separated our work was during the beginning of the research with the first step of the literature search, where we both explored different aspects to gather existing definitions in the research field as well as the different existing frameworks. We narrowed it down to 10 frameworks and each of us analysed 5 frameworks. We shared our analysis during brainstorming sessions. Apart from those phases, we majorly worked together. In fact, one of the strengths of this research is the many brainstorming sessions and work sessions that were done together in order to develop the BRU-C framework. Brainstorming sessions permit us to question the work and take a step back each time. We are proud to present the results of our collaboration.

Chapter 2

Urban Circularity - State-of-the-art

2.1 Urban Circularity definitions

When analysing the current field of research surrounding urban circularity, a lot of definition arises. In the context of the 21st century post-industrial European cities, the concept of "circularity" is gaining leverage in "sustainability" architectural and urban debates. The transitions towards "circular" systems seem obvious, but their implementation in urban contexts remain vague [11]. While the terms circular economy have been hanging around for a while and it can be easily related to concept of loops, and a transition from linear to circular systems [9], but the term "urban circularity" is an emerging concept [11]. This state-of-the-art will attempt to explore the definitions of circularity, and related concepts. Because our end-objective is to create a framework which assesses urban circularity in urban projects, we will also investigate circular practices and design concepts. This section will finally overlook some important actors in Brussels.

To clarify, assessing circularity in urban projects goes hand in hand with urban planning and design. Urban planning and design focus on land use and transformation of land and on urban resource management with an objective to improve the urban environment in the public and the private sector. Cities are complex structures that are in a constant state of metamorphosis [17]. Urban planning aids in improving and requalifying cities or creating new urban areas by developing solutions. The most important concept here is the improvement of the quality of life, whether it be for the citizens or their surroundings, and its interaction with the natural environment [18].

To tackle the current climate changes issues, a circular approach can change the way the resources (materials, energy, water, land, etc.) are consumed and produced in cities, by diminishing the overall consumption globally. A circular approach tackles other types of urban problems such as waste disposal, greenhouse gas emissions, pollution-related issues, and socio-economic problems such as affordable housing, diversifying economy, engaging collaborative communities in cites. All in all, circularity can improve the quality of life in urban environments [19].

Circularity in cities is progressively the topic of policy innovations, urban strategies and research and development agendas. The circular economy shift is being considered more as a sustainable city concept. But currently, this concept is more prevalent in the economic sphere, and how circular economy creates economic, social and environmental resilience in urban contexts is blurry [20]. Circular cites are cities which practices circular economy principles to close resource loops in collaboration with the city's stakeholders including citizens, community members, businesses, and knowledge partners in order to achieve its vision of a future-proof city [14]. In circular economy, the concept of loops is essential. Circular economy is considered as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops [21].

The principles of circular economy are divergent and are integrated in various ways by the leading actors of the market. The definitions of circular economy are numerous. A circular economy is, according to the Ellen MacArthur Foundation, a system that is regenerative by intention and design. It aims to design "out" waste and replaces this "end-of-life" concept with restoration. It permits the transition towards renewable energy, suppresses the exploitation of toxic chemicals, an impediment to reuse. Elimination of waste is put forth via the design of superior materials, products, systems, and business models [9]. Circular economy can be also defined as a continuous positive development system that is regenerative and restorative by design and always maintains the value of components at their highest [8]. It can also be defined as an economical system of exchange and production that aims to improve resource efficiency and diminish environmental impact at every stage of the product's life cycle all the while improving individual well-being. The local scale of this economical model is essential [7].

A. Bortolotti et al. presents 3 interpretations of circularity for circular urbanism. The first interpretation refers to the resource efficiency paradigm and basically considers circularity as the optimisation process of closing the loops of resource and waste management within the urban system. In this interpretation, the urban system has a role of being regenerative and wherein the outputs are equivalent to the inputs, with no extra inputs needed. The second interpretation is related to the recirculation of urban/territorial/regional metabolism paradigm which promotes connections between cities and its hinterlands through strategies such as regrouping the resources, the minimisation of distances between the workplaces and the residences or between the production and consumption domains. In this paradigm, the circularity is all in all thought out as a principle for rethinking the relationship between the city and its hinterland. The third and last interpretation is thinking circularity as a holistic concept to undoubtedly rebalance the relationship between humans and nature. It is related to the ecological paradigm and aims at deploying a whole-systems approach to rethink the economic and social relations to rebalance the human-nature relationship. It is a paradigm which stretches on the long term, and challenges today's modernist thinking [22].

Urban circularity refers to the application of the circular economy concept at the urban scale, aiming to create sustainable cities that minimise waste and maximise the reuse of resources. It implies creating and monitoring urban systems where materials and energy are used in cycles, rather than in linear processes that end in waste disposal. Urban circularity encompasses the 3 dimensions of economic, environmental and social pillars of sustainability, and it requires a integrated approach that considers the interweaving of these aspects within the city. It aims to integrate and optimise resource flows across the entire urban landscape, from buildings and infrastructure to consumption and production patterns [20].

Urban circularity is also defined as an emerging concept. There is a new culture of circularity with an aim to be less consuming and wasteful all the while being attentive to social, economic and environmental factors. It integrates the concept of "frugality". All in all, urban circularity is an approach that seeks to foster more resource-efficient, resilient, and equitable behaviours and practices. It implies minimising the overall net inputs (resources) and outputs (waste) of urban areas—including extraction, manufacturing, disposal processes, logistics, transportation, and supporting infrastructure—while maximising the value of existing local material stocks. It also fosters the idea of considering beyond-human perspectives, and beyond utilitarian narratives that separate cities from natural ecosystems and recognising the interconnectedness of all the participants of the ecosystem [11].

2.2 Circular Design Principles

G.C. Verga and A.Z. Khan developed the ladder of value retention, which was based on the R's imperatives [23] and on the concept of narrowing, slowing, and closing the loops [24]. The 9 R's imperatives which are refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover, and re-mine are classified according to the categories (narrow, slow, and close loops) [25]. This ladder permits to differentiate the circular inspired actions and demonstrate that some have more impact than others. The circular economy (CE) discourse, despite its conceptual ambiguities, is often conveyed through various lists of strategies. These strategies are depicted as loops, pyramids, ladders, and hills, each illustrating ways to retain value and suggesting steps for transitioning towards more circular practices [25]. This value retention ladder is quite relevant in our opinion in the case of an urban circularity framework. It can be for example used to categorise different well-known circular design strategies in the case of buildings.

Circular design is defined by European Investment Bank as the first step to enable circularity and to create value. The plethora of design strategies that improve circularity in the built environment can be grouped into three main categories: design to reduce (optimising resource efficiency and minimising material use, further decreasing material flows, etc.), design for recyclability (adopting a circular design approach that supports deconstruction, disassembly, modularity, and material reuse), and design for longevity and flexibility (extending the lifespan of buildings) [26]. This principle promotes flexibility and time-proofness in constructed buildings. The principles of flexibility and future adaptability are also supported by another research by the Vrije Universiteit van Brussels. Conventional design and construction practice should be challenged because of their inactive stance. Buildings and built environment should be considered as dynamic elements, because this will have a significant impact on resource consumption and the quality of life. Buildings should be durable, meaning that they should resist the wear and tear of the environment in which it is placed and its socio-economic context. This dynamism forces buildings to resist to obsolescence by using them differently and adapting them new needs of the inhabitants and their neighbourhood [8].

The Architectural Engineering Department of the Vrije Universiteit Brussel developed 3 approaches that they integrated in their circular design building tool which fight for the extension of the life of built environment and promotes the idea of moving towards closing material loops. The 3 approaches are: design for longevity, design for disassembly, and design for reuse. Design for longevity implies refusing new construction and revalorising and refurbishing the existing. Design for disassembly or reversible building design considers the creation of building elements that can be disassembled without damage. Design for reuse aims to diminish the use of non-renewable materials and support the use of reclaimed materials and building components that can be reemployed, repaired, remanufactured or recycled [27].

2.3 Main actors and distinguishable research

In the context Brussels, there is an Agreement of the Brussels-Capital Region Government that commits Brussels to shift towards a circular economy. The Agreement indicates that the region will craft a strategic vision of the environment as a resource that not only creates local employment by transitioning from a linear to a circular economy but also strengthens the capacity of local businesses to tap into new markets. Via the Regional Program of Circular Economy (PREC), Brussels strives to offer its citizens an attainable alternative that promotes local economy while still answering to the citizens' needs in terms of housing, sourcing, working, commuting, entertainment and the business's demands in terms of reducing costs, expanding, innovating, and hiring, leading to an increase in the overall quality of life of the people of Brussels [7]. This program illustrates Brussels' ambitions in terms of circularity. It represents a road map for Brussels and contains all measures that Brussels intend to support in the years to come. A budget was also cut out. In this changing context, frameworks are being developed and used. A well-known and frequently used one is GRO, a sustainability assessment tool which integrates circularity principles and evaluates buildings and their surroundings [12]. Be Sustainable created a toolbox to aid public entities to assess sustainability in neighbourhoods [16]. The Vrije Universiteit Brussel also developed a framework named Circular Building Design [28]. These four frameworks are a good representation of the ongoing research and transition in Brussels.

When looking at actors and leading research at the scale of Europe, we can denote Ademe, Metabolic, and Arup. Ademe is the agency in charge of the ecological transition in France and advocates for a quick transition to a sober and united society. It aims to create employment and to engage in more human perspectives [29]. They developed a theoretical framework which integrates circular economy at the urban scale. Arup developed the City Resilience Index, a framework assessing resilience and classifying cities [30]. Not an actor but distinguishable research is the Urban Circularity Assessment Framework (UCAF) made by F. Vanhuyse, a framework for planning, monitoring, evaluation and learning from circular economy transition in cities [10].

Metabolic stands out as a pioneering force in sustainability and circularity research, particularly in the Netherlands. Founded in 2012 by Eva Gladek, the Rotterdam-based organisation has become a global leader in the field. With a substantial body of literature and publications, Metabolic is dedicated to developing practical strategies and tools to facilitate circular and sustainable projects. The company's extensive research, exemplified by its involvement in projects like Ceuvel and Schoonschiep, in collaboration with Space&Matter, underscores its commitment to a circular economy. Their work on the Buiksloterham project, where they created a vision, road map, and action plan for transforming an industrial site into a circular neighbourhood, is a prime example of their influence [31]. Metabolic's contribution to this research is invaluable due to their wealth of knowledge and a range of methodologies for achieving circularity. Their frameworks, such as the City Circular Framework and the Circular Urban Scan, as well as their Seven Pillars of the Circular Economy principle, provide robust tools for assessing and guiding urban circular development. These frameworks have been instrumental in shaping this thesis as they helped shape and understand the concept of urban circularity at the scale of neighbourhood [31][1][32].

Two international leaders that should be underlined are the BRE Global Limited and the U.S. Green Building Council. BRE Global Limited developed BREEAM, a sustainability assessment framework with adapted versions depending on the countries [15]. The U.S. Green Building Council developed LEED-ND, the Leadership in Energy and Environment design. They developed a version for neighbourhood development [3]. These frameworks are certification tools, labelling the sustainable projects and putting them at the forefront of the market.

Chapter 3

Analysis of existing frameworks

For the analysis of existing frameworks, an array of 10 frameworks was chosen. The selection of the tools was executed in a way to cover different scopes ranging from local to international, from the building scale to the city scale and from sustainable assessments to circular assessments method. The idea was to also find tools with different method of assessment varying from qualitative to quantitative. Some of these tools were already previously known. The analysed tools are the following:

- Circular Building Design (VUB's tool)
- Be Sustainable's Toolbox
- GRO
- Regional Program of Circular Economy (PREC)
- BREAAM Communities
- LEED for Neighbourhood Development (LEED-ND)
- City Resilience Index (CRI)
- Urban Circularity Assessment Framework (UCAF)
- Ademe
- Circular Urban Scan (Metabolic's Tool)

Be Sustainable's Toolbox, GRO, Circular Building Design, and the Regional Program of Circular Economy (PREC) are all Belgian frameworks. Be Sustainable's Toolbox was designed for the Brussels-Capital Region and is to be steered by public actors and governmental actors. This tool assesses sustainability at the district scale and guides the urban designers in the design of a sustainable district. Be that as it may, the tool already integrates circular thinking as it talks about materials and resources [16]. GRO qualifies itself as an in-depth sustainability assessment framework. However, it in fact entirely integrates principles of circular economy, the "people-planet-profit" principles and climate responsive design, making it an interesting tool to analyse. Furthermore, it can be compared to the BREEAM assessment method but is adapted to the Belgian context [12]. Circular Building Design was endorsed by the Architectural Engineering faculty of the Vrije Universiteit Brussel. It is a qualitative tool that acts as a guide to the designers and clients towards well-considered design choices in circular building. It is a very extensive tool on circular practices and with its focus on circular design, reinforces parts of this research which are not necessarily supported by the rest of the frameworks [28].

The Regional Program of Circular Economy (PREC) is a Brussels' governmental framework with a focus on circular economy. It is not an assessment tool. Nevertheless, it helps contextualise circular economy in the Brussels-Capital Region. It clarifies Brussels' vision and objectives for circular economy as it fixes a road map for the years to come. This framework is used by public actors as a guide as well [7]. The PREC and Ademe are the only tools of this analysis which explicitly focuses on the aspects of circular economy. They are both governmental tools, but Ademe is a French tool. The only differences between Ademe and PREC is that while the PREC is in fine a road map for Brussels, Ademe's approach is circular economy integrated at the urban scale. Ademe contains a qualitative assessment tool also for public actors. However, its method is very much adapted to the French systems [33].

BREAAM Communities, LEED-ND, and CRI are well-known tools which are urban-scale sustainability or resilience assessment methods. These tools cover the international scope of this selection. BREEAM is initially an English tool but has adapted versions depending on the countries. BREEAM Communities is the large-scale version of the sustainability assessment tool [15]. LEED for Neighbourhood Development is an American tool used to assess sustainability in both green buildings and neighbourhood design. This tool is interesting as it includes both scales [3]. The City Resilience Index is a tool developed by ARUP and assesses resilience in cities. It is an international tool that mixes both qualitative and quantitative methods of assessment, making it a very interesting approach for an early-design phases [30].

The Urban Circularity Assessment Framework (UCAF) and the Circular Urban Scan (CUS) are tools that resulted from the literature search which seemed the most relevant to this research. The UCAF was one of the first tools found during the literature search on Cible+ and is a tool that evaluates circular economy at the city scale. What was interesting with this tool is their approach to circular economy. It enlarges the insights on circular economy strategies as well as the urban stocks and flows [10]. The Circular Urban Scan is a tool developed by Metabolic. Metabolic is a Dutch organisation with a mission to transition to an economy that is regenerative and 'circular' by design. They provide guidance to governments, businesses, and NGOs and they give out data and build strategies and tools. The Circular Urban Scan is one of them, and it fully integrates their systems thinking. The approach of this tool is at an urban scale and is very accessible making it an interesting tool to dig into [34].

As demonstrated, this panoply of tools is diverse and covers a large spectrum of existing frameworks and tools. The analysis of the different frameworks revolved around understanding the objectives and the scope of each tool, of highlighting the different criteria or questions posed and their definitions, to understand the respective method of assessment. To do so, a synthesis of each tool was made. In the synthesis, figure the criteria and their definitions disposed in a way to visually quickly understand the scope of the tool. Because the tools often had different approaches and different axes of interventions, coloured categories were defined during the analysis to differentiate the specificity of each criterion. These categories were chosen based on what was most apparent in the tools. The legend of each category and their respective colours in the visual representation is as follows:

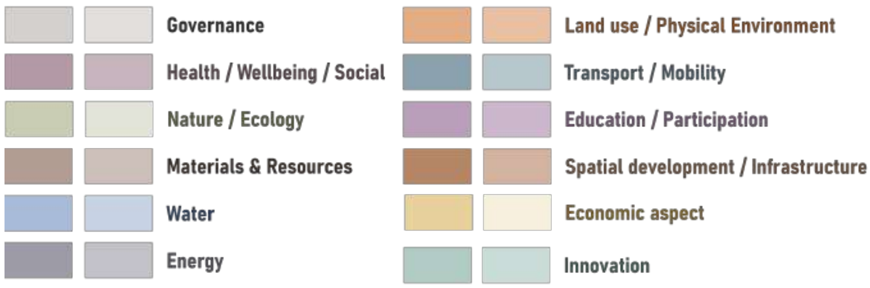

Figure 3.1: Legend of the colours representing the categories of the analysis

3.1 Circular Building Design - a VUB's tool

Circular Building Design was born from a research project named "Le Bâti Bruxellois: Source de nouveaux Materiaux (BBSM)" led by the Architectural Engineering department of the Vrije Universiteit Brussel (VUB). Published in 2019, the research resulted in a brochure and a guidebook to build circularly. The brochure is a synthesis of the guidebook. The tool was engineered to accompany the designers during the early-design phase of the project and clients in the decision-making process. It is a tool to guide and inspire that catalogues the insights and experience of design practitioners, researchers, and organisations from Brussels. The objective of the tool is to help make well-thought design choices to close the material loops and minimise waste [28]. The tool first contains three approaches to shift towards more circular practices which are design for longevity, disassembly, and reuse. Then the centre of the tool consists in 16 circular design qualities (see fig.3.2) that makes possible more effective reuse, recycling or renewal of buildings and building components. The tool also provides design concepts which combine circular design qualities and a series of strategic actions [27].

The strongest element of this tool is its demonstration of circular building. The guide and the brochure both provide an ease in comprehension of the different concepts presented and strikes as a pedagogical tool. It fulfilled its objective of being a highly accessible tool both for clients and designers. In our opinion, to make information as accessible as possible, the use of a brochure should be done by all early-design frameworks. The downside is that it is only related to buildings in general, building systems and products meaning that it is less adapted to neighbourhood-scaled projects. As it can be observed in the synthesis (fig.3.2), the framework talks extensively about materials and resources. The circular design qualities are relevant and cover the gaps often present in the other analysed frameworks. In our opinion, these design qualities should be considered in the tool developed in this thesis. Furthermore, the idea of flexibility and time-proofness is put forth again and again and is a fundamental element in circular building which should also be considered in an urban circularity tool. As a matter of fact, the guidebook writes "rather than permanent solutions for temporary and changing needs, we need dynamic assets that can evolve together with new technical developments and user demands" [27].

Figure 3.2: Synthesis of the analysis of the Circular Building Design framework [27]

3.2 Be Sustainable's Toolbox

Be Sustainable created the Toolbox to help create exemplary projects, to create a springboard for innovating solutions, and to share inspiring resources to tackle social and environmental challenges of Brussels. To kick-off one's sustainability action, Be Sustainable developed the Be Sustainable Chart which elaborates the 10 objectives for creating sustainable districts in Brussels [16]. The chart aligns with the objectives of sustainable development of the United Nations and the Regional Sustainable Development Plan (PRDD) of the Brussels Capital Region [35]. The Toolbox contains 3 tools, wherein the 10 objectives are broken down. The three tools are the Quickscan, the Compass, and the Memento. The sustainability criteria are defined according to both qualitative and quantitative indicators [16].

The Quickscan tool helps to obtain a first glimpse on the level of sustainability of the neighbourhood project. It works based on 50 key questions related to the Chart and permits a quick analysis. The questions are organised according to the themes of the Chart, with different sub questions depending on the phase of the project. The tool provides a guidebook containing the qualitative questions and an Excel file to evaluate the project in a more methodical way. Its goal is to help understand the different important aspects of a sustainable neighbourhood and how to improve it. Overall, the Toolbox is a purely indicative tool and is not a certification tool [35]. The Compass is the tool used by sustainable district facilitators who accompany the designers in the project. The Compass is employed to determine the strong and weak points as well as the opportunities of the existing district, to aid in the development of a holistic vision, and to create a dashboard as a monitoring tool during the different phases of the project. The Memento regroups the theory surrounding the Chart and present typical strategies [16].

The analysis of this framework was focused on the Quickscan tool as it contained both a guide and an Excel file permitting a preliminary evaluation of the project. The assessment method is based on a subjective opinion of the assessor. Each question and sub question are presented with an explanation, and when possible, a qualitative method of assessing it. When possible, the Excel also refers to known actors and reference documents for certain actions. The assessor will choose an option to answer the sub questions ranging from "very bad" to "very good". The results are presented via bar diagrams. After analysing the Excel, it can be observed that the tool is straightforward and very easy to manipulate. Because it is only a qualitative tool, it is also easy to make a quick assessment. The qualitative questions also already provide some leads on how to take measures without even consulting the Memento, making a very pedagogical tool. The downside of the tool is that it is not a quantitative tool and is known to be mostly used by government-led district projects.

The 10 objectives of the chart are shown and defined in the synthesis (fig.3.3). The associated questions are also shown in keywords to understand the scope of the tool. It is visible from the synthesis that the Toolbox is one of the analysed frameworks which covers the most categories of intervention. As a matter of fact, based on this tool alone, almost all the colour-categories that were defined (see fig.3.1) are considered. The fact that the tool is based on the ten objectives makes it very easy to apprehend what the important aspects are for a sustainable district. Even at a district level, the question of materials and resources is put forth, and here the concept of circularity is the basis of this objective.

GOALS	KEY QUESTIONS	OBJECTIVES
VISION = a sustainable, low-carbon, resilient city with a high-quality living environment, & improvement of its environmental impact.	**VIS01** is the vision anchored in its context ? **VIS02** does the vision provide a transversal and ambition framework ? **VIS03** is the vision reinforced by the achieved projects ? **VIS04** is the vision implemented in a respectful manner ? **VIS05** does the vision offer sustainable transition ?	= Identify the opportunities, challenges & actors = determination of concrete framework, objectives to coherently direct the projects = concretise the vision at each step resiliently & coherently = anticipate the implementation phases in a respectful way towards the context = maintain long term sustainable ambitions
MANAGEMENT AND PARTICIPATION = collaborative and participatory in respect to sustainable economic principles.	**MAN01** management process = resilient ? **MAN02** durable financial strategy ? **MAN03** sustainable (construction) site management ? **MAN04** sustainable management of the neighbourhood's life ?	= stimulation of the interactions between actors = guarantee financial feasibility, use of adapted financial models = concretise the vision at each step resiliently & coherently = implication of the users in the neighbourhood's life + monitoring of its activities
HUMAN ENVIRONMENT = social, economic and commercial vitality. Inclusive & adaptable.	**HUM01** good site analysis of social & economical context ? **HUM02** social vitality in the neighbourhood ? **HUM03** neighbourhood = inclusive ? **HUM04** socio economic view to the sustainable site management ? **HUM05** stimulation of economic vitality ?	= good understanding of the dynamics put into place = mixity of functions and people : equilibrium, inclusivity, social cohesion, economy = equal opportunities, different type of housing, affordability = optimised site management for workers & local residents = sustainable and circular economy
SPATIAL DEVELOPMENT = open spaces and buildings, efficient, accessible, & adaptable over time and coherent with the surrounding context.	**SPA01** diagnostic focus on understanding the systems in place ? **SPA02** open spaces = backbone of the neighbourhood ? **SPA03** neighbourhood = appropriable by its users ? **SPA04** site = temporary use ? **SPA05** management methods anticipated in an evolutive way ?	= understanding the context under different dimensions = link between new/existing, hierarchy & structure/diversity = open space = meeting space, combination of various usage = life of the district integrated during the construction = quality and resilience of spaces for different occupations times, functions
MOBILITY = accessibility, use of active modes & public transport for all users.	**MOB01** mobility strategy in the quarter ? **MOB02** open spaces & infrastructures = adapted to mobility ambitions ? **MOB03** neighbourhood = optimised for logistic mobility ? **MOB04** site = sustainable in terms of mobility ? **MOB05** encouragement of alternative uses and mobility services ?	= understanding the global mobility context = mobility influences users' behaviour = consider deliveries, heavy loads transportation = site = not a burden to the quarter's life = alternatives modes of transportation, infrastructures, etc.
NATURE DEVELOPMENT = presence of nature in territorial, structuring, landscaping, evolving, social and health aspects.	**NAT01** knowledge of natural elements = mutual profit ? **NAT02** use of nature strategy as a concept ? **NAT03** green spaces = extra social value ? **NAT04** site = sustainable in terms of nature development ? **NAT05** green spaces management in the long term ?	= consider natural context, identify strong & weak points = implement qualitative ecosystems = green spaces = responses to the diversity of uses & needs = let nature take its place before, during & after the site = implement a proper management plan for green spaces
WATER CYCLE = water management strategy that integrates water resource and as a risk.	**WAT01** knowledge of hydraulic environment = mutual profit ? **WAT02** water strategy = landscape strategy ? **WAT03** optimisation of the water cycle ? **WAT04** increasing the connection of the water with the users ? **WAT05** site = sustainable in terms of water cycle ? **WAT06** structured water management ?	= elaborate integrated strategy for water cycle = integrate the water management strategies into landscape = valorisation of the existing water & reduction of wastewater = valorisation of the water = extra value = no pollution in the water = guide the project manager with a water management plan
PHYSICAL ENVIRONMENT = aims to efficient use of land limiting the physical quality of life (soil, air quality of life, noise, heat, wind, views, odours, etc.).	**PHY01** consideration of the physical context ? **PHY02** reasonable, qualitative and adequate use of land ? **PHY03** minimisation of the physical impact on the environment ? **PHY04** site = sustainable in terms of physical environment ? **PHY05** information & sensibilisation of the users to the physical environment ?	= understand the constraints = maintain healthy soils, demineralisation, restoration of land = thermal and visual comfort, air quality, acoustical comfort = optimise environmental aspects in the site = visible environmental aspects & explained to the users
MATERIALS & RESSOURCES = circular strategy for managing resources.	**MAT01** identification of existing resources ? **MAT02** valorisation of the existing resources/materials ? **MAT03** new resources = introduced in an optimised way ? **MAT04** site = sustainable management of resources ? **MAT05** actions & infrastructures for prevention and waste sorting ?	= know the reusable resources = strategy for managing the materials on site = proper choice of resources (origin, quality, quantity) = properly manage resource on site = waste manage at the source
ENERGY = a bioclimatic strategy, integrating renewable energy sources.	**ENE01** identification of existing energy potentials ? **ENE02** bioclimatic design of the quarter ? **ENE03** minimisation of energy demand ? **ENE04** optimisation of the energy resources at the scale of the quarter ? **ENE05** site = performant in terms of energy ? **ENE06** quarter = performant in terms of energy ?	= impact of the environmental factors on the energy strategy = organising open/green spaces to minimise energy demand = minimising energy needs = valorisation of renewable energy, use of non-renewable = minimise energy consumption during construction = measure & evaluate & readapt the quarter's performance

Figure 3.3: Synthesis of the analysis of Be Sustainable's Toolbox [35]

3.3 GRO

The tool is named after a feminine Norwegian name signifying growth. GRO's initial objective is to permit the realisation of sustainable projects. The aim was to create an easy-access tool which would aid the project during the process. GRO is applicable to projects of all sizes and functions. It is a tool permitting to increase the sustainability of the building and is also a guide to reach a more sustainable design. GRO is also an evaluation and monitoring tool which aims to make visible the different aspects of sustainable and circular construction throughout the design phase. GRO is currently adapted to the preparation and conception phase only. This tool does not provide certification [12].

The concept of the GRO tool is to use the integrated design process to create future-oriented buildings. During the process of design, several principles are put forth. The principle of "people planet profit" constitutes a pillar of GRO. The use of circular economy helps improve this pillar. Particular attention is given to climate responsive design where the aim is to use as much as natural building techniques as possible and limit the use of energy intensive techniques. The idea is to use low-tech methods to reduce the energy consumption (see fig.3.4) [12].

The “People Planet Profit” principle consists of the consideration of all the different pre-occupations in buildings. It is the idea of finding the best possible solution all the while considering the different needs. The 3 axis of the principle all have their weight and specificity. People is about how each person counts. The designed building should respond to the user's comfort. It should be inclusive, qualitative and functional. It should respect and preserve the cultural heritage all the while creating shared value. Planet is about the protection of our ecosystem. This axis focuses on reducing the negative impact on the environment as well as reducing destruction and maximising conservation of goods. More precisely, it focuses on the reduction of the use of primary materials and the optimisation of technical and biological cycles towards closed loops. Profit focuses on the fusion of interest concerning future-oriented buildings, the prolongation of the building's life cycle, on the democratisation of the building, on the long-term management of it and on the integration of new circular economical models [12].

In circular economy, primary materials are used to the infinity. Entirely closed loops and absence of trash or residue is an ideal which might never be reached but is the ultimate objective. All along the lifetime of a building, several circular cycles are considered: repair, reuse, refurbish, remanufacture, recycle. These strategies ensure a longer use of the materials and installations with the best quality possible. These materials are rebooted in the system thanks to one of these cycles. This principle is also called “waterfall” where the objective is to keep the material in the cycle of best quality as long as possible before going to more inferior qualities. The principle of waterfall is important in circular construction as this idea of preventing, maintaining and creating value requires a different way of thinking, designing and building [12].

The tool consists of criteria sheets containing qualitative and quantitative criteria divided into 3 categories: people, planet and profit. Each worksheet defines the requirements, evaluations, and proofs. There is also a worksheet for "climate responsive design". It also consists of 2 synthesis files (building and site). GRO can be personalised by choosing the criteria, then fixing the level of global ambition (or fixing the level of performance of each criterion). These can be fixed with the synthesis files.

After analysing this tool, it was obvious that the tool is quite extensive as it contained both a manual and Excel files for the in-depth assessment of the durability of a project. One of its biggest assets is that the tool is adapted to the Brussels' context. It is, in our view, a very good sustainability assessment tool because of the sustainability concepts it integrates including climate responsive design and the 3 Ps of sustainability. The guide is clear and acts already as an aid to educate the designers and the clients on the different factors. The Excel files are clear as well, and provides spider web diagrams to compare results. The fact that the tool is organised according to the 3 Ps of sustainability makes it a very readable tool. The method of assessment is based on credits and is quite straightforward. A special appreciation can be given to the fact that the sustainable ambitions can be defined by the designers and the clients.

When analysing the colours with our colour code, it is observable that there is an emphasis on social well-being and comfort. It is also noticeable that the factors related to the planet pillar are more numerous than the others. The category of governance is not visible, but it is compensated by citizens participation in the project with the factor "user's influence". One of its other strengths is that it also integrates fundamental concepts of circularity such as future adaptability, frugal use of energy resources, flexibility in terms of uses and the circularity of materials. One of the downsides is that it is clearly not a tool that can be used at the city's scale in our opinion. Nevertheless, there exists a category dedicated to the site which integrates mobility factors and spatial development factors making it a more complete tool for its scale of intervention.

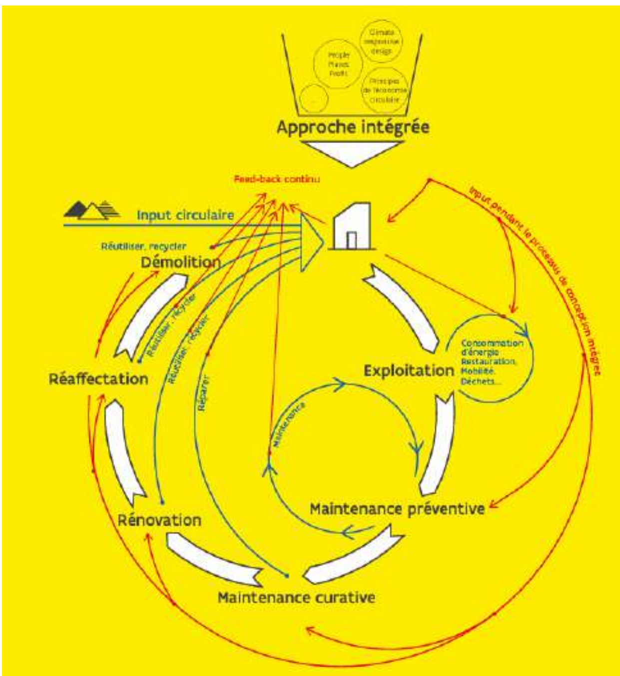

Figure 3.4: The integrated approach of GRO

PEOPLE

BIN1 ACOUSTIC	Good acoustics to increase the users' comfort
BIN2 THERMAL COMFORT	Encourage comfort and wellbeing throughout the seasons
BIN3 INTERNAL AIR QUALITY	Guarantee healthy internal air quality via an adequate ventilation exempt of air contaminants
BIN4 VISUAL COMFORT	Improve natural lighting for a higher level of comfort and wellbeing. Artificial lighting complements the natural lighting
SOC1 PATRIMONIAL VALUE	Contribute to the cultural landscape by preserving and valorising the existing
SOC2 SECURE DESIGN	Criminal prevention to guarantee socially secure buildings and environments
SOC3 INTEGRAL ACCESSIBILITY	A good design creates opportunities and supports users whereas a bad design creates obstacles and lacks inclusivity
GEB1 USER'S INFLUENCE	The possibility of individually influencing one's comfort increases users' satisfaction

PLANET

ENE1 ENERGY PERFORMANCE	Aim for highly energetically efficient buildings with a performant envelop
ENE2 RENEWABLE ENERGY	Increase the proportion of renewable resources
ENE3 HIGH PERFORMANCE APPLIANCES	Reduce the energy consumption by providing devices & installations with high energy performance
MAT1 PRIMARY MATERIAL CONSERVATION	Maintain primary materials in loops by recycling, reusing and repairing them
MAT2 CHOICE OF MATERIAL	Use environmentally-friendly materials which have no negative impact on human health
MAT3 MATERIAL PASSPORT	A ledger of existing materials in real estate goods
WAT1 WATER CONSUMPTION REDUCTION	Reduce drinkable water consumption thanks to economy of water devices, a good design and a good control system
WAT2 WATER RECYCLING	Reuse of rainwater and grey water to reduce drinkable water consumption
WAT3 WATER EVACUATION	Limit the water volume and debit to be thrown out and prevent the pollution of waters
OMG1 BIODIVERSITY	Promote local biodiversity
OMG2 ENVIRONMENTAL IMPACT	Limit light pollution, the shading of the surrounding elements, wind nuisance and urban heat island effect
OMG3 SUSTAINABLE SITE MANAGEMENT	On site, pay attention daily to the environment, of the surroundings and to security

PROFIT

LCC1 EASY MAINTENANCE	Reduce maintenance costs and repair costs
LCC2 EASY CLEANING	Promote easy and efficient cleaning in the design
LCC3 LOW ENERGY CONSUMPTION	Reduce energy consumption costs
TOE1 FUTURE ADAPTABILITY	Flexibility, function neutrality and a design for disassembly
TOE2 USE BY THIRD PARTIES	Offer the possibility to open the building and its surroundings to third parties, make it a useful common use in time & in space
BEH1 ENERGY MONITORING	Equip the necessary instalments to register, analyse and if necessary, adjust and optimise energy consumption

SITE

MOB1 BY PUBLIC TRANSPORT	Promote a durable mobility plan
MOB2 BY BIKE	Provide a secure and enjoyable environment for bicycle users
MOB3 BY FOOT	Provide a secure and enjoyable environment for pedestrians
MOB4 BY CAR OR MOTORBIKE	Guarantee accessibility to the site
MA1 SPATIAL QUALITY	Synergy between the quarter and the good spatial quality have a positive impact on the environment
MA2 USE OF THE GROUND & THE SPACE	Protect ecological areas and prioritise the use of polluted soils and patrimonial values
MA3 ATTRACTIVENESS OF THE ENVIRONMENT	The diversity of landscapes and proximity of the amenities increases the attractiveness
MIL1 FLOODING	Avoid building in flooding areas
MIL2 EXTERNAL AIR QUALITY	Atmospheric pollution has a negative impact on human health, particularly on vulnerable groups (young)
MIL3 EXTERIOR NOISES	Noises are the biggest form of nuisance

GRO is applicable to all projects of all sizes and functions. It is a tool permitting to increase the durability of the building and is also a guide to reach a more durable design. GRO is also an evaluation and monitoring tool which aims to make visible the different aspects of durable and circular construction throughout the design phase. The qualitative and quantitative criteria are divided into 3 categories: people, planet and profit. GRO can be personalised by choosing the criteria, then fixing the level of global ambition (or fixing the level of performance of each criterion).

CONCEPT USED

- integrated design process • principles of people-planet-profit
- principles of circular economy • "climate responsive design"

Figure 3.5: Synthesis of the analysis of the GRO tool [12]

3.4 PREC - Regional Program of Circular Economy

PREC stands for Regional Program of Circular Economy. The PREC strives to offer Brussels citizens a viable alternative that promotes local economy and responds to the needs of citizens (housing, sourcing, working, commuting, entertainment), and businesses (reducing costs, expanding, innovating, hiring), while enhancing the overall quality of life for the people of Brussels [7].

The three main objectives of the PREC are to:

- Reshape the environment challenges into economic opportunities
- Relocate the economy to Brussels to produce locally, reduce travel, optimise land use, and create added value for the citizens of Brussels
- Contribute to job creation

This program contains 111 measures and actions categorised in 4 different strategic categories which are the transversal measures, the sectoral measures, the territorial measures, and the governance measures [7].

In the program, it is said that circular economy will be effective in the Brussels-Capital Region (BCR) if it is coordinated with the development of the various territorial levels (local, communal, regional, and interregional). The Regional Program of Circular Economy will serve as the backbone. The PREC aims to bring forth a holistic vision of circularity and to propose a practical set of levers which implies different governmental instances, different regional and municipal actors, private, public and associative actors with the goal to tackle the different challenges. There are multiple levers to influence both supply (production, planning, construction, renovation) and demand (transition towards more responsible behaviours), including project-scale initiatives, master plans, neighbourhood development contracts, calls for sustainable citizen projects, and metropolitan area strategies [7].

The main actions exerted by each strategic category is presented in the synthesis (fig.3.6). This program is not a tool nor a framework per se but is a guide made by Brussels for the entire Brussels-Capital Region and presents a road map for the years to come to implement the actions which will answer to their objectives. This tool is relevant in contextualising the current ambitions for circular economy in Brussels, to understand the level of interventions and the axes of interventions. When analysing the colours of the synthesis, it is clearly a tool focused on economical aspects. Because of its holistic and governmental perspectives, a lot of actions involve both the companies, industries, and local businesses. It tackles the question of circular economy at the scale of the city and impacts the different economical actors.

On the one hand, the downside is that this is only a program, and it does not provide an assessment method. It also tackles only the overall view of the economy and does not evaluate a project in particular. On the other hand, it is the only analysed framework which tackles the questions of employment, goes in depth into local businesses and how to tackle circular economy in the industries, and also does not neglect the importance of materials and resources.

Figure 3.6: Synthesis of the analysis of the PREC [7]

3.5 BREEAM Communities

BREEAM is a sustainability assessment method for buildings and was created by BRE Group. It was first created in the 1990s and was the world's first environmental assessment method. Over the years, it has been updated and a adapted to other development types, designs and life cycle stages. It is now used in over 50 countries. It uses a balanced scorecard approach with tradeable credits to help the market to achieve its own environmental performance objectives. In BREEAM Communities, the environmental assessment method is broadened to take a more holistic approach to sustainability, giving greater attention to the social and economic impacts of development. BREEAM Communities constitutes a framework that helps planners, local authorities, developers, and investors integrate and evaluate sustainable design in the masterplanning of new communities and regeneration projects [15].

BREEAM has been developed to adhere to the following core principles [15]:

1. Guarantee quality through an accessible, holistic, and balanced measure of sustainability impacts.
2. Utilise quantified metrics for assessing sustainability.
3. Implement a flexible approach, refraining from prescriptive specifications and design solutions.
4. Base the quantification and calibration of cost-effective performance standards on the best available science and practices to define sustainability.
5. Pursue economic, social, and environmental benefits jointly and simultaneously.
6. Provide a common assessment framework tailored to local contexts, including regulations, climate, and sector specifics.
7. Ensure construction professionals are active participant in both the development and operations phases to broader knowledge sharing and inclusivity.
8. Endorse third-party certification to ensure independence, credibility, and consistency of the label.
9. Use existing industry tools, practices, and standards when possible to support policy and technology developments, build on existing skills and understanding, and minimise costs.
10. Employ stakeholder consultation to inform ongoing development in line with the core principles and the evolving standards for performance, accounting for policy, regulation, and market capability.

The methodology of BREEAM communities follows 3 steps: (1) establishing the principles, (2) determining the layout, (3) designing the details. The issues are grouped into five assessment categories and each issue is thoroughly considered via appropriate criteria. Sustainability issues often impact the three pillars of sustainability (economic, environmental, and social). The categories of BREEAM aim to explain more clearly the intentions of each issue. The

6 categories and their definitions are visible in the first part of the synthesis (fig.3.7). The categories are: (1) Governance (GO); Social and economic well-being (SE); Resources and Energy (RE); Land use and Ecology (LE); Transport and movement (TM); Innovation (Inn) [15].

A BREEAM rating is made via the BREEAM Communities tool and is determined by the assessor. The assessor must determine the number of credits to award to each assessment aligned with the criteria. The credits achieved in each assessment issue are multiplied by the corresponding individual credit weighting leading to a weighted score for each issue. The weighted scores are summed to determine the category score and extra percentages can be added to relevant categories to incentivise innovating methods. The weighting system was developed to determine the impact of each category on the 3 pillars of sustainability.

The synthesis (fig.3.7-3.8) shows the working principle of the tool. In the 3 steps, the criteria of the 6 categories are broken down and explained. Their respective credits are shown. When analysing the colours of the synthesis, it is discernible that the categories of factors that are the most presents in the criteria are nature, mobility, governance, social, energy, water. There are some aspects for economy and land use, but these are less prominent than the other categories. Like LEED-ND (see section 3.6), a lot of the criteria focus on the well-being of the citizens in an urban context. The category of mobility and governance are in almost all the tools and therefore demonstrates its important in an urban-scaled tool.

CATEGORY

GOVERNANCE (GO)
Encourages community participation in decisions regarding the design, construction, operation, and ongoing management of the development. (9,3%)
Total criterion : 14

SOCIAL & ECONOMIC WELLBEING (SE)
To foster a robust economy with ample employment opportunities and flourishing businesses (14,8%). To build a socially cohesive community (17,1%). To reduce the environmental impacts on the health and well-being of occupant (10,8%)
Total criterion : 17

RESOURCES & ENERGY (RE)
Focuses on the sustainable utilisation of natural resources and the reduction of carbon emissions (21,6%) Total criterion : 7

LAND USE & ECOLOGY (LE)
Supports sustainable land use practices and ecological improvements. (12,6%)
Total criterion : 6

TRANSPORT & MOVEMENT (TM)
Focuses on designing and providing transport and movement infrastructure that promotes the use of sustainable transportation options. (13,8%). Total criterion : 6

INNOVATION (INN)
Recognises and encourages the adoption of innovative solutions that deliver environmental, social, or economic benefits, particularly those not acknowledged elsewhere in the rating system.

STEP	CRITERION	GOALS	CREDITS
STEP 1 Establishing the principles	GO.01 – CONSULTATION PLAN	GO.01 – To ensure the needs, ideas and knowledge of the community are used to enhance stakeholder engagement throughout the design, planning and construction phases.	1
	SE.01 – ECONOMIC IMPACT	SE.01 – To boost economic well-being by attracting investment, creating jobs, and supporting and improving existing economic activities in the local and surrounding areas.	2
	SE.02 – DEMOGRAPHIC NEEDS & PRIORITIES	SE.02 – To ensure that development plans for housing, services, facilities, and amenities are aligned with local demographic trends and priorities.	1
	SE.03 – FLOOD RISKS ASSESSMENT	SE.03 – To ensure that the development is aware of the flood risk in the development and implement appropriate measures to minimise flooding risks for both the development and surrounding areas.	2
	SE.04 – NOISE POLLUTION	SE.04 – To ensure that the development is designed to mitigate noise impacts, including addressing noise from existing sources, preventing potential noise conflicts among future occupants, and shielding nearby noise-sensitive areas from development-related noise.	3
	RE.01 – ENERGY STRATEGY	RE.01 – To recognise and promote initiatives aimed at reducing operational energy demand, lowering consumption, and cutting carbon dioxide emissions.	11
	RE.02 – EXISTING BUILDINGS & INFRA	RE.02 – To consider the embodied carbon in existing buildings and infrastructure and to support their re-use where feasible.	2
	RE.03 – WATER STRATEGY	RE.03 – To design developments that minimise water demand through efficient practices and suitable supply options, taking into account current and predicted future water availability.	1
	LE.01 – ECOLOGY STRATEGY	LE.01 – To safeguard existing natural habitats whenever possible, and if not feasible, to minimize and mitigate impacts while enhancing biodiversity on the site and in the surrounding area	1
	LE.02 – LAND USE	LE.02 – To promote the (re)development of previously developed or contaminated land over pristine, undeveloped land.	3
	TM.01 – TRANSPORT ASSESSMENT	TM.01 – To implement transport and movement strategies that lessen the impact on existing infrastructure and enhance both environmental and social sustainability in transportation.	2

Figure 3.7: Synthesis of the analysis of the BREEAM Communities tool - part 1 of 2 [15]

STEP	CRITERION	GOALS	CREDITS
STEP 2 Determining the layout	GO.02 – CONSULTATION & ENGAGEMENT GO.03 – DESIGN REVIEW	GO.02 - To incorporate the needs, ideas, and knowledge of the community and key stakeholders to enhance the quality and acceptance of the development throughout the design process	2
		GO.03 - To have the masterplan reviewed by the community and other key stakeholders, ensuring it supports a vibrant, healthy, functional, and inclusive development.	2
	SE.05 – HOUSING PROVISION SE.06 – DELIVERY OF SERVICES, FACILITIES & AMENITIES SE.07 – PUBLIC REALM	SE.05 - To address and minimise social inequalities and promote inclusivity by providing appropriate housing within the development.	2
		SE.06 - To ensure that essential facilities are available and located within a reasonable and safe walking distance.	7
		SE.07 - To foster social interaction by designing inviting and dynamic public spaces.	2
	SE.08 – MICROCLIMATE SE.09 – UTILITIES	SE.08 - To create a comfortable outdoor environment..	3
		SE.09 - To provide easy access to site services and communication infrastructure with minimal disruption, allowing for future service expansion	3
	SE.10 – ADAPTING TO CLIMATE CHANGE	SE.10 – To ensure the development is resilient to both current and anticipated climate change impacts..	3
	SE.11 – GREEN INFRASTRUCTURE	SE.11 – To guarantee access to high-quality natural and urban	4
	SE.12 – LOCAL PARKING	SE.12 – To design parking solutions that are appropriate for users & well integrated into the development.	1
	SE.13 – FLOOD RISK MANAGEMENT	SE.13 – To minimise, delay and manage rainfall discharge to public sewers and watercourses, reducing the risk of localised flooding, water pollution, and other environmental damage.	3
	LE.03 – WATER POLLUTION	LE.03 – To guarantee measures that protect local watercourses from pollution and other environmental damage.. .	3
	LE.04 – ENHANCEMENT OF ECOLOGICAL VALUE LE.05 – LANDSCAPE	LE.04 – To maximise the ecological value of the development through enhancement effort.	3
		LE.05 – To respect and, where possible, enhance the character of the landscape by designing features that complement the local environment.	5
	TM.02 – SAFE AND APPEALING STREETS	TM.02 – To create safe and inviting spaces that foster human interaction and a positive sense of place.	4
	TM.03 – CYCLING NETWORK TM.04 – ACCESS TO PUBLIC TRANSPORT	TM.03 – To encourage cycling both as leisure activity and alternative to driving motorised vehicle by providing efficient cycle network and sufficiently safe. .	1
		TM.04 – To ensure frequent and convenient public transport connections to major transit nodes like trains, bus or trams, and local centers.	4
STEP 3 Determining the details	GO.04 – COMMUNITY MANAGEMENT OF FACILITIES	GO.01 – To support communities in actively participating in the development, management, and ownership of the selected facilities.	3
	SE.14 – LOCAL VERNACULAR	SE.14 – To ensure that the development reflects local character while also establishing its own distinct identity.	2
	SE.15 – INCLUSIVE DESIGN SE.16 – LIGHT POLLUTION SE.17 – TRAINING AND SKILLS	SE.15 - To foster an inclusive community by enhancing accessibility for current and future residents.	3
		SE.16 - To minimise light pollution by designing adequate site lighting.	3
		SE.17 - To contribute to the local area by improving skills and training.	3
	RE.04 – SUSTAINABLE BUILDINGS RE.05 – LOW IMPACT MATERIALS	RE.04 – To enhance sustainability of all buildings within the development.	6
		RE.05 – To reduce the environmental impact of construction by using low-impact materials for public spaces design.	6
	RE.06 – RESOURCE EFFICIENCY	RE.06 – To promote resource efficiency by minimising waste during construction phase and throughout the development's lifecycle.	4
	RE.07 – TRANSPORT CARBON EMISSIONS	RE.07 – To decrease car-related pollution emission by providing a viable alternatives to car ownership.	1
	LE.06 – RAINWATER HARVESTING	LE.06 – To effectively manage surface water runoff to minimise water demand.	3
	TM.05 – CYCLING FACILITIES TM.06 – PUBLIC TRANSPORT FACILITIES	TM.05 – To invest in adequate cyclist's facilities to promote soft mobility.	2
		TM.06 - To encourage regular use of public transport year-round by providing safe and comfortable transport facilities.	2

Figure 3.8: Synthesis of the analysis of the BREEAM Communities tool - part 2 of 2 [15]

3.6 LEED for Neighbourhood Development (LEED-ND)

LEED is an acronym for Leadership in Energy and Environmental Design. The LEED Reference Guide for Neighbourhood Development was created by the U.S. Green Building Council (USGBC) [3]. With the recognition of numerous problems of climate change, economic stagnation, food crisis and more because of rapid urbanisation, LEED buildings demonstrates that there are benefits of green design approach to reduce environmental impact and to restore natural systems. Neighbourhoods are essential elements of urban change and innovation. Because of the rapid urbanisation, community planning processes which are ideal for green intervention and transformation are necessary. The LEED-ND is a tool to make exemplary sustainable neighbourhood [3].

LEED is a voluntary, market driven, consensus-based tool that is both a guide and an assessment tool. It is a framework for identifying, implementing, and measuring green building and neighbourhood design, construction, operations, and maintenance. This tool can be used for all types of buildings and for neighbourhood developments. LEED aims to optimise the use of natural resources, promote regenerative and restorative methods, maximise the positive and minimise the negative environmental and human health impacts generated by the construction industry, and create comfortable indoor environments for building inhabitants. LEED sets standards for green building going from the interiors to the scale of entire neighbourhoods [3].

LEED's Goals are the following:

- To mitigate contributions to global climate change.
- To improve individual health and overall well-being.
- To safeguard and rejuvenate water resources.
- To protect, enhance, and restore biodiversity and ecosystem services.
- To promote sustainable and regenerative material resource cycles.
- To develop a greener economy.
- To advance social equity, environmental justice, community health, and quality of life.

These goals are the bases for the LEED's prerequisites and credits which are categorised in the LEED-ND rating system as Smart Location and Linkage (SLL), Neighbourhood Pattern and Design (NPD), and Green Infrastructure and Buildings (GIB). Each credit is allocated points based on the importance of its contribution to the goals. The result is a weighted average, and the most important credits are given the greatest weights. Certification is possible with this tool and has 4 levels: certified, silver, gold, platinum [3].

The synthesis of the tool (fig.3.9) shows the 3 categories of prerequisites and credits. With the colouring system, it can be observed that the SLL category is more related to environment, land use, ecology and water. The idea of conservation, preservation, minimisation of negative impact is supported. The second category NPD is more related to the well-being of the inhabitants in the neighbourhood, education and social factors. The GIB category focuses more on energy, energy performance of buildings, and material and resources. Once the analysis of this tool was made, it was discernible that the biggest strength of this tool was the abundance of urban design factors coupled with sufficient definitions and methods of calculations. It was the tool which insisted the most on the urban scale of projects and its implications. Evidently, being a sustainability assessment tool, an entire category was dedicated to environmental factors. Moreover, there were strategies on how to implement a sustainable project, which locations should be preferred and more.

The tool was equipped with a reference guide to explain the tool and any preliminary calculations of surfaces which would be useful to prepare the terrain for the calculations of the prerequisites and credits. The tool also contained a manual explaining each prerequisite and credit. The explanations are clear and accessible, and each cheat sheet presented a definition, its points, and an in-depth method of calculation. Because a lot of the urban design factors can be relevant in the case of an urban circularity tool, this makes it a very valuable framework. The tool also contained an Excel file, which regrouped all the prerequisites and credits and their weighing point, to help determine the certification grade of the project. It is interesting to observe the employment of the principle of "prerequisites" rendering the tool to be stricter. Because the category of NPD possesses various factors related to the well-being, education and social aspects, this constitutes a good basis for a potential social category of factors in an urban circularity tool, given that social factors are hard to calculate. Another asset of this tool is that similarly to the City Resilience Index (see section 3.7), a mix was made between qualitative and quantitative assessment methods depending on the factor.

A negative aspect of this tool in our opinions is that it lacks design factors related to materials and resources. There are only 5 credits out of the 51 prerequisites and credits which are related to materials and resources and none of them are prerequisites. It is overall a critique which can be made for all the sustainability assessment tools of this analysis. In a nutshell, this framework is a very good tool to assess the sustainability at the neighbourhood scale and would constitute as a good base for an urban circularity tool despite the lack of factors related to materials and resources that is according to use one of the fundamentals of urban circularity.

Figure 3.9: Synthesis of the analysis of the LEED-ND tool [36]

3.7 City Resilience Index (CRI)

The City Resilience Index (CRI) was developed by Arup. It was designed to enable cities to measure and monitor the multiple factors that contribute to their resilience. The Index's main objective is to identify strengths and weaknesses and track relative performance over time. This means it will not provide a comparison between cities, nor a ranking of the most resilient cities in the world. Nevertheless, it will provide a common basis of measurement to facilitate dialogue and knowledge-sharing between cities. The CRI is intended to be used by city governments who are the most competent to gather data, but it can be used by organisations and individuals. One of the tool's intentions is to provide the means for cities to capture the perspectives of the more vulnerable groups as they tend to suffer more from the impacts of disruptions and failures [30].

Its structure revolves around 4 dimensions, 12 goals, and 52 indicators which are fundamental for the resilience of cities. The 4 dimensions are Health and Well-being, Economy and Society, Infrastructure and Environment, Leadership and Strategy. The Index exists as an online platform, permitting cities to access all around the world. The 12 goals reinforce these dimensions and to achieve resilience, every city should strive towards these targets. These targets are what matters most universally when a city is tackling a range of chronic problems or a sudden catastrophe, based on their research. However, their relative importance depends on each city. The 52 indicators add further precision to the goals and identify the critical factors which contribute to the resilience of urban systems. The indicators integrate the seven qualities of resilient systems which are: (1) reflective, (2) flexible, (3) integrated, (4) robust, (5) resourceful, (6) inclusive, (7) redundant [30].

The CRI tool allows cities to gauge their current performance, identify suitable actions to enhance resilience and monitor their progress. To do so, the 52 indicators are assessed quantitatively and qualitatively. Each indicator possesses an average of 3 prompt questions per assessment. The quantitative assessment is based on proxy measurements which indicates how the city is currently performing. It permits it to set up a baseline and identify the aspects that need strengthening. The qualitative assessment permits to project future performance. Both are scored between 1 to 5 varying from the worst possible scenario to the best one. The combination of these two will allow cities to gain a deeper understanding of the systems, processes and functions that define a city's resilience profile [30].

After analysing this tool, it can be inferred that its biggest assets are its clarity and accessibility of use. Its methodology is easy and very understandable. The structure of the tool accounts for this clarity as the division into dimensions, goals, indicators and questions is quite straightforward. Their representation in a circle diagram shows that a good visual representation in a such complex tool is essential. As a matter of fact, all of these are points that should be taken into account in the making of a urban circularity tool. On the downside, the tool could be criticised in terms of substance as the City Resilience Index encompasses the idea of circularity within the framework, but their framework is about Resilient City which is an even larger domain of expertise than circularity or circular economy. Furthermore, even if the tool's organisation exhibits clarity, there are a lot of questions and indicators. Even if it is exhaustive, one could argue that it would be too exhaustive for an early-design phase tool.

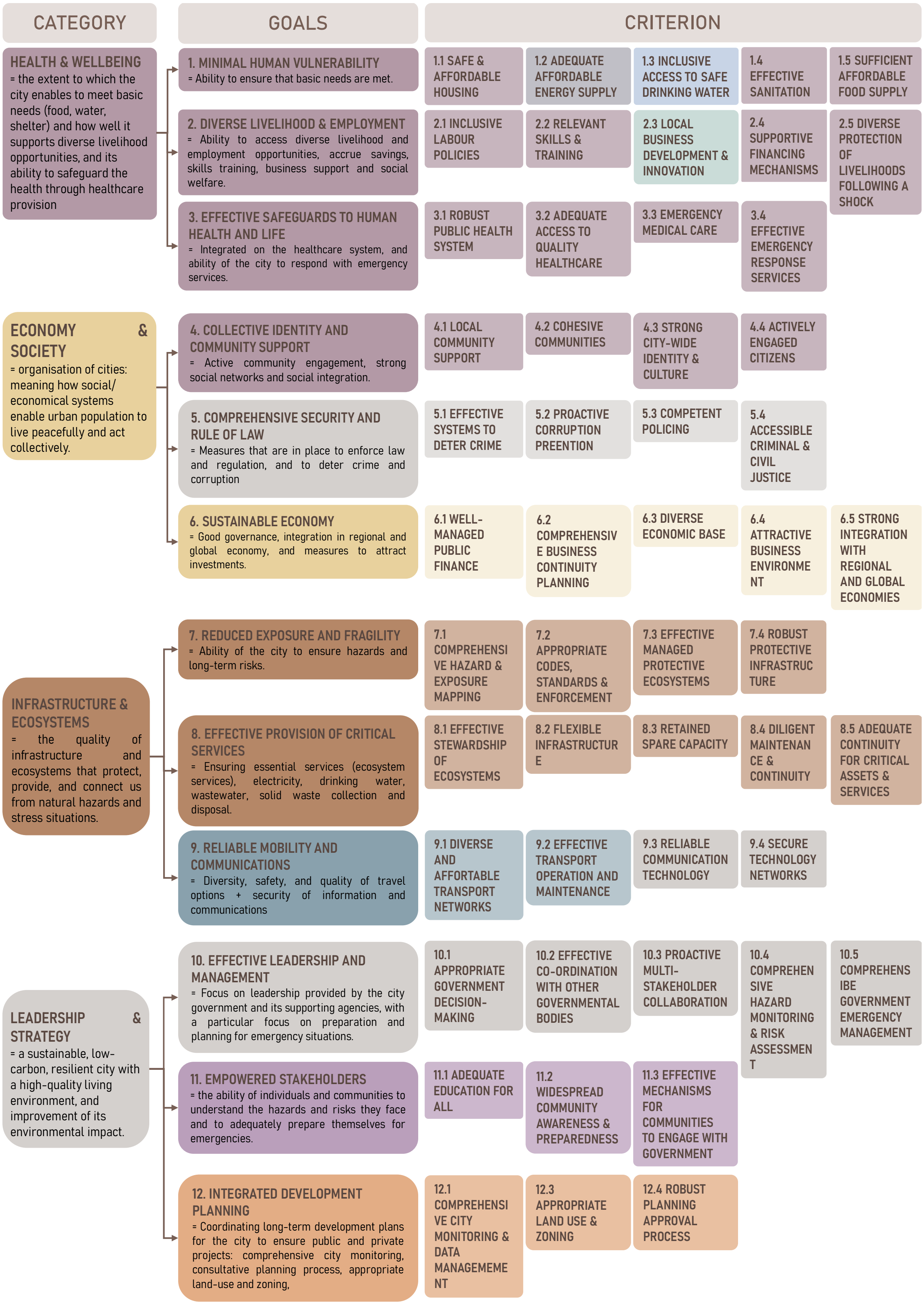

Figure 3.10: Synthesis of the analysis of the City Resilience Index Framework [30]

3.8 Urban Circularity Assessment Framework (UCAF)

The Urban Circularity Assessment Framework is a tool created to support the planning, monitoring, evaluation, and learning on circular economy at a city's scale. The framework goes further than materials and energy flows, waste and wastewater industries, and recycling and recovering strategies towards other sectors, R-strategies, incorporation of environmental impacts, and socio-economic assessment. The tool functions on the Theory of Change (ToC) which explains how changes are expected to occur or how they have occurred. It is a method widely used in the development sector and allows decision-makers to anticipate better, and to monitor and evaluate different interventions. ToCs are non-linear by showing different pathways that lead to the consequence, and naturally explain why a certain action will cause the impact. The tool therefore uses the ToC methodology to monitor the impacts of CE and links it to a wider sustainability agenda. It can be used for planning, monitoring, evaluation, and learning [10].

The framework is visible in fig.3.11. Each of the components are interconnected meaning that the diagram can be read from left to right, vice versa or even from the middle, making it very flexible. Each of the components are influenced by their neighbouring components. To evaluate the city's level of circular economy, the framework assesses the main components of:

1. Urban Circular Economy Vision
2. Governance and participation
3. Circular Economy strategies (R-strategies)
4. Urban Stock and Flows
5. The Triple Bottom Line [10]

Each component is shown in the synthesis (fig.3.11) and for each of these components, there are a set of guiding questions. Therefore, it is a qualitative assessment method.

Concerning the components of the tool, it can be observed that the Triple Bottom Line component concerns the 3 Ps of Sustainability, which is also used in the tool GRO (3.3). In both tools the 3 pillars of sustainability are entirely integrated into the tool but both approaches turn towards circular aspects. It seems fundamental for these tools to interweave this concept into a circular framework.

After analysis, it was concluded that this tool is a good qualitative framework to assess urban circularity. The questions are relevant to determine the circularity level of a project. One of its advantages is that it can be used in any phases of the project and from any starting point of the framework. This shows the tool is quite flexible and holistic and the tool demonstrates how the different components are linked together and how they are influenced by each other. The questions are well thought out and pushes to reflect on the decisions made in a project. Nevertheless, at a first glance, this framework seems confusing and a lot less accessible than the other tools. Moreover, the questions and the overall framework do not provide a grading system or active answers which permit to assess if the project is circular or not and at what point it is.

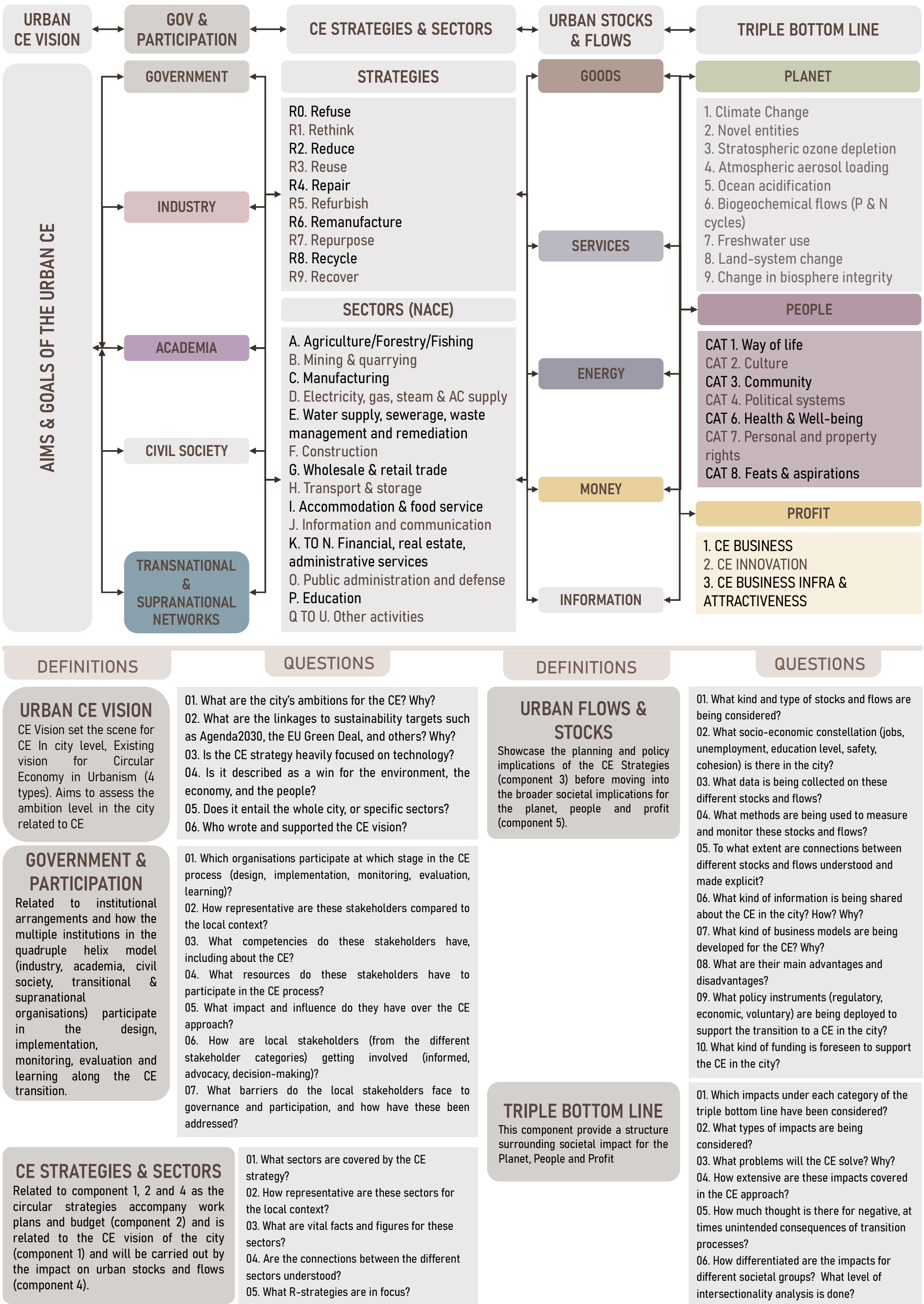

Figure 3.11: Synthesis of the analysis of the Urban Circularity Assessment Framework [10]

3.9 Ademe

Ademe is a tool designed to assess the circular economy of a project or a region. It is destined for urban development plans, urban projects, and urban planning documentations. It is adapted to all types of territories, and also collective projects. It was created for decision-makers and actors of urbanism to steer their projects towards and in the challenges of circular economy. The guide contains methodological recommendations and tools to initiate and facilitate a circular economy approach as well as 9 case studies. The recommendations are based on the 7 pillars of circular economy as well as the trio of their integration into urban planning which are flows, uses, and new economies (see fig.3.12) [33].

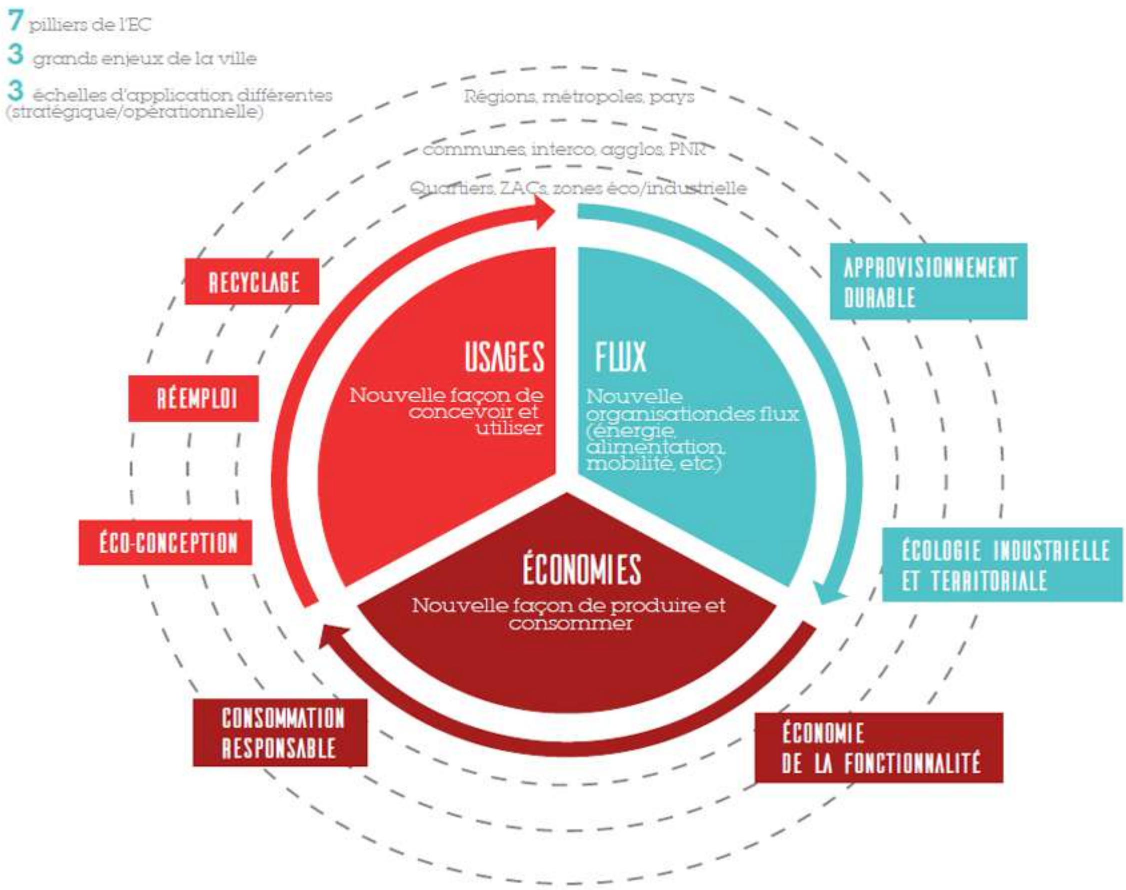

Figure 3.12: The 7 pillars of circular economy and the trio flows/uses/new economies [37]

Ademe is a purely qualitative tool and proposes a set of axes of intervention and qualitative objectives. The toolbox contains a guide explaining all the qualitative objectives, annexes containing the feedback of the 9 case studies, Excel files for the assessment of the project, a helping guide for the determination of the Terms of References, and an informative Power-Point presentation for educational purposes. The 5 axes of interventions are presented in the synthesis (see fig.3.14). In the framework, there are 4 preliminary steps before establishing the assessment of the project which consist in first defining the strategic and operational perimeters of action, then connecting the different actors of a project, followed by considering the 5 phases of the life cycle of the project (design phase, construction phase, life phase, second life phase, end of life), and finally considering the uses/flows/economies (see fig.3.13). The Excel files are a diagnostic tool that can then be used to fix ambition in terms of circular economy and help make evolve the project. The assessment should be made in the beginning of the reflections, during the reflections with all the involved actors, and after the reflections when the road map created for the project has been made. The 3 phases are represented in a spider web diagram to analyse the progression of the reflection [33].

Once the analysis of this tool was made, it could be concluded that the tool's strength was its integration of the circular economy principles at the scale of an urban project. Another asset it has is the fact that the assessment can be made at every phase of the project. This permits to follow the project on the long term. However, the tool was tailored to the French administrative systems which makes it less accessible for other countries to use it. Furthermore, there were 3 Excel files which were hard to decipher and not easy of use. Overall, the theory of the tool was very accessible as opposed to the practical side of the assessment which is very hard to navigate in.

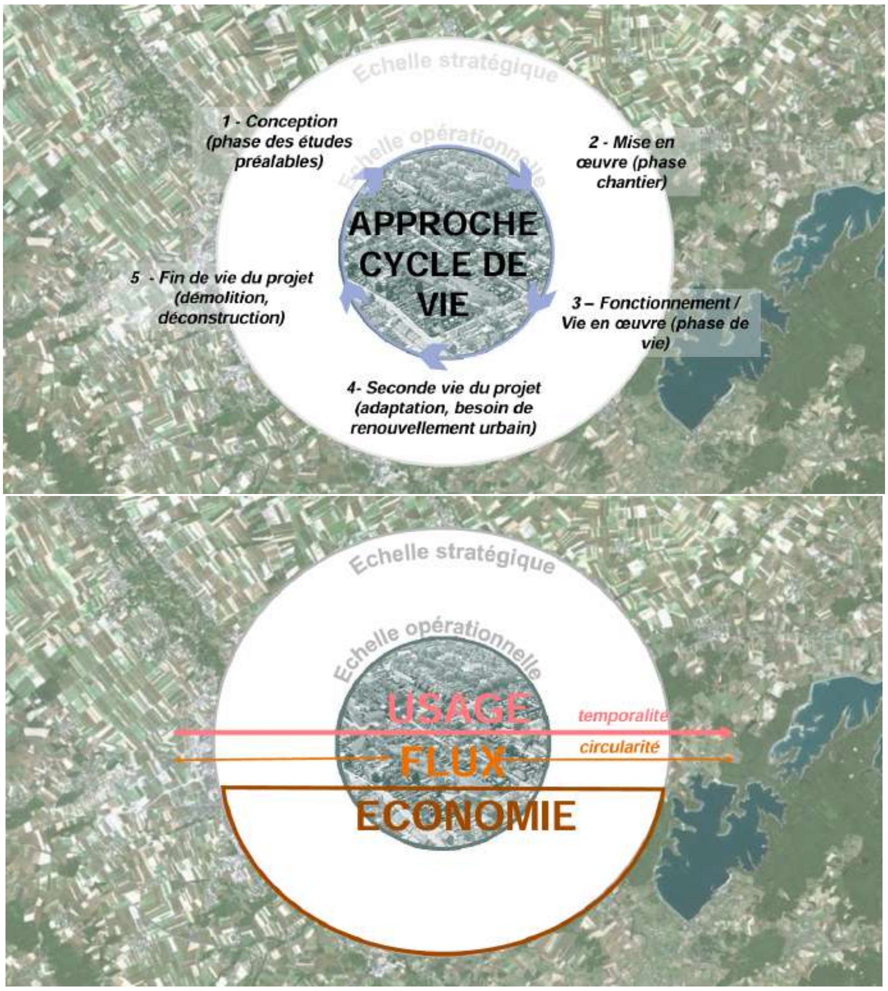

Figure 3.13: Scheme representing the 4 preliminary steps [37]

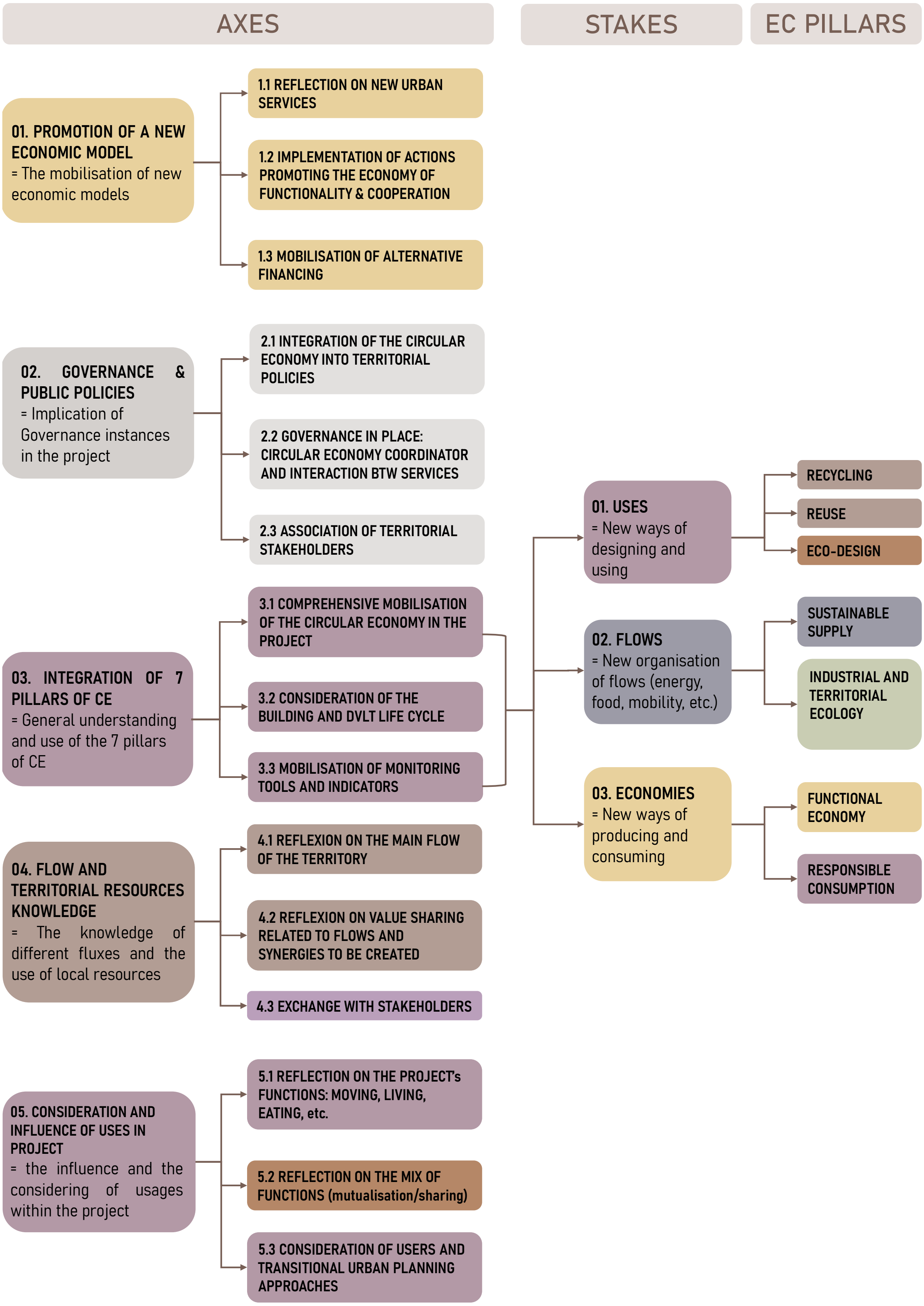

Figure 3.14: Synthesis of the analysis of the Ademe tool [37]

3.10 Circular Urban Scan (CUS) - Metabolic's tool

The Circular Urban Scan (CUS) is a tool developed by Metabolic as a holistic benchmarking tool which evaluates and monitors the sustainability of cities. The tool acts essentially as a scanner with a goal to accelerate the transition and is based on systems thinking by scanning material, energy, water, biodiversity, culture, well-being and economic value. Systems thinking is the approach at the heart of the Circular Urban Scan [1]. Instead of looking at individual aspects of a problem separately, systems approach studies how the different parts of the system are interacting. It is an effective approach when being faced with complex interdependent challenges. Metabolic tackles the question of sustainability in an integrated way, because finding solutions require deep understanding of the system and acknowledgement that challenges like human health, climate change, biodiversity loss and economic stagnation are inextricably linked [38].

For the cases of cities, where many complex aspects interact dynamically and impacting each other and the entire system, the systems thinking approach can help understand the various interdependences and answer simultaneously a plethora of challenges with sustainability integrated solutions. The Circular Urban Scan implements a fundamental system thinking model to the urban environment which consists of 7 pillars: materials, energy, water, biodiversity, society and culture, health and well-being, and value. Each pillar uses two metrics designed to be accessible to every city and using open-source data. Each metric is valued between 0 and 10 [1]. Each pillar and metric is defined in the synthesis (see fig.3.15 and fig.3.16).

The analysis of this tool shows that the different pillars of sustainability concur with the categories of most of the tools analysed. This reinforces the idea that to assess circularity at an urban scale and in a circular economy context, it is necessary to assess the environmental aspects (water, biodiversity), the materials and resources aspects, the energetic aspects, the social aspects including the health and wellbeing, and the economical aspects as well. When comparing this tool with the Circular Building Design tool for example, which is more focused on buildings and objects, it is observed that urban circular vision is intrinsically intertwined with sustainability aspects.

In terms of the elaboration of the tool itself, it can be said that it is visually self-explanatory, easy to use and straightforward, with good supporting documentation. The scoring system from 1 to 10 is clear and visually engaging. It is purely quantitative and based on an open-source data methodology. The downside of this tool is that it only assess the circular state of a city at a given time, which means that the tool can not be used for design processes. This tool may lack a guide towards more circular practices, which makes it less educational than other tools. Furthermore, other tools like Be Sustainable's Toolbox (section 3.2) contained a lot of qualitative questions and very little quantitative methods. This tool lies at the opposite end of the assessment spectrum and covers only the quantitative methods. To push the tool further, qualitative questions should have been developed to push further the reflection.

Another negative aspect is the interpretation of the results. As a matter of fact, a series of case studies were done in several cities around the world. 14 global cities that were scanned. The studied cities were Amsterdam, Singapore, Seoul, Toronto, Hong Kong, Paris, Rio de

Janeiro, Sydney, Johannesburg, Mexico City, Buenos Aires, Istanbul, Teheran and New York City. They were selected according to multiple criteria related to location, economics and size [1]. They were ranked according to the highest number. However, there is no interpretation of the results. It would have been interesting to compare results according to the different pillars to understand which city excelled in what pillar. The rating is only based on a number and there is no interpretation on whether or not that is good or bad nor what is.

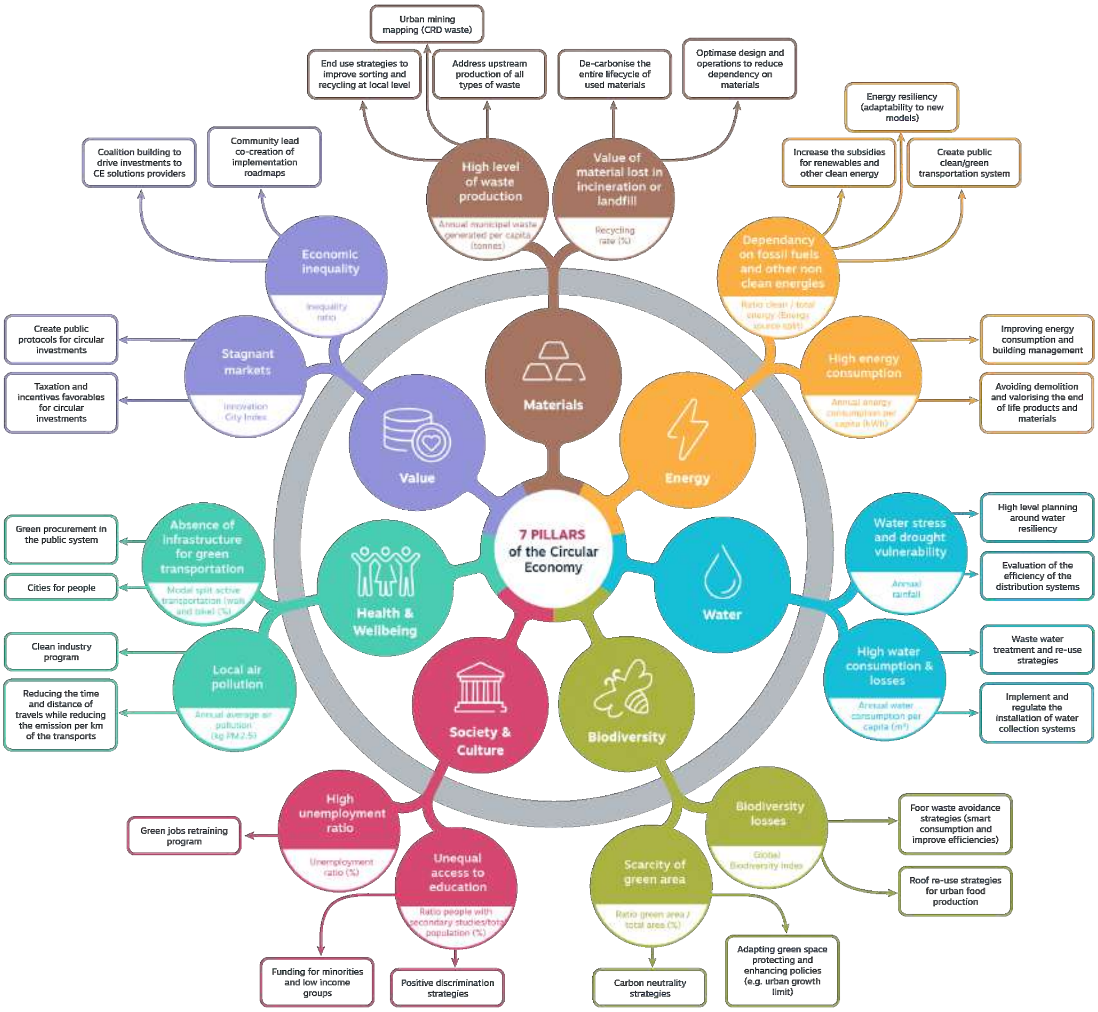

Figure 3.15: Scheme showing the 7 pillars of circular economy applied to a city scan [1]

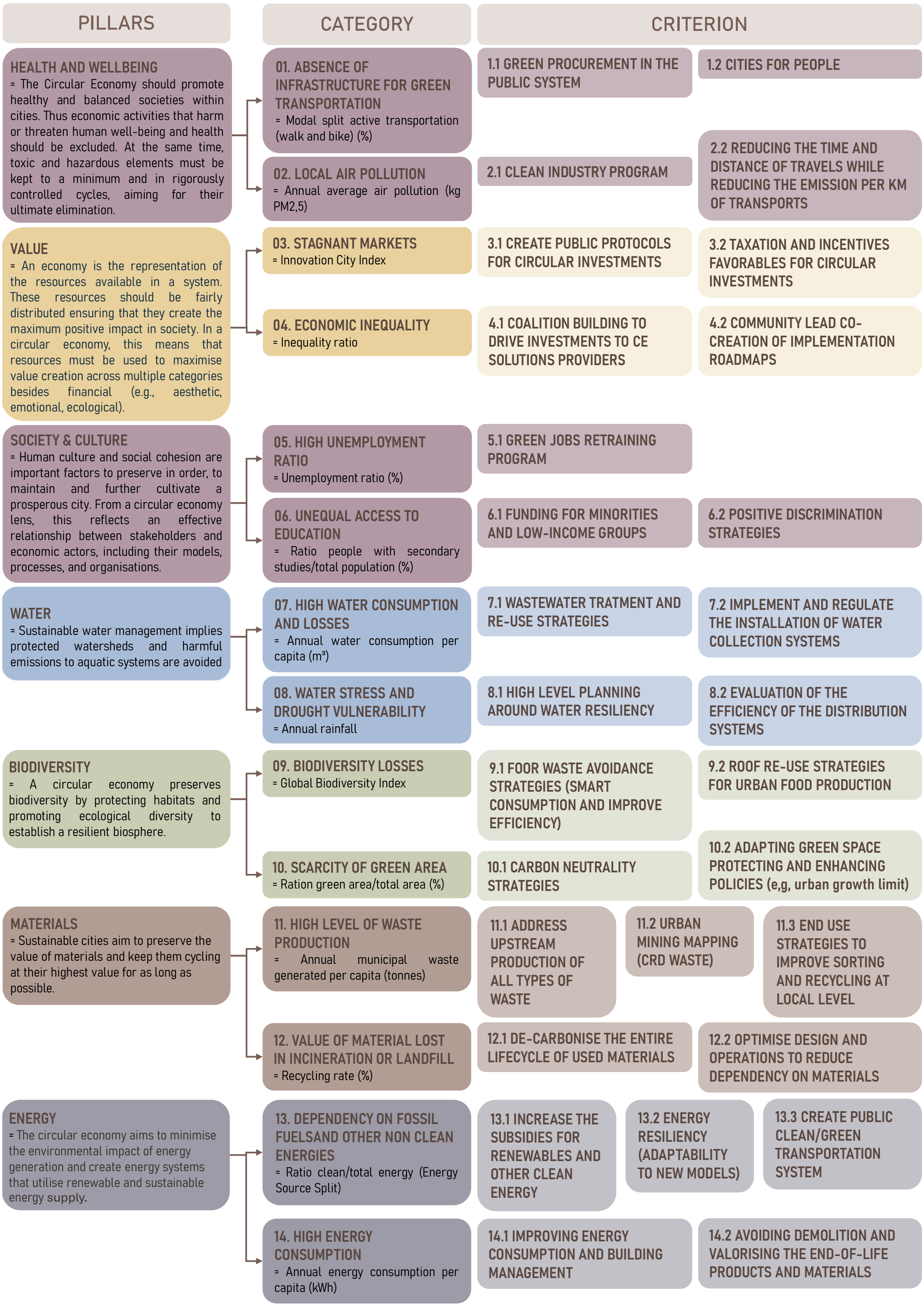

Figure 3.16: Synthesis of the analysis of the Circular Urban Scan (CUS) tool [1]

Chapter 4

BRU-C - An Urban Circularity Framework

This chapter presents the urban circularity framework which was elaborated during the research. The name of the framework is BRU-C, a framework adapted to the context of Brussels, and which assesses circularity in urban-scaled projects. This tool was designed to be employed in early-design phases to compare different urban design solutions that would lead to more circularity. This tool is destined for urban designers, architects and public entities working on urban development projects. The toolbox contains a brochure for a quick assessment and instructive purposes and an Excel file for the in-depth assessment. This chapter will start with the definition of urban circularity that will guide the entire approach of the tool. Followed is the definition of the 4 goals of the framework. Then a presentation of the final product is done to provide a global view of the tool. The tool is then deconstructed and each axis of intervention, design factor and criterion will be defined. An explanation of the evolution of the framework will also be developed to explain how the preliminary tool was obtained and how it matured to the final toolbox. Finally, the toolbox will be presented and more precisely, the operating instructions for the Excel file.

4.1 Definition of urban circularity

In the interest of elaborating a definition of urban circularity that will be the drive of the whole tool, we decided to highlight the different definitions, concepts and principles that would support the concept of urban circularity (see fig.4.1). The definition of urban circularity elaborated by A.Z. Khan and G.C. Verga serves as a solid ground, but the synthesis permits us to realise what we want to put forth in the tool and in general in the field of circularity. These are broken down to elaborate the final definition used in this framework.

As a reminder, according to A.Z. Khan and G.C. Verga, urban circularity is an approach that seeks to foster more resource-efficient, resilient, and equitable behaviours and practices. It implies minimising the overall net inputs (resources) and outputs (waste) of urban areas—including extraction, manufacturing, disposal processes, logistics, transportation, and supporting infrastructure—while maximising the value of existing local material stocks. It also encourages considering more-than-human perspectives, moving beyond utilitarian narratives that separate cities from natural ecosystems, and recognising the interconnectedness of all ecosystem participants [11]. This definition also underlines the principle of frugality which relates to being less wasteful and less consuming all the while being attentive to social economic and environmental factors. Here, there is a clear demonstration of the intertwining of sustainability and circularity principles. Sustainability is defined as the balanced integration of economic performance, social inclusiveness, and environmental resilience, to the benefit of current and future generations [21]. We believe that the concepts of frugality, resilience, and just behaviours and practices are fundamental concepts in urban circularity.

Urban circularity draws its pathway in the circular economy, and circular economy is tight knitted with the concept of loops. Circular economy is considered as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops [21]. This concept of narrowing, slowing and closing loops is capital in all types of circularity [24]. At the urban scale, circular cites are cities which practices circular economy principles to close resource loops in collaboration with the city's stakeholders—including citizens, community members, businesses, and knowledge partners—to achieve its vision of a future-proof city [14]. The important aspect to remember here is the principle of loops and the participation of citizens (see fig.4.1).

When looking at circularity at the scale of a building and not a city, circular design is the first step to make possible circularity and create value. Flexible and future-proof buildings are the result. Various design strategies that enhance circularity in the built environment can be grouped into three main categories: design to reduce (optimising resource efficiency and minimising material use, further decreasing material flows, etc.), design for recyclability (adopting a circular design approach that supports deconstruction, disassembly, modularity, and material reuse), and design for longevity and flexibility (extending the lifespan of buildings) [26]. Here, the most essential elements are creating flexibility and time-proofness.

Keeping all these important concepts into account, and based on the definition of A.Z. Khan and G.C. Verga, the definition of urban circularity that we developed for the BRU-C framework is as followed:

Urban circularity is an emerging concept aiming for frugal, resilient, and just behaviours and practices in urban development. In urban circularity, a valorisation of local materials as resources, towards a system of narrowing, slowing, closing loops as an objective to reduce the overall net total of inputs and outputs, is shouldered by every actor of the ecosystem. Any new creation of value should harbour flexibility and future-proofness. This arising responsible consumption is attentive to social, economic and environmental factors.

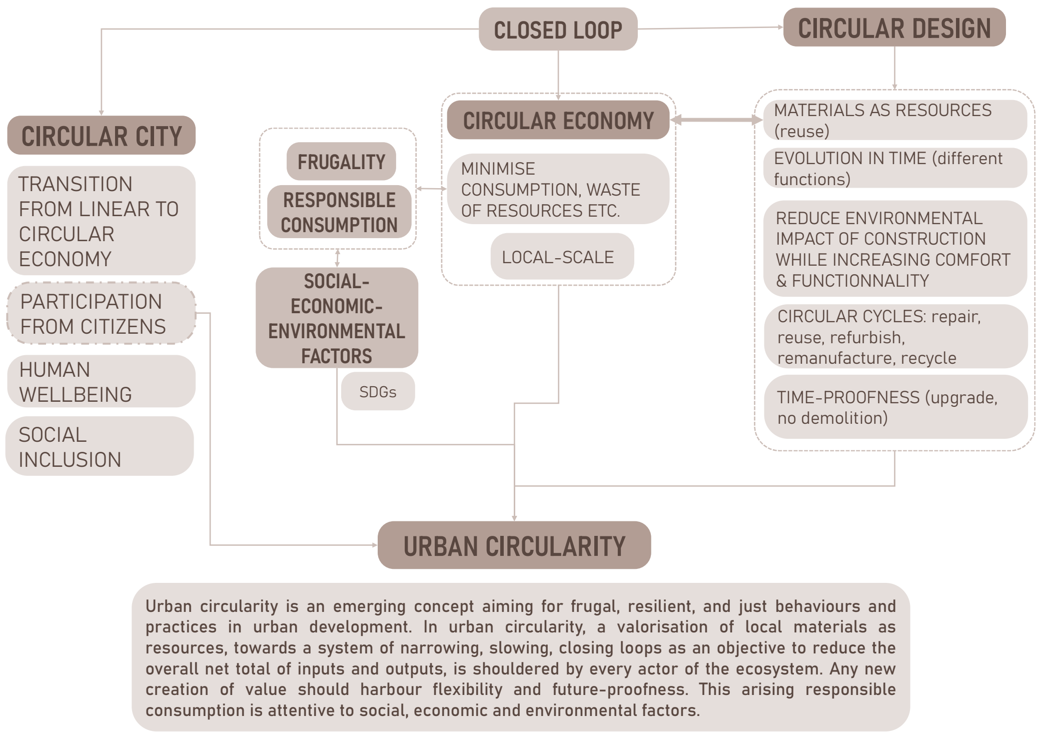

Figure 4.1: Overview of the important definitions related to urban circularity

4.2 Definition of the 4 goals

The BRU-C framework possesses 4 goals which are to assess the time-proofness, the material intensity, the environmental quality and the community involvement of each urban development project. The goals are defined as followed:

- **Time-proofness**: This implies that from the urban-scale to the material scale, the project must be resistant to the effects of time. With the objectives of minimising consumption, reducing waste of resources, the project should be able to evolve through time, to be flexible and adaptable to future uses. Upgrades should be prioritised over demolitions

- **Material intensity**: This corresponds to material flows and consumptions in a project. In the project, particular attention should be paid on the management of materials, towards more closed loops and circular practices, with responsible choices of materials in respect to circular cycles (repair, reuse, refurbish, remanufacture, recycle). Lower material intensity indicates a higher degree of circularity.

- **Environmental quality**: The effect of a project or action on the natural environment should be considered, considering ecological disruption and natural resources to reduce the overall environmental footprint.

- **Community Involvement**: The active participation of local residents in the process that shapes their community, integrating social aspects within projects to enhance circularity through participation, education and social well-being.

4.3 The elaborated framework

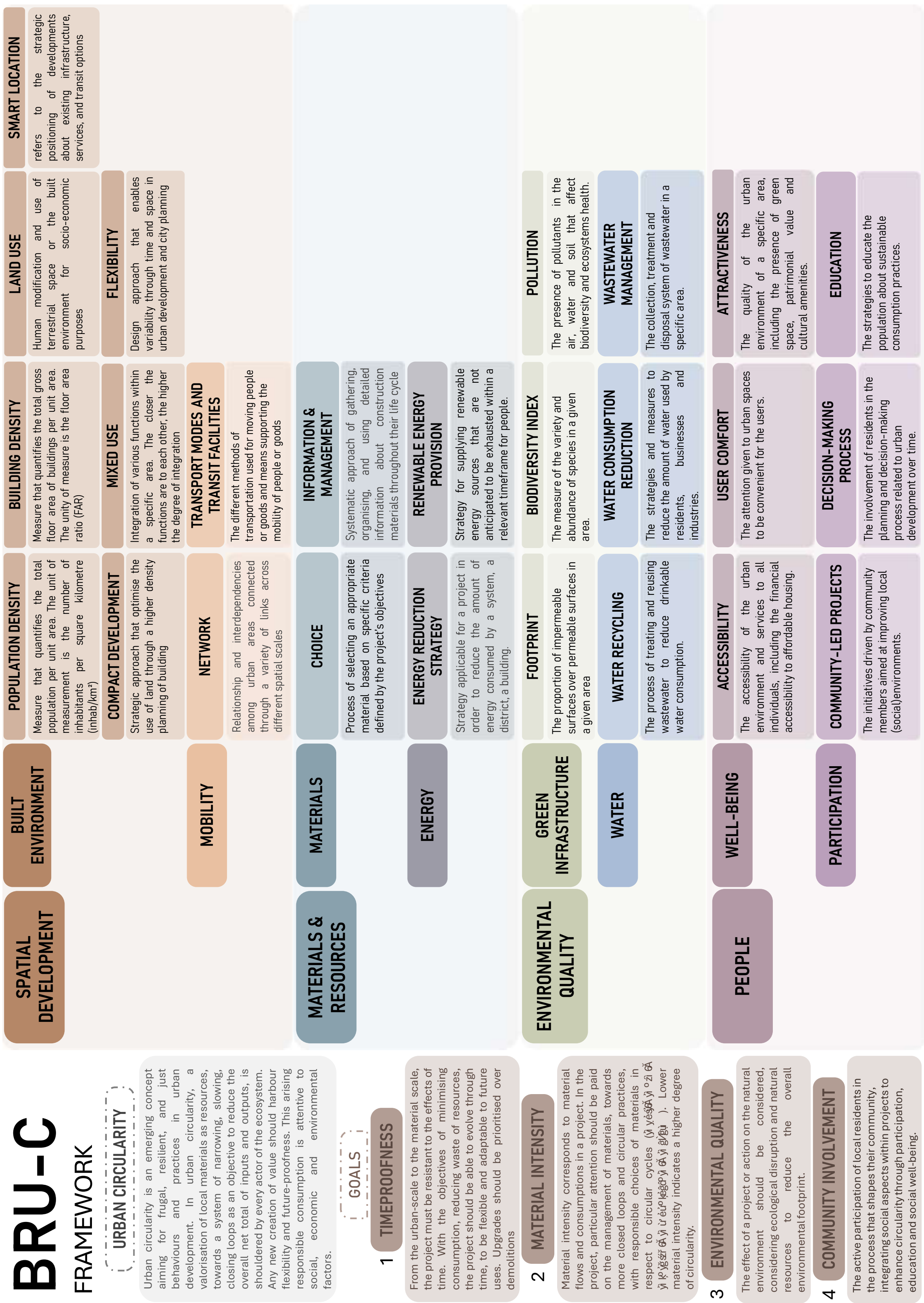

Figure 4.2: Final framework overview

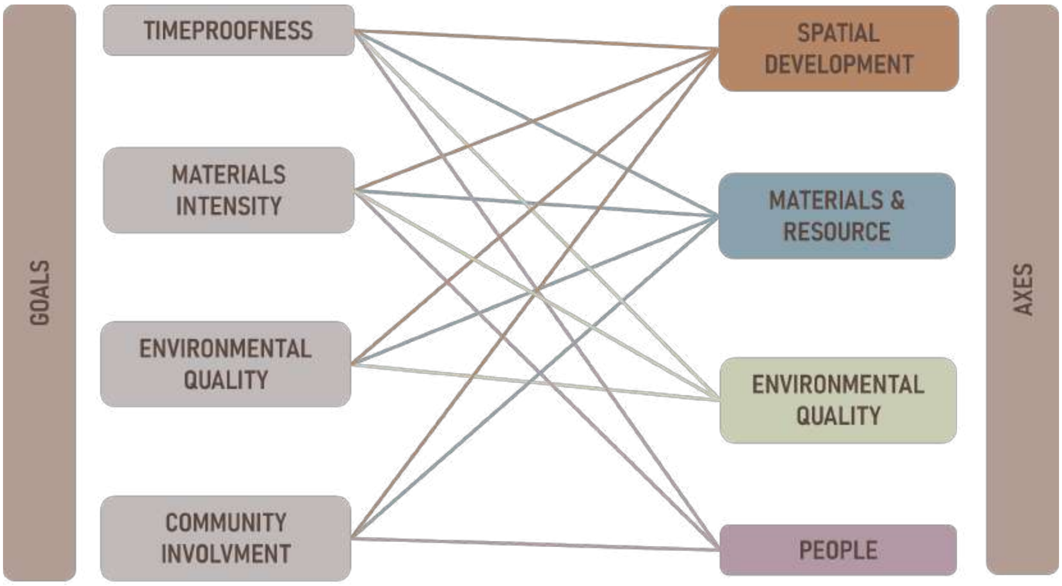

Figure 4.3: Correlations between the goals and the axes of the framework

		SPATIAL DEVELOPMENT		MATERIALS & RESOURCES		ENVIRONMENTAL QUALITY		PEOPLE	
		BUILT ENVIRONMENT	MOBILITY	MATERIALS	ENERGY	GREEN INFRASTEUC TURE	WATER	WELLBEING	PARTICIPATION
SPATIAL DEVELOPMENT	BUILT ENVIRONMENT		X			X	X	X	
	MOBILITY	X			X	X		X	
MATERIAL & RESOURCES	MATERIALS	X			X				X
	ENERGY	X	X	X		X	X	X	X
ENVIRONMENTAL QUALITY	GREEN INFRA.	X	X	X	X		X	X	X
	WATER	X			X			X	X
PEOPLE	WELLBEING	X	X		X	X	X		
	PARTICIPATION	X		X	X	X	X		

Figure 4.4: Correlations between the different criteria of the framework

4.3.1 The 4 axis of intervention

The framework developed in this master thesis aims to assess the level of circularity of neighbourhood-sized projects, and this section will introduce and explain its development and operation. It details how the four goals are addressed through four interconnected axes, each subdivided into design factors, with each design factor assessed according to specific design criteria. The four primary axes are spatial development, materials and resources, environmental quality and people. Each axis represents a critical dimension of the framework, collectively contributing to the urban circularity definition proposed (section 4.1).

The first axis, **Spatial Development**, encompasses spatial design and development strategies with a focus on urban data and values. It addresses the organisation and planning of physical spaces and urban settings.

The second axis, **Materials and Resources**, concerns the management of material flows, resource utilisation, and sustainability practices. This axis emphasises the importance of resource conservation, responsible consumption, and the implementation of strategies that foster sustainability throughout the life cycle of materials and energy.

The third axis, **Environmental Quality**, focuses on environmental quality and addresses pollution issues as well as the relationship between natural ecosystems and human activities. This axis is crucial for urban circularity as it ensures the consideration of the environment and natural resources within the circularity framework.

The fourth axis, **People**, focuses on the social dimensions of circularity, including the well-being and engagement of individuals within the urban environment. This axis recognises that the success of circularity in urban design depends on its impact on people and their overall well-being and quality of life. It is essential as it encompasses the human factors impacting the circular evolution of a neighbourhood and should not be neglected in an urban circular framework.

These four axes are subdivided into a series of design factors, which act as specific areas of intervention within the framework. These design factors function as specialised disciplines that address various aspects of the axes, providing targeted strategies and methodologies for implementation. Within each design factor, criteria are established to assess interventions, which may include both qualitative and quantitative measures. These criteria will be evaluated using a 5-point scoring system, which will be detailed in section 4.3.2.1.

In summary, the proposed framework provides a comprehensive approach to addressing the four goals through its four axes. The interconnections between these axes and their respective design factors can be seen in fig.4.4. The subsequent section will delve into the detailed definitions of each design factor and their associated criteria, providing a thorough understanding of how these elements contribute to the framework's objectives. It is also important to note that, given the scope of this thesis and the limited timeframe for developing this framework, the focus was set on the Spatial Development and Materials and Resources axes due to their closer correlation with urban design practice. Future research might explore the other two axes further, as their influence on the final assessment could impact the evaluation of project development in different ways.

4.3.2 The design factors and how to calculate them

4.3.2.1 Global evaluation methodology

The global evaluation method for the framework employs a 5-point scoring system, which is ultimately translated into an alphabetical grading system. To determine the final grades, each design factor is assessed on a scale of up to 5 points. This approach ensures a fair distribution of points without weighting the criteria based on their relevance. Since evaluating the urban circularity of a neighbourhood involves addressing all four axes equally following the proposed definition and given their interconnected nature this method aims to provide a balanced assessment.

In this scoring system, each design criterion is assessed and given a score out of 5 points. The methodology for assigning these points depends on whether the criterion is qualitative or quantitative, with further details provided in the following section. Each design factor consists of multiple criteria, and since the number of criteria can vary, we calculate the average score of all criteria within a factor to determine a final score out of 5 points for that factor (see fig.4.5).

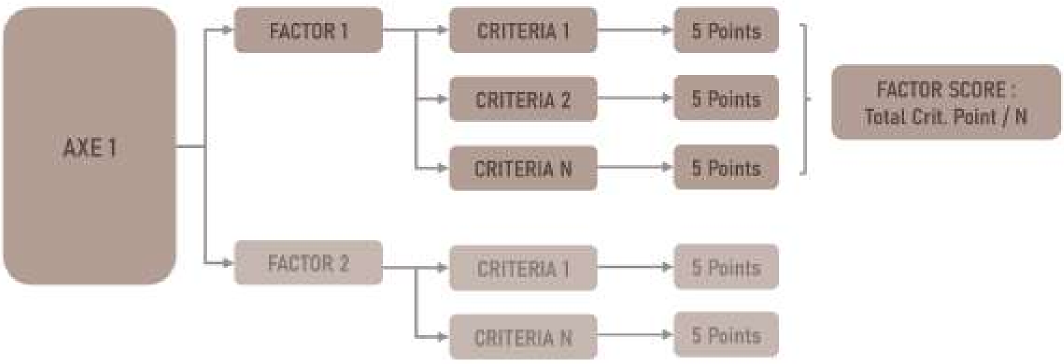

Figure 4.5: The scoring system of BRU-C

Finally, each axis is evaluated based on the sum of its design factors. Each axis includes 2 factors, making the maximum score for each axis 10 points (5 points per factor). Therefore, the total maximum score for the framework presented is 20 points. If the framework included all four axes, the maximum possible score would be 40 points.

4.3.2.2 POPULATION DENSITY

Definition: Population density is the measure that quantifies the total population per unit area. The unit of measurement is the number of inhabitants per square kilometre (inhab/km^2) [39].

Aim: To ensure that project development is based on local demographics, it is important to consider population density. The amount of materials and energy needed decreases in more densely populated areas, making it a key factor for relevant area of circularity [39].

Method: The assessment methodology is based on a quantitative calculation of the population density, which is determined by the number of inhabitants per area. The population density is evaluated using a 5-point scale, with the scale based on the population data from Brussels. Higher population density results in a higher point value on the scale [40].

CATEGORY	BUILT ENVIRONMENT		
CRIT.1	POPULATION DENSITY		
TYPE	QUANTITATIVE ASSESSMENT		
METHOD	Follow these steps	[inhab/km^2]	Score
	STEP 1 - Calculate the total land area within the perimeter of your site. **STEP 2 -** Determine the number of inhabitants within the site perimeter. **STEP 3 -** Calculate the population density using the following formula: $Population\ density = \frac{Total\ Number\ of\ Inhabitant\ [inhab]}{Total\ Land\ Area\ [km^2]}$	> 18 000	5
		14 000 – 18 000	4
		8 000 – 14 000	3
		5 000 – 8 000	2
		< 5 000	1

4.3.2.3 BUILDING DENSITY

Definition:Building density is the measure that quantifies the total gross floor area of buildings per unit area [41]. The unity of measure is the floor area ratio (FAR) [42].

Aim: The assessment methodology includes evaluating building density using the Floor Area Ratio (FAR) for a particular site and rating it on a 5-point scale. A higher FAR value earns more points on this scale due to the improved land efficiency. This 5-point scale is based on the density scale of the Brussels-Capital region [43].

Method: The assessment methodology includes evaluating building density using the Floor Area Ratio (FAR) for a particular site and rating it on a 5-point scale. A higher FAR value earns more points on this scale due to the improved land efficiency. This 5-point scale is based on the density scale of the Brussels-Capital region [43].

CATEGORY	BUILT ENVIRONMENT		
CRIT.2	BUILDING DENSITY		
TYPE	QUANTITATIVE ASSESSMENT		
METHOD	Follow these steps	FAR	Score
	STEP 1 Calculate the total land area within the perimeter of your site.	> 3	5
	STEP 2 Determine the total usable Gross Floor Area (GFA) within the site perimeter.	2 – 3	4
	STEP 3 Calculate the building density through the Floor Area Ratio using the following formula:	0,9 – 2	3
		0,6 – 0,9	2
	$\text{Building density (FAR)} = \frac{Total\ \text{GFA}\ [\text{km}^2]}{Total\ Land\ Area\ [km^2]}$	< 0,6	1

4.3.2.4 LAND USE

Definition: Land use refers to the human modification and use of terrestrial space or the built environment for socio-economic purposes [44][45].

Aim: To ensure that development projects are executed out in a way that minimises environmental impact, prioritises the use of previously developed or contaminated land, and conserves or enhances ecological areas and green spaces [15].

Method: The assessment methodology involves assigning 1 point for each positively answered question. These questions act as a checklist to identify circular behaviour associated with land use [15]. If all the questions are answered positively, the criteria will be awarded a maximum of 5 points.

CATEGORY	BUILT ENVIRONMENT			
CRIT.3	LAND USE			
TYPE	QUALITATIVE ASSESSMENT			
METHOD	Answer to the following question with 'yes' or 'no'		Answer	Score
	LU 1	Is the project's development located within the boundaries of an existing city, suburbs, or a town, rather than in a rural underdeveloped area?	Yes No	1 0
	LU 2	Is at least 75% of the proposed development site located on land that has been previously developed or built upon, as opposed to greenfield or undeveloped land?	Yes No	1 0
	LU 3	Does the project development prioritise the use of contaminated land and avoid the use of ecological areas? (please note that we consider soil contamination levels higher than 75% as high priority, levels between 50 – 75% as medium-high priority, and levels below 50% as low priority).	Yes No	1 0
	LU 4	Does the project development include a plan to address any environmental contamination or issues on the site prior to the start of construction?	Yes No	1 0
	LU 5	Does the project development include specific measures to protect existing ecological areas (such as wetlands, forests, or wildlife habitats) and plans to enhance the site's green spaces through landscaping, planting native species, or creating new green areas?	Yes No	1 0
			Total / 5	

4.3.2.5 SMART LOCATION

Definition: Smart Location refers to the strategic positioning of developments about existing infrastructure, services, and transit options [36].

Aim: To promote a design approach that encourages the development of urban areas within or near existing areas with transit infrastructure, and to minimise the expansion of a region's footprint. The approach prioritises and promotes the redevelopment of existing areas over creating new ones [36].

Method: The assessment method involves a qualitative approach using a hierarchical strategy scale with a 5-point system. Strategies are assigned points based on their rigor, with stricter strategies earning more points. This method is inspired by the LEED-ND methodology to assess Smart Location [36].

CATEGORY	BUILT ENVIRONMENT		
CRIT.4	SMART LOCATION		
TYPE	QUALITATIVE ASSESSMENT		
METHOD	Does the project's development comply to the prerequisite condition?	Answer	Score
PRE-REQUISITE	For all projects, to assess the access to water: 1 - Locate the project on a site with existing water and wastewater infrastructure. Or 2 - Locate the project within a legally adopted, publicly owned planned water and wastewater area and provide new water infrastructures	Yes	Go to STEP 2
		No	0
STEP 2	Select the strategy that suits your project the most:		Score
STRATEGY 1	The project has access to water AND is located in a previously developed site that is not an adjacent site or infill site.		1
STRATEGY 2	The project has access to water AND is located in an adjacent site with connectivity that is also a previously developed site.		2
STRATEGY 3	The project has access to water AND is located in an infill site that is not a previously developed site.		3
STRATEGY 4	The project has access to water AND is located in an infill site that is also a previously developed site.		4
STRATEGY 5	The project has access to water AND is located in an infill site that is also a previously developed site AND allocate places to insert the strategies from Category B.		5
SUPPL. INFO	CATEGORY B	Transit corridor	Position the project on a site with existing or planned transit services so that at least 50% of the dwelling units and non-residential entrances (including existing buildings) are within a 400-meter walking distance of at least one bus, streetcar, or rideshare stop.
		Mixed Use	Locate the project near existing uses such that the project boundary is within a 400-meter walking distance of at least five uses

4.3.2.6 COMPACT DEVELOPMENT

Definition: Compact development is a strategic approach that optimise the use of land through a higher density planning of building [46].

Aim: To ensure that land use, functional diversity, and a more sustainable way of transport is not overlooked in the project development [36].

Method: The method for assessing compact development is inspired by LEED-ND [36]. This approach focuses on the density of functions relative to the land area. The main calculation involves dividing the surface area dedicated to a particular function by the buildable land area allocated for that function. The evaluation uses a 5-point scale, with specific calculations detailed in the table below.

<table>
<tr><td>CATEGORY</td><td colspan="4">BUILT ENVIRONMENT</td></tr>
<tr><td>CRIT.5</td><td colspan="4">COMPACT DEVELOPMENT</td></tr>
<tr><td>TYPE</td><td colspan="4">QUANTITATIVE ASSESSMENT</td></tr>
<tr><td>METHOD</td><td>Follow these steps</td><td>DU/hectares</td><td>FAR</td><td>Score</td></tr>
<tr><td rowspan="5"></td><td rowspan="5">STEP 1 – Calculate the total floor area within the perimeter of your site.

STEP 2 – Calculate the total floor area of the following functions: residential and non-residential

STEP 3 – Calculate the percentage of residential land area and the percentage of non-residential land area over the total floor area

STEP 4 – Determine the total residential land area, and the total non-residential land area. Divide the project's total dwelling units by the total residential land area to obtain the residential density (in DU/hectares). Divide the non-residential floor area by the non-residential land area to determine the non-residential density (FAR)

STEP 5 – Referring to the Table on the right, find the appropriate points for the densities of the residential and nonresidential components.

STEP 6 – If the points differ, calculate the residential component's points by multiplying its point value by its percentage of the total floor area, and do the same for the nonresidential component by multiplying its point value by its respective percentage. Then add the two scores</td><td>> 25 and ≤ 32</td><td>> 0.75 and ≤ 1.0</td><td>1</td></tr>
<tr><td>> 32 and ≤ 45</td><td>> 1.0 and ≤ 1.25</td><td>2</td></tr>
<tr><td>> 45 and ≤ 62</td><td>> 1.25 and ≤ 1.75</td><td>3</td></tr>
<tr><td>> 62 and ≤ 94</td><td>> 1.75 and ≤ 2.25</td><td>4</td></tr>
<tr><td>> 94</td><td>> 3.0</td><td>5</td></tr>
</table>

4.3.2.7 MIXED-USE

Definition: The mix of uses in an urban area refers to the integration of various functions within a specific area. The closer the functions are to each other, the higher the degree of integration [35].

Aim: To maximise the diversity of functions within a specific area within walking distance in order to create a more resilient neighbourhood and enhance its social, urban, and economic dynamics [35].

Method: The assessment methodology combines both qualitative and quantitative approaches. The quantitative approach uses a scale system inspired by the LEED-ND framework. This system evaluates the diversity of functions within a 400-meter radius from a specific point and allocates points accordingly. The scoring is based on the variety of functions present within this radius, with a maximum of 4 points possible [36]. To address the issue of monofunctionality, which the quantitative method alone may not fully capture, we introduce an additional qualitative assessment. This method involves a question designed to evaluate the extent of monofunctionality within the 400-meter radius. This question contributes an additional 1 point to the total score. The combined qualitative and quantitative assessments result in a final score of up to 5 points.

CATEGORY	BUILT ENVIRONMENT			
CRIT.6	MIXED USE			
TYPE	QUALITATIVE & QUANTITATIVE ASSESSMENT			
METHOD	Follow these steps		Nbr.	Score
	STEP 1	Calculate the diversity of use by determining the number of each type of function distributed within the site perimeter.	< 4	0
			4 – 7	1
			8 – 11	2
			12 – 19	3
			> 20	4
	STEP 2	Answer the following question	Answer	Score
		MIX1 – Does any single function dominate the functional distribution in the district, accounting for significantly more than the other functions?	Yes No	0 1
			Total /5	

4.3.2.8 FLEXIBILITY

Definition: Flexibility in urban planning is a design approach that enables variability through time and space in urban development and city planning [47].

Aim: To encourage the design thinking process of a city to be more adaptable and accommodate the perspective of future modifications within the built environment [12]. The question of temporary use and flexibility within urban planning is non-negligible in the resilience and frugality of the urban context and stands in the continuity of the idea of reuse and repurpose at the scale of an area, a building [35].

Method: The methodology assessment is based on a qualitative analysis of the project's capacity to allow temporary and flexible elements within the built environment through a series of questions. The composition of the question is based on two criteria derived from the GRO and Be Sustainable's toolbox, which we consider relevant and related to each other, and should be equally investigated [35][12]. Thus, the scoring system for the two questions is divided into equal value points of 2.5 points per question. Points are earned if the project answers positively to the question.

CATEGORY	BUILT ENVIRONMENT			
CRIT.7	FLEXIBILITY			
TYPE	QUALITATIVE ASSESSMENT			
METHOD	Respond to the following question with 'yes' or 'no'		Answer	Score
	FLEX 1	Is temporary or transitory use possible for this building or site?	Yes No	2,5 0
	FLEX 2	Is future adaptability possible for this building and/or site?	Yes No	2,5 0
			Total /5	

4.3.2.9 NETWORK

Definition: Network refers to the relationship and interdependencies among urban areas connected through a variety of links across different spatial scales [48].

Aim: To evaluate the transportation networks and infrastructure in the scope of conserving land while improving the various transportation method to foster a well-served and connected community [36]. The establishment of a well-connected district can reduce time spent in transit and enhance access to essential services [30].

Method: The assessment methodology for this criterion consists of two quantitative questions.

The first question measures the level of connectivity of an urban area by counting the number of nodes/street connections within a specific perimeter. Based on the number of nodes, specific point values are assigned to a range of connectivity levels – the more nodes, the higher the connectivity and point allocation. The maximum score for this category is 2 points [36].

The second question, inspired by the LEED-ND methodology, addresses the issue of accessibility in Brussels-City. However, it was found that the American LEED-ND standard was not easily applicable to the accessibility system in Europe, especially for a metropolitan city like Brussels. Consequently, the methodology was interpreted and the zoning system proposed by the Regional Urban Regulation [49] was used as an alternative to assess the level of accessibility within the framework. The RRU provides a 3-leveled accessibility map for the Brussels-Capital Region, with a certain amount of points attributed depending on the zone in which the project is located. A maximum of 3 points can be assigned to this question, with a higher-ranked zone receiving more points.

CATEGORY	MOBILITY			
CRIT.1	NETWORK			
TYPE	QUANTITATIVE ASSESSMENT			
METHOD	Follow these steps		Nodes	Score
	STEP 1	Calculate the number of intersections (nodes) per km^2 by identifying all the intersections within the project perimeter. Ensure you do not count connections that lead to dead ends or parking entries.	< 116	0
			116 – 154	1
			> 154	2
			Zone	Score
	STEP 2	Identify the zone where the project is located by consulting the accessibility zone map created by the RRU of Brussels.	Zone A	3
			Zone B	2
			Zone C	1
			Total /5	

4.3.2.10 TRANSPORT MODES AND TRANSIT FACILITIES

Definition: Transport modes and transit facilities refer to the different methods of transportation used for moving people or goods [50] and relate to means supporting the mobility of people or goods [51].

Aim: To assess the mobility strategy and its influence on urban infrastructure, and to ensure the development of high-quality infrastructure that promotes alternative modes of transportation [15]. The goal is to create a transportation system that makes it easy for citizens to navigate and be well-served, reducing the reliance on individual transportation methods and promoting a more circular approach to transportation modes and transit facilities.

Method: The assessment methodology involves a cumulative point system based on a set of qualitative questions. These questions cover important strategies for creating a circular city, focusing on sustainability and repurposing existing practices. One crucial aspect of this approach is to assess the different types of transportation and the supporting infrastructure. Points are accumulated for each question answered positively. Each question addresses specific aspects related to transportation modes and transit facilities outlined in frameworks such as BE.SUSTAINABLE, GRO, LEED-ND, and CUS [35][12][36][1].

CATEGORY	MOBILITY			
CRIT.2	TRANSPORT MODES & TRANSIT FACILITIES			
TYPE	QUALITATIVE ASSESSMENT			
METHOD	Answer to the following question with 'yes' or 'no'		Answer	Score
	TMTF 1	Is there a comprehensive mobility strategy in the project that aims to reduce the use of motorised vehicles and promote non-motorised (soft) mobility practices?	Yes No	1 0
	TMTF 2	Is there a comprehensive parking strategy that includes optimising spaces to support soft mobility, and providing sufficient bike parking space or flexible parking infrastructure?	Yes No	1 0
	TMTF 3	Is shared transportation available or/and actively promoted within the project area, along with multiple self-service soft mobility options?	Yes No	1 0
	TMTF 4	Is there a strategy to improve infrastructure and connectivity to support sustainable transportation options, such as cycling lanes and pedestrian pathways?	Yes No	1 0
	TMTF 5	Does the strategy include plans for enhancing road connections and overall infrastructure to reduce travel time and improve the efficiency of the transportation network?	Yes No	1 0
			Total / 5	

4.3.2.11 CHOICE

Definition: A choice, in the context of materials and circularity, is the process of selecting an appropriate material based on specific criteria defined by the project's objectives [52].

Aim: To ensure that the selected materials are chosen conscientiously based on their origin, utility, and environmental impact. Circular design encourages considering the broader system surrounding materials to make informed choices when introducing materials into a system [53].

Method: The assessment methodology proposed in this framework is based on a list of design qualities [27] and a framework combined with an R-ladder system [25] to create a 5-point scale system translated into a 5-strategy system. Depending on the strategy selected, a certain number of points is allocated based on the conditions for each strategy. This creates a strict system in terms of materials, as the concept of circularity is well developed around the material flow [53].

The assessment methodology involves a set of design qualities distributed into three categories that create a 5-point scaled system in which the project has to comply with one of the 5 strategies and thus earn a certain amount of points according to the strategy selected. The allocation of points for each strategy relates to the hierarchisation of the three strategies concept elaborated by the R-ladder system that distributes the concept choice of materials into 3 strategies: Narrow the loop, Slow the loop, and Close the loop [25].

By understanding the concept of these 3 strategies, we distributed the list of design qualities proposed by the VUB Circular Tool into these 3 categories of strategies:

- "Narrow the loop" implies consuming in a more sober manner, particularly emphasising the R-imperatives of Refuse and Reduce. Refuse involves consuming less to prevent waste production and rejecting certain non-circular or polluting materials. Reduce focuses on extending the life of materials, using them efficiently, maintaining them, and using fewer materials per unit of production, which can also refer to dematerialisation for producers.

- "Slow the loop" includes the imperatives of Resell/Reuse, Repair/Restore, Refurbish, Remanufacture, and Repurpose. Resell/Reuse involves reintroducing products into the economy after their initial use and reusing products with necessary rework or repair.

- "Close the loop" implies Recycling, Recovering (energy), and Remining [11].

Based on this hierarchy, the list of design strategies exploited by the Circular Building Design tool was integrated into the related category to form 3 assessment categories: Required category, Category A, and Category B. As we consider closing the loop as the basic system of circularity, we attributed more points and emphasis to the fact that narrowing the loop should be an imperative in order to tackle the principle and be stricter. The Required Category is an imperative condition to be able to earn a point. The assessment system works as a 5-level scale that should be imperative to obtain at least one point, creating a scaled 5-strategy system that allows having more or fewer points depending on the level of percentage of building material maintenance as a conditional value and thus allows the freedom to tackle the list of design strategies allocated in categories A and B. Because of the hierarchy between the design.

CATEGORY	MATERIALS & RESOURCES					
CRIT.1	CHOICE					
TYPE	QUALITATIVE ASSESSMENT					
METHOD	What strategy would you use to evaluate the impact of materials in the project? Select one of the following strategies.					Score
	STRAT 0	Less than 10% of the existing buildings are maintained				0
	STRAT 1	The project must include 4 strategies from category A and 2 strategies from category B, with the requirement that 10-20% of the existing buildings be maintained.				1
	STRAT 2	The project must include 3 strategies from category A and 2 strategies from category B, with the requirement that 20-30% of the existing buildings be maintained.				2
	STRAT 3	The project must include 2 strategies from category A and 2 strategies from category B, with the requirement that 30-50% of the existing buildings be maintained.				3
	STRAT 4	The project must include 2 strategies from category A and 1 strategy from category B, with the requirement that 60-70% of the existing buildings be maintained.				4
	STRAT 5	The project must include 2 strategies from category A and/or from category B, with the requirement that 70-100% of the existing buildings be maintained.				5
SUPPL. INFO	REQUIRED	Maintaining			Refuse	
	CATEGORY A	Compatible	Multipurpose	Reuse	Accessible	Simple
		Varied/ Diversity	Independent	Manageable	Reversible	Durable
	CATEGORY B	Recycle	Renewed	Safe & Healthy	Compostable	Pure

4.3.2.12 INFORMATION AND MANAGEMENT

Definition: Material information and management refers to the systematic approach of gathering, organising, and using detailed information about construction materials throughout their life cycle [12][54].

Aim: To minimise waste on the construction site, ensure the transparency and availability of information about the selected materials, and highlight the importance of this information for achieving a closed-loop system [36].

Method: The assessment methodology involves assigning 1 point for each affirmative answer. These questions act as a checklist to identify circular practices related to resource waste management and information transparency. All questions are based on criteria drawn from a combination of the GRO, PREC, and Be Sustainable's frameworks [7][12][54][35].

CATEGORY	MATERIALS & RESOURCES			
CRIT.2	INFORMATION & MANAGEMENT			
TYPE	QUALITATIVE ASSESSMENT			
METHOD	Answer to the following question with 'yes' or 'no'		Answer	Score
	MNGT 1	Does the project development plan to include a strategy to implement material passports in the project?	Yes No	1 0
	MNGT 2	Does the project development plan to implement a sustainable waste management strategy on site?	Yes No	1 0
	MNGT 3	Does the project development plan to implement a sustainable waste management strategy off site?	Yes No	1 0
	MNGT 4	Does the project development plan to optimise materials management on site considering factors such as space, timing, storage, delivery, and removal?	Yes No	1 0
	MNGT 5	Does the project development plan to implement a strategy to boost local resources and good food?	Yes No	1 0
			Total / 5	

4.3.2.13 ENERGY REDUCTION STRATEGY

Definition: Energy reduction strategy is a strategy applicable for a project in order to reduce the amount of energy consumed by a system, a district, a building [12][15].

Aim: To encourage the development of strategies in the design phases project to minimise the energy demand and consumption through a series of reduction strategies at different scales, while maintaining operational efficiency and performance [15].

Method: The assessment methodology uses a cumulative point system to evaluate a set of qualitative questions concerning energy reduction strategies at various levels. Each proposed solution is assessed with a binary 'yes' or 'no' answer to acquire a point. A maximum of 5 points can be obtained when all strategies are taken into account within the project. Each strategy carries a value of 1 point, reflecting the perspective that addressing energy reduction at the neighbourhood level implies a combination of strategies. No singular strategy is deemed superior; instead, they complement each other based on the resource management hierarchy to establish a systematic approach to action [35][31].

CATEGORY	ENERGY			
CRIT.1	ENERGY REDUCTION STRATEGY			
TYPE	QUALITATIVE ASSESSMENT			
METHOD	At which level does the project implement an energy strategy? Choose "yes" or "no" for any of the listed strategies you follow. If none apply, select "nd."		Answer	Score
	ENE 1	Energy Demand Reduction : Implementation of measures to minimise the energy needs of the building.	Yes No	1 0
	ENE 2	Resource Synergy : Optimise the use of locally available resources and energy cascade such as local heat, waste heat, etc. to enhance energy efficiency.	Yes No	1 0
	ENE 3	Building-level Renewable Energy Supply : Supply the remaining energy needs with renewable sources at the individual building level.	Yes No	1 0
	ENE 4	Neighbourhood-level Renewable Energy Supply : Implementation of renewable energy solutions strategies at the neighborhood scale.	Yes No	1 0
	ENE 5	Smart Energy Management: Use advanced technologies to monitor and manage energy supply and usage efficiently.	Yes No	1 0
			Total / 5	

4.3.2.14 RENEWABLE ENERGY PROVISION

Definition: Sustainable Energy Provision refers to a strategy for supplying renewable energy sources that are not anticipated to be exhausted within a relevant timeframe for the humans [55].

Aim: To increase the proportion of energy supplied from renewable sources [12].

Method: The assessment methodology uses a 5-point scale system to evaluate the proportion of renewable energy integrated into the project. The score is determined by the percentage of renewable energy supplied for the project, based on the European Parliament's objectives for reducing fossil fuel energy consumption. The Parliament aims to achieve a 49% proportion of sustainable energy for the building sector by 2030 [56]. Therefore, the maximum point value is set at this standard. As achieving 49% is a significant accomplishment, points will still be allocated to projects aiming for lower proportions.

CATEGORY	ENERGY		
CRIT.2	RENEWABLE ENERGY PROVISION		
TYPE	QUALITATIVE ASSESSMENT		
METHOD	Select the ratio that suits your project's ambition the most:	Answer	Score
	Based on the district's energy needs and the intended reduction strategy, select the ratio that most closely matches the project's goal for providing renewable energy sources.	< 9,8	0
		9,8 – 19,6	1
		19,6 – 29,4	2
		29,4 – 39,2	3
		39,2 – 49	4
		> 49	5
		Total / 5	

4.4 Evolution of the Framework

Once the analysis of the existing frameworks and the determination of pros and cons of each framework was achieved, we reviewed thoroughly the type of assessment methodology, the number of factors, the ease of use and the structure of the frameworks to create a basis for the elaboration of our framework.

After analysis, different framework distinguished themselves for different reasons. First, the method of presentation and organisation of the CRI was what stood out the most and was the one that inspired the structure of the BRU-C framework. The same type of format and comprehensive hierarchy would be used for this framework. Also, the organisation of quantitative and qualitative assessment methodology was also an interesting methodology. We proceeded to the decision to keep it as an example on how to organise and assess the project. Even if the main drawback of the CRI was that the factors assessed and proposed were not directly related to circularity, the form was a good inspiration to better convey the information and to make it easy to understand.

Two other frameworks were distinctive for their comprehensive assessment methodology, and score-rating system which were the LEED-ND and the BREEAM-Communities. Because of their long and extensive factors and categories, they have a long super detailed assessment methodology that was complete enough to understand but too hard to apply because there was nothing made to do the calculation easily as they were both quantitative-based framework. Nevertheless, the focus on these tools was given thanks to their large spectrum of factors which turned out to be useful for the definition of our own design factors

The last framework that struck us as useful to study was the Circular Urban Scan. As a matter of fact, in opposition to LEED-ND and BREEAM or CRI, this framework was less extensive with a super easy to use and understandable framework, rated on a basis of 10 points given per category. Overall, the whole system was easy to understand and calculate but as the framework was solely based on data selection - so only quantitative, resulting to a limited number of factors. When following the definition of urban circularity of BRU-C, it seemed relevant to create a framework structure placed somewhere in between the Circular Urban Scan and the City Resilience Index. The structure of the BRU-C framework is therefore inspired by the structure of CRI, starting from the broader aspect to the defined criteria.

The framework has had an evolution in four distinct phases: first, the establishment of the definition of urban circularity as well as the elaboration of goals for which our framework will be based on. After defining and establishing the main goals of the framework, the second phase was to research a certain amount of design factors that we should be able to define and assess in a qualitative way. To do so, we used the benchmarks the existing factors of the different frameworks analysed beforehand to define what were the common factors and categories the different frameworks had in common. Once the benchmarking was executed, we decided to classify them to establish a set of main "axes" that could encompass the most represented factors/categories.

At this stage, the urban circularity definition, the goals and the main axes were set. The third phase of development started. For this step, the intention was to find a dozen of categories/factors that could answer the 4 goals of the framework. To do so, we decided to reuse the previously benchmarked categories and to match them with goals to eliminate the ones that were the least relevant with respect to our framework ambitions.

When the relevant factors from the benchmarking phase were chosen and defined, a myriad of criteria were to be determined. To achieve that, we proceeded in two steps: the choice of relevant criteria, and the organisation into a preliminary framework. The criteria that were chosen from the existing frameworks possessed existing methods of calculations, making them fitting for the quantitative ambitions of the frameworks. Working with existing methods of assessments permits to create a base to test on concrete case studies. The relevant criteria were attributed to their respective design factors to create a preliminary framework, ready to be tested out.

The fourth and final phase consisted in the refinement phase through tests and simulations. In this phase, the defined criteria were tested out in a first case study which was the Cityforward project. This whole phase is about a continuous back and forth (see fig.4.6), trial and error system in which a project is tested out abruptly in the preliminary framework in order to see where it goes well and where it goes south for each criteria benchmarked. This way we can identify the more relevant criteria as well as the most relevant methodology assessment. During this first test, some categories saw themselves completely mutate due to the inputs of the project raising new questions concerning the relevance, the usefulness and the assessment of some criteria, keeping in mind the objective of creating a score value system and a grading system.

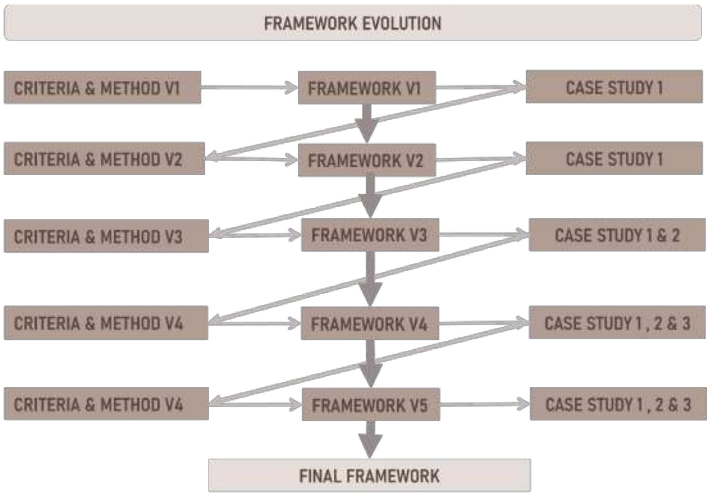

Figure 4.6: Refinement methodology of the framework

Basically, the first outcome with the first Cityforward test was that the elaborated Excel sheet layout was not intuitive and needed to be optimises. In terms of substance, we realised that some of the criteria selected should be merged in a way to answer better our goals and ambitions. For example, in the beginning, we established two distinct criteria for the energy design factor which were the "Energy Reduction Strategy" criteria and the "Sustainable Design Strategy" criteria. After testing, we concluded that both methodologies and strategies are inherently linked together and made more sense once merged. Moreover, it was concluded that some elements did not have the correct assessment methodology, and that some information was not necessary for certain calculations but was rather for awareness (e.g., percentage of space allocated to soft mobility and hard mobility).

In a nutshell, the first test was useful for testing the layout of the Excel file, methodologies, encodings, and the initial values introduced. To make the tool accessible, we adapted little by little the input values to information available on different websites and maps of the Brussels' open source data. To improve the Excel file and check if the methodologies are still applicable to other projects, information from the Buiksloterham project and the Defense project were collected.

The second attempt of refinement was made thanks to the data collected from the Defense project and the Buiksloterham project. Certain qualitative questions have been refined. For example, the mobility criterion required a revision of the methodology, and the land use criterion required a questioning of the relevance of some questions and its assessment method. There was also a reconsideration of the relevance of keeping the Green Infrastructure criterion in the Built Environment category, as the calculated values had already been foreseen for the Environment category, if even it can be considered part of the built environment. Additionally, it has a greater impact on the comfort principle related to the People section, which is not developed in our thesis, so this was an additional argument not to include it. In summary, this testing was useful for consolidating the assessment methods, checking for unnecessary data, and improving the methodology. Furthermore, the tests were helpful to create a simpler layout, given that this was one of the issues identified with analysis of the existing frameworks.

The data collected from both the Defense and Buiksloterham projects allowed for refining the qualitative questions because we possessed more information regarding the project strategies compared to the Cityforward project. This in turn enhanced the quality of questions and reduced the "data-intensive" elements that were unnecessary and more time-consuming. Due to the scope of this thesis, we are unable to provide a detailed exploration of the evolution of the framework and assessment tool. However, it is possible navigate through the Appendix A to see how the preliminary framework and assessment tool have evolved over time.

			RESILIENCE	SUSTAINABILITY			CIRCULARITY					
			CRI	BREEAM-COMM	LEED-ND	BE. SUST	PREC	UCAF	ADEME	GRO	VUB TOOL	CUS
SPATIAL DEVELOPMENT	BUILT ENVIRONMENT	POPULATION DENSITY		X								
		BUILDING DENSITY										
		LAND USE	X	X	X	X		X		X		
		SMART LOCATION	X	X	X					X	X	
		COMPACT DVLPT			X	X						
		MIXED USE			X				X			
		FLEXIBILITY	X	X		X			X	X	X	
	MOBILITY	NETWORK	X	X	X					X		X
		TRANSPORT MODES & TRANSIT FACILITIES	X	X	X	X	X	X		X		X
MATERIAL & RESOURCES	MATERIALS	CHOICE		X	X	X	X	X	X	X	X	X
		INFORMATION & MANAGEMENT	X	X	X	X	X			X		X
	ENERGY	ENERGY REDUCTION STRATEGY		X	X	X				X		X
		RENEWABLE ENERGY PROVISION			X	X			X	X		X
ENVIRONMENTAL QUALITY	GREEN INFRA.	PERMEABILITY		X				X		X		X
		BIODIVERSITY INDEX		X	X	X		X		X		X
		POLLUTION		X	X	X		X		X		X
	WATER	WATER MANAGEMENT	X	X	X	X		X		X		X
		WATER CONSUMPTION REDUCTION		X	X	X				X		X
PEOPLE	WELLBEING	ACCESSIBILITY	X	X	X					X		X
		COMFORT	X	X						X		X
		ATTRACTIVENESS	X	X				X		X	X	
	PARTICIPATION	COMMUNITY-LED PROJECT	X	X	X			X				X
		DECISION MAKING PROCESS	X	X								X
		EDUCATION	X	X		X	X	X	X			X

Figure 4.7: Benchmarking of the different criteria of the BRU-C tool

4.5 How to use the toolbox - a guiding brochure and an in-depth assessment tool

4.5.1 The components of the BRU-C's toolbox

In this section, the final toolbox of the BRU-C framework is presented. The toolbox contains a brochure and an Excel File. The brochure's objective is to communicate in a comprehensive way the framework. It presents the overview of the BRU-C framework. The Excel file translates the elaborated framework into an in-depth assessment of urban projects. In this section, the final version of these tools in the context of this research are presented. For the Excel, an explanation of the process and mindset is given. Then, a guide to the operation of the tool is given.

All the components of the Toolbox can be downloaded via this link: `https://1drv.ms/f/s!AtWQt8eP7aqCgaVR6QYJjjDwuOlq9w?e=VfHUzJ`

4.5.2 The Brochure

The choice of a brochure as a media was inspired by the Circular Building Design tool (section 3.1). Their brochure is small and easy to carry with and unfolds into a single-page brochure. This design was inspiring to use in our research mainly because of its practicability. Therefore, the design of BRU-C's brochure was done on a single A2 paper format, that could be folded and transported by the designers. The Brochure presents the framework in its entirety including the definition of urban circularity, the 4 goals of the tools, the 4 axis of interventions, the design factors, the criteria and how to calculate them. The Brochure still requires some extra work but is accessible in the online drive (see section 4.5.1).

4.5.3 The Excel

4.5.3.1 Purpose of the tool

Following an in-depth research and analysis of 10 widely recognised frameworks in the areas of circularity, sustainability, and resilience, we concluded that most of the frameworks had their own unique methodologies for evaluating various topics. Some were user-friendly but lacked extensive criteria, while others offered a comprehensive set of criteria but were either complex to use or involved lengthy and detailed processes. Our approach led us to conclude that we wanted to create a framework that would be quite extensive in the field of circularity and sustainability, and user-friendly. The goal was to create a tool that not only guides the design process but also allows users to test and simulate scenarios in the project development. The framework would have to be able to assess the project based on easily and manageable data that can be easily obtained in early-design phases. Given the abundance of frameworks available on the market, we identified a gap in the field of urban circularity assessment. There is a need for a framework that can serve as a tool to assist designers and users in the decision-making process, helping to guide and create more circular urban projects. This mindset guided our elaboration of the Excel file, which translates the framework into an in-depth assessment method.

4.5.3.2 Structure of the Excel

The Excel sheets can be utilised in two distinct ways: firstly, to evaluate a project's circularity according to the framework's definition, and secondly, as a guide for project development, serving as a checklist to ensure the project incorporates or advances specific strategies. The Excel file is divided into 4 chapters. The first chapter corresponds to the first page of the Excel file wherein is presented a global overview and data comparison between 4 projects scenarios. This page grants a direct overview of the score for each category of the framework for each scenario as well as the final rating score for each scenario. A spiderweb is also displayed permitting to compare the different scenarios and observe in which categories they perform.

The second chapter of the Excel presents the "Scenario's Assessment" page where 4 scenarios can be assessed at the same time. Each scenario is calculated via the code defining the assessment methodology and to make it user-friendly, the only task the user must do is to input the necessary data in the highlighted cases. This sheet can be read from left to right. It figures individuals block of information that correspond to the different design factors. Each block can be read from top to bottom. At the top of the layout of the sheet reside general guidelines explaining how to use the tool.

The assessment in the scenario's sheet follows 3 steps. The first step is the "Data Collection" which consist in collecting all relevant design data for urban project. We designed this step in a way that the date could be retrieved through the plans of the project or through the open-source data base of Brussels. The relevant data are related to the built environment and the mobility aspects as they are information that can be easily defined from basic plans and open-source documentation related to the studies city. All the calculation needed to assess the criterion are handled by the Excel. Because this section is data-based, it can be filled with the existing situation or in the projected situation.

After collecting and inputting the design data in the first step, the users can move onto the second step, called "qualitative assessment", in which the qualitative questions related to the project development must be answered. The assessment method (as explained in section 4.3.2) is based on a "yes or no" type of question. The user is expected to answer positively to the question if reflection on the question was made. Depending on the answer, the framework will allocate the respective amount of point. In case of uncertainty or if the project does not mention this aspect yet, there is a possibility to choose "n.d." which refers to "no data". This will still result to 0 points but offers the user the possibility to show in the results that that certain aspect was put on hold. In the layout of the second step, there is a dark strip at the beginning of each block that provides instructions to follow or specific questions. The user either must select the strategy the project aims to do or answer yes or no to the questions.

Now that the step 1 and 2 have been accomplished, the Excel sheet proceeds to make all the calculation at once in step 3. All the scores for each question can be seen in the step 3, "Framework Calculation and Scoring". This step details and recapitulates the scores for each answer. The Excel sheet of this step was made for the calculations and the allocation of point and therefore provides an overview of the total score per category. The overview layout can also help the user to already identify the strengths of the project and the areas that would need improvement. As explained, each framework category are evaluated on an easy and intuitive scoring system of 5 points.

The third chapter is named "Index" and acts as an aid containing a set a useful links from which the user can find some data for Brussels city. The final chapter is the "Score" sheet which represents a synthesis of all the final scores per design factors, the final rating score (A to E) and the final spider web containing all the comparable scenarios.

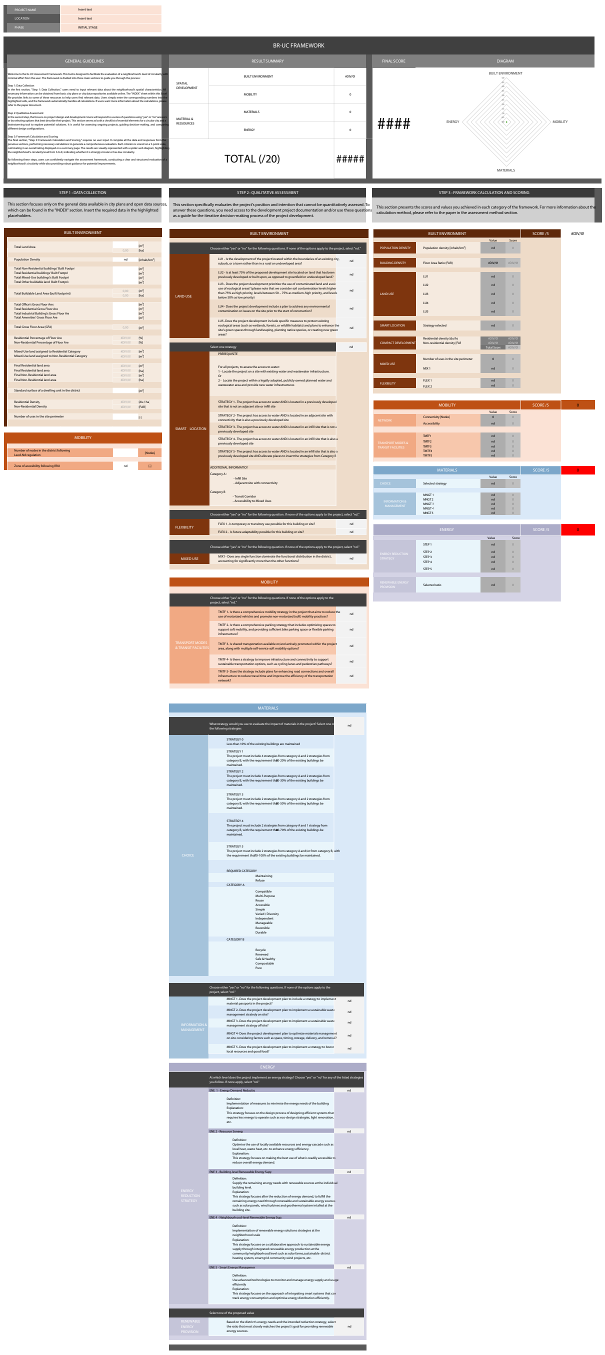

Figure 4.8: The Excel's file overview

4.5.3.3 Grading system

The scoring system used to evaluate the design factors involves adding up the points for each specific criterion. Each criterion is assessed using a 5-point scale, which is further divided into qualitative and quantitative values. More details about how to assess each design factor and understand the scoring system are explained in the "The design factors and how to calculate them" section 4.3.2. In summary, the final score for each design factor ranges from 0 to 5, and the total sum of scores for all design factors are rated on a colour scale from A to E. The higher the score, the more aspects of circularity are addressed.

The grading system used in the framework is a combination of a colour scale and a rating system. Each design factor is assigned a final score value, but we chose to use a colour grade system to represent the final performance on a spectrum rather than with a specific number [57]. The final alphabetical grading system was developed based on the rating system proposed by the BREEAM-Community framework, combined with the 5-point scale system proposed by the City Resilience Index (CRI) for assessing each criterion.

The evaluation of the framework's final score is built upon the allocation of total maximum points to each design factor. Given that only 2 design factors were thoroughly researched and identified in this thesis, the resultant score is confined to a maximum value of 20 points. The grading system operates according to the following criteria:

- Grade A: Final score higher than 16 and up to 20 - The circularity aspect of the project is considered "VERY GOOD."
- Grade B: Final score above 12 and up to 16 - The circularity aspect of the project is considered "GOOD."
- Grade C: Final score above 8 and up to 12 - The circularity aspect of the project is considered "SATISFACTORY."
- Grade D: Final score above 4 and up to 8 - The circularity aspect of the project is considered "IN NEED OF IMPROVEMENT."
- Grade E: Final score up to 4 - The circularity aspect of the project is considered "MEDIOCRE."

4.5.3.4 Interpretation of the results

This Excel was designed to assess a project in various phases or to assess various scenarios for the same project. The utility of the spiderweb diagram is to observe how each scenario thrives and is which specific categories. Because the assessment methodology is based on a scoring system over 5 points, the categories are equivalent, making it easy to see when a project tends to develop strategies in a certain category. The level of circularity in the framework is defined by the total set of actions in the categories. Given that the categories stem from the urban circularity definition, the more categories you tackle, the more circular the urban project can be, and the spiderweb diagram is a excellent media to showcase the final results in a graphic way. The spiderweb diagram also highlights the strengths and weaknesses in terms of circularity for each project and permits to compare several scenarios together and observe the evolution of each category depending on the scenarios making it a helpful tool to either convince a client or to decide a final proposition for a project [57]. Be that as it may, it is important in our opinion to go further than the spiderweb and the grading system to interpret the results. Taking a step back to gain perspective and consider the project in its context and its specificity is essential as well.

It is also important to remind that our framework in his thesis was only developed on 2 categories out of the 4 which are "Built environment" and "Resources and Materials". It does not encompass the 2 other categories of "Environmental Quality" and "People". To have a better overview of the circularity of a project, the 4 categories should be assessed. For the time being, our assessment values are provisory.

Chapter 5

Case studies and simulations

5.1 Masterplan Cityforward

5.1.1 Project Description

The Cityforward project is considered as a pivotal transformation in the Brussels' European Quarter. Traditionally dominated by a heavily monofunctional area and encompassing a lot of European Institutions, the Commission seeks to reduce and reorganise its office spaces in order to enhance sustainability, which involves a transfer of 21 buildings, composed of over 300 000 m^2 of floor plan to the Belgian Fund Cityforward. This strategic real estate initiative aims to revitalise the European Quarter by redeveloping and reprogramming these 21 properties. Cityforward is willing to recreate a dynamic shift from the current office-centric landscape to a more mixed and vibrant urban environment. The project seeks to integrate at least 30% of the redevelopment to residential unit and amenities, and the other 70% to redevelop and renovate the existing offices spaces into more sustainable office spaces [58].

5.1.2 Urban context

The studied area is situated within the Brussels' city centre, specifically in the European Quarter of the municipality of Brussels. The Cityforward project encompasses 21 buildings dispersed across the Brussels municipality and the Saint-Josse-ten-Noode municipality. For the simulations of this case study, the building block 130 (Ilôt 130) was chosen to further dive into. This building block is the biggest part of the masterplan is the current main focus of the project owners, making it the part of the project with the most documentation. To maintain consistency and ensure a comparable measurement of space for the three projects being assessed, a "neighbourhood" perimeter was defined corresponding to a 400-metre radial area around the megablock 130 of the Cityforward masterplan (see fig.5.1). This 400-metre radius is based on the concept of a five-minute walk, developed by the Congress for the New Urbanism [59]. We chose this measure to define an area that would be comparable to the other projects and to establish clear boundaries, making it function like a neighbourhood. Given the scope and essence of this thesis, which aims to assess circularity at the neighbourhood level rather than the building level, this approach allows us not only to compare the different projects but also to evaluate the impact of the Cityforward project on its surroundings.

The megablock 130 constitutes one-third of the total 300 000m^2 area of the Cityforward project and serves as the initial phase, offering substantial information regarding the project's objectives. The evaluation of changes within this building and its surrounding area is anticipated to have a more significant influence compared to the smaller dispersed buildings throughout the city.

Within the 400-metre radial area around the building block 130, 12 buildings out of the 21 within the project were included, covering a total area of 92 hectares (see fig.5.2). The project's current location falls within the European Quarter, renowned for its monofunctional nature and hosting the highest concentration of office buildings in the Brussels-Capital Region, as per the Neighbourhood Monitoring Report [40]. With a 91% impermeable surface rate, the European Quarter is characterised by high built density, limited green spaces, and a greening rate of less than 20%. The zone is predominantly comprised of office spaces, with minimal residential areas, currently accommodating fewer than 4000 inhabitants per square kilometre [40].

The zone boasts excellent public transportation access, experiences high traffic due to two main thoroughfares, "Rue Belliard" and "Rue de la Loi" and is connected to a national road. Classified as Zone A in the Regional Urbanism Regulations (RRU), it is considered one of the most well-connected zones in the masterplan [49]. Because of the size of the megablock 130, we anticipated that evaluating the impact of changes in that building on the surrounding environment would be more significant than assessing smaller, dispersed buildings across the city.

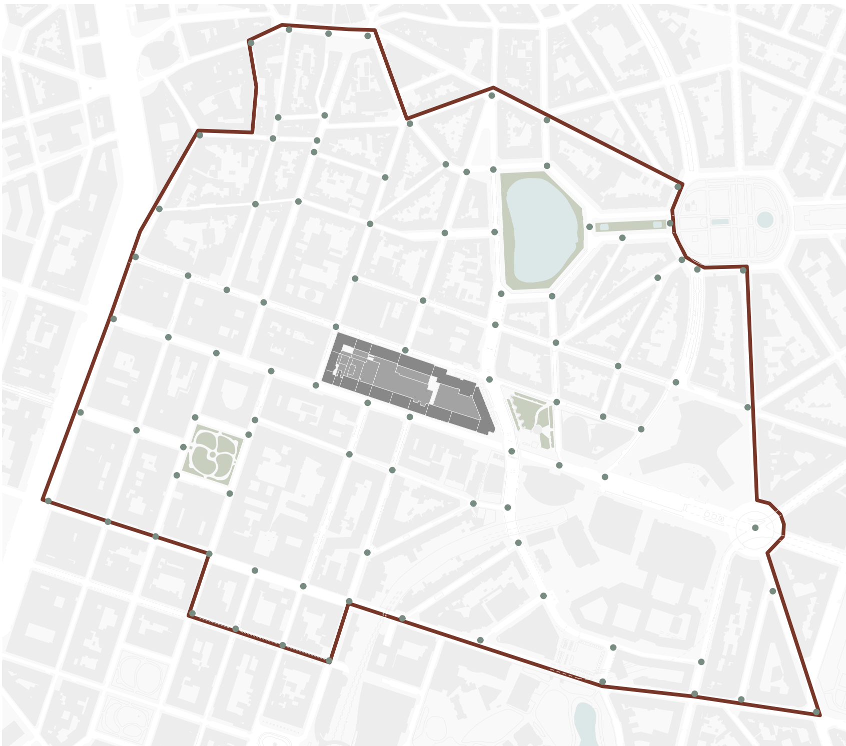

Figure 5.1: Developed plan showing perimeter surrounding the building block 130 and the determined nodes

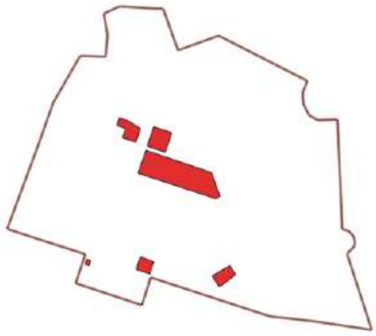

Figure 5.2: Scheme showing the different buildings of the Portfolio that are included in the 400m radial area surrounding the building block 130 [58]

5.1.3 Ambitions and Vision

This project has an ambitious budget of 880 million euros is looking to transform the European quarter into a more sustainable one, with cutting edge technology and sustainable buildings. The project Cityforward operates on several levels to make significant impact and on the transformation the European Quarter. It proposes strategies to bring more mixity by modifying the uses and programs for the 21 buildings. The plan aims to redistribute the space into 70% offices, 25% housing, and 5% facilities and amenities. This distribution is detailed across the 21 buildings, as illustrated in fig.5.3 [58].

Planned distribution table across the portfolio and by building/cluster

Programme	Office	Housing	Shops/Amenities
Total %	**70%**	**25%**	**5%**
ILOT 130	70%*	25%	5%
J 54	97%	-	3%
J 70	96%	-	4%
BEL 68 - TR 74	100%	-	-
SC 11	100%	-	-
LUX 46 - MON 59	32%	58%	10%
VM 18	95%	-	5%
BEL 232 - FROI 101	100%	-	-
DE MOT 24-28	-	87%	13%
PALMERSTON	-	100%	-
MADOU	70%	25%	5%
BORSCHETTE	70%	25%	5%

*excluding volumetric rebalancing (see *Table of planned volumetric redistribution over the entire portfolio*, p. 14)

Figure 5.3: The distribution of functions accross the 21 buildings of the Cityforward portfolio [58]

Through the project, they aim to promote a wide range of urban development strategies that diversify and open up the district to the public. This includes activating ground floors and creating more public spaces by implementing a vertical separation of functions. They also emphasise the importance of dedensification and renovating buildings, opting for deconstruction or demolition only when absolutely necessary [58].

5.1.4 Scenario 1

5.1.4.1 Step 1

As previously explained, the first scenario only includes the design data values available from plans and open-source databases. The section (4.5.3.2) explain the different metrics and parameters that define the initial situation. The following data are described to have a better overall overview of the project. The population density in the area is 3982.1 inhabitants per square kilometre, which is the average for the European quarter and its surroundings which counts for less than 5000 inhabitant/km^2 in the excel. To calculate the compact development of the project, it was necessary to gather the footprint data of the project. This parameter is divided into non-residential, residential, mixed-use, and other buildable areas within the block. It also counts the gross floor area (GFA) of the project which includes totals GFA for offices, amenities, and residential spaces. Detailed values for both footprint and GFA are provided in fig.5.4, which illustrates all the gathered design data from the existing site plans. This table provides a comprehensive view of the initial situation, taking into account the total number of inhabitants in the sector. The standard surface area of dwelling units was determined through a quarterly report from 2022 disclosed by the Immoweb barometer, which estimated the mean value of an apartment in the Etterbeek district to be around 111 square metres [60]. As for the functions and the mixity of the district, we counted that the district includes nine different functions: mainly facilities like healthcare, schools, cultural activities, sports, hotels, housing, offices, restaurants, and local shops. The connectivity of the district is represented by the number of nodes, which totals 87 according to the LEED standards, and the zone accessibility is classified as Zone A. In conclusion, the following table (fig.5.4) visually summarises all the gathered design data, including detailed information about the inhabitants, footprints, gross floor areas, functions, and connectivity. This data forms the basis for the initial situation assessment of the project, providing a comprehensive understanding of the existing conditions and setting the stage for further analysis.

BUILT ENVIRONMENT		
Total Land Area	922529	[m^2]
	92,25	[ha]
Population Density	< 5 000	[inhab/km^2]
Total Non-Residential buildings' Built Footpr	315582,7	[m^2]
Total Residential buildings' Built Footpri	47239,8	[m^2]
Total Mixed-Use buildings's Built Footpri	142638,7	[m^2]
Total Other buildable land Built Footpri	119289,1	[m^2]
Total Buildable Land Area (built footprint)	624750,30	[m^2]
	62,48	[ha]
Total Office's Gross Floor Are	2933514,8	[m^2]
Total Residential Gross Floor Are	422353,3	[m^2]
Total Industrial Building's Gross Floor Are	0	[m^2]
Total Amenities' Gross Floor Are	154343,8	[m^2]
Total Gross Floor Area (GFA)	3510211,90	[m^2]
Residential Percentage of Floor Are	12,03	[%]
Non-Residential Percentage of Floor Are	87,97	[%]
Mixed-Use land assigned to Residential Category	1716247,55	[m^2]
Mixed-Use land assigned to Non-Residential Category	12547622,45	[m^2]
Final Residential land area	1763487,35	[m^2]
Final Residential land area	176,35	[ha]
Final Non-Residential land area	12982494,25	[m^2]
Final Non-Residential land area	1298,25	[ha]
Standard surface of a dwelling unit in the district	111	[m^2]
Residential Density	21,58	[du / ha]
Non-Residential Density	0,88	[FAR]
Number of uses in the site perimeter	9	[-]

MOBILITY		
Number of nodes in the district followi Leed-Nd regulation	87	[Nodes]
Zone of acessibility following RRU	Zone A	[-]

Figure 5.4: Table of the initial data of the step 1 - Cityforward

5.1.5 Scenario 2

5.1.5.1 Step 1

BUILT ENVIRONMENT		
Total Land Area	922529	[m²]
	92,25	[ha]
Population Density	< 5 000	[inhab/km²]
Total Non-Residential buildings' Built Footpri	298704,7	[m²]
Total Residential buildings' Built Footpri	47239,25	[m²]
Total Mixed-Use buildings's Built Footpri	164127,7	[m²]
Total Other buildable land Built Footpri	112705,04	[m²]
Total Buildable Land Area (built footprint)	622776,69	[m²]
	62,28	[ha]
Total Office's Gross Floor Are	2904522	[m²]
Total Residential Gross Floor Are	445497,8	[m²]
Total Industrial Building's Gross Floor Are	0	[m²]
Total Amenities' Gross Floor Are	160192,1	[m²]
Total Gross Floor Area (GFA)	3510211,90	[m²]
Residential Percentage of Floor Are	12,69	[%]
Non-Residential Percentage of Floor Are	87,31	[%]
Mixed-Use land assigned to Residential Category	2083023,23	[m²]
Mixed-Use land assigned to Non-Residential Category	14329746,77	[m²]
Final Residential land area	2130262,48	[m²]
Final Residential land area	213,03	[ha]
Final Non-Residential land area	14741156,51	[m²]
Final Non-Residential land area	1474,12	[ha]
Standard surface of a dwelling unit in the district	111	[m²]
Residential Density	18,84	[du / ha]
Non-Residential Density	0,87	[FAR]
Number of uses in the site perimeter	9	[-]

MOBILITY		
Number of nodes in the district followi Leed-Nd regulation	87	[Nodes]
Zone of acessibility following RRU	Zone A	[-]

Figure 5.5: Table of the projected data of the step 2 - Cityforward

5.1.6 Step 2

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	LAND USE	
LU1	Is the project's development located within the boundaries of an existing city, suburbs, or a town, rather than in a rural underdeveloped area?	
	ANSWER	EXPLANATION
	Yes	The development of the project is located within the boundaries of an existing city, specifically in the city centre of Brussels, rather than in a rural underdeveloped area.
LU2	Is at least 75% of the proposed development site located on land that has been previously developed or built upon, as opposed to greenfield or undeveloped land?	
	ANSWER	EXPLANATION
	Yes	100% of the proposed development site is located on land that has been previously developed, as the project primarily involves renovation rather than development on greenfield or undeveloped land.
LU3	Does the project development prioritise the use of contaminated land and avoid the use of ecological areas? (please note that we consider soil contamination levels higher than 75% as high priority, levels between 50 – 75% as medium-high priority, and levels below 50% as low priority)	
	ANSWER	EXPLANATION
	Yes	The project development prioritises the use of contaminated land and avoids ecological areas.
LU4	Does the project development include a plan to address any environmental contamination or issues on the site prior to the start of construction?	
	ANSWER	EXPLANATION
	No	No consideration is given to the development of contamination within the scope of the project.
LU5	Does the project development include specific measures to protect existing ecological areas (such as wetlands, forests, or wildlife habitats) and plans to enhance the site's green spaces through landscaping, planting native species, or creating new green areas?	
	ANSWER	EXPLANATION
	Yes	The project aims to achieve a certain level of "greenification" of the district and is willing to de-densify the inner blocks, incorporate green roofs, and minimise the use of minerals as much as possible.

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	SMART LOCATION	
QUESTION	Select one strategy	
	ANSWER	EXPLANATION
	Strategy 5	The project has access to water, is located on a previously developed infill site, and allocates space to implement strategies from Category B, including "Transit Corridor" and "Accessibility to Mixed Uses."

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	FLEXIBILITY	
FLEX 1	Is temporary or transitory use possible for this building or site?	
	ANSWER	EXPLANATION
	Yes	The project promotes the temporary use of vacant spaces, allowing for the temporary occupation of vacant office spaces to test programs for final development and potential maintenance when space allows.
FLEX 2	Is future adaptability possible for this building and/or site?	
	ANSWER	EXPLANATION
	Yes	The project aims to promote adaptability by designing construction elements and buildings with technical and spatial flexibility. This will make it easier to reuse or repurpose them in the future.

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	MIXED USE	
MIX 1	Does any single function dominate the functional distribution in the district, accounting for significantly more than the other functions?	
	ANSWER	EXPLANATION
	Yes	Despite the project's goal to introduce more housing in the district, only 30% of the project is allocated to housing and amenities combined - 25% for housing and 5% for amenities. This means that the remaining 70% is designated for office use, creating an imbalance and maintaining a monofunctional approach.

CATEGORY	MOBILITY	
CRITERIA	TRANSPORT MODES & TRANSIT FACILITIES	
TMF 1	Is there a comprehensive mobility strategy in the project that aims to reduce the use of motorised vehicles and promote non-motorised (soft) mobility practices?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered.
TMF 2	Is there a comprehensive parking strategy that includes optimising spaces to support soft mobility, and providing sufficient bike parking space or flexible parking infrastructure?	
	ANSWER	**EXPLANATION**
	Yes	The project aims to optimize underutilised spaces, including converting underground parking for commercial use and reducing parking spaces in line with public transport accessibility.
TMF 3	Is shared transportation available and/or actively promoted within the project area, along with multiple self-service soft mobility options?	
	ANSWER	**EXPLANATION**
	Yes	The project is located in RRU's Zone A. It is the most connected area with plenty of sharing transport options.
TMF 4	Is there a strategy to improve infrastructure and connectivity to support sustainable transportation options, such as cycling lanes and pedestrian pathways?	
	ANSWER	**EXPLANATION**
	Yes	The project aims to enhance infrastructure and connectivity for sustainable transportation by creating a passageway within the Block 130 complex, linking Rue de la Loi to Rue Joseph II and providing access to the Maelbeek Metro station. This will improve accessibility for pedestrians and cyclists.
TMF 5	Does the strategy include plans for enhancing road connections and overall infrastructure to reduce travel time and improve the efficiency of the transportation network?	
	ANSWER	**EXPLANATION**
	No	No strategy is being proposed or considered regarding the mobility infrastructure and road connections.

CATEGORY	MATERIALS	
CRITERIA	CHOICE	
QUESTION	What strategy would you use to evaluate the impact of materials in the project? Select one of the following strategies	
	ANSWER	**EXPLANATION**
	Strategy 1	The project aims to minimise building destruction by promoting maintenance, renovation, and the reuse of materials, including bio-sourced and recycled materials. It plans to retain 10 to 15% of the foundation and above-ground surfaces. Emphasising renovation over complete demolition and reconstruction, the project advocates for sustainable materials and urban mining. Given the specific data on reusing 10 to 15% of the building, we assign a Strategy 1 rating, which may vary based on project details.

CATEGORY	MATERIALS	
CRITERIA	INFORMATION & MANAGEMENT	
MNGT 1	Does the project development plan to include a strategy to implement material passports in the project?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered.
MNGT 2	Does the project development plan to implement a sustainable waste management strategy on site?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered.
MNGT 3	Does the project development plan to implement a sustainable waste management strategy off site?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered.
MNGT 4	Does the project development plan to optimise materials management on site considering factors such as space, timing, storage, delivery, and removal?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered.
MNGT 5	Does the project development plan to implement a strategy to boost local resources and good food?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered.

CATEGORY	ENERGY	
CRITERIA	ENERGY REDUCTION STRATEGY	
QUESTION	At which level does the project implement an energy strategy? Choose "yes" or "no" for any of the listed strategies you follow. If none apply, select "nd."	
ENE 1	Energy Demand Reduction : Implementation of measures to minimise the energy needs of the building	
	ANSWER	**EXPLANATION**
	Yes	They are legally required to have passive house buildings in Brussels. They proposed it in the document, stating they want energy efficiency.
ENE 2	Resource Synergy : Optimise the use of locally available resources and energy cascade such as local heat, waste heat, etc. to enhance energy efficiency.	
	ANSWER	**EXPLANATION**
	Yes	The project mentions that they seek to find different synergies to develop energy production and technical facilities.
ENE 3	Building-level Renewable Energy Supply : Supply the remaining energy needs with renewable sources at the individual building level.	
	ANSWER	**EXPLANATION**
	Yes	The project promotes sustainable development by focusing on energy, biodiversity, and water management. It includes initiatives such as solar panels, on-site water management, rainwater and greywater reuse, and green roofs. Additionally, it emphasises the careful selection of materials, colors, and the enhancement of energy efficiency to reduce the reliance on air conditioning.
ENE 4	Neighbourhood-level Renewable Energy Supply : Implementation of renewable energy solutions strategies at the neighborhood scale.	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered.
ENE 5	Smart Energy Management: Use advanced technologies to monitor and manage energy supply and usage efficiently	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered.

CATEGORY	ENERGY	
CRITERIA	RENEWABLE ENERGY PROVISION	
	Based on the district's energy needs and the intended reduction strategy, select the ratio that most closely matches the project's goal for providing renewable energy sources.	
	ANSWER	**EXPLANATION**
	nd	No strategies are being proposed or considered.

5.1.7 Results

PROJECT NAME	CITYFORWARD
LOCATION	BRUSSELS

RESULT SUMMARY				
BR-UC FRAMEWORK			SCENARIO 1	SCENARIO 2
SPATIAL DEVELOPMENT	BUILT ENVIRONMENT	POPULATION DENSITY	1	1
		BUILDING DENSITY	5	5
		LAND USE	0	4
		SMART LOCATION	0	5
		COMPACT DEVELOPMENT	0,88	0,87
		MIXED USE	2	2
		FLEXIBILITY	0	5
	MOBILITY	NETWORK	3	3
		TRANSPORT MODES & TRANSIT FACILITIES	0	3
MATERIALS & RESSROUCES	MATERIALS	CHOICE	0	1
		INFORMATION & MANAGEMENT	0	0
	ENERGY	ENERGY REDUCTION STRATEGY	0	3
		RENEWABLE ENERGY PROVISION	0	0
FINAL SCORE /20			2,77	8,27
RATING			E	C

SPIDER WEB

SCENARIO's OVERVIEW

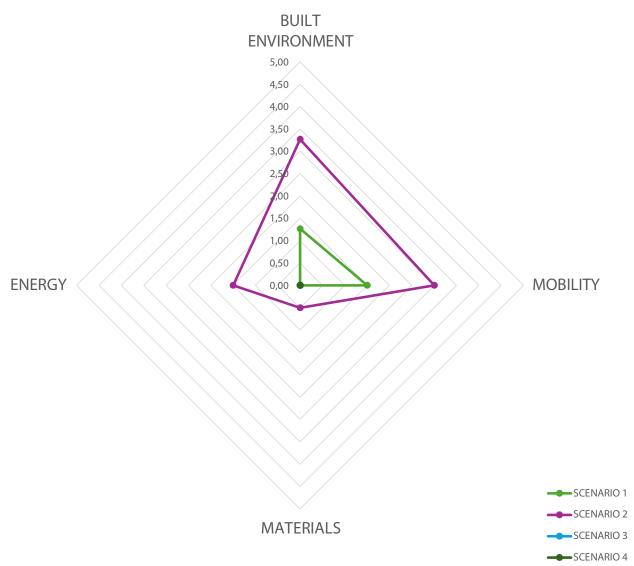

Figure 5.6: Result summary and spiderweb diagram of the Cityforward test

5.2 Buiksloterham

5.2.1 Project Description

The Buiksloterham neighbourhood in Amsterdam is poised to become a pioneering model for urban transformation with its focus on circular, smart, and biobased development. Positioned just five minutes from Amsterdam's historic centre across the IJ river, Buiksloterham stands out as a unique opportunity due to its industrial past and current status as a largely undeveloped area. This distinctive position provides the flexibility to implement innovative solutions and serve as a testing ground for new urban strategies [31].

5.2.2 Urban context

Buiksloterham is a district that is considered as an Industrial Zone housing many water-based industry buildings. This district is characterised by little to no dedicated public spaces nor practicable green spaces (see fig.5.7). Aside from the current users that are mainly workers as there are not a lot of residential space, the district is characterised by the many brownfields and wasteland which are direct consequences from the local industry. They remain inaccessible due to the contaminant coming from the industry. The existing zoning of Buiksloterham is highly monofunctional and hyper built, rendering their grounds highly impervious. The main interest and typical nature of the district is the presence of water around and within the district (see fig.5.8) [31].

Figure 5.7: Zoning - Buiksloterham - 2014 [31]

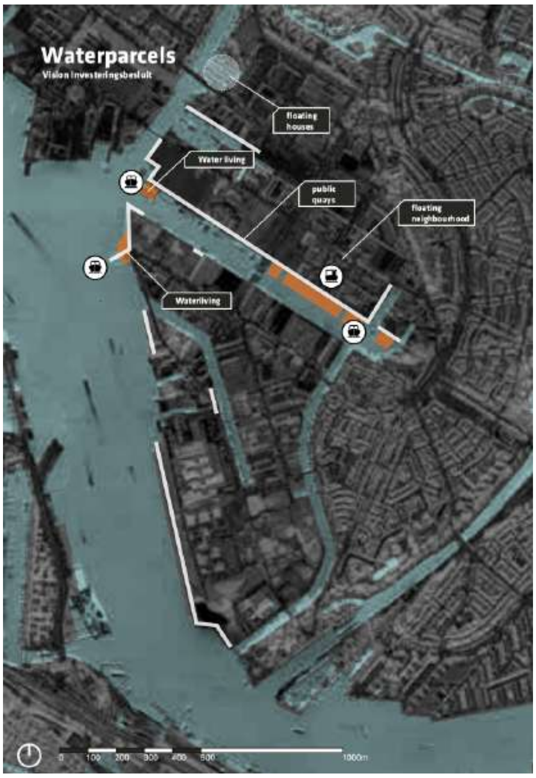

Figure 5.8: Water - Buiksloterham - 2014 [31]

5.2.3 Ambitions and Vision

Buiksloterham's overarching ambition is to function as a living laboratory for sustainable urban development. The project aims to spearhead Amsterdam's shift towards a more circular and biobased city by integrating advanced practices in resource management. The vision encompasses creating a neighbourhood that effectively manages energy, water, and nutrient cycles while minimising waste and maximising local resource use [31].

Buiksloterham's key strategies involve both systemic and technical approaches to drive its transformation into a model of circular, smart, and biobased development. Systemically, the neighbourhood will be designated as a Living Lab, fostering an environment for experimental practices and innovation. The neighbourhood intends to take a wide range of actions, including implementing strategies in the fields of energy, product and materials, water, ecosystem and biodiversity, infrastructure and mobility, socio-cultural aspects, economy, and health and wellbeing. Due to the scope of the thesis, we will only focus on the actions related to our defined design factors [31].

An inclusive governance structure will be developed to support these efforts, alongside new financial incentives and mechanisms to encourage investment and participation. Additionally, the project will establish robust urban sensing and open data infrastructure to enhance transparency and decision-making, while implementing a Circular Neighbourhood Action Plan to guide the transition [31].

On the technical front, the focus will be on achieving a fully renewable energy supply and advancing water management practices. The project will also promote alternative mobility options to reduce dependency on traditional vehicles and will use soil as a natural resource to support ecological balance and urban agriculture. A key technical goal is to close material loops, aiming to minimise waste and optimise recycling processes. Together, these strategies are designed to showcase how urban areas can evolve sustainably, demonstrating practical solutions for resource efficiency, resilience and circularity [31].

5.2.4 Scenario 1

5.2.4.1 Step 1

The data available represents the initial situation of Buiksloterham as of 2014. These data were evaluated in support of the analysis for the Buiksloterham project. This information forms a comprehensive base, offering extensive insights. In 2014, Buiksloterham, a 100-hectare district near Amsterdam's City Centre, exhibited a remarkably low population density, with just 252 inhabitants. The district encompassed a total floor area of 300 000 square metres, with 53.24 hectares comprising buildable land, encompassing wastelands, developed zones, and non-developed areas (see fig.5.7) [31].

Function-wise, the district mainly served industrial production, with an estimated gross floor area of 201 545.725 square metres. Additionally, office spaces covered approximately 42 173.275 square metres, amenities allocated 29 341 square metres, and housing accounted for 8 980 square metres of total floor area. The prevalent residential typology in 2014 comprised 3-storey single-family units, each with a footprint of roughly 69 square metres [31].

Notably, Buiksloterham encompassed 14 distinct functions, other than offices, industry, and housing. It presented a diverse landscape of facilities, including a concentration of second-hand and antique stores, numerous car repair businesses, garages, and other unconventional functions. Educational institutions included three traditional schools and three specialised schools, such as martial arts, dance, and cooking schools. Yet, it lacked essential facilities like supermarkets, healthcare services, elderly care amenities, clothing shops, pharmacies, and non-restaurant retail food outlets (see fig.5.9) [31].

Figure 5.9: Typology - Buiksloterham - 2014 [31]

In terms of mobility, Buiksloterham's historical identity as a water-based industrial area significantly impacted its road connectivity. The existing mobility network is relatively basic, incorporating 17 roads totaling around 6 kilometres in length, alongside 5 kilometres of cycle and footpaths. Only three charging stations, each with six charging points, are available, and the absence of car-sharing options is notable. The area is served by a single bus route from the central station, and the southern part of the neighbourhood experiences poor connectivity, with bus stops situated more than 400 metres from each other (see fig.5.10) [31].

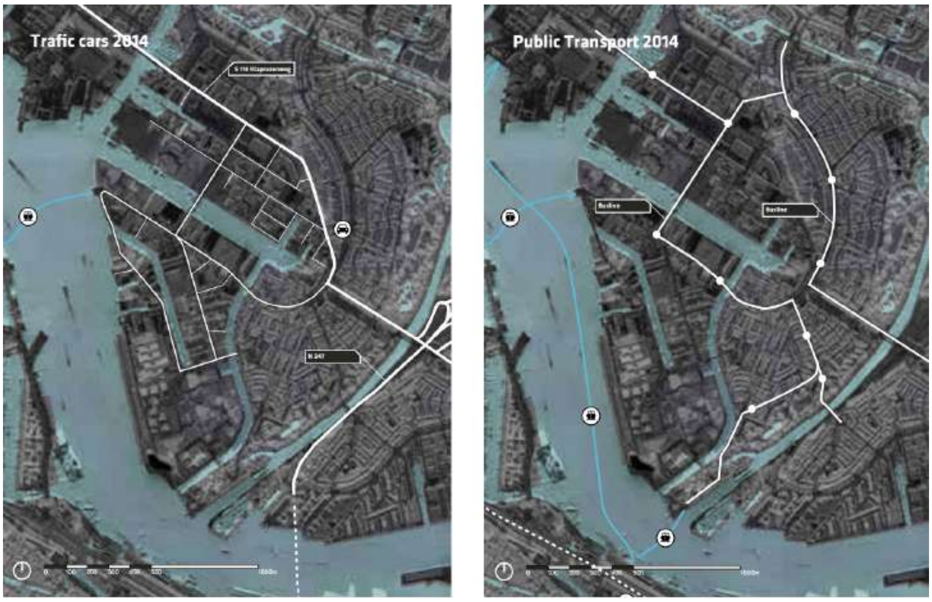

Figure 5.10: Mobility - Buiksloterham - 2014 [31]

BUILT ENVIRONMENT		
Total Land Area	1000000	[m²]
	100,00	[ha]
Population Density	< 5 000	[inhab/km²]
Total Non-Residential buildings' Built Footpr	400000	[m²]
Total Residential buildings' Built Footpri	8980	[m²]
Total Mixed-Use buildings's Built Footpri	0	[m²]
Total Other buildable land Built Footpri	177535	[m²]
Total Buildable Land Area (built footprint)	586515,00	[m²]
	58,65	[ha]
Total Office's Gross Floor Are	42173,275	[m²]
Total Residential Gross Floor Are	26940	[m²]
Total Industrial Building's Gross Floor Are	201545,725	[m²]
Total Amenities' Gross Floor Are	29341	[m²]
Total Gross Floor Area (GFA)	300000,00	[m²]
Residential Percentage of Floor Are	8,98	[%]
Non-Residential Percentage of Floor Are	91,02	[%]
Mixed-Use land assigned to Residential Category	0,00	[m²]
Mixed-Use land assigned to Non-Residential Category	0,00	[m²]
Final Residential land area	8980,00	[m²]
Final Residential land area	0,90	[ha]
Final Non-Residential land area	577535,00	[m²]
Final Non-Residential land area	57,75	[ha]
Standard surface of a dwelling unit in the district	207	[m²]
Residential Density	144,93	[du / ha
Non-Residential Density	0,91	[FAR]
Number of uses in the site perimeter	17	[-]

MOBILITY		
Number of nodes in the district followi Leed-Nd regulation	85	[Nodes]
Zone of acessibility following RRU	Zone C	[-]

Figure 5.11: Table of the initial data of the step 1 - Buiksloterham

5.2.5 Scenario 2

5.2.5.1 Step 1

By 2034, Buiksloterham will have undergone a significant transformation, guided by an ambitious sustainability policy and development approach. The primary goal is to enhance waste and emissions reductions, cut energy and water consumption, boost biodiversity, and improve social and community cohesion and health. These early-set goals will enable the municipality to establish clear sustainability targets and direct development efforts toward achieving these objectives.

The neighbourhood's population is projected to grow substantially from 252 to 6 429 inhabitants, while the workforce will increase from 4 660 to 17 700 workers. The gross floor area (GFA) will expand to 1 000 000 square metres, with an equal split between residential and working spaces—500 000 square metres each. This development will be complemented by a comprehensive strategy for mobility and recreational facilities, incorporating water-based amenities (see fig.5.12) [31].

Figure 5.12: Zoning - Buiksloterham - 2034 [31]

To accommodate the rising population density of 6 500 residents and an additional 8 000 workers, Buiksloterham will see a 30% increase in road infrastructure, expanding from the current 17 roads totalling 6.1 kilometres (see fig.5.13). Major access roads will be widened from a 2x1 lane to a 2x2 lane configuration to manage increased traffic. The network for bicycles will be significantly enhanced, with provisions for at least one bike parking space for every 25 square metres of housing (see fig.5.14). Because of this, we assume that the connectivity will increase by 30% and thus we assume that we will have around 110 nodes in total in the future [31].

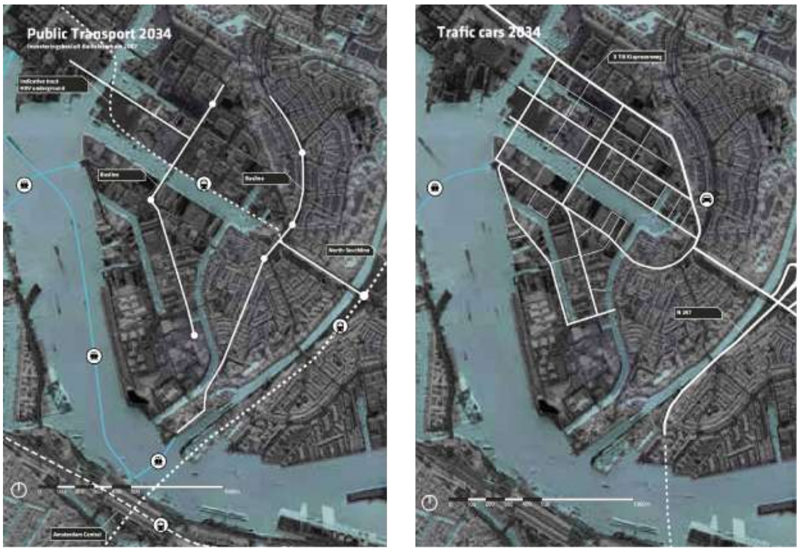

Figure 5.13: Mobility - Buiksloterham - 2034 [31]

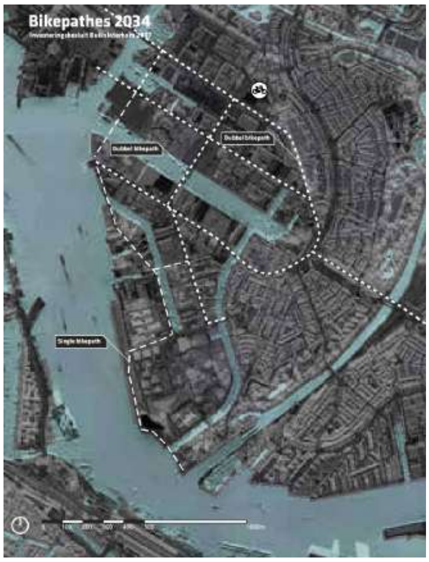

Figure 5.14: Mobility of bikes - Buiksloterham - 2034 [31]

Commercial space will be developed, with 7 200 square metres designated for this purpose. Although the total number of parking spots will remain at 6 000 due to parking policies, improvements in public transportation are planned. These improvements will include better connections between bus services and ferries, with all residential areas within a 400-metre radius of access points (see fig.5.15) [31].

Figure 5.15: Typology - Buiksloterham - 2034 [31]

Infrastructure upgrades will include a mix of systems for drinking water, wastewater, electricity, and gas, alongside the creation of a heat district network, a waste-to-energy plant, and an integrated water network. Buiksloterham will be utilised as a testbed for innovations in the water cycle, focusing on energy, water, and nutrient management. A continuous green link will be established, connecting Klaprozenscheg with the broader Amsterdam North area, further enhancing the neighbourhood's sustainability and integration into the city's fabric [31].

BUILT ENVIRONMENT		
Total Land Area	1000000	[m²]
	100,00	[ha]
Population Density	5 000 - 8 000	[inhab/km²]
Total Non-Residential buildings' Built Footpr	286643	[m²]
Total Residential buildings' Built Footpri	8980	[m²]
Total Mixed-Use buildings's Built Footpri	237313	[m²]
Total Other buildable land Built Footpri	0	[m²]
Total Buildable Land Area (built footprint)	532936,00	[m²]
	53,29	[ha]
Total Office's Gross Floor Are	542173,27	[m²]
Total Residential Gross Floor Are	526940	[m²]
Total Industrial Building's Gross Floor Are	201545,725	[m²]
Total Amenities' Gross Floor Are	36541	[m²]
Total Gross Floor Area (GFA)	1307200,00	[m²]
Residential Percentage of Floor Are	40,31	[%]
Non-Residential Percentage of Floor Are	59,69	[%]
Mixed-Use land assigned to Residential Category	9566226,49	[m²]
Mixed-Use land assigned to Non-Residential Category	14165073,51	[m²]
Final Residential land area	9575206,49	[m²]
Final Residential land area	957,52	[ha]
Final Non-Residential land area	14451716,51	[m²]
Final Non-Residential land area	1445,17	[ha]
Standard surface of a dwelling unit in the district	83,7	[m²]
Residential Density	6,57	[du / ha
Non-Residential Density	0,60	[FAR]
Number of uses in the site perimeter	18	[-]

MOBILITY		
Number of nodes in the district followi Leed-Nd regulation	110,5	[Nodes]
Zone of acessibility following RRU	Zone C	[-]

Figure 5.16: Table of the projected data of the step 2 - Buiksloterham

5.2.6 Step 2

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	LAND USE	
LU1	Is the project's development located within the boundaries of an existing city, suburbs, or a town, rather than in a rural underdeveloped area?	
	ANSWER	**EXPLANATION**
	Yes	The development of the project is located within the boundaries of an existing city, specifically near the city center of Amsterdam, rather than in a rural area.
LU2	Is at least 75% of the proposed development site located on land that has been previously developed or built upon, as opposed to greenfield or undeveloped land?	
	ANSWER	**EXPLANATION**
	Yes	Over the total buildable land, 70% of the project is being built on existing developed land. The remaining 30% of the project site is on industrial wasteland.
LU3	Does the project development prioritise the use of contaminated land and avoid the use of ecological areas? (please note that we consider soil contamination levels higher than 75% as high priority, levels between 50 – 75% as medium-high priority, and levels below 50% as low priority).	
	ANSWER	**EXPLANATION**
	Yes	The industrial nature of the site has led to 80% of the land already being contaminated with immobile contaminants such as heavy metals and asbestos. Consequently, the project development prioritises the use of contaminated land while avoiding ecological areas.
LU4	Does the project development include a plan to address any environmental contamination or issues on the site prior to the start of construction?	
	ANSWER	**EXPLANATION**
	Yes	The project includes a plan to use bioremediation techniques to clean the polluted soil before construction. Additionally, the polluted areas will be temporarily used for biomass production to contribute to material and energy production while also rebuilding local biodiversity.
LU5	Does the project development include specific measures to protect existing ecological areas (such as wetlands, forests, or wildlife habitats) and plans to enhance the site's green spaces through landscaping, planting native species, or creating new green areas?	
	ANSWER	**EXPLANATION**
	Yes	In response to the current low biodiversity and the disconnection of existing green areas due to contamination, the project is aimed at developing accessible open green spots and new recreational areas around the water landscape, including the creation of a green shore along the IJ at the head of the Grasweg, through strategic landscaping and development to enhance the site's green spaces, thereby contributing to local biodiversity and providing new public recreational areas.

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	SMART LOCATION	
QUESTION	Select one strategy	
	ANSWER	**EXPLANATION**
	Strategy 5	The project has access to water, is located on a previously developed infill site, and allocates space to implement strategies from Category B, including "Transit Corridor" and "Accessibility to Mixed Uses."

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	FLEXIBILITY	
FLEX 1	Is temporary or transitory use possible for this building or site?	
	ANSWER	**EXPLANATION**
	Yes	The project promotes the temporary use of currently unused land for biomass production by growing bamboo or willow. This approach not only helps to clean polluted soil but also produces valuable fuel and building materials.
FLEX 2	Is future adaptability possible for this building and/or site?	
	ANSWER	**EXPLANATION**
	Yes	The project promotes the adoption of a flexible infrastructure plan designed to evolve and adapt over time to address the evolving needs of society. It emphasises the importance of incorporating flexibility in materials, buildings, and construction methods, as well as in economic and governance aspects. This involves zoning real estate assets to be economically adaptable based on current needs and market conditions, as well as developing building systems that enable adaptability.
CATEGORY	BUILT ENVIRONMENT	
CRITERIA	MIXED USE	
MIX 1	Does any single function dominate the functional distribution in the district, accounting for significantly more than the other functions?	
	ANSWER	**EXPLANATION**
	No	The new layout offers a diverse range of functions, with a decreased focus on industrial functions and a more even distribution of residential, commercial, and industrial spaces. The new breakdown consists of approximately 40% for both housing and offices, 15% for industrial spaces, and 3% for amenities.

CATEGORY	MOBILITY	
CRITERIA	TRANSPORT MODES & TRANSIT FACILITIES	
TMF1	Is there a comprehensive mobility strategy in the project that aims to reduce the use of motorised vehicles and promote non-motorised (soft) mobility practices?	
	ANSWER	**EXPLANATION**
	No	Due to the district's original focus on water transport rather than automotive mobility and public transportation, adjustments are needed in the mobility plan. With an anticipated 30% increase in automotive traffic due to the growing population, the proposal involves a corresponding 30% increase in road capacity. Additionally, there is a focus on expanding bicycle access through road widening. However, it's essential to note that the current plan gives more weight to motorised transportation over non-motorised options.
TMF2	Is there a comprehensive parking strategy that includes optimizing spaces to support soft mobility, and providing sufficient bike parking space or flexible parking infrastructure?	
	ANSWER	**EXPLANATION**
	No	The project mandates at least one bike parking space per 25 square meters of residential housing, supporting cycling integration. However, the primary focus remains on traditional parking solutions, with plans to add 5,000 new spaces to the existing 6,000, despite an initial goal to cut parking by 50%. Since the bike parking provision primarily meets regulatory requirements without additional strategic measures, the project does not fully satisfy the criteria for a comprehensive and flexible parking strategy.
TMF3	Is shared transportation available or/and actively promoted within the project area, along with multiple self-service soft mobility options?	
	ANSWER	**EXPLANATION**
	No	The project aims to enhance the availability of on-demand, zero-emissions mobility through an expanded vehicle-sharing system, primarily focusing on car sharing. While this approach promotes shared transportation and contributes to the circular economy, it remains predominantly within motorised transport spectrum. To achieve a more circular and sustainable neighborhood, soft mobility options should be given greater emphasis. Given the project's current focus and the strict requirements for soft mobility, it is concluded that the proposed measures are insufficient, as they do not adequately address the balance needed for effective soft mobility integration.
TMF4	Is there a strategy to improve infrastructure and connectivity to support sustainable transportation options, such as cycling lanes and pedestrian pathways?	
	ANSWER	**EXPLANATION**
	Yes	The project encompasses a comprehensive strategy to enhance infrastructure and connectivity to support more sustainable transportation modes. In addition to widening roads to accommodate increased traffic and dedicated bicycle lanes, the strategy includes plans to improve public transportation through better integration of bus and ferry services. This will ensure that all areas are within 400 meters of accessible transport points. Furthermore, the project aims to extend public transportation infrastructure over water using fossil fuel-free technologies, thereby advancing the overall sustainability of the transportation network.
TMF5	Does the strategy include plans for enhancing road connections and overall infrastructure to reduce travel time and improve the efficiency of the transportation network?	
	ANSWER	**EXPLANATION**
	Yes	The strategy includes plans to enhance road connections and overall infrastructure to improve transportation efficiency and thus reduce travel time. Key measures involve widening the major access road from a single lane in each direction to a dual lane configuration, expanding the road network by 30% from the current 17 roads totaling 6.1 kilometres. It also includes creating strategic bike paths linking Buiksloterham to the new Noord-Zuid Metro line and extending public transport infrastructure over water using fossil fuel-free methods. These initiatives collectively aim to streamline traffic flow and enhance connectivity within the transportation network

CATEGORY	MATERIALS	
CRITERIA	CHOICE	
QUESTION	What strategy would you use to evaluate the impact of materials in the project? Select one of the following strategies	
	ANSWER	**EXPLANATION**
	Strategy 5	The project plan aims to retrofit at least 75% of existing buildings using innovative financing options and Dutch tax deductions covering up to 41.5% of investment costs. It promotes design for disassembly, adaptability, flexibility and the use of ecological materials. Key interventions include designing for reuse, substituting concrete with reusable materials, and using recovered components. Material passports and BIM systems will optimize design and record material properties. The plan targets near-full material recovery (99%) for new buildings and promotes circular construction practices, with a focus on local, recycled, and ecological materials, including bamboo flooring. New buildings will be designed for near-total material recovery, making Buiksloterham a model for circular building principles.

CATEGORY	MATERIALS	
CRITERIA	INFORMATION & MANAGEMENT	
MNGT 1	Does the project development plan to include a strategy to implement material passports in the project?	
	ANSWER	**EXPLANATION**
	Yes	The project plans to introduce material passports to record material properties and origin for the new buildings to reduce material flow.
MNGT 2	Does the project development plan to implement a sustainable waste management strategy on site?	
	ANSWER	**EXPLANATION**
	No	The project plans to implement a waste separation system to enhance the quality of waste streams, addressing to the broader concept of the entire neighbourhood but does not provide specifications for the construction sector.
MNGT 3	Does the project development plan to implement a sustainable waste management strategy off site?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered for that category.
MNGT 4	Does the project development plan to optimize materials management on site considering factors such as space, timing, storage, delivery, and removal?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered for that category.
MNGT 5	Does the project development plan to implement a strategy to boost local resources and good food?	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered for that category.

CATEGORY	ENERGY	
CRITERIA	ENERGY REDUCTION STRATEGY	
QUESTION	At which level does the project implement an energy strategy? Choose "yes" or "no" for any of the listed strategies you follow. If none apply, select "nd."	
ENE 1	Energy Demand Reduction : Implementation of measures to minimise the energy needs of the building	
	ANSWER	**EXPLANATION**
	Yes	The project aims to set a standard for Climate Neutral Buildings by adhering to Passive House Standards, which can reduce heating energy demand by up to 90%. It will replace traditional heating with heat recovery ventilation systems, relying on internal heat sources and minimal secondary heating. This approach has the potential to save approximately 290 million MJ of energy, or 29% of Buiksloterham's projected energy demand for 2034.
ENE 2	Resource Synergy : Optimise the use of locally available resources and energy cascade such as local heat, waste heat, etc. to enhance energy efficiency.	
	ANSWER	**EXPLANATION**
	Yes	The project aims to optimise the use of locally available resources by integrating heat recovery systems within buildings, utilising waste heat and warm wastewater to enhance energy efficiency and reduce overall energy needs at the building level.
ENE 3	Building-level Renewable Energy Supply : Supply the remaining energy needs with renewable sources at the individual building level.	
	ANSWER	**EXPLANATION**
	Yes	The project proposes to meet remaining energy needs at the building level by implementing renewable energy strategies, including the installation of solar panels, green roofs, and an electric efficiency plan. Additionally, it aims to maximise solar daylight through the use of solar lightbulbs and skylights.
ENE 4	Neighbourhood-level Renewable Energy Supply : Implementation of renewable energy solutions strategies at the neighborhood scale.	
	ANSWER	**EXPLANATION**
	yes	The project proposes a strategy to promote the renewable energy supply at the neighbourhood level by the intention to implement a DC Smart Grid and produce energy from biomass derived from vegetation in polluted areas.
ENE 5	Smart Energy Management: Use advanced technologies to monitor and manage energy supply and usage efficiently	
	ANSWER	**EXPLANATION**
	Yes	The project promotes the integration of a smart energy management system to monitor and feedback the distribution of energy in the local smart grid.

CATEGORY	ENERGY	
CRITERIA	RENEWABLE ENERGY PROVISION	
	Based on the district's energy needs and the intended reduction strategy, select the ratio that most closely matches the project's goal for providing renewable energy sources.	
	ANSWER	**EXPLANATION**
	> 49 %	Based on the district's energy needs and the intended reduction strategy, the project aims to achieve a 100% renewable energy supply for the remaining energy demand after implementing significant reductions. Specifically, the project plans to reduce total energy demand by 60%, with local renewable energy generation covering most of the remaining needs. However, existing technologies may not fully meet up to 25% of household energy demand, highlighting the need for future exploration of emerging technologies and larger renewable energy installations. Thus, the closest matching ratio for the project's provision of renewable energy sources is 100% of the remaining energy demand.

5.2.7 Results

PROJECT NAME	BUIKSLOTERHAM
LOCATION	AMSTERDAM

RESULT SUMMARY				
BR-UC FRAMEWORK			SCENARIO 1	SCENARIO 2
SPATIAL DEVELOPMENT	BUILT ENVIRONMENT	POPULATION DENSITY	1	2
		BUILDING DENSITY	1	3
		LAND USE	0	5
		SMART LOCATION	0	5
		COMPACT DEVELOPMENT	1,36	0,00
		MIXED USE	3	4
		FLEXIBILITY	0	5
	MOBILITY	NETWORK	1	1
		TRANSPORT MODES & TRANSIT FACILITIES	0	2
MATERIALS & RESSROUCES	MATERIALS	CHOICE	0	5
		INFORMATION & MANAGEMENT	0	1
	ENERGY	ENERGY REDUCTION STRATEGY	0	5
		RENEWABLE ENERGY PROVISION	0	5
FINAL SCORE /20			1,41	12,93
RATING			E	B

SPIDER WEB

SCENARIO's OVERVIEW

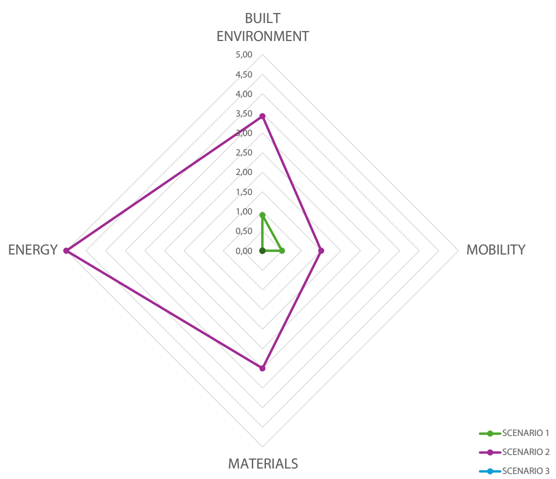

Figure 5.17: Result summary and spiderweb diagram of the Buiksloterham test

5.3 PAD Defense

5.3.1 Project Description

A PAD (Master Development Plan) is a regional urban planification tool with the aim to determine the development framework for strategic centres or neighbourhoods by defining both the vision and the guidelines for the development of the area it covers. The PAD therefore contains guidelines related to land use, building characteristics, public spaces, mobility or heritage. The PAD can contain 2 types of regulations: strategic requirements and reglementary requirements. The strategic requirements guide the authorities in the issuing of urban permits. Reglementary requirements are regulations which cannot be transgressed. The PAD aligns with and is the continuum of the Regional Sustainable Development Plan (PRDD) which constitutes the vision of the regional development on the mid and long term. More specifically, it outlines the Brussels Capital Region development project. It coordinates the different actions, initiatives, objectives or concrete projects which will permit Brussels to become a sustainable, modern and inclusive neighbourhood city in which its inhabitants can prosper. The PAD will therefore put forth its more specific objectives which are compatibles with the other strategies of the Region [61].

The Defense Project is a collaboration between Perspective Brussels, the Omgeving department of the Flemish Authorities, the Master Architects (Bouwmeester) of the Brussels and Flemish regions, Brussels Environment, the ANB, the VLM, the VMM, the Agricultural and Fishing Division, the OVAM, and the Braban Wallon Province. The objective of this mission was to develop an ambition urban landscape and ecological vision, to reinforce the network of open and green spaces in Brussels and around it. This reinforced network will house different functions and answer to the current demographic and economical changes [61].

5.3.2 Urban Context

The perimeter of the studied site is transregional. The extended studied area covers 300 hectares spread out in the Brussels Capital Region and the Flemish Region. That area comprises the restricted studied areas which are the Defense development plan situated in Brussels and the GRUP (Gewestelijke Ruimtelijk Uitvoeringplan) situated in the Flemish Region for a total surface area of 180 hectares. The Defense PAD measures 100 hectares (see fig.5.18). The Defense plot belongs to the Belgian National Defense and is located at the entry of Brussels near the National Airport of Zaventem. It is surrounded at the North by an economical zoning, on the West by the Brussels', Evere's, and Schaerbeek's cemeteries, and on the east by the Woluwe valley and a residential zone. The PRDD envisions a reconversion of this site into a new urban quarter, with a newly developed residential function, and a new tertiary axis between the European Quarter and the Zaventem Airport by implementing diverse tertiary functions, leading to an improved image of this important entry to the city. The creation of an open space between the Brussels-Capital Region and the Flemish Region as well as a new green space is also an ambition of the PRDD [61].

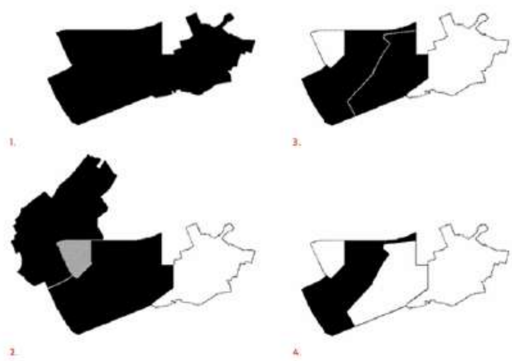

Figure 5.18: The different perimeters - 1.Extended studied area (300 hectares), 2.GRUP/Defense PAD/ Bordet PAD (375 hectares), 3.GRUP/Defense PAD (180 hectares), 4.Defense PAD (100 hectares) [61]

On the one side, the site is favoured with a rich green network made of green spaces, large open spaces, gardens, and green rail connections. In particular, the cemeteries on the west side of the site as well as the Woluwe valley are open green spaces that cover an area of 300 hectares. On the other side, the urban morphology shows a fragmented territory (see fig.5.19). The different layers of functions are juxtaposed without any real coherence between them. On the Defense studied area, there are mostly economical activities, and public equipment, and very minimal housing. Furthermore, the cemetery and the different highly frequented axes reinforce the fragmentation of the site. Very little space is given to soft mobility because the Defense site is currently inaccessible to the public. However, surrounding the site lies the regional and interregional cycling network, connecting Brussels with the Flemish Region, harbouring important bicycle highways [61].

Figure 5.19: The current urban morphology of the Defense project and its surroundings [61]

In terms of mobility, the PAD is located on the outskirts of Brussels, at the city's edge. This area has historically been underserved by public transportation, largely due to its previous use and the dominance of regional motorways. The extensive automobile infrastructure surrounding the site contributes to limited transportation options. Connectivity between the northern and southern parts of the site is particularly poor due to its former NATO function. Overall, the site initially has only 41 accessible nodes, making it the least connected of the three assessed projects to date. Nevertheless, due to its peripheral location, it offers a regional cycling road and a high-speed bike path near the TGV road. While the immediate vicinity has some public transport options, the site itself remains relatively isolated with limited public transport access (see fig.5.20) [62].

Figure 5.20: The initial situation for the mobility of the PAD Defense [62]

5.3.3 Ambitions and Vision

The main objective of this PAD is to reconnect the Defense site with the rest of the city and to articulate it in a way to:

- Integrate the project into a larger scope of vision;
- Change the site into a new mixed-use sustainable quarter housing the new general quarters for the Defense, a new metropolitan park, diverse economical activities, housing, and public equipment that answers to the needs of its inhabitants;
- Transform the Leopold II Boulevard into a new international tertiary axis by making it more diverse and revalorising it. This will in turn make the economical offer more diverse. The Defense project will be able to study the possibility of implementing mid-sized office buildings for international firms interested in the proximity of both the airport and a direct access to the city centre.

The vision of this project is :

- to develop a densified urban tissue with coherent spaces and mixed functions linking different monofunctional zones;
- to revitalise and reconnect open spaces all the while integrating ecology and circularity, to increase the visibility of vehicular circulation, to optimise the multimodal nodes and to restore the missing connections for all the users;
- to create viable quarters wherein its equipment and housing respond to the needs of its inhabitants;
- To exploit the economic potential of the site [61].

5.3.4 Scenario 1

5.3.4.1 Step 1

BUILT ENVIRONMENT		
Total Land Area	900000	[m²]
	90,00	[ha]
Population Density	< 5 000	[inhab/km²]
Total Non-Residential buildings' Built Footpri	85055	[m²]
Total Residential buildings' Built Footpri	7880	[m²]
Total Mixed-Use buildings's Built Footpri	0	[m²]
Total Other buildable land Built Footpri	0	[m²]
Total Buildable Land Area (built footprint)	92935,00	[m²]
	9,29	[ha]
Total Office's Gross Floor Are	467867	[m²]
Total Residential Gross Floor Are	43161	[m²]
Total Industrial Building's Gross Floor Are	0	[m²]
Total Amenities' Gross Floor Are	0	[m²]
Total Gross Floor Area (GFA)	511028,00	[m²]
Residential Percentage of Floor Are	8,45	[%]
Non-Residential Percentage of Floor Are	91,55	[%]
Mixed-Use land assigned to Residential Category	0,00	[m²]
Mixed-Use land assigned to Non-Residential Category	0,00	[m²]
Final Residential land area	7880,00	[m²]
Final Residential land area	0,79	[ha]
Final Non-Residential land area	85055,00	[m²]
Final Non-Residential land area	8,51	[ha]
Standard surface of a dwelling unit in the district	98	[m²]
Residential Density	558,91	[du / ha
Non-Residential Density	0,92	[FAR]
Number of uses in the site perimeter	8	[-]

MOBILITY		
Number of nodes in the district followi Leed-Nd regulation	41	[Nodes]
Zone of acessibility following RRU	Zone C	[-]

Figure 5.21: Table of the initial data of the step 1 - PAD Defense

5.3.5 Scenario 2

5.3.5.1 Step 1

The PAD Defence project aims to redevelop the upper part of the site by focusing on existing built land while preserving the surrounding green areas. The primary objective is to concentrate construction within the already developed areas to minimise the impact on undeveloped land. Although the project plans to partially retain and renovate the iconic H building at the southern edge of the development, this building will be the sole existing structure to be kept, with only partial reuse envisaged (see fig.5.22).

In terms of functions, the development will be divided into two main zones: an urbanised quarter occupying approximately 30 hectares at the upper part of the site, and a substantial metropolitan park at the southern end. This park will encompass a total of 53.8 hectares, comprising 38.8 hectares designated for a cemetery and 15 hectares allocated for a park/forest. This extensive green space, located in the southern part of the PAD perimeter, is designed to foster social interaction and enhance biodiversity. Within the buildable zone, a green corridor and clearing will be established to provide a seamless connection between the residential areas in the north and the lush green spaces in the south.

For the urbanised quarter, the project introduces a balanced mix of uses, with 50% of the area allocated to residential purposes, 50% to commercial activities, and 3% designated for amenities (see fig.5.22). One of the superblocks in the urbanised quarter will accommodate a variety of functions, including a designated area for tertiary sector production. This area will be strategically linked to the economic zone at the edge of the site, enhancing the project's integration into the broader economic landscape and supporting sustainable urban development.

Figure 5.22: Mass plan of the projected situation of the PAD Defense [62]

The project aims to tackle sustainability issues, with the application of high standards in energy efficiency, including Zero Energy Buildings and water recovery systems. The urban fabric features an orthogonal grid with a constant 15-metre profile, providing a framework that supports high adaptability to changing economic and programmatic conditions. This grid includes generic blocks of approximately 50 x 50 metres, which offer considerable flexibility in building placement. The grid system also supports minimal car impact by preserving the interior of the neighbourhood from vehicular access and introducing a high-quality urban landscape platform. The projected building density ranges from 2 to 2.5 (see fig.5.23) [62].

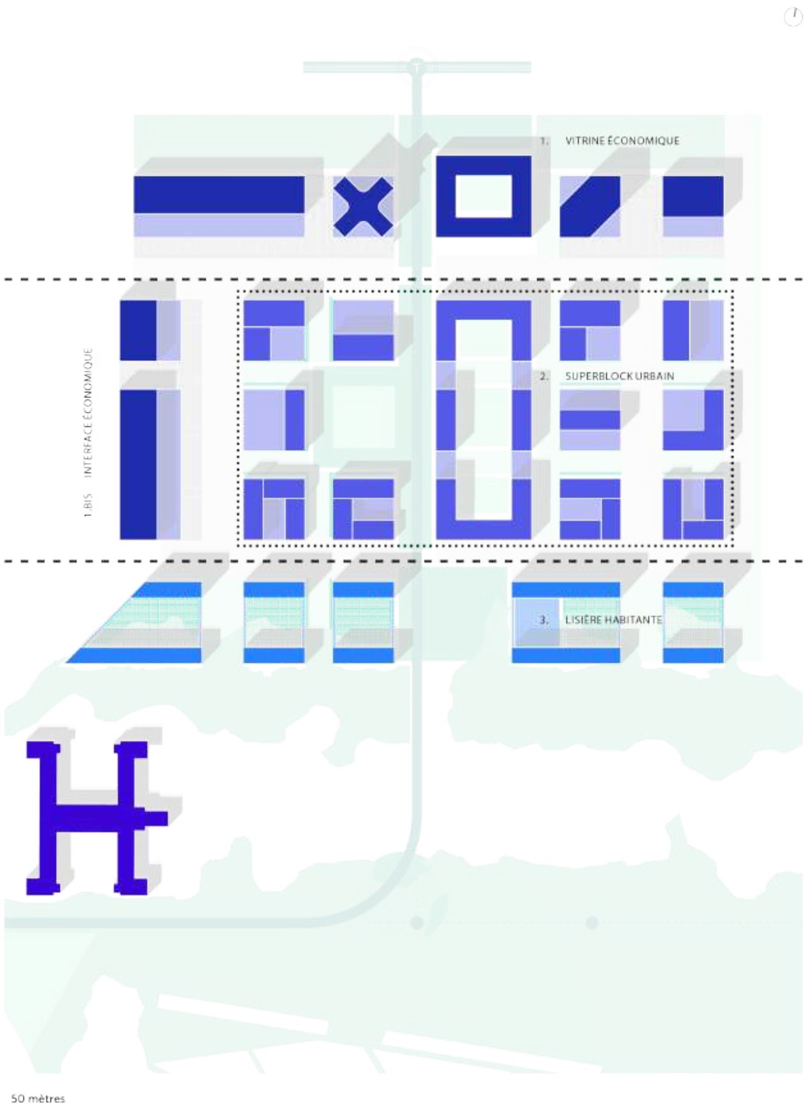

Figure 5.23: Zoning of the projected situation of the PAD Defense [62]

There is also a strategy to enhance the mobility within the perimeter as it was highly undeserved in terms of transport but also in term of connectivity, a plan is proposed focusing on increasing the use of soft mobility and will to connect the site's perimeter to the other big metropolitan entities and thus create it kind of a hub at the edge of the city to integrate this peripheral area more effectively into Brussels' broader economic landscape (see fig.5.24) [62].

Figure 5.24: Mobility in the projected situation of the PAD Defense [62]

The project aims to favour the cycling infrastructure and enhance the diversity of mobility opportunities either by sharing or by self-service systems but also improve the quality of infrastructures to make it a comfortable quarter. The project addresses the area's current inadequate road infrastructure by upgrading street and road quality to enhance accessibility, particularly for bicycles. This improvement aims to better connect the district with major metropolitan areas [62].

Finally, the PAD Defence project aspires to become a Positive Energy District (PED), a concept defined by JPI Urban Europe as an urban area or group of connected buildings characterised by high energy efficiency and flexibility [63]. A PED ensures carbon neutrality by producing no greenhouse gas emissions and generates an annual surplus of renewable energy that can be utilised locally or regionally. The project focuses on significantly reducing energy demand by constructing highly energy-efficient buildings. These buildings will feature compact, modular, and flexible designs, optimised for multipurpose use. The aim is to adhere to the highest energy efficiency standards, including the implementation of Zero Energy Buildings (ZEBs) [63].

BUILT ENVIRONMENT		
Total Land Area	900000	[m^2]
	90,00	[ha]
Population Density	< 5 000	[inhab/km^2]
Total Non-Residential buildings' Built Footpr	26719,79	[m^2]
Total Residential buildings' Built Footpri	14771,93	[m^2]
Total Mixed-Use buildings's Built Footpri	27741,45	[m^2]
Total Other buildable land Built Footpri	0	[m^2]
Total Buildable Land Area (built footprint)	69233,17	[m^2]
	6,92	[ha]
Total Office's Gross Floor Are	150000	[m^2]
Total Residential Gross Floor Are	197280	[m^2]
Total Industrial Building's Gross Floor Are	0	[m^2]
Total Amenities' Gross Floor Are	50000	[m^2]
Total Gross Floor Area (GFA)	397280,00	[m^2]
Residential Percentage of Floor Are	49,66	[%]
Non-Residential Percentage of Floor Are	50,34	[%]
Mixed-Use land assigned to Residential Category	1377575,83	[m^2]
Mixed-Use land assigned to Non-Residential Category	1396569,17	[m^2]
Final Residential land area	1392347,76	[m^2]
Final Residential land area	139,23	[ha]
Final Non-Residential land area	1423288,96	[m^2]
Final Non-Residential land area	142,33	[ha]
Standard surface of a dwelling unit in the district	98	[m^2]
Residential Density	14,46	[du / ha]
Non-Residential Density	0,50	[FAR]
Number of uses in the site perimeter	11	[-]

MOBILITY		
Number of nodes in the district followi Leed-Nd regulation	65	[Nodes]
Zone of acessibility following RRU	Zone C	[-]

Figure 5.25: Table of the projected data of the step 2 - PAD Defense

5.3.5.2 Step 2

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	LAND USE	
LU1	Is the project's development located within the boundaries of an existing city, suburbs, or a town, rather than in a rural underdeveloped area?	
	ANSWER	**EXPLANATION**
	Yes	The development of the project is located within the boundaries of an existing city, specifically at the limit of Brussels-City.
LU2	Is at least 75% of the proposed development site located on land that has been previously developed or built upon, as opposed to greenfield or undeveloped land?	
	ANSWER	**EXPLANATION**
	Yes	The entire project is being developed on existing built land, with a strong emphasis on preserving the surrounding greenfields. The focus is on concentrating construction within already developed areas to minimize the impact on undeveloped land.
LU3	Does the project development prioritise the use of contaminated land and avoid the use of ecological areas? (please note that we consider soil contamination levels higher than 75% as high priority, levels between 50 – 75% as medium-high priority, and levels below 50% as low priority).	
	ANSWER	**EXPLANATION**
	Yes	The project emphasis the use of contaminated land to avoid having to touch at the surrounding greenfields and thus disturb the ecological areas around.
LU4	Does the project development include a plan to address any environmental contamination or issues on the site prior to the start of construction?	
	ANSWER	**EXPLANATION**
	No	The project does not propose a specific strategy for addressing contamination but acknowledges the need for decontamination due to the site's previous use as a National and NATO defense headquarters.
LU5	Does the project development include specific measures to protect existing ecological areas (such as wetlands, forests, or wildlife habitats) and plans to enhance the site's green spaces through landscaping, planting native species, or creating new green areas?	
	ANSWER	**EXPLANATION**
	Yes	The PAD Defense project designates a total of 53.8 hectares as a "Green Protected Area," which includes 38.8 hectares for a cemetery with an expansive greenfield and an additional 15 hectares allocated as a park/forest. This combined green area, located in the southern part of the PAD perimeter, is aimed at fostering social interaction and promoting biodiversity. Within the buildable zone, a clearing and a green corridor will be developed to seamlessly connect the residential area in the north with the lush green spaces in the south.

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	SMART LOCATION	
QUESTION	Select one strategy	
	ANSWER	**EXPLANATION**
	Strategy 5	The project has access to water, is located on a previously developed infill site, and allocates space to implement strategies from Category B, including "Transit Corridor" and "Accessibility to Mixed Uses."

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	FLEXIBILITY	
FLEX 1	Is temporary or transitory use possible for this building or site?	
	ANSWER	**EXPLANATION**
	No	No provisions for temporary use are specified in the PAD, nor is there any information regarding potential reuse of site/building for temporary accommodation.
FLEX 2	Is future adaptability possible for this building and/or site?	
	ANSWER	**EXPLANATION**
	Yes	The project anticipates significant potential for adaptability by employing a flexible 15-meter grid framework and 50 x 50-meter blocks, which facilitate versatile building placement and adjustments. The design concept standardizes the new "living quarter" to maximize adaptability, reversibility, and compactness.

CATEGORY	BUILT ENVIRONMENT	
CRITERIA	MIXED USE	
MIX 1	Does any single function dominate the functional distribution in the district, accounting for significantly more than the other functions?	
	ANSWER	**EXPLANATION**
	No	Previously, the neighbourhood was entirely monofunctional. However, the current project introduces a balanced mix of 50% residential and 50% commercial use, with 3% allocated to amenities. This makes the project distinctly oriented towards a mixed-use approach.

CATEGORY	MOBILITY	
CRITERIA	TRANSPORT MODES & TRANSIT FACILITIES	
TMF1	Is there a comprehensive mobility strategy in the project that aims to reduce the use of motorised vehicles and promote non-motorised (soft) mobility practices?	
	ANSWER	EXPLANATION
	Yes	The project proposes a strategy to improve mobility within the Residential quarter, which previously had limited circulation due to its use as a national defense and NATO area. The new plan aims to enhance the use of soft mobility options and establish car-free zones in certain areas. The main objective is to reduce reliance on motorised vehicles while integrating this peripheral area into Brussels' economic landscape. To achieve this, the project plans to introduce new tram and bus lines, connect to the new Metro Line 3, and develop a bicycle RER network.
TMF2	Is there a comprehensive parking strategy that includes optimizing spaces to support soft mobility, and providing sufficient bike parking space or flexible parking infrastructure?	
	ANSWER	EXPLANATION
	Yes	The current PAD area lacks adequate soft-mobility parking and is primarily served by motorised vehicle parking due to the surrounding urban context. However, the project proposes a flexible parking strategy, introducing a reversible, mixed-use parking system that can adapt based on demand. With the introduction of a car-free area and proximity to a nearby bicycle RER, the bike parking strategy is integrated with the overall soft-mobility plan
TMF3	Is shared transportation available or/and actively promoted within the project area, along with multiple self-service soft mobility options?	
	ANSWER	EXPLANATION
	Yes	The project plans to introduce at least two 'mobi-punt' stations within the PAD perimeter to create a diverse range of transportation options. Additionally, they aim to implement a mobi-punt outside the PAD perimeter. A mobi-punt is a neighborhood-level transport hub where various sustainable and shared transportation modes are interconnected. To establish a mobi-punt, essential components include a car-sharing system and self-service bicycle storage. The project also aims to introduce zones for car-sharing and sufficient quantities of two-wheeled vehicle options within the district.
TMF4	Is there a strategy to improve infrastructure and connectivity to support sustainable transportation options, such as cycling lanes and pedestrian pathways?	
	ANSWER	EXPLANATION
	Yes	Due to the district's previous use, the area suffers from poor road infrastructure and accessibility. However, there are plans to improve street and road quality to enhance accessibility for bicycles, with the goal of better integrating the site and connecting it to major metropolitan areas. The project also includes the creation of dedicated bicycle paths within the district and the establishment of two car-free axes.
TMF5	Does the strategy include plans for enhancing road connections and overall infrastructure to reduce travel time and improve the efficiency of the transportation network?	
	ANSWER	EXPLANATION
	Yes	Currently, the district is poorly served by public transport due to its previous use, with services limited to the site's edge. The mobility plan aims to reduce travel time and connect the district to major areas of Brussels. With the Bordet hub and train station at the edge of the PAD, the plan includes integrating the existing transport network with the PAD perimeter. This will involve extending a new metro line, expanding two existing tram lines, and introducing bus routes deep into the district.

CATEGORY	MATERIALS	
CRITERIA	CHOICE	
QUESTION	What strategy would you use to evaluate the impact of materials in the project? Select one of the following strategies	
	ANSWER	**EXPLANATION**
	Strategy 0	Despite the existing infrastructure in the upper part of the PAD where the new residential quarter will be developed, the only mention of building maintenance or reuse is about the iconic H building at the south edge of the quarter, which they plan to partially reuse. Given that the total Gross Floor Area (GFA) of the site is 654 448.5 square meters, retaining 100% of the H building would account for only 5.1% of the total area, falling short of the required 10%. Furthermore, there is no strategy outlined for either reusing or dismantling buildings to promote a more circular approach to construction within the district.

CATEGORY	MATERIALS	
CRITERIA	INFORMATION & MANAGEMENT	
MNGT 1	Does the project development plan to include a strategy to implement material passports in the project?	
	ANSWER	**EXPLANATION**
	Nd	The project does not specify any strategies related to materials.
MNGT 2	Does the project development plan to implement a sustainable waste management strategy on site?	
	ANSWER	**EXPLANATION**
	Nd	The project does not specify any strategies related to materials.
MNGT 3	Does the project development plan to implement a sustainable waste management strategy off site?	
	ANSWER	**EXPLANATION**
	Nd	The project does not specify any strategies related to materials.
MNGT 4	Does the project development plan to optimize materials management on site considering factors such as space, timing, storage, delivery, and removal?	
	ANSWER	**EXPLANATION**
	Nd	The project does not specify any strategies related to materials.
MNGT 5	Does the project development plan to implement a strategy to boost local resources and good food?	
	ANSWER	**EXPLANATION**
	Yes	In the GRUP/PAD project, which is an extensive initiative connecting the GRUP area in the Flemish region to the PAD perimeter, they plan to introduce a landscaped zone for agroforestry. This semi-natural green space will support agricultural production on-site, managed in an environmentally respectful manner. Potential agroforestry areas are indicated on the landscape strategy plan, aiming to establish a sustainable and resilient agricultural model that aligns with soil, water, biodiversity, and quality of life protection. Additionally, the urban superblock will include various functions, with a designated area for tertiary sector production connected to the economic area at the edge of the site.

CATEGORY	ENERGY	
CRITERIA	ENERGY REDUCTION STRATEGY	
QUESTION	At which level does the project implement an energy strategy? Choose "yes" or "no" for any of the listed strategies you follow. If none apply, select "nd."	
ENE 1	Energy Demand Reduction : Implementation of measures to minimise the energy needs of the building	
	ANSWER	**EXPLANATION**
	Yes	The project aims to reduce energy demand by developing highly energy-efficient buildings with compact, modular, multipurpose, and flexible infrastructure. The goal is to achieve the highest standards of energy efficiency through Zero Energy Buildings.
ENE 2	Resource Synergy : Optimise the use of locally available resources and energy cascade such as local heat, waste heat, etc. to enhance energy efficiency.	
	ANSWER	**EXPLANATION**
	Yes	The project aims to create synergies between buildings to reuse and redirect heat losses from functions such as ventilation systems, cooling towers, data centers, and waste heat. The goal is to reintroduce this heat into the energy cycle by integrating functions in vertical layers.
ENE 3	Building-level Renewable Energy Supply : Supply the remaining energy needs with renewable sources at the individual building level.	
	ANSWER	**EXPLANATION**
	Yes	The project aims to fulfill energy needs by implementing energy production strategies at the building level, including photovoltaic panels, heat pumps, and geothermal applications, in order to address the demand through renewable methods.
ENE 4	Neighbourhood-level Renewable Energy Supply : Implementation of renewable energy solutions strategies at the neighborhood scale.	
	ANSWER	**EXPLANATION**
	Yes	Although some building-level strategies are proposed, the project primarily emphasizes collective energy production through wind power, heat networks, communal cogeneration, and the reuse of waste heat from wastewater and the Evere Commune incinerator. The district aims to become a Positive Energy District, characterized by high energy efficiency and integration. he introduction of various renewable energy strategies at the district level ensures more effective energy production and accessibility
ENE 5	Smart Energy Management: Use advanced technologies to monitor and manage energy supply and usage efficiently	
	ANSWER	**EXPLANATION**
	No	No strategies are being proposed or considered for that category.

CATEGORY	ENERGY	
CRITERIA	RENEWABLE ENERGY PROVISION	
	Based on the district's energy needs and the intended reduction strategy, select the ratio that most closely matches the project's goal for providing renewable energy sources.	
	ANSWER	**EXPLANATION**
	Nd	Aside from the proposed reduction energy strategy, there was no data available to specify the exact quantity of renewable energy the district aims to achieve.

5.3.6 Results

PROJECT NAME	PAD DEFENSE
LOCATION	BRUSSELS

RESULT SUMMARY				
BR-UC FRAMEWORK			SCENARIO 1	SCENARIO 2
SPATIAL DEVELOPMENT	BUILT ENVIRONMENT	POPULATION DENSITY	1	1
		BUILDING DENSITY	1	1
		LAND USE	0	4
		SMART LOCATION	0	5
		COMPACT DEVELOPMENT	1,34	0,00
		MIXED USE	2	3
		FLEXIBILITY	0	2,5
	MOBILITY	NETWORK	1	1
		TRANSPORT MODES & TRANSIT FACILITIES	0	5
MATERIALS & RESSROUCES	MATERIALS	CHOICE	0	0
		INFORMATION & MANAGEMENT	0	1
	ENERGY	ENERGY REDUCTION STRATEGY	0	4
		RENEWABLE ENERGY PROVISION	0	0
FINAL SCORE /20			1,26	7,86
RATING			E	D

SPIDER WEB

SCENARIO's OVERVIEW

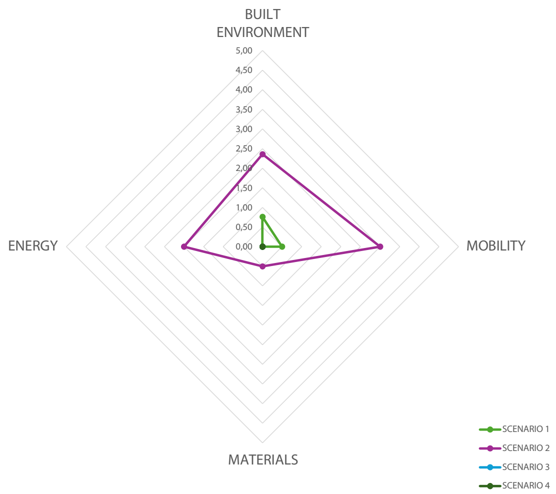

Figure 5.26: Result summary and spiderweb diagram of the Defense test

Chapter 6

Results and discussion

6.1 Critique of the case studies results

The subsequent sections will provide a comprehensive analysis of the case study results. Initially, a comparative assessment of the initial and projected scenarios will be conducted to identify project evolution. This will be followed by a detailed examination of the projected scenario, including an overview of the final score and a visual representation of the project's circularity performance. A refined analysis of each design factor will then be undertaken to understand the specific drivers of the project's overall score. Finally, the adequacy of the final grade in reflecting the project's circularity achievements will be critically evaluated.

6.1.1 Cityforward

The Cityforward project achieved a final C-level grade, categorised as "satisfactory" based on the developed framework (see fig.5.6). The initial scenario (5.1.4) yielded a total score of 2.8 out of 20 points, with relatively equal contributions from the Built Environment and Mobility factors. A comparison with the projected scenario (5.1.5) revealed no changes in scores for criteria related to Population Density, Building Density, Compact Development, Mixed Use, and Network. This indicates that while the project aimed to increase housing and diversity, it had no measurable impact on these spatial development factors. These results reveal that the project's location, rather than its specific interventions, contributed significantly to the relatively high score in the spatial development category (see fig.5.6).

In the projected scenario, Built Environment emerges as the strongest dimension with a score of 3.3/5, followed by Mobility at 3.0. In contrast, Energy and Materials exhibit lower performance at 1.5 and 0.5 respectively (see fig.6.1

On one hand, the high score for Built Environment is primarily attributed to strong performance in Building Density, Smart Location, and Flexibility criteria, each achieving the maximum score. On the other hand, Population Density and Mixed Use scored lower, contributing to the overall factor score of 3.3 out of 5. An unexpected finding is the relatively low score for Compact Development (0.9/5) despite earning a maximum score for Building Density, indicating potential inconsistencies in the data or the assessment methodology (see fig.6.1.

BUILTENVIRONMENT				SCORE /5	3,3
		Value	Score		
POPULATION DENSITY	Population density [inhab/km²]	< 5 000	1		
BUILDING DENSITY	Floor Area Ratio (FAR)	3,8050	5		
LAND USE	LU1	Yes	1		
	LU2	Yes	1		
	LU3	Yes	1		
	LU4	No	0		
	LU5	Yes	1		
SMART LOCATION	Strategy selected	Strategy 5	5		
COMPACT DEVELOPMENT	Residential density [du/ha	18,8404	0		
	Non-residential density [FAR	0,8731	1		
		Total Score	0,9		
MIXED USE	Number of uses in the site perimeter	9	2		
	MIX 1	Yes	0		
FLEXIBILITY	FLEX 1	Yes	2,5		
	FLEX 2	Yes	2,5		

MOBILITY				SCORE /5	3
		Value	Score		
NETWORK	Connectivity [Nodes]	87	0		
	Accessibility	Zone A	3		
TRANSPORT MODES & TRANSIT FACILITIES	TMTF1	No	0		
	TMTF2	Yes	1		
	TMTF3	Yes	1		
	TMTF4	Yes	1		
	TMTF5	No	0		

MATERIALS				SCORE /5	0,5
		Value	Score		
CHOICE	Selected strategy	Strategy 1	1		
INFORMATION & MANAGEMENT	MNGT 1	No	0		
	MNGT 2	No	0		
	MNGT 3	No	0		
	MNGT 4	No	0		
	MNGT 5	No	0		

ENERGY				SCORE /5	1,5
		Value	Scc		
ENERGY REDUCTION STRATEGY	STEP 1	Yes	1		
	STEP 2	Yes	1		
	STEP 3	Yes	1		
	STEP 4	No	0		
	STEP 5	No	0		
RENEWABLE ENERGY PROVISION	Selected ratio	nd	0		

Figure 6.1: Results step 3 - Cityforward

As explained previously, the project's location within a densely populated urban center contributed significantly to the overall Built Environment score, as several criteria were inherently satisfied due to the site's characteristics. However, a closer analysis reveals that the project's functional limitations have negatively impacted its performance. The neighbourhood's persistent monofunctionality, with only 25% of the development project dedicated to housing, has constrained opportunities for mixed-use development and population growth in the area. Consequently, the actual project has had a limited impact on population density and diversity in terms of our circular standards.

The Mobility factor achieved a moderate score of 3 out of 5. While the project's location within a highly accessible area contributed positively to this score, the overall impact on mobility within the densely populated city center is limited. The project's mobility-related strategies were constrained by the existing urban context (see fig.6.1. In contrast, the Materials and Energy factors scored significantly lower, with values of 0.5 and 1.5 respectively. This indicates a clear absence of dedicated strategies to address these crucial dimensions of circularity within the project (see fig.6.1).

The Cityforward project demonstrates a clear emphasis on Spatial Development, contributing significantly to its overall circularity score. However, a closer examination reveals that the project's performance is closer to the lower end of the satisfactory range than its initial C grade might suggest. While the framework's focus on Spatial Development is commendable, the limited attention given to Resources and Materials significantly impacts the overall circularity profile. The absence of comprehensive data for the Environmental Quality and People axes further complicates a precise assessment. Given the project's limited emphasis on social and environmental considerations, it is plausible that incorporating these dimensions would result in a lower overall score. This suggests that the project's alignment with broader circularity principles is questionable.

These findings highlight the need for a more nuanced grading system and potentially stricter criteria to accurately reflect the circularity performance of projects. Additionally, the inclusion of the missing axes is crucial for a comprehensive assessment of a project's sustainability.

6.1.2 Buiksloterham

The Buiksloterham project achieved a final B-level grade, categorised as "good" based on the developed framework (see fig.5.17). The initial scenario (5.2.4) yielded a total score of 1.4 out of 20 points. This score is distributed as such: 0.9/5 for the Built Environment Factor and 0.5/5 for the Mobility Factor. A comparison with the projected scenario (5.2.5) revealed significant improvements in several key areas. For instance, the Population Density, Building Density, and Mixed-Use criteria all show increased scores after the development project. However, the Network component remains unchanged, despite plans to expand road infrastructure by 30% (see fig.5.17). One notable exception is the Compact Development criterion, which decreased. This reduction suggests that the project's expansion into previously unused land led to a less compact neighbourhood. While this spread of functions might be seen as a negative in terms of circularity, it can also be justified as a necessary compromise to redevelop polluted zones. Therefore, although this outcome may seem unfavourable from a circularity perspective, it could be justified depending on the project's broader goals and needs.

Focusing solely on the projected scenario, the spiderweb diagram (see fig.5.17) provides a visual representation of the project's circularity performance across four key dimensions. Notably, the project achieved a perfect score of 5/5 in the Energy factor, highlighting a strong emphasis on this aspect of circularity. Built Environment follows with a score of 3.4/5, while Materials and Mobility scored 3/5 and 1.5/5 respectively.

When diving deeper into the scoring value, the data indicates that, in pursuit of the 2034 circularity goal, the project team prioritised energy-related strategies, implementing a comprehensive set of initiatives in this domain at the building level but also the neighbourhood level (see fig.6.2).

The second-highest scoring factor in the assessment is the Built Environment, with a final score of 3.4/5. When we break down this factor into its criteria, it is clear that the project's ambitions and development efforts are yielding positive results. Our assessment tool highlights significant key strengths in this factor including increased building density, improved land use, mixed-use functionality, and higher population density (see fig.6.2). However, while the smart location score is high due to the project's proximity to the city center, the compact development score dropped to zero, reflecting the spread-out nature of the new functions. This is not necessarily a negative outcome, but it raises questions about the assessment methodology.

In the closely scored Materials factor, the standout achievement is the strategic approach to material selection, which boosted the overall score for this category. However, the Information and Management criterion did not perform as well, which is a potential drawback. This suggests that while the project focused on material choice, it missed opportunities to strengthen the management aspects crucial for achieving a circular neighbourhood (see fig.6.2).

The final and weakest category in this project is the Mobility factor. A closer look at the criteria reveals that the neighbourhood's accessibility and connectivity are significant weaknesses. The area suffers from poorly developed public transport infrastructure and traffic issues, likely due to its industrial and water-based nature. Our framework does not account for water-based transport, which is a key aspect of this Amsterdam project, so some points may have been overlooked. Nevertheless, the initial poor transport infrastructure and the minimal interventions made were insufficient to establish a truly circular approach to the movement of goods and people (see fig.6.2).

BUILT ENVIRONMENT				SCORE /5	3,4
		Value	Score		
POPULATION DENSITY	Population density [inhab/km^2]	5 000 - 8 000	2		
BUILDING DENSITY	Floor Area Ratio (FAR)	1,3072	3		
LAND USE	LU1	Yes	1		
	LU2	Yes	1		
	LU3	Yes	1		
	LU4	Yes	1		
	LU5	Yes	1		
SMART LOCATION	Strategy selected	Strategy 5	5		
COMPACT DEVELOPMENT	Residential density [du/ha	6,5749	0		
	Non-residential density [FAF	0,5969	0		
		Total Score	0,0		
MIXED USE	Number of uses in the site perimeter	18	3		
	MIX 1	No	1		
FLEXIBILITY	FLEX 1	Yes	2,5		
	FLEX 2	Yes	2,5		

MOBILITY				SCORE /5	1,5
		Value	Score		
NETWORK	Connectivity [Nodes]	110,5	0		
	Accessibility	Zone C	1		
TRANSPORT MODES & TRANSIT FACILITIES	TMTF1	No	0		
	TMTF2	No	0		
	TMTF3	No	0		
	TMTF4	Yes	1		
	TMTF5	Yes	1		

MATERIALS				SCORE /5	3
		Value	Score		
CHOICE	Selected strategy	Strategy 5	5		
INFORMATION & MANAGEMENT	MNGT 1	Yes	1		
	MNGT 2	No	0		
	MNGT 3	No	0		
	MNGT 4	No	0		
	MNGT 5	No	0		

ENERGY				SCORE /5	5
		Value	Scc		
ENERGY REDUCTION STRATEGY	STEP 1	Yes	1		
	STEP 2	Yes	1		
	STEP 3	Yes	1		
	STEP 4	Yes	1		
	STEP 5	Yes	1		
RENEWABLE ENERGY PROVISION	Selected ratio	>49	5		

Figure 6.2: Results step 3 - Buiksloterham

In conclusion, the Buiksloterham project has made a commendable effort to address various aspects of circularity. The project received a B-level grade, which is a positive outcome in theory. However, with a score of 12.9 out of 20, it falls at the lower end of this grade range. It's important to acknowledge that the score might have been higher if two undeveloped aspects of circularity had been included, as discussed in the previous analysis chapter as they were major axis in the project developed by Metabolic [31].

Despite the 12.9/20 score, which reflects the strict nature of our assessment framework, the project is relatively well-oriented toward circularity and makes significant strides toward creating a circular neighbourhood. This underscores the framework's rigor, as it can be challenging to achieve higher scores, even for projects with strong circularity initiatives.

6.1.3 PAD Defense

The PAD Defense project achieved a final D-level grade, categorised as "in need of improvement" based on the developed framework (see fig.5.26). The initial scenario (5.3.4) yielded a total score of 1.26 out of 20 points. This score is distributed as such: 0.8/5 for the Built Environment Factor and 0.5/5 for the Mobility Factor. A comparison of the initial and projected scenarios (5.3.5) indicates limited overall improvement, with only minor changes in Mixed-Use (an increase of one point) and Compact Development (a slight decrease) (see fig.5.26). These results suggests that the project's goal to enhance the diversity of functions in the district was met, as they successfully moved away from a monofunctional design to a more balanced mix of uses. However, the building density remained largely unchanged, as the project involved rebuilding on existing land, maintaining a similar building footprint.

Regarding the "Network" criterion, despite the poor initial connectivity due to the initial site's defense-related restrictions, the final score shows no improvement in terms of connectivity in this area. This is surprising, given the significant space and strategy allocated to developing mobility infrastructure within the site when identifying qualitative matters. This outcome may indicate that the criteria used for evaluation are overly strict and may not fully capture the progress made in improving connectivity.

Focusing solely on the projected scenario, the spiderweb diagram (see fig.5.26) highlights the strengths and weaknesses of the PAD Defense project. In this case, the diagram clearly shows that the project's strongest area is the Mobility factor, with a score of 3/5, followed by the Built Environment with a score of 2.4/5. The Energy factor achieved 2/5, while the Materials factor lagged behind with just 0.5/5 (see fig.6.3).

BUILTENVIRONMENT		Value	Score	SCORE /5	2,4
POPULATION DENSITY	Population density [inhab/km²]	< 5 000	1		
BUILDING DENSITY	Floor Area Ratio (FAR)	0,4414	1		
LAND USE	LU1	Yes	1		
	LU2	Yes	1		
	LU3	Yes	1		
	LU4	No	0		
	LU5	Yes	1		
SMART LOCATION	Strategy selected	Strategy 5	5		
COMPACT DEVELOPMENT	Residential density [du/ha	14,4580	0		
	Non-residential density [FAR	0,5034	0		
		Total Score	0,0		
MIXED USE	Number of uses in the site perimeter	11	2		
	MIX 1	No	1		
FLEXIBILITY	FLEX 1	No	0		
	FLEX 2	Yes	2,5		

MOBILITY		Value	Score	SCORE /5	3
NETWORK	Connectivity [Nodes]	65	0		
	Accessibility	Zone C	1		
TRANSPORT MODES & TRANSIT FACILITIES	TMTF1	Yes	1		
	TMTF2	Yes	1		
	TMTF3	Yes	1		
	TMTF4	Yes	1		
	TMTF5	Yes	1		

MATERIALS		Value	Score	SCORE /5	0,5
CHOICE	Selected strategy	Strategy 0	0		
INFORMATION & MANAGEMENT	MNGT 1	nd	0		
	MNGT 2	nd	0		
	MNGT 3	nd	0		
	MNGT 4	nd	0		
	MNGT 5	Yes	1		

ENERGY		Value	Sco	SCORE /5	2
ENERGY REDUCTION STRATEGY	STEP 1	Yes	1		
	STEP 2	Yes	1		
	STEP 3	Yes	1		
	STEP 4	Yes	1		
	STEP 5	No	0		
RENEWABLE ENERGY PROVISION	Selected ratio	nd	0		

Figure 6.3: Results step 3 - PAD Defense

From this diagram, we can understand that the project prioritised a major aspect of the project development within a more developed circular transportation system. The design approach appears to have nearly "equally" targeted the areas of Built Environment, Energy, and Mobility, with a stronger emphasis on Mobility due to the site's peripheral location in the Brussels-Capital Region, where connectivity was a major concern. However, the diagram also reveals a missed opportunity in the area of Materials, a critical component in urban circularity. The low score in this field significantly impacted the overall project score, indicating that more attention should have been given to material & resources strategies.

When breaking down the factors into their respective criteria, we observe that in the Built Environment category, the project scores well in land use and smart location, primarily because it is situated within an already developed urban area. This makes it relatively easy to earn points in this category. However, the scores for population density, building density, and compact development are notably low. This can be attributed to the project's location on the outskirts of Brussels, where lower density is expected. While these values do not align with the strict requirements of our circularity framework, this doesn't necessarily imply poor performance; rather, it reflects the project's context within the urban fabric. The project was not intended to create a dense metropolitan area at the city's edge, which explains the lower density scores.

For the Mobility factor, the project successfully meets criteria related to various transport modes and transit facilities, indicating a well-thought-out and relatively circular mobility plan. However, the site's connectivity and accessibility within Brussels remain limited, largely due to its remote location. Although significant efforts were made to improve this factor, there is still room for further development to achieve a fully circular mobility plan following the results of the framework (see fig.6.3).

The Energy factor in this project seems only partially developed. A significant portion of the points was awarded for the project's vision to address energy efficiency and production within the district. However, while the project earned points for its broad vision, it lost points due to the lack of specific targets for renewable energy provision. Although having a vision for energy efficiency is commendable, a project that aims to produce renewable energy within its boundaries should provide concrete details and commitments. The absence of these specifics led to a lower score in this category, despite the project's stated goal of becoming a Positive Energy District (PED) neighbourhood [62].

Finally, the biggest shortfall of the project is in the Materials factor, which was largely neglected. The decision to preserve only one building from the existing structures, despite the potential to retain more, highlights a missed opportunity to incorporate major circular principles. The project's approach to materials information and management was also lacking, with no available or proposed strategies. This is particularly disappointing, as a more forward-thinking approach to construction site supervision and organisation could have been implemented since they aim to destroy almost all the existing buildings. While it might be early in the project to fully develop these plans, a mention of circular material strategies would have been beneficial. The only points earned in this factor came from the intention to manage and produce food within the site, aligning with their broader supposed circularity goals.

In conclusion, the project achieved a final score of 7.9 out of 20, placing it within the D-level category. While this score suggests a degree of progress towards circularity, it also highlights areas for substantial improvement, particularly in the Materials factor. The Built Environment and Energy factors likewise require further development to achieve a more pronounced circularity profile. Given the project's borderline performance between the D and C levels, a more comprehensive assessment incorporating the missing Environmental Quality and People axes is necessary to accurately evaluate its overall circularity performance. The inclusion of these additional dimensions could potentially influence the final grade, as the project demonstrated significant initiatives in these areas [62].

6.1.4 Framework Performance Analysis

After analysing the results of the three case studies separately, a comparative analysis will be conducted to identify commonalities, disparities, and emerging trends in their circularity performance. By examining the projects' strengths and weaknesses within the framework, valuable insights into the framework's effectiveness and potential areas for improvement can be derived. This comparative approach will contribute to a deeper understanding of the factors influencing project success and the challenges associated with achieving circularity in different urban contexts.

The comparative overview diagram (see fig.6.4) provides a visual representation of the three projects' relative circularity performance across the four key dimensions and when analysing the score values for each criterion, a nuanced analysis reveals distinct patterns and priorities among the projects.

PROJECT NAME	SUMMARY COMPARISON
LOCATION	BRUSSELS - AMSTERDAM

RESULT SUMMARY					
BRU-C FRAMEWORK			CITYFORWARD	BUIKSLOTERHAM	PAD DEFENSE
SPATIAL DEVELOPMENT	BUILT ENVIRONMENT	POPULATION DENSITY	1	2	1
		BUILDING DENSITY	5	3	1
		LAND USE	4	5	4
		SMART LOCATION	5	5	5
		COMPACT DEVELOPMENT	0,87	0,00	0,00
		MIXED USE	2	4	3
		FLEXIBILITY	5	5	2,5
	MOBILITY	NETWORK	3	1	1
		TRANSPORT MODES & TRANSIT FACILITIES	3	2	5
MATERIALS & RESSROUCES	MATERIALS	CHOICE	1	5	0
		INFORMATION & MANAGEMENT	0	1	1
	ENERGY	ENERGY REDUCTION STRATEGY	3	5	4
		RENEWABLE ENERGY PROVISION	0	5	0
FINAL SCORE /20			8,27	12,93	7,86
RATING			C	B	D

Figure 6.4: Results Summary - Comparison of the 3 case studies

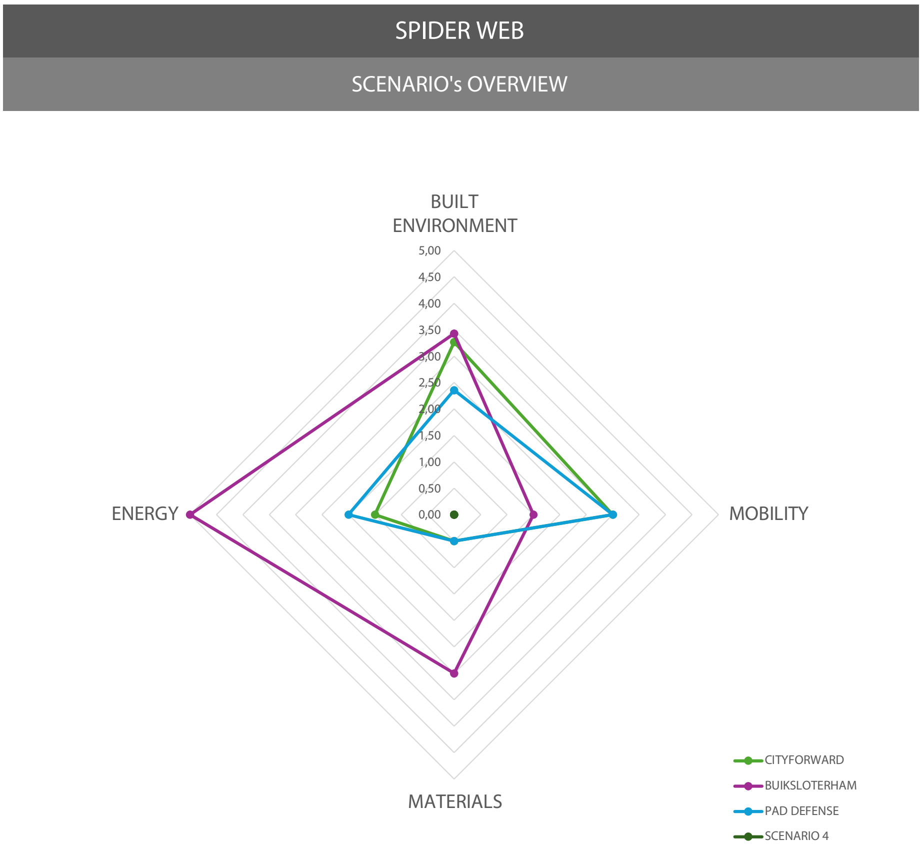

Figure 6.5: Results Spiderweb - Comparison of the 3 case studies

When focusing on the spiderweb (see fig.6.5), we are striked by the difference of zone of actions between the three project: Buiksloterham emerges as the frontrunner in terms of overall circularity, exhibiting particular strength in the Energy and Materials factors, while in contrast, the Brussels-based projects, Cityforward and PAD Defense, exhibit a more balanced circularity profile that put more emphasis into mobility strategy and the built environment. However, the results show that both Brussels-based projects share a common challenge in the Materials factor, indicating a potential gap in circular economy strategies related to resource management and waste reduction.

A comparative analysis of the case studies reveals the complex interplay between circularity strategies and urban context. The varying performance across different dimensions highlights the challenges and opportunities associated with implementing circular economy principles in diverse settings. By examining the specific actions taken in each project, we can identify key differences in approach and their implications for overall circularity outcomes. This comparative perspective prompts further investigation into the factors driving these variations.

6.2 Framework Limitation

When comparing the two Brussels-based projects together, the results revealed a surprising similarity in overall scores despite a distinct emphasis on circularity strategies. This observation prompted a deeper investigation into the framework's ability to differentiate between projects based on their specific urban contexts.

While the BRU-C framework effectively identifies core circularity principles, it operates as a generalised tool that requires user interpretation to assess feasibility within specific urban settings. As such, it serves as a foundational assessment and guiding mechanism rather than a definitive prescriptive approach tool. This limitation underscores the importance of combining the framework with in-depth knowledge of local conditions for the decision-making processes of an urban development project.

To illustrate this point, the Circular City Framework (see fig.6.6) developed by Metabolic offers valuable insights into how the location of a site influences the potential for implementing circular strategies [31].

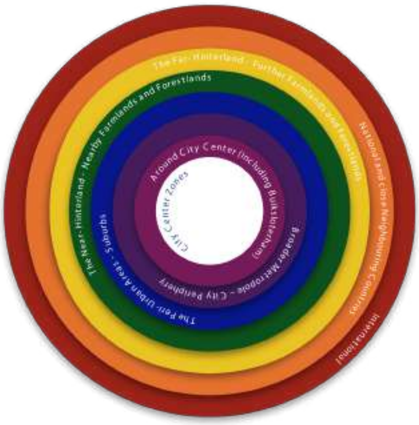

Figure 6.6: Circular City Framework [31]

By defining clear boundaries for circular strategies based on geographic context, this framework offers a nuanced understanding of how circularity can be pursued in different urban environments. While the BRU-C framework offers a valuable tool for identifying potential circular opportunities within a project, it does not explicitly define the limitations imposed by different urban contexts. The framework assumes a degree of adaptability, but it does not provide specific guidance on tailoring circular strategies to unique urban conditions.

The Circular City Framework offers a perspective on how the urban form influences circularity potential. By delineating urban areas into concentric zones, it quantifies the impact of proximity to resources and infrastructure on material flows. This approach provides a benchmark for assessing the BRU-C framework's capacity to capture the complexities of different urban settings [31].

While the BRU-C framework serves as a valuable initial assessment tool, its effectiveness is amplified when combined with a contextual analysis informed by models like the Circular City Framework. This integrated approach enables a more nuanced evaluation of a project's circularity performance, identifying both strengths and weaknesses in relation to its specific urban environment. By incorporating geographic context into the assessment process, practitioners can develop more targeted and effective circularity strategies.

Under the lens of the Circular City Framework, the Cityforward project, located in the White Zone of the Framework, encompasses the challenges and opportunities inherent to dense urban centers. While benefiting from strong accessibility and infrastructure, the project's potential for radical transformation is constrained by limited space. In alignment with the framework's recommendations, the project prioritised health, wellbeing, and energy efficiency, recognising the potential for significant gains in these areas within such a context. However, the framework's limitations became apparent in the areas of material cycle closure and mobility, where the existing urban fabric imposed significant constraints.

The high building density and established infrastructure, while offering certain advantages, hindered the project's ability to implement large-scale interventions to improve material cycles and mobility. This discrepancy highlights the need for tailored strategies that address the specific challenges posed by dense urban environments. While the project achieved some success in certain areas, the potential for greater circularity, particularly in materials management and mobility, was limited by the urban context.

The Circular City Framework's assertion that dense urban areas face greater challenges in achieving closed-loop systems is supported by the Cityforward project's experience. This emphasizes the need for innovative approaches and potentially different performance metrics for projects located in such environments.

The Buiksloterham project, situated within the Purple Zone of the Circular City Framework (see fig.6.6), occupies a transitional space between the urban core and the periphery. This location offers a unique set of opportunities and challenges for implementing circular economy principles. While sharing some characteristics of both the dense city center and the suburban fringe, this zone presents a greater degree of flexibility for experimentation and innovation. The lower population density and existing infrastructure in the Purple Zone provide a more inclined environment for testing circular strategies such as renewable energy generation, waste management systems, and material recycling within the site perimeter. The project's ability to leverage available land and resources to implement these initiatives is facilitated by the less constrained urban context compared to the city center.

However, challenges related to transportation and accessibility, common to many peri-urban areas, may require additional attention. Balancing the development of circular economy initiatives with the provision of essential services like public transportation and infrastructure will be crucial for the long-term success of the project.

The Circular City Framework's assertion that peri-urban areas offer greater potential for closed-loop systems is corroborated by the BRU-C Framework analysis of the Buiksloterham project. This project demonstrated a wider range of integrated circular strategies due to its extensive development. While the project successfully implemented means to achieve circular practices, as anticipated by the Circular City Framework, mobility challenges inherent to peri-urban areas persisted. Nonetheless, the Buiksloterham project could have further emphasized information and material management given its advantageous urban context.

The PAD Défense project is located in the Violet Zone, representing the urban periphery according to the Circular City Framework (see fig.6.6). Following the Circular City Framework theory, this location typically offers greater flexibility for implementing circular strategies due to lower density and demand. Based on the framework's assumptions, the project should have exhibited a higher potential for circularity, particularly in the areas of materials and resources [31].

However, the project's actual performance diverged from these expectations, resulting in the lowest overall score among the three case studies. While the absence of data on the Environmental Quality and People axes may have influenced the final score, the project's limited progress in materials management and resource efficiency remains a significant concern.

This discrepancy highlights the importance of considering not only geographic location but also specific project-level factors in determining circularity outcomes. While the PAD Defense project benefited from a favorable urban context, it failed to fully capitalise on the opportunities presented by its location.

The comparative analysis of the three case studies, when viewed through the lens of the Circular City Model, reveals a complex interplay between project-specific factors and broader urban context. They highlighted the need for a nuanced understanding of how geographic location shapes circularity outcomes. While the framework provides a valuable foundation for assessing circularity performance, it is evident that a one-size-fits-all approach is insufficient in well designing a circular neighbourhood. In fine, tailoring circularity strategies to specific urban contexts is essential for maximising their effectiveness.

Ultimately, achieving a high level of circularity requires a holistic approach that considers both the project-specific factors and the broader urban context. By combining the insights gained from the Circular City Framework with a detailed analysis of individual projects, it is possible to develop more effective and circular urban development strategies.

6.3 Critique of the Framework

6.3.1 Efficiency of the tool and pros and cons

The BRU-C framework we developed is the fruit of the studies done on the existing frameworks. We attempted to exploit the strengths of the frameworks and capitalise on the areas that the existing frameworks did not address. Consequently, BRU-C possesses many pros and cons. The efficiency of the tool can also be criticised in some parts.

The aim of this tool was to assist designers, urbanists and architects in the integration of circular ambitions in the design of the urban projects. It is an early-design phase tool and simulates different scenarios for comparison. Taken that into account, we accomplished the research task. Its biggest assets are that it is easy to manipulate, and because it is an early-design phase tool, it is much less data-intensive than other tools.

In terms of format, it is an advantage that the toolbox of BRU-C contains 2 supports. A carry-on that aids the clients and the designers in the decision-making process, and a technical tool that thoroughly examines design solutions. The evaluation display permits the users to observe the qualities of the project, and the tool succeeded in being a playful, pedagogical tool that compares different scenarios and solutions.

The fact that the tool helps in the decision-making process of the design of a project and aids the development of the urban project is an important pillar of the framework. The Circular Urban Scan by Metabolic was a good example of a project but it remained to global and did not assist in the development of a project (see section 3.10). The BRU-C framework distinguished itself on those aspects. Moreover, the tool was tailored to the Brussels Capital Region. In fact, we tried to adapt the inputs in the step one of the framework to Brussels' open-access data, in a way to facilitate the finding of the information for the user.

The approach we took on for this tool is a stricter mindset, with the conviction that this mentality would have a bigger impact on the long run. We aspired for our tool to be stricter and demanding in terms of circular ambitions, keeping in mind that any future project should be really impactful. This is why, for the qualitative questions, we drew the decision to only have the options to answer yes or no. The absence of options in between would force projects to engage more in their circular ambitions. Another impacting example of our mindset is the approach we had for material choices. Even if we based in on the R-Ladder [25], it seemed fundamental to us to insist on 0 destruction strategies, maintaining a maximum of the existing buildings, which are at the heart of circular practices.

The development of the BRU-C tool did come with certain weaknesses. One of them is that the framework can not assess the current stage of the site, as opposed to the Circular Urban Scan which is designed to do so. Another one is that the grading system should be modified. In our opinion, it should include variations such as B+ and B- to better situate the project in the urban circularity scale. Indeed, one of the case studies, Cityforward, obtained a grade of C, but it was at the limit of being D-graded (see section 5.1.7). The addition of plus and minus in the grades will give more precision to the assessment and the addition of excellent levels named A++ will incentivise projects to reach higher levels of circularity.

A big downside of our tool is that the existing frameworks that assess circularity implicated themselves with principles of circular economy. Because our tool had the aim of tackling urban design factors, a lot of them were intrinsically linked to sustainable factors. The BRU-C tool overall neglected the economic aspects even if some criteria are indirectly linked to economy. It also bypasses governance aspects whereas we determined it was essential to insist on the principles of frugality and responsible consumption. Some of the governance aspects are still linked to the design factors defined in the People axe.

6.3.2 What is different from the existing frameworks

The analysis of 10 nitpicked existing frameworks permitted to understand what the frameworks covers, what their approach were, what the factors and criteria they presented, and what their strengths and weaknesses were as a tool (see section 3). The different grey areas that the existing frameworks did not tackle was what we aimed to cover with the developed assessment tool. Several specificities permit our framework to distinguish itself from the other tools. But because the existing framework possess many strengths, there are also a lot of similarities.

First, the urban design factors that relay circularity ambitions are more emphasised in the BRU-C framework than most of the other frameworks. The only tool which highlighted well both sustainable design factors and circular design factors in our opinion, is the GRO tool (see sections 3.3). As a tool that assessed sustainability while integrating circular economy principles, it integrates well both towards design, but it was not engineered for neighbourhood-scaled urban projects. The BRU-C framework initiated a good attempt to do so. As a matter of fact, when examining the benchmarking of the criteria (see fig.4.7), we can have a general overview of the different types of design factors the BRU-C tool covers. The benchmarking of the criteria also demonstrates that the existing frameworks did not address a lot of factors related to built environment and urban design. The majority focused on either circular economy principles, and sometimes more specifically the circular aspects of materials and resources, but little of the urban design factors. Meanwhile, there is a clear influence of urban design factors on urban circularity. One typical example is connectivity in a city. A connected-city will facilitate the 5-minute city principle and increase local circularity. The benchmarking also permitted us to notice that a lot of social factors were mentioned in the existing tools, but their definition remained vague. We saw that as an opportunity to try out social factors in our tool which integrated more circular practices, linked to our definition of urban circularity such as responsible consumption, community-led projects and more.

In terms of structure, even if the configuration of our tool was highly inspired by the City Resilience Index's structure, we attempted to simplify the logic to a maximum. We aimed for a smaller number of criteria with the aim of making the assessment less time consuming and permit to have an accessible overview. We attempted to find middle ground between a too general tool and a too data-intensive tool.

6.3.3 Shortcomings

Because of the boundaries and timeframe of this research, we were not able to carry out the development of the framework to its final stage for the 4 axes of intervention. This research was faced with some shortcomings and limitations in the development of the criteria, in the case studies and in the development of the assessment method.

To begin, there were 4 axes of intervention: Materials and Resources, Built Environment, Environmental Quality, and People. In the case of this research, we decided to limit the development and testing of the framework to the 2 axes Material and Resources and Built Environment. For the 2 other axes, we did start to select design factors and their respected criteria via the benchmarking process, but we did not develop the methods of calculations nor test them in the case studies. As demonstrated in the discussion of the case studies, if those axes had been developed, it would have influenced the overall grade of the case studies as it would have represented more of the projects' ambitions.

To continue, during the various tests of the case studies, we concluded that there were drawbacks in some of the criteria developed. If the timeframe of the thesis was prolonged, we would have attempted to take on these limitations and retested them. The different criteria that required more work in our point of view are broken down in the next paragraphs

The Built Environment design factor revealed certain shortcomings in the Smart Location and Compact Development criteria, while also highlighting the Density criteria as a relevant factor for criticism, which will be examined in greater detail in the following paragraphs.

First, when analysing the existing framework, our analysis revealed a surprising oversight in existing frameworks: the underrepresentation of density as a critical factor in circularity (see fig.4.7). While intuitively recognised as a significant influence on various aspects of sustainable development, density has not been a criteria adequately integrated into assessment tools. Following our analysis, population density, in conjunction with building density, exerts a profound impact on a city's circular potential. Higher densities can facilitate shorter transportation distances, reduced energy consumption, and optimised land use. Furthermore, usually, dense urban environments can foster a circular economy by creating conditions conducive to waste reduction, resource sharing, and the development of local economies [31].

Despite its significance, effectively incorporating density into the assessment framework proved challenging. The limitations of existing methodologies, such as the overreliance on floor area ratios, hindered our ability to accurately capture the complex relationship between density and circularity. Furthermore, assigning equal weight to population and building density within the overall framework appears inaccurate. Given the significant variations in population and building size across different urban contexts, a fixed point system may not adequately reflect the true impact of these factors on circularity. To effectively address the complex relationship between density and circularity, further research is recommended. This could involve developing a composite density index encompassing both population and building density, or alternatively, integrating density considerations into multiple criteria. To accurately reflect the varying impact of different criteria on circularity, a weighting system should be established to assign proportional scores.

Secondly, regarding the "Smart Location" criterion, its initial formulation demonstrated a tendency to be overly permissive, particularly within the dense urban environment of Brussels. The criteria, as originally conceived, may have inadvertently rewarded projects that met minimal standards rather than truly exceptional examples of smart location principles. To enhance the effectiveness of the "Smart Location" axis, several refinements can be considered. For instance, developing context-specific indicators that reflect the unique characteristics of urban environments is crucial. This involves incorporating quantitative assessments of proximity to public transport, green spaces, and essential services. Such refinements would prevent the axis from inadvertently awarding full points to projects simply due to their location within an already developed urban area, a common characteristic of Brussels.

Thirdly, considering that the criterion of “Compact Development” is expected to achieving circularity goals. By maximising land use efficiency and promoting mixed-use development, it contributes to reduced resource consumption and waste generation. However, translating this concept into a quantifiable metric proved to be a complex task. The methodology derived from the LEED-ND framework, designed for the context of sprawling American cities, exhibited clear limitations when applied to European, and specifically Belgian, urban environments. The emphasis on residential and non-residential floor area ratios, while relevant in certain contexts, failed to capture the nuanced complexities of European urban fabric, characterised by a mix of building typologies and land use patterns.

Moreover, the calculation method, focusing on the ratio of residential and non-residential floor areas, obscured the underlying goal of assessing overall development density and mixed-use intensity. A more holistic approach that considers factors such as building height, street network configuration, and public space distribution is necessary to accurately measure compact development. To address these limitations, the following recommendations are proposed: the development of a context-specific methodology involving a new calculation method tailored to European urban characteristics. Additionally, exploring how urban form factors, such as block shape, size, and street orientation, influence compact development should be incorporated into the assessment.

The mobility factors, while providing a foundational overview of urban transportation, necessitates further refinement to comprehensively assess the complexities of contemporary mobility systems. One of the limitation is that the current methodology for assessing accessibility, primarily focused on the Brussels context, restricts the framework’s applicability to other urban environments. While the framework was initially designed for the Brussels-Capital Region, to enhance its applicability and generalisation, a more robust approach would be interesting to investigate. Developing a standardised methodology capable of evaluating accessibility across diverse urban environments is crucial for expanding the framework’s scope. This could be achieved by incorporating a variety of metrics, such as public transport coverage, typology of walking and cycling infrastructure, and time-spent to navigate in the neighbourhood. Additionally, considering accessibility from the perspective of different user groups, including the elderly, disabled, and low-income populations, would enhance the framework’s inclusivity.

The "Network" criterion, adapted from LEED-ND standards, proved to be a significant challenge when applied to the European urban context. The standardised 400-meter radius for assessing neighborhood connectivity was found to be overly restrictive, as demonstrated by the consistently low scores obtained across our case studies. This suggests a potential mismatch between the metric and the realities of European cities, where diverse urban structures and densities prevail. To rectify this, a more nuanced approach is required, involving the exploration of alternative methodologies and their application to a wider range of projects to establish a more reliable and context-sensitive assessment of network connectivity.

Considering the “Materials” factor, the material management and choice criteria present a promising foundation for assessing circularity within urban projects. By emphasizing material selection and lifecycle considerations, it effectively contributes to the overall framework. However, to fully realise its potential, several refinements are essential. In general, while the axis appropriately focuses on construction materials, a more comprehensive approach encompassing the entire material lifecycle, from extraction to end-of-life, would provide a more holistic perspective. This expansion would necessitate the inclusion of additional criteria that assess the environmental impacts of material production, transportation, and overall consumption depending on the sector.

Firstly, we observed that the "Information and Management" criterion presents some challenges during the assessment of the three projects as they are still in the early design phase. One could argue that this criterion places too much emphasis on implementation details more relevant to later stages of the design process. However, we consider this criterion essential within the context of a circular system. Despite its importance, the three projects reviewed demonstrate that such design factors are neither adequately discussed nor envisioned during the early design phase, which is crucial as it is the stage where key decisions are made.

Considering the energy factors, while providing a broad overview, could benefit from further refinement in the future. While the initial criteria and assessment methods effectively highlight energy considerations within a circularity framework, their application to diverse projects revealed a need for more detailed sub-categories encompassing various energy types and associated industries. In general, we came to the conclusion that given the quantitative nature of energy, the absence of numerical data is a limitation in this framework. While detailed and data-driven energy assessments can be considered beyond the scope of this study, developing a simplified calculation method, such as estimating solar potential based on roof area, could enrich the framework in terms of circular potential practices in the studied zone. Also, one of the shortcomings in this design factor is the focus on buildings might overshadow the energy role of other urban systems like transportation. Incorporating criteria that address these interconnections would strengthen the framework.

The Energy Reduction Strategy criterion introduces a promising concept of a hierarchy of reduction strategies, providing a valuable framework for project development. However, its current placement within the criteria is somewhat ambiguous, as it extends beyond merely establishing a hierarchy for energy reduction. To enhance clarity, dividing this criterion into separate reduction and production strategies would be beneficial, allowing for a broader and more precise application of the point system. While the hierarchy serves as a useful checklist, it is important to recognise that some strategies may align more closely with sustainability than circularity. Although sustainability is inherently linked to circularity, the current assessment approach seems more inclined to award points based on sustainable practices rather than a circular perspective.

The Renewable Energy Provision criterion, though designed to prioritise renewable supply sources, may unintentionally penalise projects with limited renewable potential. To address this, it could be beneficial to introduce a new parameter that quantifies the potential energy contribution within the site perimeter, a concept that could be explored further in future research. By refining this aspect, the energy criteria could offer a more comprehensive and nuanced assessment of energy performance in circular urban development.

When diving into the criticism of the method of assessment of the BRU-C tool, the testing of the case studies permitted us to identify an area of improvement. The grading system varying from A to E for the results is a very good measure because it provides a sense of what is good or bad. It provides a scale of reference to see how circular a project is and labels it better than a numbers and a spider web diagram. Be that as it may, the grading system does not permit one to take a step back. As demonstrated by Metabolic, there are subtleties depending on where the project is in the city, whether it is located close to the city centre or on the outskirts of the city [31]. The combination of the grading system and the spiderweb diagram provides a good visual representation of the results but does not integrate these nuances even for awareness.

To finish, with additional time, we would have like to approach the test of the case studies in another angle. Indeed, it would have been interesting to test one project with different scenarios of designs. This means that we would have tested the BRU-C framework on the purpose for which it was created. For example, the PAD Défense would have been an interesting case study to try out. In this project, their intentions were to do a tabula rasa, and reconstruct everything. Only one building is in open discussion on whether it should be kept. In our perspective, the PAD Défense was a project with a lot of potential. Therefore, we would have simulated 2 extras scenarios with different design solutions, to compare the 3 different projections.

Chapter 7

Conclusion

The city of Brussels is undergoing a significant shift towards more sustainable building practices, aligning with the broader societal transition towards circular economy principles. Originating as an economic strategy, circularity has evolved into a core concept in various domains, including building design. At its essence, circularity in building seeks to establish closed-loop systems for materials and resources, minimising waste and maximising resource efficiency. Historically, the building industry's focus on circularity has primarily centered on material flows and management. While this is a crucial aspect, it represents only a fraction of the broader circular economy framework. To address this gap, this thesis delves into the integration of circular principles within the realm of urban design. Specifically, it aims to develop a methodology for evaluating the circularity potential of urban projects during their early design stages. This research proposes to create a circular assessment framework tailored to the needs of urban planners and stakeholders in the context of the Brussels-Capital Region. The framework will enable both qualitative and quantitative analyses of urban design projects, providing a practical tool to guide decision-making towards more circular outcomes. To achieve this, the thesis explores three primary research questions:

- How can a set of design factors be selected to quantity and qualify urban circularity in an urban development project?
- How can a tool be developed to quantify and qualify urban circularity in order to assist urban designers in early-phase design?
- How can the urban circularity of a development project in the Brussels-City Region be evaluated?

By addressing these research questions, this thesis aims to contribute to the advancement of circular urban development by providing a robust and accessible framework for evaluating the circularity performance of urban projects.

As a first step, a comprehensive review of existing frameworks in the fields of sustainability, circularity, and resilience was conducted. This analysis, detailed in the "Analysis of existing frameworks" section (3), examined the structure, function, and application of these frameworks, identifying both their strengths and weaknesses. Through a meticulous comparison of the ten selected frameworks, a dataset of recurring criteria and factors was compiled. This consolidated information served as the foundation for developing a preliminary framework, incorporating the most prevalent elements identified in the benchmark.

Secondly, building upon the analysis of existing frameworks, a comparative study of assessment methodologies was undertaken to identify potential tools for quantifying and qualifying design values. To refine criteria selection and test their applicability, three case studies of urban development projects in Brussels and Amsterdam were analysed. Through an iterative process of refinement and testing, each criterion was assigned a specific assessment methodology, combining both quantitative and/or qualitative approaches to measure its impact on the framework.

Following the establishment of assessment methodologies for the identified criteria, a comprehensive assessment process was developed. The aim was to create a user-friendly tool capable of generating quantifiable results and supporting informed decision-making for urban designers. A 5-point scoring system was implemented for each assessment methodology, culminating in an overall circularity score for the project. To enhance the tool's practical application, it was designed to facilitate the comparison of multiple design strategies within a single platform. In essence, the final framework encompasses four primary axes defining circularity, divided into eight design factors and further subdivided into twenty-four assessable criteria. The resulting toolkit includes a user-friendly brochure outlining the framework and serving as a checklist for stakeholders. Additionally, an Excel-based tool enables urban planners to simulate various project scenarios and compare potential outcomes aligned with circularity goals.

While a growing body of research has explored the intersection of circular economy principles and urban design frameworks, a significant gap persists in the development of quantitative assessment methodologies for circularity at the neighbourhood scale. As cities like Brussels strive to achieve greater circularity, the demand for practical tools to guide and evaluate circularity in early-stage urban projects becomes critical. However, existing frameworks in the circular economy domain often prioritise qualitative assessments or, when quantitative, rely heavily on data-intensive approaches that may overlook non-quantifiable yet essential aspects of urban design. This overreliance on data-intensive methodologies can hinder their applicability in the early stages of project development when comprehensive data is limited.

To bridge this gap, this thesis introduces a new framework that combines qualitative and quantitative assessment methods to evaluate circularity at the urban project level. By providing a balanced approach, the framework aims to capture the multifaceted nature of circularity in urban environments, considering both tangible metrics and intangible qualities. This holistic perspective enables practitioners to make informed decisions and track progress towards circularity goals throughout the project life cycle.

Despite the innovative nature of the proposed framework, our research has identified several areas for improvement. These limitations could be addressed in future work to enhance the framework's applicability and robustness.

Firstly, due to the scope and resource constraints of this thesis, only two axes of action were fully developed in the elaboration of the framework: Spatial development and Materials&Resources. This significantly impacted the overall assessment, as half of the intended framework remained undeveloped. Consequently, the case studies results can only be considered as provisional and preliminary, as they do not comprehensively assess circularity as we defined it. The inclusion of the Environmental Quality and People axes in future research would provide a more comprehensive and accurate assessment of the circular performance of these projects.

The second limitation we faced was concerning the development of assessment criteria. As we ended up restricting the existing framework analysis to ten, many of which lacked detailed assessment methodologies suitable for direct application or transferable method in our framework. Consequently, some criteria are required to develop a new, context-specific assessment method or a more in-depth exploration of existing approaches employed in other frameworks.

A third limitation concerned the geographic scope of the study. As the research study was to elaborated a framework that enables to evaluate the circularity at the level of the neighbourhood, we applied this statement in neighbourhood of approximately 100 hectares based on a 5-minute walking distance theory. All the case studies complied to this concept in order to allow us to have a common ground to compare the results of the projects in the end. While this 5-minute walk distance neighbourhood facilitated data collection, it restricted the analysis to a specific scale of project development which lead to have assessment methodology specifically designed for this scale. The scope of this research was limited to a specific project scale, restricting the analysis to a particular development size. Consequently, the framework's applicability to smaller or larger projects remains unexplored. To broaden the framework's relevance, future studies should explore its use on different-sized projects.

A fourth limitation was the challenge of assigning appropriate weights to the framework's criteria. Given the research scope, a comprehensive methodology for determining the relative importance of each criterion could not be fully developed. To enhance the framework's precision and reliability, future research should prioritise the development of a robust weighting system. This could involve expert elicitation, statistical analysis, or other quantitative techniques to ensure that the framework accurately reflects the contribution of each criterion to overall circularity.

A final limitation lies in the restricted capacity to test the framework's application across multiple project scenarios. While a core objective was to develop a tool adaptable to assess various project stages, the absence of a real-world project undergoing multiple phases prevented a comprehensive evaluation. Although the framework's potential to support decision-making throughout a project development is evident, empirical validation through a comparative case study spanning different scenarios remains a crucial next step to comprehensively assess its effectiveness in a real-world decision-making process.

In conclusion, by integrating both qualitative and quantitative methodologies, the framework presents a valuable tool for urban planners, architects, and stakeholders to evaluate the circular performance of their project. However, while the framework is robust in its current form, there are several important avenues for future development that warrant exploration to fully maximise its potential.

While this research has made significant strides in developing a framework for assessing urban circularity, there remains substantial potential for further refinement and expansion. By addressing these areas, future research can contribute to the evolution of a more resilient, sustainable, and circular approach to urban development, ultimately supporting the creation of cities that are better equipped to meet the environmental challenges of the 21st century.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Open AI's ChatGPT and Gemini AI in order to text-editing and rewriting the text of the thesis. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

This declaration does not apply to the use of basic tools for checking grammar, spelling, references etc. If there is nothing to disclose, there is no need to add a statement.

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Appendices

A Appendix 1

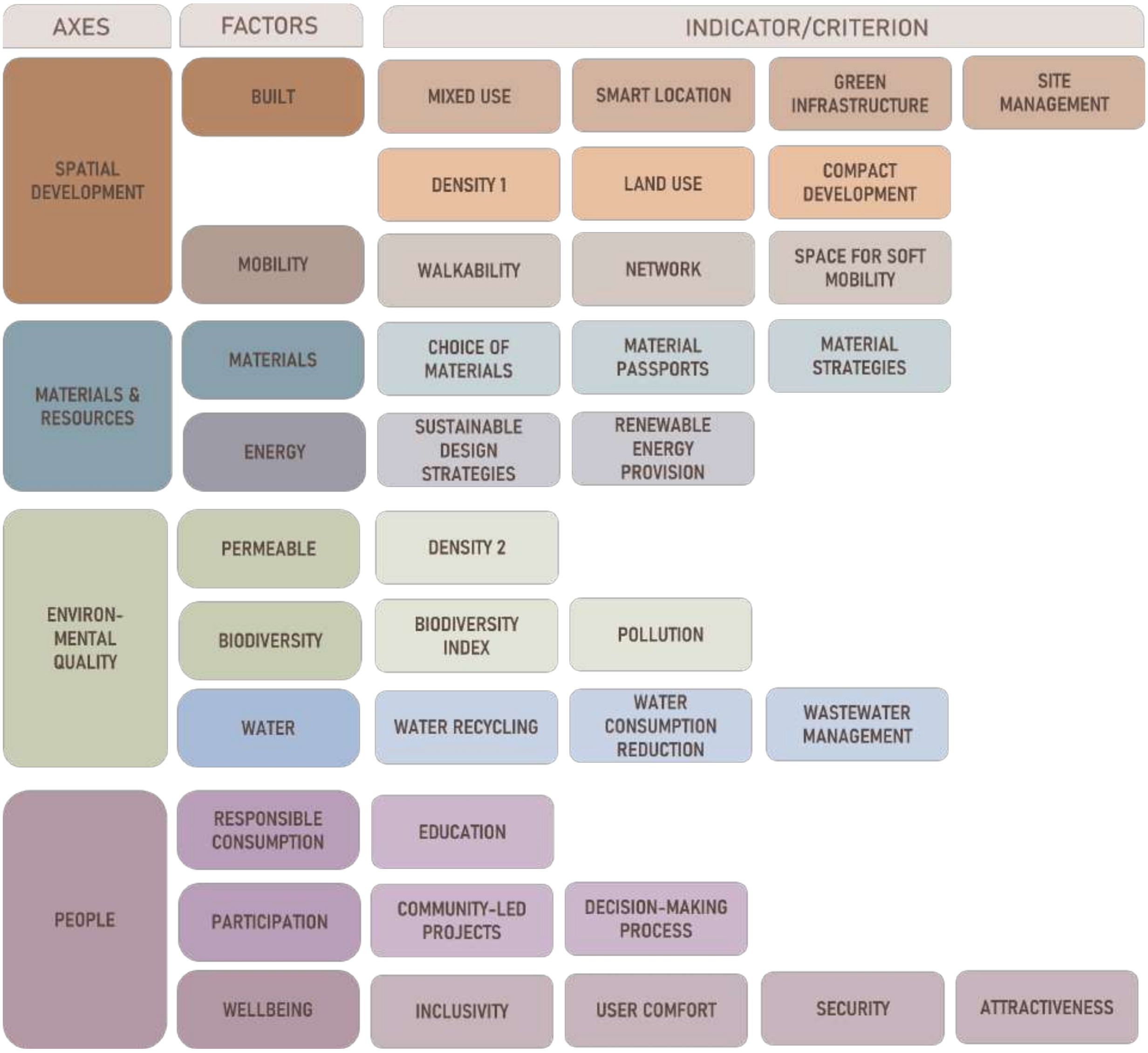


Figure 1: Preliminary Framework - Version 1.0

DATA COLLECTION			CALCULATION					
GENERAL INFORMATION	Value	Unit	Variable	Result	Unit	Point	Total	[-]
Total Land Area	1	[m²]	Population density	0	[inhabt/m²]			
Total Population		[inhabitant]	Residential density	0	[Units/m²]			
Total number of building stock		[units]	Non-Residential density	0	[Units/m²]			
Total number of housing units		[units]						
Total number of non-residential units	0	[units]						
DENSITY	Value	Unit	Variable	Result	Unit	Point	Total	0
Total gross floor area (GFA)		[m²]	Floor Area Ratio (FAR)	0	[-]		5	
LAND USE	Value	Unit	Variable	Result	Unit	Point	Total	0
Total polluted soil		[m²]	Land Use Ratio	0	[-]		4	
Total built footprint		[m²]	Polluted Land Ratio	0	[-]		1	
MIXED USE	Value	Unit	Variable	Result	Unit	Point	Total	0
Number of uses in the district		[-]	Number of uses in the district	0	[-]		4	
Total area of office building		[m²]	Office building ratio	#DIV/0!	[%]			
Total area of housing unit	0	[m²]	Housing building ratio	#DIV/0!	[%]			
Total area of retail facilities		[m²]	Retail building ratio	#DIV/0!	[%]			
Total area of industrial building		[m²]	Industrial building ratio	#DIV/0!	[%]		1	
Total area of educational facilities		[m²]	Educational facilities ratio	#DIV/0!	[%]			
Total area of cultural facilities		[m²]	Cultural facilities ratio	#DIV/0!	[%]			
Total area of healthcare facilities		[m²]	Healthcare facilities	#DIV/0!	[%]			
GREEN INFRASTRUCTURE	Value	Unit	Variable	Result	Unit	Point	Total	0
Total permeable area	1	[m²]	Green Area Ratio	100	[%]		5	
Total Non-permeable area	1	[m²]	Non-permeable area	100	[%]			
SOFT MOBILITY	Value	Unit	Variable	Result	Unit	Point	Total	0
Total Gross Circulation area	1	[m²]	Soft mobility ratio	0	[%]		5	
Total soft mobility area		[m²]						
HARD MOBILITY	Value	Unit	Variable	Result	Unit	Point	Total	0
Total building footprint		[m²]	Hard mobility ratio	100	[%]		4	
Total Hard mobility area (excluding parking spot)	1	[m²]	Total parking spot	0	[units]		1	
Number of parking spot on the street		[units]						
Number of parking spot underground		[units]						
ACCESSIBILITY	Value	Unit	Variable	Result	Unit	Point	Total	0
Zone of accessibility		[-]	Zone of accessibility	0	[-]		5	
NETWORK	Value	Unit	Variable	Result	Unit	Point	Total	0
Number of intersection nodes		[-]	Number of intersection nodes	0	[-]		5	
SUSTAINABLE DESIGN STRATEGIES	Value	Unit	Variable	Result	Unit	Point	Total	0
RENEWABLE ENERGY PROVISION	Value	Unit	Variable	Result	Unit	Point	Total	0

Figure 2: Preliminary Tool - Assessment System Part.1 Version 1.0

CHOICE	Strategy		Select a scenario		Point
REQUIREMENT	REUSE	SCENARIO 0	REQUIREMENT	NO REUSE	0
CATEGORY A	x				
	x				
	x	SCENARIO 1	REQUIREMENT	10-20% building is reused	
	x				
	x		CAT. A	X	
				X	1
CATEGORY B	x				
	x		CAT. B	X	
	x			X	
	x			X	
	x				
		SCENARIO 2	REQUIREMENT	20-30% building is reused	
			CAT. A	X	
				X	2
			CAT. B	X	
				X	
		SCENARIO 3	REQUIREMENT	30-50% building is reused	
			CAT. A	X	
				X	3
			CAT. B	X	
		SCENARIO 4	REQUIREMENT	60-70% building is reused	
			CAT. A	X	4
			CAT. B	X	
				X	
		SCENARIO 5	REQUIREMENT	70-100% building is reused	
			CAT. A or B	X	5
				X	

Figure 3: Preliminary Tool - Assessment System Part.2 Version 1.0

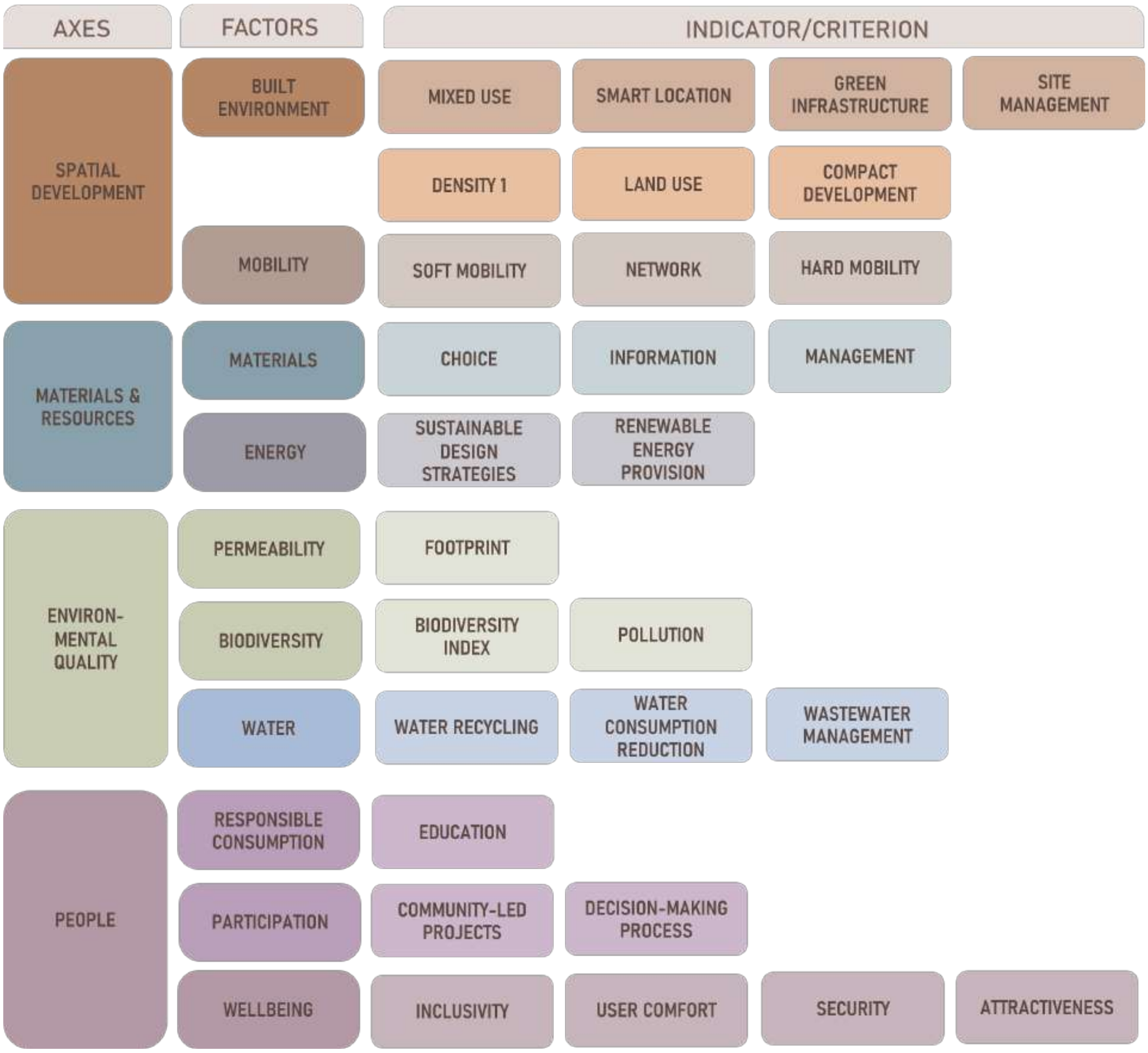


Figure 4: Preliminary Framework - Version 2.0

ID CARD	
Name	ILOT 130
Neighboorhoud	Quartier Européen
City	Bruxelles
Phase	1

DATA COLLECTION | CALCULATION

GENERAL INFORMATION	Value	Unit	Variable	Result	Unit	Point	Total [-]	Scale
Total Land Area	922529	[m²]						
Total Land Area	0,922529	[km²]	Total Population	3673,602731	[inhabtant]	Low		
Population Density	3982,1	[inhabitant/km²]	Residential density	0,792383292	[Units/m²]			
Total number of building stock	1628	[units]	Residential density	31,53285625	%			
Total number of housing units	1290	[units]	Non-Residential density	0,207616708	[Units/m²]			
Total number of non-residential units	338	[units]	Non-Residential density		%			
Total gross area of housing	1385531	m²						
Total gross floor area	4393928	m²						

DENSITY	Value	Unit	Variable	Result	Unit	Point		Total 5
Total gross floor area (GFA)	4393928	[m²]	Floor Area Ratio (FAR)	4,762915854	[-]	5	5	

LAND USE	Value	Unit	Variable	Result	Unit	Point		Total 2
Total non-polluted soil	46468,35	[m²]	Land Use Ratio	55,68357959	[%]	2	3	
Total built footprint	513697,17	[m²]	Polluted Land Ratio	94,96293883	[-]	0	2	

MIXED USE	Value	Unit	Variable	Result	Unit	Point		Total 2
Number of uses in the district	9	[-]	Number of uses in the district	9	[-]	2	4	
Total area of office building	3008397	[m²]	Office building ratio	70	[%]			
Total area of housing	1385531	[m²]	Housing building ratio	25	[%]			
Amenities		[m²]	Amenities	5	[%]			
						0	1	

GREEN INFRASTRUCTURE	Value	Unit	Variable	Result	Unit	Point		Total 0
Total permeable area (excluding green infra)	103692,2596	[m²]	Permeable ratio	11,24	[%]	0	4	
Total Non-permeable area	818836,7404	[m²]	Non-permeable ratio	88,76	[%]			
Total Green infrastructure	41178,17	[m²]	Green area ratio	4,463617946	[%]	0	1	

NETWORK	Value	Unit	Variable	Result	Unit	Point		Total 3
Number of intersection nodes	87	[-]	Number of intersection nodes	87	[-]	0	2	
Zone of accessibility	A	[-]	Zone	A		3	3	

MOBILITY	Value	Unit	Variable	Result	Unit	Point		Total 0
Total soft mobility area		[m²]	Infrastructure soft	0	[%]			
Total hard mobility area		[m²]	Infrastructure hard	0	[%]		1	
Security: road large enough for 2 bikes	No	[-]	Security	No	[-]	0	1	
On-street parking available		[-]	Parking availability	0	[-]	0	1	
Diversity of soft mobility alternatives		[-]	Presence of alternatives	0	[-]	0	1	
Strategy to enhance quality and surface of soft mobility		[-]	Enhancement strategy	0	[-]	0	1	

SUSTAINABLE DESIGN STRATEGY	Value	Unit	Variable	Result	Unit	Point		Total 2
Passive Design	A = 1	[-]	Chosen strategy	B	[-]	2	5	
Energy Efficient Building	B = 2	[-]						
Net Zero Buildings	C = 3	[-]						
Positive Energy District	D = 4	[-]						
Sustainable Plus Energy Neighborhood	E = 5	[-]						

ENERGY REDUCTION STRATEGY	Value	Unit	Variable	Result	Unit	Point		Total 3
Reduce carbon emission at building level	A = 1	[-]	Chosen strategy	A	[-]	3	5	
Reduce Carbon emission at island/block level	B = 3	[-]				D		
Reduce Carbon emission at neighborhood level	C = 5	[-]						

RENEWABLE ENERGY PROVISION	Value	Unit	Variable	Result	Unit	Point		Total 0
		[-]	Chosen strategy	A	[-]	0	5	
		[-]						

MATERIALS CHOICE	Value	Unit	Variable	Result	Unit	Point		Total 1
REQUIREMENT	REUSE	[-]	Chosen strategy	10-20% Reuse	[-]	1	5	
CATEGORY A	x	[-]						
	x	[-]						
	x	[-]						
	x	[-]						
	x	[-]						
CATEGORY B	x	[-]						
	x	[-]						
	x	[-]						
	x	[-]						
	x	[-]						

MATERIALS MANAGEMENT	Value	Unit	Variable	Result	Unit	Point		Total 1
Material passeport is applied or considered	Yes	[-]	Material passeport	Yes	[-]	0	1	
Waste management on site is applied or considered	Yes	[-]	Waste management on site	Yes	[-]	0	1	
Sustainable waste management off site is applied or considered	Yes	[-]	Waste management off site	Yes	[-]	1	1	
Optimisation of materials on site	Yes	[-]	Material optimisation	Yes	[-]	0	1	
Local Resources and good food	Yes	[-]	Local resources	Yes	[-]	0	1	

SMART LOCATION	Value	Unit	Variable	Result	Unit	Point		Total 5
Access to water	A = 0	[-]	Requirement achieved	Yes	[-]	-	-	
Previously developed site not adjacent	A 1	[-]	Chosen strategy	A 1	[-]	5	5	
Previously developed site adjacent	A 2	[-]						
Infill site who was not a previously developed	A 3	[-]						
Infill site who was a previously developed site	A 4	[-]						
Transit Corridor	A4 + B1	[-]						
Accessible to mixed uses	A4 + B2	[-]						

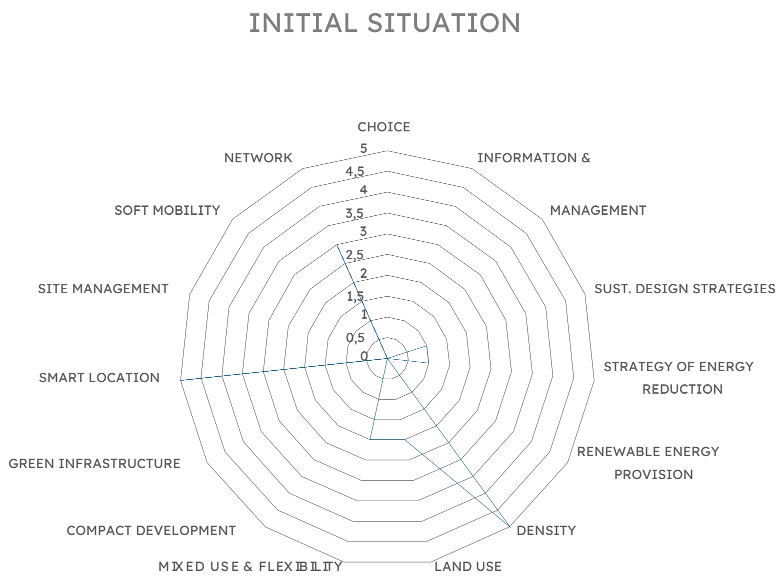
COMPACT DEVELOPMENT	Value	Unit	Variable	Result	Unit	Point		Total 0
Total floor area	4393928	[m²]	Residential Ratio	31,53285625	[%]		5	
Total Residential Area	1385531	[m²]	Non-Residential Ratio	68,46714375	[%]	0		
Total Non-Residential Area	3008397	[m²]						

Figure 5: Preliminary Tool - Assessment System - Version 2.0

ID CARD	
Name	ILOT 130
Neighboorhoud	Quartier Européen
City	Bruxelles

			PHASE 0	PHASE 1
MATERIALS & RESSROUCES	MATERIALS	CHOICE	0	1
		INFORMATION & MANAGEMENT	0	1
	ENERGY	SUST. DESIGN STRATEGIES	1	2
		STRATEGY OF ENERGY REDUCTION	1	3
		RENEWABLE ENERGY PROVISION	0	0
SPATIAL DEVELOPMENT	BUILT ENVIRONMENT	DENSITY	5	5
		LAND USE	2	2
		MIXED USE & FLEXIBILITY	2	2
		COMPACT DEVELOPMENT	0	0
		GREEN INFRASTRUCTURE	0	0
		SMART LOCATION	5	5
		SITE MANAGEMENT		
	MOBILITY	SOFT MOBILITY	0	0
		NETWORK	3	3
		Final score / 70	19	24

Figure 6: Preliminary Tool - Result System - Version 2.0



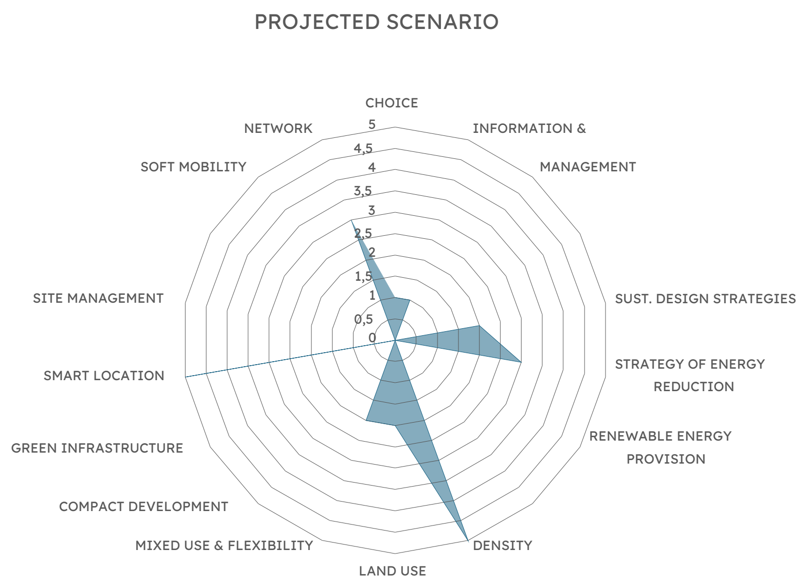


Figure 7: Preliminary Tool - Result System 2 - Version 2.0

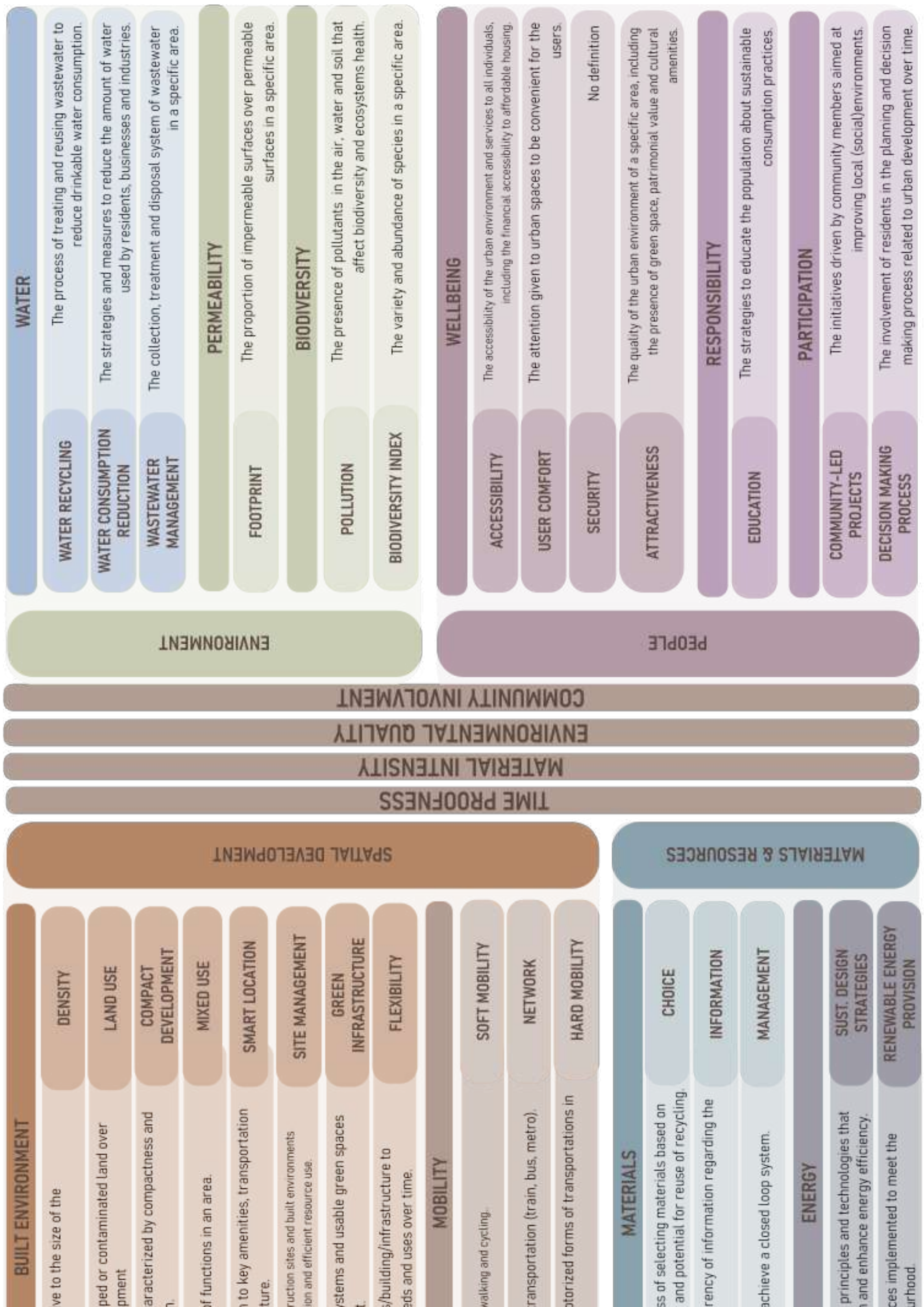


Figure 8: Preliminary Framework - Version 3.0

Project Name		
Project Location		
Result summary	Total point	Score
	max point	

STEP 0 : GENERAL SITE ANALYSIS

This section only focuses on the general data you can find on city plans and open data sources that you can find in the section "INDEX". Insert the needed data in the colored cases.

Total Land Area		[m²]
Total Land Area		[ha]
Population Density		[inhab/km²]
Total Inhabitant		[inhab]
Total Building stock		[units]
Total Residential stock		[units]
Total Non-Residential stock		[units]
Residential Density		[du / ha]
Non-Residential Density		[du / ha]
Total Built Footprint		[m²]
Total Gross Floor Area (GFA)		[m²]
Total Permeable Area		[m²]
Total Green Infrastructure		[m²]
Total Polluted Soil		[m²]
Total Office Area	95874	[m²]
Total Housing Area	4842	[m²]
Total Industrial Building Area		[m²]
Total Amenities Area		[m²]
Number of uses in the district		[-]
Total Area given to total circulation (including on-street parking)		[m²]
Total Area given to soft mobility		[m²]
Total Energy Need for Offices	6,71118	[GWh]
Total Energy Need for Housing	0,106524	[GWh]
Specific Total Energy Need		[GWh]
Total Energy Need in the district	6,817704	[GWh]
Clean Energy Ratio implemented		[%]
Clean Energy to produce	0	[GWh]
Number of nodes in the district following Leed-Nd regulation		[Nodes]
Zone of acessibility following RRU	Zone A	[-]
Mean soil contamination		[%]

Figure 9: Preliminary Tool - Assessment System Part.1 - Version 3.0

Figure 10: Preliminary Tool - Assessment System Part.2 - Version 3.0

CALCULATION & RESULT

Category	Criterium	Value	Unit	SCORE
DENSITY	FAR		[-]	
LAND USE	Question 1	Yes	[%]	1
	Question 2	No	[%]	0
	Question 3	Yes		1
	Question 4	No		0
	Question 5	No		0
MIXED USE	Number or uses		[-]	
	Bonus point		[-]	
GREEN INFRASTRUCTURE	Permeability Ratio		[%]	
	Green Area Ratio		[-]	
COMPACT DEVELOPMENT	Residential Ratio		[du/ha]	
	Non-Residential Ratio		[du/ha]	
TRANSPORT & TRANSIT FACILITIES	Infrastructure		[%]	
	Quality & Security		[-]	
	Parking		[-]	
	Alternatives		[-]	
	Strategy		[-]	
NETWORK	Connectivity		[-]	
	Accessibility	Zone A	[-]	3
RENEWABLE	Clean Energy Ratio	39,2 - 49	[GWh]	4
ENERGY REDUCTION	Strategy 1 A	Yes		2
	Strategy 1 B	Yes		1
	Strategy 2	No		0
SMART LOCATION	Selected Strategy	S.2	[-]	2
MATERIALS CHOICE	Selected Strategy	S.1	[-]	1
MATERIALS MANAGEMENT	Material passeport	Yes	[-]	1
	Waste management on site	0	[-]	
	Waste management off site	0	[-]	
	Material optimisation	0	[-]	
	Local resources	0	[-]	
FLEXIBILITY	Strategy 1	Yes	;	1
	Strategy 2	0	[-]	#N/A

Figure 11: Preliminary Tool - Assessment System Part.3 - Version 3.0

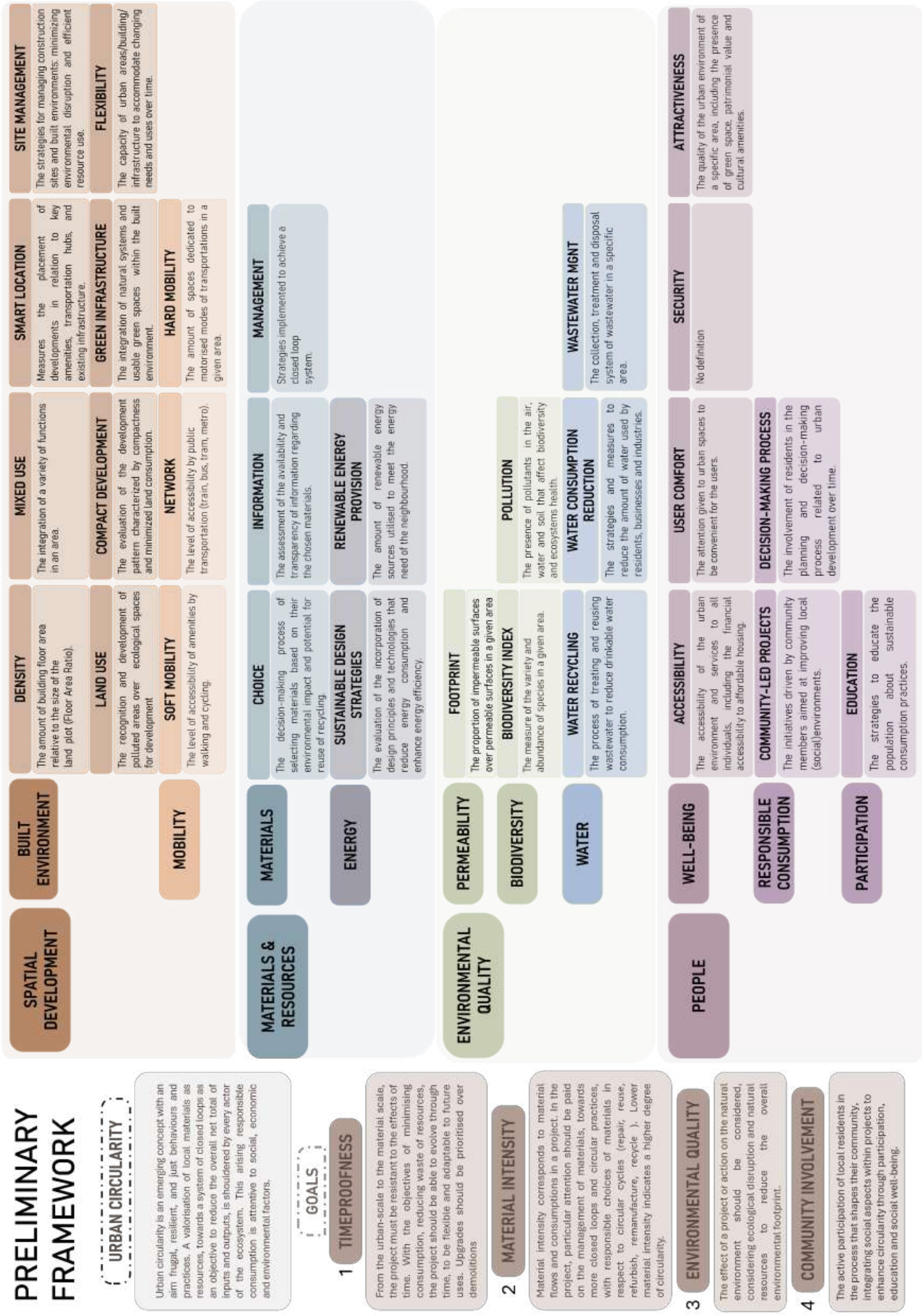


Figure 12: Preliminary Framework - Version 4.0

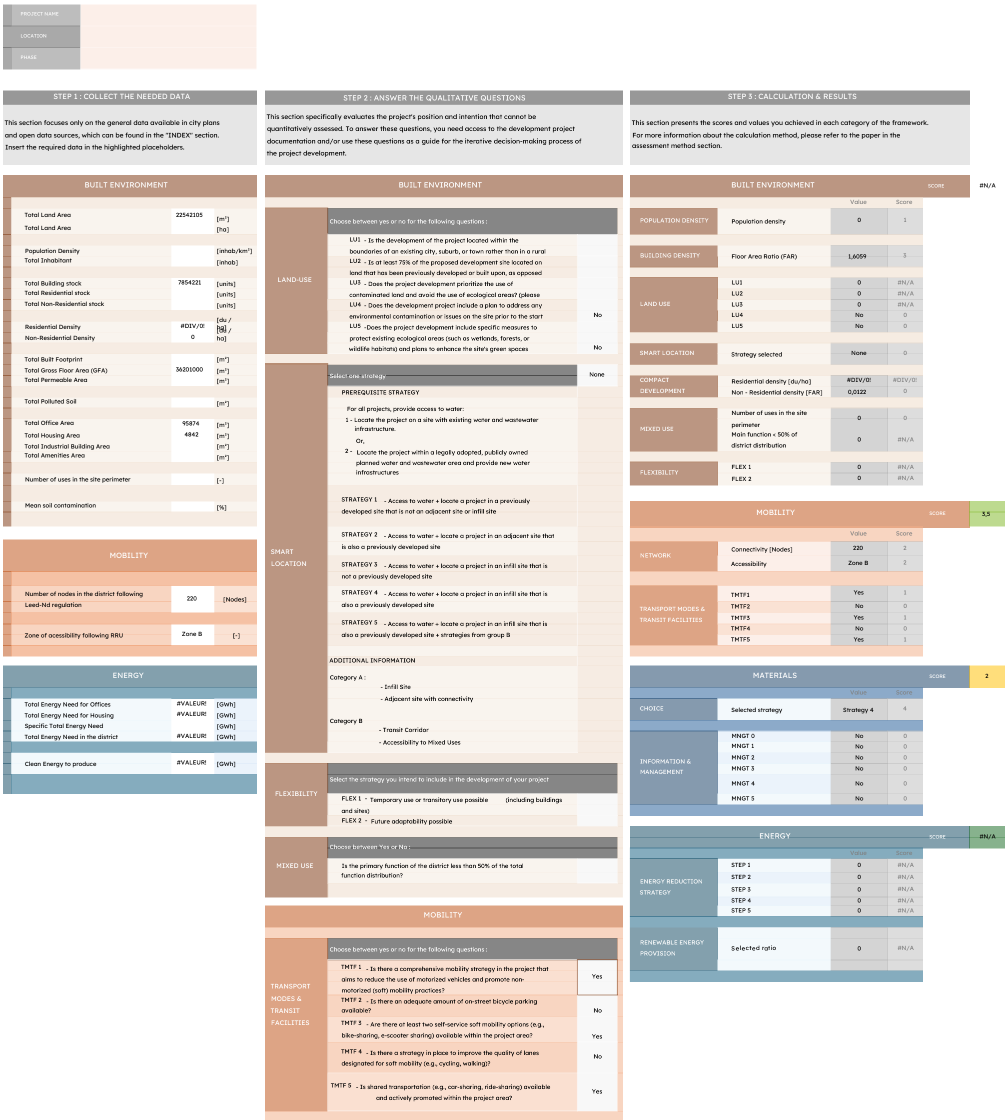


Figure 13: Preliminary Tool - Assessment System Part.1 - Version 4.0

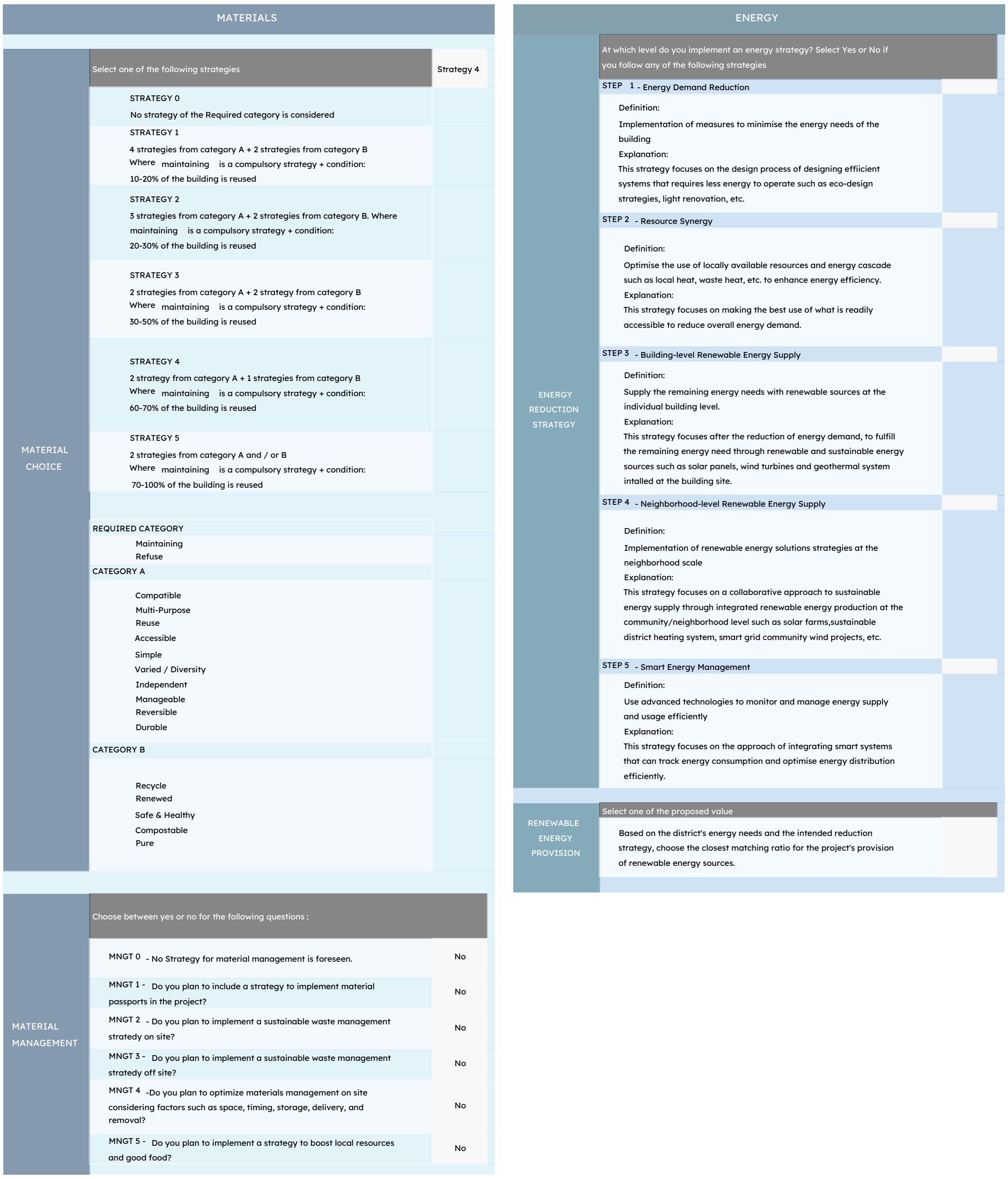


Figure 14: Preliminary Tool - Assessment System Part.2 - Version 4.0

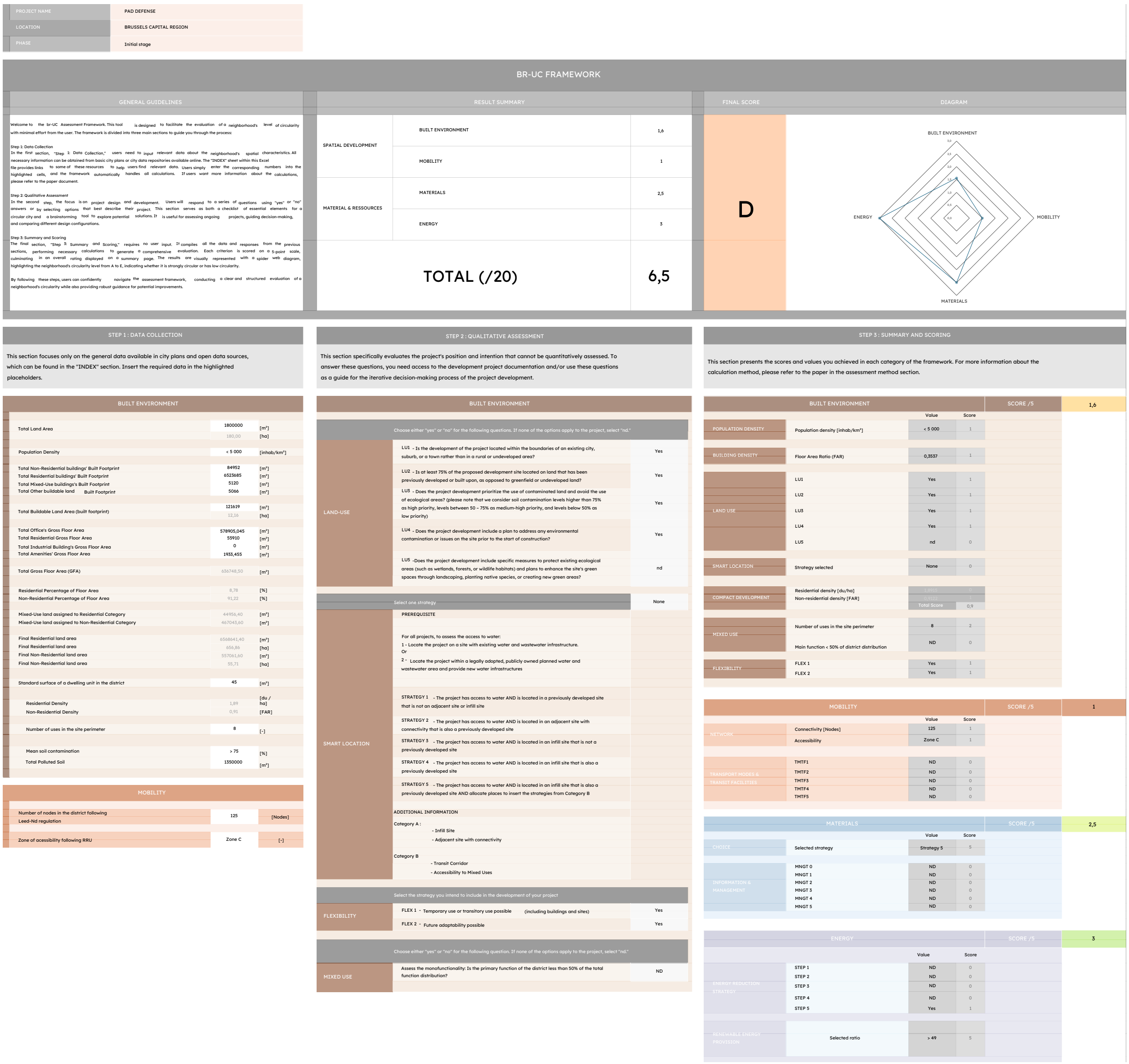
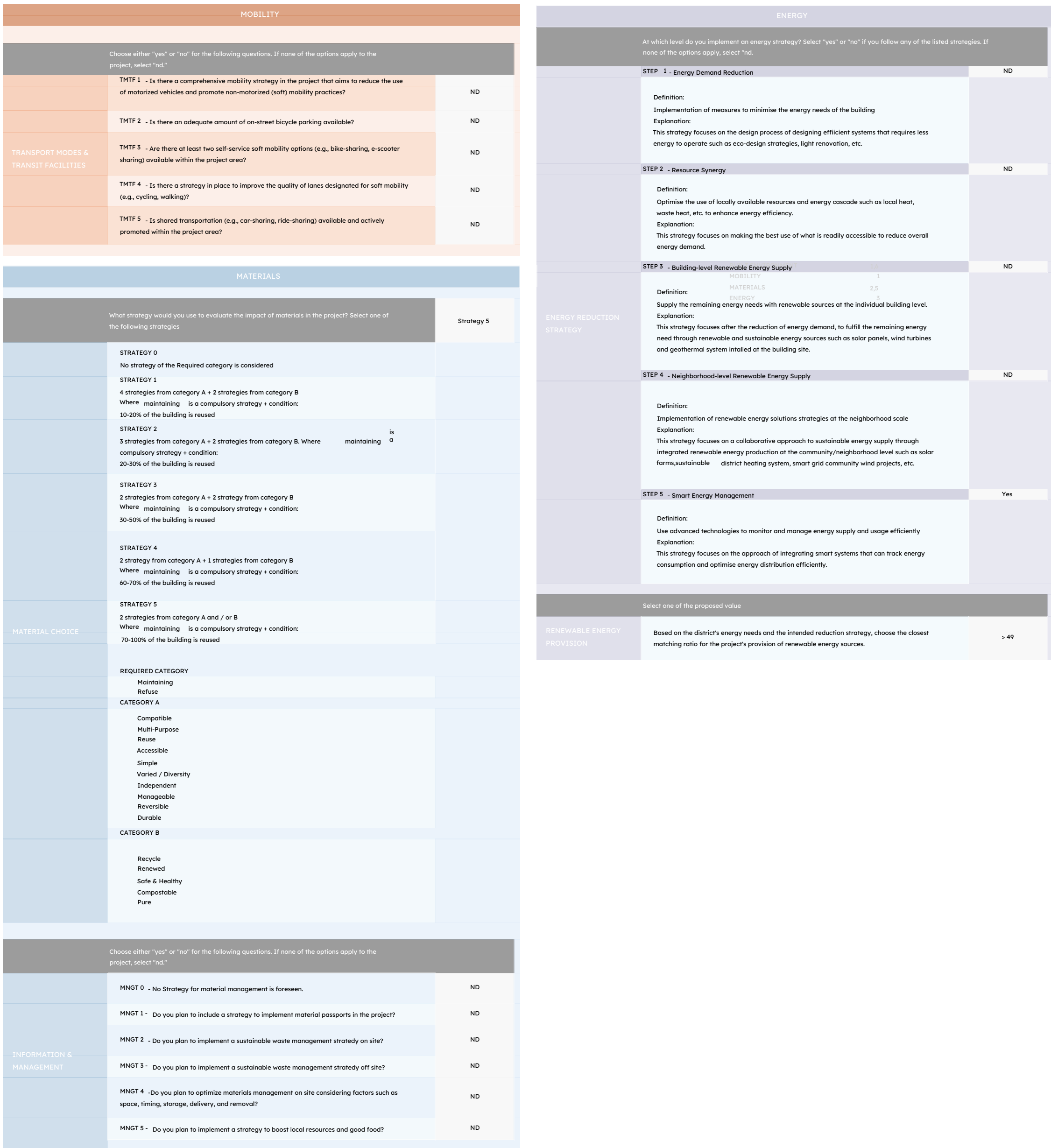


Figure 15: Preliminary Tool - Assessment System Part.1 - Version 5.0



MOBILITY		
	Choose either "yes" or "no" for the following questions. If none of the options apply to the project, select "nd."	
TRANSPORT MODES & TRANSIT FACILITIES	TMTF 1 - Is there a comprehensive mobility strategy in the project that aims to reduce the use of motorized vehicles and promote non-motorized (soft) mobility practices?	ND
	TMTF 2 - Is there an adequate amount of on-street bicycle parking available?	ND
	TMTF 3 - Are there at least two self-service soft mobility options (e.g., bike-sharing, e-scooter sharing) available within the project area?	ND
	TMTF 4 - Is there a strategy in place to improve the quality of lanes designated for soft mobility (e.g., cycling, walking)?	ND
	TMTF 5 - Is shared transportation (e.g., car-sharing, ride-sharing) available and actively promoted within the project area?	ND

MATERIALS		
	What strategy would you use to evaluate the impact of materials in the project? Select one of the following strategies	Strategy 5
MATERIAL CHOICE	STRATEGY 0 No strategy of the Required category is considered	
	STRATEGY 1 4 strategies from category A + 2 strategies from category B Where maintaining is a compulsory strategy + condition: 10-20% of the building is reused	
	STRATEGY 2 3 strategies from category A + 2 strategies from category B. Where maintaining is a compulsory strategy + condition: 20-30% of the building is reused	
	STRATEGY 3 2 strategies from category A + 2 strategy from category B Where maintaining is a compulsory strategy + condition: 30-50% of the building is reused	
	STRATEGY 4 2 strategy from category A + 1 strategies from category B Where maintaining is a compulsory strategy + condition: 60-70% of the building is reused	
	STRATEGY 5 2 strategies from category A and / or B Where maintaining is a compulsory strategy + condition: 70-100% of the building is reused	
	REQUIRED CATEGORY Maintaining Refuse	
	CATEGORY A Compatible Multi-Purpose Reuse Accessible Simple Varied / Diversity Independent Manageable Reversible Durable	
	CATEGORY B Recycle Renewed Safe & Healthy Compostable Pure	

	Choose either "yes" or "no" for the following questions. If none of the options apply to the project, select "nd."	
INFORMATION & MANAGEMENT	MNGT 0 - No Strategy for material management is foreseen.	ND
	MNGT 1 - Do you plan to include a strategy to implement material passports in the project?	ND
	MNGT 2 - Do you plan to implement a sustainable waste management stratedy on site?	ND
	MNGT 3 - Do you plan to implement a sustainable waste management stratedy off site?	ND
	MNGT 4 -Do you plan to optimize materials management on site considering factors such as space, timing, storage, delivery, and removal?	ND
	MNGT 5 - Do you plan to implement a strategy to boost local resources and good food?	ND

ENERGY		
	At which level do you implement an energy strategy? Select "yes" or "no" if you follow any of the listed strategies. If none of the options apply, select "nd.	
ENERGY REDUCTION STRATEGY	STEP 1 - Energy Demand Reduction	ND
	Definition: Implementation of measures to minimise the energy needs of the building Explanation: This strategy focuses on the design process of designing effiicient systems that requires less energy to operate such as eco-design strategies, light renovation, etc.	
	STEP 2 - Resource Synergy	ND
	Definition: Optimise the use of locally available resources and energy cascade such as local heat, waste heat, etc. to enhance energy efficiency. Explanation: This strategy focuses on making the best use of what is readily accessible to reduce overall energy demand.	
	STEP 3 - Building-level Renewable Energy Supply	ND
	Definition: Supply the remaining energy needs with renewable sources at the individual building level. Explanation: This strategy focuses after the reduction of energy demand, to fulfill the remaining energy need through renewable and sustainable energy sources such as solar panels, wind turbines and geothermal system intalled at the building site.	
	STEP 4 - Neighborhood-level Renewable Energy Supply	ND
	Definition: Implementation of renewable energy solutions strategies at the neighborhood scale Explanation: This strategy focuses on a collaborative approach to sustainable energy supply through integrated renewable energy production at the community/neighborhood level such as solar farms,sustainable district heating system, smart grid community wind projects, etc.	
	STEP 5 - Smart Energy Management	Yes
	Definition: Use advanced technologies to monitor and manage energy supply and usage efficiently Explanation: This strategy focuses on the approach of integrating smart systems that can track energy consumption and optimise energy distribution efficiently.	
	Select one of the proposed value	
RENEWABLE ENERGY PROVISION	Based on the district's energy needs and the intended reduction strategy, choose the closest matching ratio for the project's provision of renewable energy sources.	> 49

Figure 16: Preliminary Tool - Assessment System Part.2 - Version 5.0

PROJECT NAME	PAD DEFENSE
LOCATION	BRUSSELS CAPITAL REGION

INTRODUCTION

Welcome to the BR-UC Assessment Framework, a comprehensive tool designed to evaluate and enhance the circularity of urban neighborhoods. This framework streamlines the assessment process, making it user-friendly and insightful. Its primary goal is to facilitate the assessment of a neighborhood's circularity.

When navigating the framework, you can find:

1. COMPARISON SUMMARY: This sheet presents a comprehensive overview of the assessments for four different scenarios. It includes scores for each category of the framework, the final rating of each project, and a radar diagram for visual comparison of the scenarios. This summary is essential for drawing conclusions about the strengths and weaknesses of each scenario, aiding users in choosing the most suitable option for project development.

2. SCENARIOS: This Excel document provides four sheets for assessing specific development scenarios. Users input data and answer qualitative questions related to the scenario in question. The framework then automatically calculates scores based on the inputs, enabling a detailed analysis of each scenario's circularity.

3. INDEX: The index sheet contains a curated list of websites and resources where users can find valuable data on spatial development, specifically for Brussels. This includes maps and open-source data stores that provide essential information needed for the assessment.

4. SCORES: This sheet lists the scoring criteria and explains how the scoring system works within the Excel framework. Understanding the scoring system is crucial for interpreting the results and making informed decisions based on the assessments.

RESULT SUMMARY

BR-UC FRAMEWORK			SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4
SPATIAL DEVELOPMENT	BUILT ENVIRONMENT	POPULATION DENSITY	1	5	1	1
		BUILDING DENSITY	1	1	1	1
		LAND USE	4	4	4	4
		SMART LOCATION	0	5	0	0
		COMPACT DEVELOPMENT	0,91	0,91	0,91	0,91
		MIXED USE	2	2	2	2
		FLEXIBILITY	2	2	2	2
	MOBILITY	NETWORK	2	5	2	2
		TRANSPORT MODES & TRANSIT FACILITIES	0	0	0	0
MATERIALS & RESSROUCES	MATERIALS	CHOICE	5	5	5	5
		INFORMATION & MANAGEMENT	0	0	0	0
	ENERGY	ENERGY REDUCTION STRATEGY	1	1	1	1
		RENEWABLE ENERGY PROVISION	5	5	5	5
FINAL SCORE /20			8,06	10,84	8,06	8,06
RATING			C	C	C	C

SPIDER WEB

SCENARIO's OVERVIEW

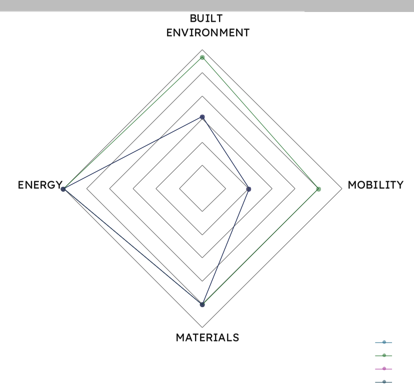


Figure 17: Preliminary Tool - Result System - Version 5.0