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Exploring Luxembourg's transition towards a Circular Built Environment through the lens of the Challenge-Oriented Regional Innovation Systems approach

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Abstract

This thesis explores Luxembourg's transition towards a circular built environment through the Challenge-Oriented Regional Innovation System (CoRIS) approach, aiming to offer a better understanding of the emergence of transformative innovation. Luxembourg, characterised by its close-knit stakeholder networks and its economic prominence within the Greater Region, faces unique challenges in its pursuit of sustainability. The current economic landscape is characterised by limited natural resources and dependence on imports, resulting in the necessity of trade relationships and cross-border supply chains with neighbouring countries. Luxembourg's growing population has intensified the demand for new buildings, infrastructure, and housing, thereby increasing pressure on resource consumption and waste management. In this context, the concept of a circular economy (CE), which aims at resource conservation and waste reduction, has moved at the forefront of public discourse in the construction sector, especially since the release of the national CE strategy in 2021.

To explore Luxembourg's transition to a circular built environment a case study research design was used. Data was collected through documentation, semi-structured interviews, and observations, which were subsequently analysed through a qualitative content analysis. The findings reveal that Luxembourg's transition to a circular built environment remains in the early stages, with CE being perceived as a concept that leaves excessive room for interpretation. Several region-specific challenges, including reluctance to embrace reused or recycled materials, increasing pressure to construct new infrastructure and housing, fragmented communication among stakeholders, and difficulties in achieving critical mass for CE practices are hindering this transition. Despite these barriers, this study identifies potential driving forces, such as extending circular public procurement policies, selective use of digital technologies, and rethinking consumption patterns.

The CoRIS framework proved instrumental in offering a comprehensive view of Luxembourg's transition towards a CE, highlighting the need for improved communication and collaboration among actors, including civil society, NGOs, and government agencies. The study emphasises the importance of strengthening regional partnerships within the Greater Region to effectively address cross-border challenges and pool resources. Additionally, enhancing regulatory frameworks to provide clearer guidelines and incentives for CE practices is crucial. This includes the introduction of mandatory circular criteria in public procurement and the development of financial mechanisms that support circular business models. This research suggests that a reconfiguration of Luxembourg's regional innovation system (RIS) would enhance a successful transition. It emphasises the need to shift from merely improving production processes to rethinking what and why of production, while also promoting organisational and institutional innovations.

Zusammenfassung

Diese Masterarbeit beleuchtet Luxemburgs Transition hin zu einer zirkulären Bauwirtschaft durch die Anwendung des Ansatzes herausforderungsorientierter regionaler Innovationssysteme (CoRIS), mit dem Ziel, ein tieferes Verständnis der Entstehung transformativer Innovationen zu bieten. Luxemburg, geprägt durch seine dichten Netzwerke von Interessensgruppen und seine wirtschaftliche Bedeutung in der Großregion, steht vor besonderen Herausforderungen auf dem Weg zur Nachhaltigkeit. Die aktuelle Wirtschaftslandschaft ist geprägt von begrenzten Rohstoffen und Importabhängigkeit, was Handelsbeziehungen und grenzüberschreitende Lieferketten mit Nachbarländern notwendig macht. Das Bevölkerungswachstum in Luxemburg hat zu einer steigenden Nachfrage nach neuen Gebäuden, Infrastrukturen und Wohnraum geführt, was den Druck auf den Ressourcenverbrauch und das Abfallmanagement erheblich verstärkt. In diesem Zusammenhang ist das Konzept der Circular Economy (CE), welches auf Ressourcenschonung und Abfallvermeidung abzielt, auch zunehmend in den Mittelpunkt der öffentlichen Debatte im Bausektor gerückt, insbesondere seit der Einführung der nationalen CE-Strategie im Jahr 2021.

Zur Analyse von Luxemburgs Transition zu einer zirkulären Bauwirtschaft wurde eine Fallstudiendesign angewandt. Die Daten wurden durch Dokumentation, teilstrukturierte Interviews und Beobachtungen erhoben und anschließend mittels qualitativer Inhaltsanalyse ausgewertet. Die Ergebnisse zeigen, dass Luxemburgs Transition zu einer zirkulären Bauwirtschaft noch in den Anfängen steckt, wobei die CE wahrgenommen wird als ein Konzept, das übermäßig Raum für Interpretation lässt. Mehrere regionsspezifischen Herausforderungen, wie die Skepsis gegenüber wiederverwendeten oder recycelten Materialien, der zunehmende Druck auf den Bau neuer Infrastrukturen und Wohnräume, fragmentierte Kommunikation zwischen den Akteuren und die Schwierigkeiten, eine kritische Masse für CE-Praktiken zu erreichen, erschweren diese Transition. Trotz dieser Hindernisse identifiziert diese Studie potenzielle Antriebskräfte, wie die Ausweitung der zirkulären öffentlichen Beschaffungspolitik, selektive Nutzung digitaler Technologien und ein Umdenken bei den Konsummustern.

Der CoRIS-Ansatz erwies sich als förderlich für das umfassende Verständnis von Luxemburgs Transition zur CE, indem er die Notwendigkeit für verbesserte Kommunikation und Zusammenarbeit zwischen Akteuren, einschließlich Zivilgesellschaft, NGOs und Regierungsbehörden, hervorhebt. Die Studie betont, dass starke regionale Partnerschaften innerhalb der Großregion wichtig sind, um grenzüberschreitende Herausforderungen effektiv zu bewältigen und Ressourcen zu bündeln. Darüber hinaus ist es entscheidend, die regulatorischen Rahmenbedingungen zu verbessern, um klarere Richtlinien und Anreise für CE-Praktiken zu schaffen. Dazu gehört die Einführung obligatorischer zirkulärer Kriterien in der öffentlichen Beschaffung sowie die Entwicklung finanzieller Mechanismen, die zirkuläre Geschäftsmodelle unterstützen. Diese Forschung suggeriert, dass die Rekonfiguration von Luxemburgs regionalem Innovationssystem (RIS) eine erfolgreiche Transition fordern würde. Sie fordert einen Fokuswechsel von der bloßen Verbesserung von Produktionsprozessen hin zu einer Überlegung, was und warum wir produzieren, sowie zur Förderung organisatorischer und institutioneller Innovationen.

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List of abbreviations

BIM	Building Information Modelling
CoRIS	Challenge-oriented Regional Innovation System
CC	Chamber of Commerce
CE	Circular Economy
CELL	Centre for Ecological Learning Luxembourg
CdM	Chamber of Skilled Trades and Crafts
CLLD	Community-Led Local Development
CNCD	National Council for Sustainable Construction
CNFPC	National Centre for Continuous Vocational Training
CO2	Carbon Dioxide
CRTI-B	Resource Centre for Building Technologies and Innovation
CSDD	Higher Council for Sustainable Development
EMAF	Ellen MacArthur Foundation
EU	European Union
FEDIL	Federation of Luxembourgish Industrials
GHG	Greenhouse Gases
GDL	Grand-Duchy of Luxembourg
Gt	Gigatonnes (billion metric tonnes)
ILNAS	Luxembourg Institute of Standardisation, Accreditation, Safety and Quality of Products and Services
IFSB	Construction Sector Training Institute
GDP	Gross Domestic Product
INAP	National Institute of Public Administration
INFPC	National Institute for the Development of Continuing Vocational Training
ISO	International Standard Organisation
LIST	Luxembourg Institute of Science and Technology
MECO	Ministry of the Economy
MECB	Ministry of the Environment, Climate and Biodiversity
MENEJ	Ministry of Education, Children and Youth
MFIN	Ministry of Finance
MIS	Mission-oriented Innovation System
MLOGAT	Ministry of Housing and Spatial Planning
MLP	Multi-Level Perspective
MMTP	Ministry of Mobility and Public Works
NGO	Non-governmental Organisation
OAI	Order of Architects and Consulting Engineers
PaaS	Product-as-a-Service
PCDS	Product Circularity Data Sheet
PNGDR	National Waste and Resource Management Plan
RIS	Regional Innovation System
SDG	Sustainable Development Goal
SoT	School of Thought

1 Introduction

The urgency of adopting a circular economy (CE) model has evolved from "circular by choice" to "circular by necessity", as highlighted by Elva Rakel Jónsdóttir at the Nordic Circular Summit 2023. This shift is particularly critical in the built environment, which, while driving economic activity and shaping communities, is also a major consumer of resources and a significant contributor to waste and greenhouse gas (GHG) emissions. On a global scale, the construction sector accounts for around 50% of all material extraction and over 35% of the EU's total waste output (EC, 2020). The concrete industry alone is responsible for approximately 8% of global anthropogenic GHG emissions (Miller & Moore, 2020). Despite the technical potential for material reuse, only 1% of building elements in North-West Europe are repurposed, highlighting a significant gap between potential and practice (EC, 2020).

Luxembourg, a small yet economically powerful nation in Central Europe, exemplifies the challenges and opportunities inherent in the transition to a circular built environment. Over the past decades, the nation has witnessed exponential economic growth, significantly influencing its resource consumption patterns and activities in the construction sector (TIR, 2016). Compared to other EU member states, its population is still increasing substantially fuelled by a heightened demand for new buildings, infrastructure, and housing, placing considerable pressure on resource consumption and waste management (Statec, 2023; TIR, 2016).

This tension between economic strength and environmental impact has provided the impetus for this research project and has already been explored by a number of scholars. By acknowledging the existence of previous work on the CE in Luxembourg, e.g., Hild (2023) or Hild and Schulz (2022), this research aims to analyse and understand the dynamics of circularity in Luxembourg's building sector through a framework that is attracts increasing attention in innovation literature: the Challenge-oriented Regional Innovation System (CoRIS) approach. Although many grand societal challenges are global in nature, the exposure of different regions to environmental and social problems varies, as do the actions required to tackle them (Isaksen et al., 2022). By recognising Luxembourg’s place-specific problems and needs, this study attempts to contribute to the country’s circularity debate. The publication of the national roadmap, entitled *Luxembourg, as a knowledge capital and testing ground for the circular economy* (Hansen et al., 2014) is considered as starting point for secondary data collection.

The study will analyse relevant material that treats the country’s transition towards a circular built environment, contextualised within the broader context of the Greater Region and the EU. Paula Hild's comprehensive dissertation on the context and practices of the CE in Luxembourg (2021), and the country's CE strategy published in 2021 provide valuable reference points for this research. Through this analysis, the research aims to illuminate the pathways through which Luxembourg can enhance its transformative capacity, thereby contributing to the development of more effective policies and practices for a sustainable built environment.

The thesis is structured as follows: Chapter 2 provides a review of the existing scientific literature on the CE concept, exploring its emergence, evolution, and relevance in the construction sector. Chapter 3 introduces the theoretical framework for this thesis, the CoRIS, which constitutes the lens through which the CE concept in Luxembourg's built environment is analysed. The methodology for this empirical research, using a case study research design and qualitative content analysis, is provided in Chapter 4. Chapter 5 presents the study's findings, outlining Luxembourg's transition to a CE, the understanding of the concept, barriers and driving forces. Chapter 6 analyses the results and their implications, leading to Chapter 7, which finishes with the concluding statement.

2 Conceptual framework – Circular Economy

In recent years, the CE concept has gained momentum in mainstream discourses and scholarly literature. This chapter delves into the historical background and evolution of the CE concept, critically examining its role within the broader sustainability debate. Additionally, it assesses the implications of CE for the built environment.

2.1 Literature review and trends in scientific publications

From 2016 to 2024, the number of publications on CE has risen significantly (Fig. 2). With half of 2024 passed and already 5,372 documents published, this number is anticipated to increase further (Alnajem et al., 2020; Goyal et al., 2021; Alcalde-Calonge et al., 2022). In 2017, the CE concept and its practices were predominantly developed and led by practitioners (policymakers, businesses, associations, etc.), and research was still in an exploratory phase, lacking a confirmatory approach and empirical evidence (Korhonen et al., 2018a, p. 37; Homrich et al., 2018. p. 537). Since then, interest in the academic field has surged, as highlighted in Figure 1, through a tenfold increase in publications from 2017 to 2023. However, this observation does not reveal the nature of the research conducted, nor does it indicate whether scholars are primarily engaged in developing new conceptual frameworks or applying existing ones to real-world cases.

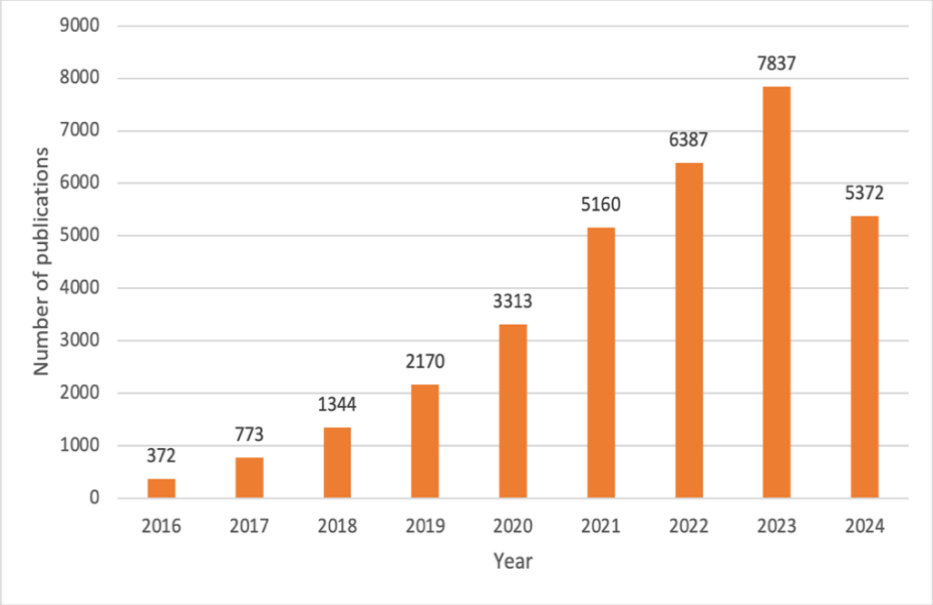

Figure 1. *Evolution of Circular Economy publications from 2016 to 2024 (source: Scopus database)*

To thoroughly understand the CE concept in relation to the built environment, a literature search was conducted using Elsevier's Scopus database. The search query "Circular Economy" AND "Built Environment" in titles, abstracts, and keywords yielded 516 documents as of July 22nd, 2024. This was initially refined to include only articles, book chapters, and books. Furthermore, the subject area was limited to social sciences and only English documents were considered, which narrowed down the selection to 113 documents: (TITLE-ABS-KEY ("circular economy") AND TITLE-ABS-KEY ("built environment")) AND (LIMIT-TO (

DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "bk")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (LANGUAGE , "English")). A systematic review process was then applied using Microsoft Excel. First, documents cited 21 times or more from the initial 113 were selected for further reading, resulting in 26 documents. Additionally, publications from 2023 and 2024 were included to capture recent and potentially less-cited works, adding 46 more documents to the list. In total, 72 sources were reviewed and evaluated based on their relevance to the research question and objectives. Table 1 presents the main documents retrieved from the Scopus research (IDs 1-7) and 6 of the most cited documents in English (IDs 8-13) for a broader understanding of the topic, yielded from the following search query (TITLE-ABS-KEY ("circular economy") AND (LIMIT-TO (LANGUAGE, "English"). Beyond the sources obtained from Scopus, additional significant references were discovered and cited through an evolutionary search process.

ID	Authors	Title	Year
1	Laurenti et al.	The socio-economic embeddedness of the circular economy: An integrative framework	2018
2	Kyrö et al.	Embodying circularity through usable relocatable modular buildings	2019
3	Weigend Rodríguez et al.	The future of the circular economy and the circular economy of the future	2020
4	Çetin	Towards a circular building industry through digitalisation: Exploring how digital technologies can help narrow, slow, close, and regenerate the loops in social housing practice	2023
5	Gillott et al.	Developing Regenerate: A circular economy engagement tool for the assessment of new and existing buildings	2023
6	Sala Benites et al.	A neighbourhood-scale conceptual model towards regenerative circularity for the built environment	2023
7	Torres Curado et al.	Circular economy: current view from the construction industry based on published definitions	2024
8	Ghisellini et al.	A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems	2016
9	Korhonen et al.	Circular Economy: The Concept and its Limitations	2018a
10	Korhonen et al.	Circular economy as an essentially contested concept	2018b
11	Kalmykova et al.	Circular economy - From review of theories and practices to development of implementation tools	2018
12	Geissdoerfer et al.	The Circular Economy e A new sustainability paradigm?	2017
13	Kirchherr et al.	Conceptualizing the circular economy: An analysis of 114 definitions	2017

Table 1. *Primary documents on Circular Economy and the Built Environment (Scopus data base)*

To identify **trends** in scientific publications on the CE framework, a search was conducted on July 23rd, 2024, using the Scopus bibliographic database with the query TITLE-ABS-KEY ("circular economy"). This search returned 32,728 documents, including various types such as articles, reviews, conference papers, and book chapters, as shown in Figure 2. The categories 'Erratum' and 'Other' have been excluded from the representation due to their low level of relevance (<0.2%).

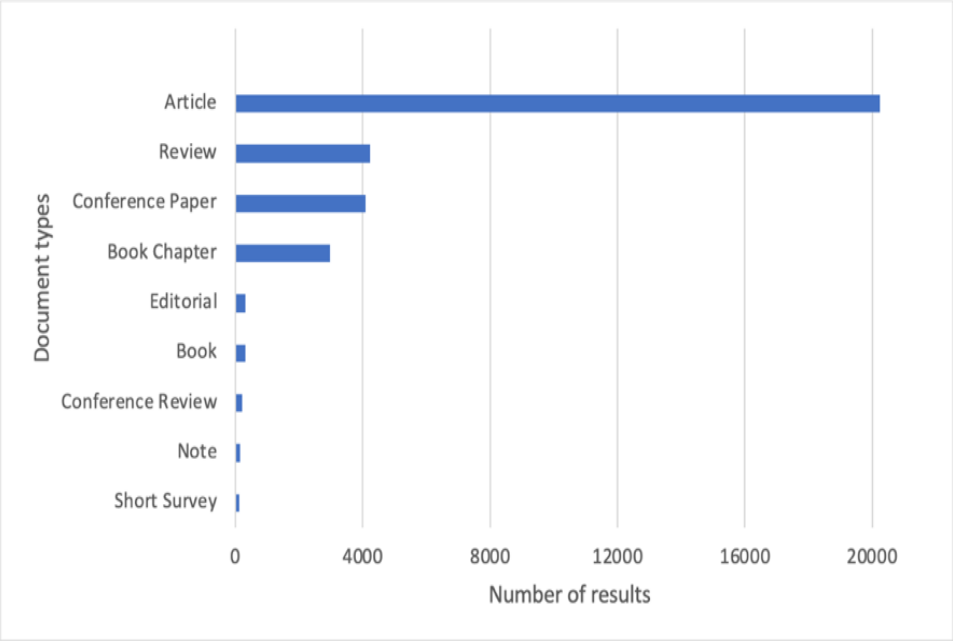

Figure 2. *Document types in a Scopus search on the CE (Scopus database)*

2.2 From linear to circular

Prior to delving into the CE model, it is essential to understand why the shift from a linear production and consumption system to a circular one has become necessary. The world is witnessing an increase in global primary material consumption to the extent that, in absence of suitable policy measures, it is projected to approximately double from 89 Gt in 2017 to 167 Gt in 2060 (OECD, 2019, p. 19). According to the 'Global Material Resources Outlook 2060', population growth, advanced living standards, and income convergence are the main drivers of global economic activity, hence material resource consumption. The construction sector is the most resource-intensive sector with global construction material use expected to more than double to 84 Gt in 2060, with high-income countries consuming a greater share (Fig. 3). This projected increase is closely linked to a wide range of environmental and social impacts such as climate change, land use, eutrophication, land, water, and human ecotoxicity as well as destroying cultural heritage, violating rights of the indigenous and increases in violence (OECD, 2019, p. 23; Tafesse et al., 2022). In 2022, the construction and building sector contributed 37% of global energy and process-related CO2 emissions and 21% of global GHG emissions (UNEP, 2023, p. 67).

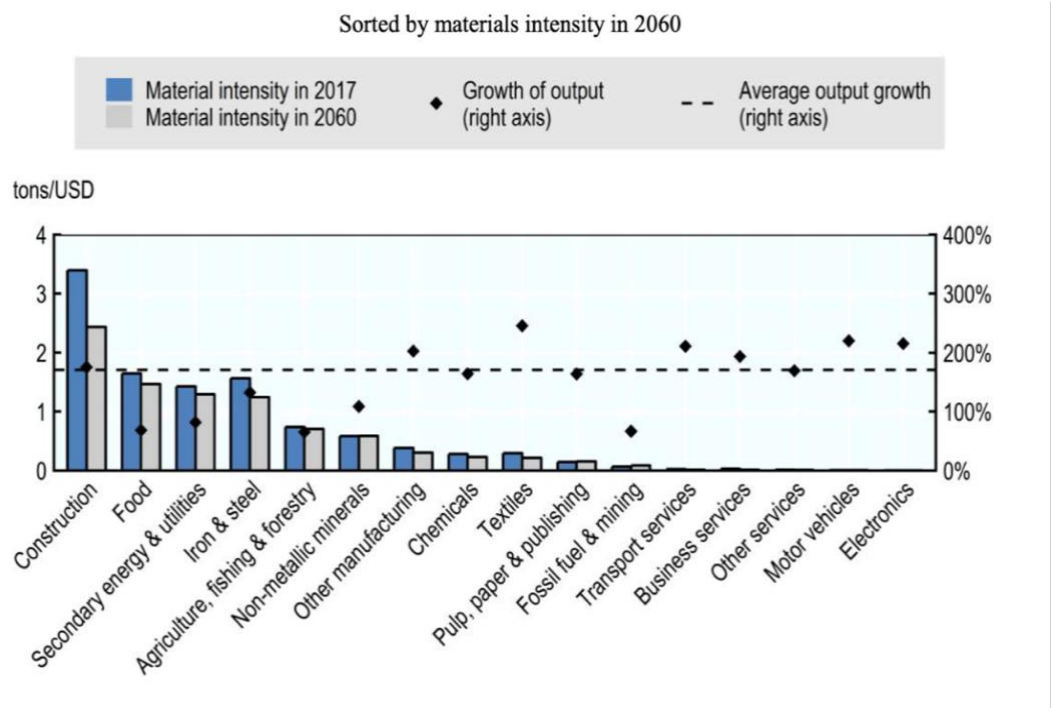

Figure 3. *Global growth is faster in less material-intensive sectors (OECD, 2019, Fig. 4.1, p.88)*

In Europe, this sector accounts for 50% of all material consumption and generates 37,5% of the EU's total waste (Herczeg et al., 2014, p. 12, Eurostat, 2023b). This is the outcome of the linear economic development model in which resources follow the widely cited take-make-use-dispose practices (Ghisellini et al., 2016). Often referred to as 'throwaway culture', in a linear economy you **take** the necessary resources, **make** products to generate profit, **use** them until they are no longer needed (not necessarily end of life) and **dispose** of them as waste. This conventional production and consumption system is rooted in unevenly distributed wealth across different geographic regions, resulting in an overflow of globally sourced material resources and energy in western societies (Geissdoerfer et al., 2017, p. 758). In this system, the low cost of materials relative to labour has led producers to focus on maximising material use and minimising labour costs. As a result, businesses have prioritised extensive material consumption and neglected reuse and recycling. This approach has been reinforced by regulations and accounting practices that do not account for the external costs of production, providing little incentive for producers to address waste. This economic model ultimately results in a linear economy, characterised by a one-way flow of resources (Sariatli, 2017, pp. 31-32). However, since our planet's supply of resources is finite and the world is urbanising rapidly, resulting in a rising material and energy consumption that ultimately increases pressure on our ecosystems, this conventional material and energy flow model is not sustainable. Using the building and construction sector as an example, this unsustainable approach becomes evident in the design of traditional buildings. A structure made from various individual components and materials installed for permanent use is ultimately demolished when its function becomes obsolete rather than due to physical deterioration. This linear way of defining and operating complicates, and even prevents valuable resources and materials contained in buildings from being reclaimed for reuse or recycled at their end-of-life (Cheshire, 2021, pp.

21-24). In response to the dissatisfaction with the predominant linear economic development, the CE approach offers an alternative flow model for our economy, one that is cyclical (Korhonen, 2018a, p. 37). CE advocates for a more environmentally responsible and sustainable approach to resource management through innovative business models and aims to enhance wellbeing and equity, addressing resource use and access across generations (EMAF, 2012 & Stahel, 2014 as cited in Ghisellini et al., 2016, p. 12). In the following chapter, the development of the CE approach, its main principles, and the connection to sustainability are addressed.

2.3 Evolution of the CE concept

2.3.1 CE definitions

While government policies, corporate strategies and academic research are showing a growing interest on the CE, the concept's underlying principles are not novel but embedded in the natural cycles of ecosystems, where waste is considered as an input. A thought that will be explained further under the concept's objectives. The CE is based on a collection of pre-existing concepts and seminal work from scientific and semi-scientific fields. Although different disciplined and Schools of Thought (SoT) have shaped the CE concept, it was predominantly influenced by environmental economics and industrial ecology, on theoretical and practical level (Torres Curado et al., 2024; Ghisellini et al., 2016, p.27). In various scientific articles environmental economists **Pearce and Turner** (1989) are mentioned as initially introducing the concept, building their theoretical framework based on studies from ecological economists Kenneth **Boulding** (1966) and **Georgescu-Roegen** (1971) (Andersen, 2006; Su et al., 2013, Ghisellini et al., 2016). However, concerns about Earth's limited resources and growth were already expressed in the 19th century by British economist David **Ricardo** (1817). Beyond being considered an alternative production and consumption model, CE principles are also seen as an approach to optimise waste management, a thought that was already introduced by **Simmonds**, who stated "When we perceive in nature how nothing is wasted, but that every substance is reconverted, and again made to do duty in a changed and beautified form, we have at least an example to stimulate us in economically applying the waste materials we make, or that lie around us in abundance, ready to be utilised" (Simmonds, 1862 as cited in Desrochers, 2005, pp. 8-9). Furthermore, the CE approach necessitates adopting a holistic perspective and employing systems thinking when implementing nature-inspired solutions, which enables the identification of underlying causes of issues and unveils new opportunities (Wautelet, 2018, p. 20). General Systems Theory, as articulated by **Von Bertalanffy** (1950), advocates for systems thinking and organisational learning within economic contexts instead of analysing elements in isolation, which serves as a foundational concept for Industrial Ecology. In the 1970s, Boulding's theoretical framework, considering Earth as a closed system, was further developed in the field of industrial economics under the concept of loop economy (**Stahel** & **Reday**,1976). Besides advocating for the sale of usage rather than ownership of goods, as sustainable business model in the loop economy (foundational ideas for the PaaS business model), Stahel later became the founder of the performance economy, another SoT influencing the CE concept (**Stahel**, 1982). Finally, it was environmental economist Allan **Kneese** (1988), who used the term "circular economy" for the

first time (Torres Curado et al., 2024, p. 2). Figure 4 illustrates different origins that influenced the CE concept. It maps relevant publications and their authors (yellow boxes), key reports (purple box), SoT (blue boxes), significant achievements (green boxes), and literature reviews (red box). The arrows indicate relationships.

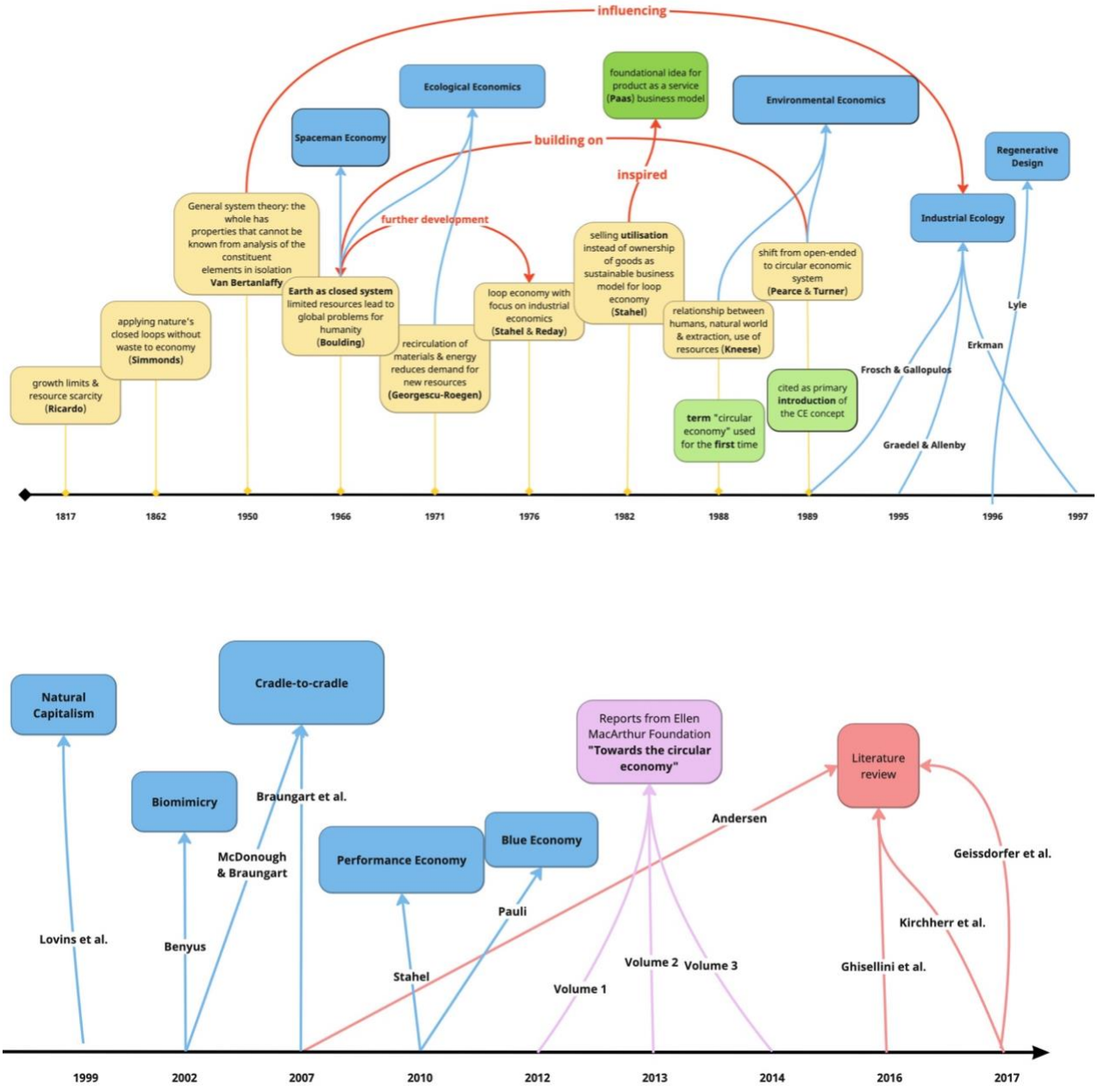

Figure 4. *Timeline of concepts and theories that shaped the CE concept (own representation)*

Given the transversal and multidisciplinary nature of CE, until now there has not been an all-embracing definition (Kirchherr et al., 2017). The modern understanding of CE and its practical applications within economic systems and industrial processes includes contributions from multiple frameworks that embrace the principle of closed-loop systems (Geissdoerfer et al.,

2017, p. 759). It can be defined as umbrella concept, defined as "a broad concept or idea used loosely to encompass and account for a set of diverse phenomena" (Hirsch & Levin, 1999, p. 200), which emerged from eight pre-existing SoTs, that further refined and developed the concept (Weigend Rodriguez et al., 2020, p. 532). They include **Spaceman economy** (Boulding, 1966), **biomimicry** (Benyus, 2002), **cradle-to-cradle** (McDonough & Braungart, 2002; Braungart et al., 2007), **natural capitalism** (Lovins et al., 1999), **industrial ecology** (Frosch & Gallopulos, 1989), **performance economy** (Stahel, 2010), **regenerative design** (Lyle, 1996) and **blue economy** (Pauli, 2010).

Weigend Rodriguez and colleagues (2020, p. 534) categorise these SoTs according to their prioritisation of economy, humankind, and environment. While spaceman economy, biomimicry, cradle-to-cradle, and natural capitalism prioritise the environment above human needs, and human needs above the global economy, industrial ecology, performance economy, and regenerative design propose a balance between the environmental, human, and economic aspects. Blue economy does not focus on contributing to a global economic model, but rather on enhancing the local economy of communities using available resources. Wautelet (2018, p. 21) differentiates between the approaches of various SoTs in addressing grand societal challenges. Spaceman economy, biomimicry, cradle-to-cradle, industrial ecology, and performance economy collectively advocate for nature-inspired solutions aimed at enhancing resource efficiency and mitigating adverse environmental impacts through systems thinking. However, performance economy and blue economy emphasise innovative business models, cradle-to-cradle focuses on the environmental impacts of products and services from a value chain and life-cycle perspective, and biomimicry addresses challenges at the product design level. Due to the transdisciplinary CE landscape, which encompasses various actors who approach the concept from distinct perspectives, practitioners and policymakers can have a different understanding of the concept, manage complexities differently and are often driven by specific and narrow agendas (Torres Curado, 2024, p. 2). However, one of the most influential definitions for CE was proposed by the **Ellen MacArthur Foundation**:

> "A [CE] is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models." (EMAF, 2012, p. 7)

The Foundation has since continued to publish reports on the subject, including a book (Webster, 2015) and has evolved into a platform for collaboration among businesses, academic institutions, and policymakers. One of its most prominent models, the CE system diagram, also known as butterfly diagram, depicts the continuous flows of materials in two main cycles. While materials in the technological cycle are maintained in circulation through different processes (share, reuse, remanufacture, recycle, etc.), materials in the biological cycle are returned to the soil to regenerate natural systems (EMAF, 2019). Several scholars have analysed the CE concept and its definitions through literature research, mentioning the EMAF definition as the most cited reference in media coverage (Geissdoerfer et al., 2017, p. 759; Schut et al., 2016, p. 15, Kirchherr et al., 2017, p. 226). Kirchherr and colleagues (2017) take

a more holistic perspective on CE by proposing a definition that aligns with sustainable development:

> "A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations." (Kirchherr et al., pp. 224-225)

2.3.2 CE strategies and policies

Besides scientific articles, reports and initiatives from business advocacy bodies and NGOs (EY, 2015, EMAF, 2012), the discourse on CE transition is increasingly being led by policymakers at supranational, national, regional levels. Definitions from the EU and China are globally acknowledged and other national governments such as Germany, Japan, France, the Netherlands, the UK, and Sweden have demonstrated efforts to tackle pressing environmental challenges through the implementation of CE principles (Korhonen et al., 2018a, p.1). Drawing from the loop economy concept, Germany became the first country to adopt the CE into national legislation with the enactment of the "Closed Substance Cycle and Waste Management Act" in 1996 (Bundestag, 1994). However, the focus was primarily on waste separation and recycling rather than on optimising material flows from production to reuse (Schulz, 2019, p. 236). Japan followed with its "Basic Law for Establishing a Recycling-Based Society" in 2002 (METI, 2004), a comprehensive legal framework for the country's move towards a recycling-based society. China has most fully integrated the implementation and development of CE concepts with an initial focus on waste elimination and resource reallocation to foster sustainable urban development and to balance population in rural and urban areas. These efforts are also reflected in the number of publications on the subject, which are predominantly from China (Geissdoerfer et al., 2017, p.769). Numerous laws and regulations (Cleaner Production, Pollution Prevention…) paved the way for the Republic's CE Promotion Law, implemented as a national strategy in 2009 is perceived as a pioneering legislation (Kalmykova et al., 2018, p. 192). The link between waste management and the CE stems from the recognition of Earth's finite ability to absorb pollutants, a concept explored in frameworks such as cradle-to-cradle (Braungart et al., 2007) and planetary boundaries (Rockström et al., 2009).

Recent approaches of the EU significantly surpass the goals of earlier regulations. The contemporary understanding of the CE aims to close material loops as comprehensively as possible (Schulz, 2019, p. 236). In 2011, the EU issued the "Roadmap to a Resource Efficient Europe", and has since continued to strive with further reports, such as the Circular European Action Plan (CEAP) in 2015 and 2020, and the European Green Deal in 2019. The CEAP explicitly emphasises the engagement of all target groups, industry, policymakers, businesses, and civil society (EC, 2020, p.2). While China's centralised political strategy is pursuing a top-down approach (e.g., bans on informal recycling to streamline waste flows), the EU is

promoting a bottom-up approach to the principle of subsidiarity (e.g., subsidising initiatives from NGOs or civil society). For instance, Sweden implemented various decentralised incentive measures such as tax breaks and subsidies (Kalmykova et al., 2018, p. 192; Uršič et al., 2024). Several other European nations have successfully integrated green political parties into their political system and decision-making processes, thereby promoting and facilitating the transition towards a CE (Heshmati, 2016, p. 3). However, within the current economic system, CE activities, such as extending the product lifespan or recycling, are often not economically profitable. This is where political intervention through direct measures, laws, and regulations (ISO 59000 series) but also indirect measures such as shifting current "production-consumption-use-waste practices", become a powerful tool in driving the transition to a CE (Hobson, 2016, p. 92).

2.3.3 CE and sustainability – critical voices

The link between sustainability and CE, as proposed by Kirchherr and colleagues (2017) has been incorporated in policy agendas (2030 Agenda for SD, Luxembourg's 3rd National Plans for SD) as well as business strategies and became cumulatively more embedded into the rules that structure social interventions and shape behaviour (Hodgson, 2005). The contemporary understanding of sustainability relates to the so-called triple bottom line, a balanced integration of economic, environmental, and social performance (Geissdoerfer et al., p. 759). In 2007, Johnston and colleagues identified approximately three hundred definitions of sustainability; this widespread adoption has resulted in a lack of clarity. To address this ambiguity, the United Nations established 17 global goals (SDGs) in 2015 to tackle environmental, social, political, and economic challenges. Despite these efforts, over three decades since the Brundtland report, data shows a continued increase in resource use, with projections suggesting a doubling by 2060 if current trends persist, indicating that sustainable development has not met its implementation promises (OECD, 2019, p. 19).

The CE aims to promote the decoupling of economic growth from resource use and environmental impacts by prioritising economic and environmental aspects of sustainable development. However, scholars have recurringly emphasised social aspects to be the "missing pillar" in CE strategies (Boström, 2012). CE is criticised for overlooking the social dimension of sustainability and focusing on environmental benefits of systems (Ghisellini et al., 2016). Murray and colleagues (2017, p. 2) highlight the need of CE to be a moral economy, "driven by discourses of ecological modernisation, environmental justice and resource (in)security". Furthermore, Pomponi and Moncaster (2017, p. 717) argued, that the implementation of circularity in the built environment lacks interdisciplinarity, emphasising the need for further exploration of the role of individuals and their place within society to identify solutions for societal challenges. Schulz (2019, p. 240) contends that the CE concept fails to adequately address sufficiency and lacks a clear definition of the nature of growth being pursued, which could lead to circularity being interpreted as a rationale for further quantitative growth. The CE's roots in environmental economics and industrial ecology might explain why, historically speaking social issues have been of lesser concern.

Nonetheless, efforts are underway to incorporate social dimensions into the CE concept. Researchers like Laurenti and colleagues (2018), Nikanorova and colleagues (2020) or Mies and Gold (2021) have been proposing new frameworks for this integration. According to Anastasiades and colleagues (2020, p. 3), the CE should be viewed as a moderate sustainability perspective. This is because it conceptually relies on technological progress as a solution to existing environmental problems (weak sustainability), but its successful implementation also requires a change in consumer behaviour, accompanied by shifts in cultural values (stronger sustainability) with politics being the main driver for change. Schroeder and colleagues (2019, p. 92) investigated how the CE paradigm supports the 17 Sustainable Development Goals (SDGs), which include 169 targets set by the United Nations. They found that CE practices contribute to 49 of these targets, while there is no connection to 35 targets. Consequently, there is significant potential for CE practices to generate synergies. With the aim of preventing possible rebounds of the CE, Laurenti and colleagues (2018) have offered a framework that considers the interplay between material flows, socio-economic factors, and decision-making processes by actors across the global value chain to address the transition. A systemic approach that integrates material considerations within a broader socio-economic context is essential for the CE to effectively achieve its promise of sustainable development. Therefore, industry and policy practitioners must evaluate sustainability aspects before implementing CE initiatives. Blum and colleagues (2021, p. 1) express this same idea by stating: "[…] the circularity of materials per se is a means, not an end in itself. ".

2.4 CE and the construction sector

The transition towards a CE in the construction sector is increasingly recognised as a critical pathway to sustainable development (Torres Curado et al., 2024; Gillott et al., 2023; Çetin, 2023). The foundation of circularity in construction lies in sustainable building principles established in the mid-1990s, where environmental challenges that rose from the sector's negative impact on resource depletion, air quality, land and water use were initially addressed (Kibert, 1994, p. 4). The significance of the built environment in global sustainability efforts cannot be overstated. Currently, the building industry operates on a predominantly linear system where natural resources are extracted, transformed into construction materials, and discarded as waste once buildings are no longer needed. It is one of the most resource- and carbon-intensive sectors globally, causing severe environmental, social, and economic problems (Çetin, 2023, p.26). According to the Global Resources Outlook by UNEP (2024, p. 135), global population growth rates are steadily dropping, raw material extraction and use continue to surge (UNEP, 2024, p. 20). The built environment accounts for 18% of total global climate and pollution impacts, having more than doubled between 1995 and 2022. This increase can primarily be attributed to rapid infrastructure development in Asia, a trend that is expected to extend to other developing regions. However, compared to low-income countries, high-income countries consume six times more materials per capita and account for ten times more climate impacts per capita (UNEP, 2024, p. 122).

In the EU, the built environment is responsible for about 50% of all materials extracted, uses 40% of the EU’s energy, and generates over one-third of its GHG emissions and waste (EC, 2022a, 2024a). Furthermore, demographic shifts such as population aging and urbanisation are

disrupting the urban-rural balance so that rural areas face the issue of under-utilised buildings, while rapidly growing cities are constructing new ones (Kyrö et al., 2018, p.76). Given that population growth in European cities is predicted to increase by 35% by 2030, issues in constructing new housing and maintaining existing structures will intensify (EC, 2022b). It becomes evident that the current linear take-make-use-dispose model in construction is unsustainable. This necessitates the development of an alternative model that addresses societal demands while respecting the natural environment, going beyond mere recycling of construction and demolition waste (Çetin, 2023; Torres Curado, 2014).

CE practices in construction include various aspects, such as the recycling of construction materials (e.g., demolition debris or concrete), life cycle assessments of buildings, the deconstruction of building elements and modules, reclaiming valuable products and materials from existing stock (urban mining), carbon storage (carbon capture and storage), the development of digital building models (BIM), logistics and procurement, and material flow management (Losacker & Fastenrath, 2023, p. 77). The aspect of effective resource management provides significant opportunities to optimise energy use, reduce GHG emissions, minimise waste generation and strengthen the use of renewable energy (UNEP, 2024, p. 135). Nevertheless, despite the encouraging potential of CE practices, innovation and collaboration dynamics are low and practical advancements lag behind commonly accepted approaches to attaining circularity (Coenen et al., 2022, p. 1; Losacker & Fastenrath, 2023, p. 77).

2.4.1 A systemic view on CE

The slow pace of innovation in the building sector might stem from the complexity of CE practices, which tend to increase with scale. Additionally, there is a lack of systemic changes towards inherently more sustainable systems, implying not only the adoption of new technologies but also significant socio-technical changes, which include a context-specific reassessment of relationships, institutions, and practices (Su et al., 2013; Köhler et al., 2019; Singh et al., 2021). In academic literature, systemic change in construction focuses mostly on individual actors, initiatives, institutions, indicators, tools, methods, or practices rather than the sector as a whole, an approach that highlights the interconnectedness and interdependencies between systems (Coenen et al., 2022, p. 22; Sala Benites, 2022). Scholars stress the necessity for practitioners to engage in interconnected multilevel activities to modify practices (Gluch & Svensson, 2018), to consider the broader sustainability transition in construction by analysing the role of municipalities within a wider context of stakeholders (Salmi et al., 2022), and to approach the transition to a circular built environment from a geographical perspective emphasising the spatial and temporal understanding of the CE (Losacker & Fastenrath, 2023). Furthermore, for CE practices to succeed, scholars in economic geography advocate for a more comprehensive approach on stakeholder networks. They stress the importance of collaboration to support knowledge transfer for policy development and implementation, while prioritising a broader sociocultural change over technological solutions (Losacker & Fastenrath, 2023; Hjaltadóttir & Hild, 2021, p. 2231; Schulz et al., 2019, p. 5). Otherwise, CE might become another concept condemned for being too closely aligned with present economic principles,

failing to recognise the possible limitations of growth and to demonstrate sustainability efforts, similar to the Green Economy (Hild & Schulz, 2022, p. 7).

2.4.2 Research gaps & the spatial dimension

Although the CE is a widely adopted concept in policymaking, the business sphere and academia, it is facing growing criticism for its lack of consideration for spatial dimensions. While research in technical and natural sciences constitutes the largest body of knowledge in the CE discourse, organisational and social sciences that address issues of reception, acceptance, and implementation of CE concepts, their spatial diffusion, or their transformative potential are underrepresented (Hild & Schulz, 2022, p.7; Korhonen et al., 2018b p. 550).

A first Scopus search on CE and innovation limited to the subject area social sciences, on July 30th, 2024, yielded the following results: (TITLE-ABS-KEY ("circular economy") AND (LIMIT-TO (SUBJAREA, "SOCI")) AND

TITLE-ABS-KEY ("innovation")) = 836
TITLE-ABS-KEY ("innovation system")) = 19
TITLE-ABS-KEY ("regional innovation")) = 6
TITLE-ABS-KEY ("regional innovation system")) = 2

While the search term innovation appears rather often in relation to the CE concept, the more specific terminologies "innovation system" and "regional innovation" appear significantly less often. There were only two search results on **CE** and **RIS**, an article and a book chapter. The article focuses on how synergies and collaborative behaviours among local stakeholders in an anaerobic digestion cluster in France contribute to the development of a CE within the region (Niang et al., 2022). However, RISs are approached as a framework for understanding how various factors like social network analysis and proximity theory can be applied and is not part of the research. The book chapter analyses the collaboration of regional stakeholders in establishing CE structures as system innovation within a region, based on the project of greening a university canteen in Germany (Weber & Heidelmann, 2019). This is the only publication of this Scopus search that elaborates on the development of regional innovation systems, however, through an organisational education perspective with less emphasis on CE strategies. They advocate greater involvement of universities in the CE-RIS-sustainability debate, asking themselves how university and the region can work closer together. Drawing on insights from a bottom-up innovation learning project, they identified sustainability innovation labs as essential drivers for enhancing the potential of RISs (Weber & Heidelmann, 2019, p. 423).

In a second Scopus search, the 113 documents related to CE and the built environment (see Chapter 2.1) were scanned for the term "innovation" by adding the search query (TITLE-ABS-KEY ("innovation") and yielded 9 results, among them 2 duplicates (2 articles that were also listed as book chapters). A qualitative analysis of the 7 remaining publications helped determining the context in which innovation was used. In one article, innovation was only mentioned in the abstract as part of the "Research and Innovation" agenda (Melella et al., 2021). However, most publications discussed innovation in the context of digitalisation, referring to

it as "digital innovation" or "innovation in digital technologies" (Çetin, 2023). Dalton and colleagues (2023) specifically addressed material (concrete, timber) and product chain innovation, highlighting the predominantly technological focus of innovation in the CE studies on the built environment. Lopez Duarte (2021) addressed innovation in the context of SDG 9 (industry, innovation and infrastructure) as green innovation, highlighting the capacity of circular cities to enhance innovation ecosystems. While the book "Towards a circular building industry through digitalisation" puts an emphasis on digital innovation, the authors also mention business model innovation and state that "very few existing studies examined CE in SHOs, e.g., from a social innovation […] and social and ecological […] perspective" (Çetin, 2023, p. 201). Furthermore, they recognize the potential of digital technologies to drive social innovation within CE processes. Azcárate-Aguerre and colleagues (2023) are the only authors using the term innovation in a multi-stakeholder systemic approach and highlight the necessity of PSS and CE practices to address changes in the management, financing, and governance aspects of products.

Innovation is addressed, rather one-sided, in the context of CE in the built environment and has not been used as an analytical tool with a focus on place-specific challenges and solutions. This master's thesis aims to strengthen the contribution of social studies in addressing innovation in the CE from a spatial perspective, by recognising the necessity of place-specificity and agency for transformative change. It therefore links the CE, as it is understood in the built environment, to an emerging concept in innovation literature that derived from the RIS approach: the CoRIS.

3 Theoretical framework – CoRIS

The CoRIS approach will serve as theoretical framework for this study (Tödtling et al., 2021). Despite the initial intention of consulting the MLP as theoretical framework, thorough examination revealed that the CoRIS approach is more suited for this study. Chapter 3.1 will address the MLP framework and the rationale for adhering to the CoRIS approach. The following chapters will offer insights into the emergence, development, and fundamental concepts of the CoRIS approach.

3.1 The MLP and its limitations

The Multi-Level Perspective (MLP) is a conceptual framework developed by Geels and colleagues that analyses transformative change in socio-technical systems. It adopts the view of "transitions as non-linear processes that result from the interplay of developments at three analytical levels: niches (the locus for radical innovations), sociotechnical regimes (the locus of established practices and associated rules that stabilise existing systems) and an exogenous socio-technical landscape [...]. Each 'level' refers to heterogeneous configurations of elements; higher 'levels' are more stable than lower 'levels' in terms of number of actors and degrees of alignment between the elements" (Geels, 2011, p. 26). Socio-technical landscapes present a stable environment, with structured activities that are changing rather slowly over time (represented with two long arrows in Figure 5). Developments in these landscapes are beyond the control of actors in regime and niches (Grin et al., 2010, p. 19). While socio-technical regimes attain stability through general rule compliance, niches are unstable configurations of social networks. The MLP suggests that tensions between those three levels are essential for

socio-technological transformation as they can weaken exiting linkages and destabilise the current equilibrium (represented with short diverging arrows in Figure 5). Incumbent regimes can be destabilised through external landscape pressure (landscape shocks like recessions) or niche innovations that gradually stabilise into a dominant design (represented with arrows growing longer and thicker in Figure 5) (Geels, 2002, p. 1262).

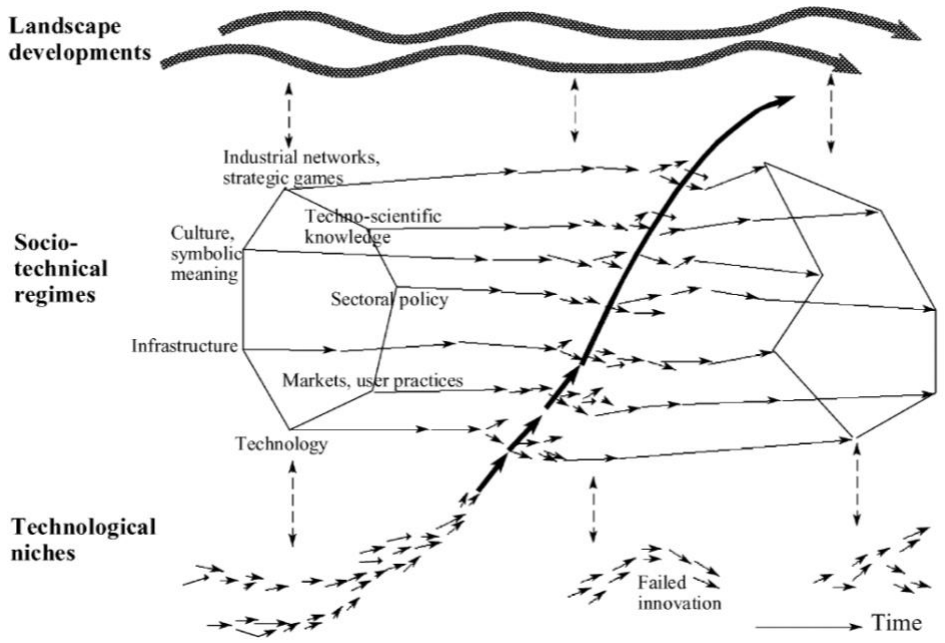

Figure 5. *Multi-Level Perspective (Geels, 2002, p. 1263)*

However, radical innovations are exposed to uncertainty and depend on windows of opportunity and multi-level interaction. If they mismatch with the existing regime, are slowed down by the length of technological development or face the commitment of incumbent actors, they might never scale up and grow (Geels, 2019; Grin, et al., 2010, p. 25). Despite its comprehensive scope, the MLP has faced criticism for its technological bias and inadequate conceptualisation of actors and agency, often perceived as too functionalist, rationalist, and structural (Hargreaves et al., 2013). Critics argue that the MLP emphasises the role of dominant market and state actors while neglecting the contributions of civil society and multi-regime interactions (Seyfang & Smith, 2007). While Geels (2011) defines regimes as intangible and underlying deep structures (engineering beliefs, routines, policy paradigms, social expectations, norms, etc.) that serve as an interpretive analytical concept inviting the researcher to investigate what lies underneath the activities of actors who reproduce system elements, scholars advocate for more operationalisation and specification of regimes. In the context of this thesis, circular building activities might be considered as niche-level innovations. However, defining the existing regime and understanding its interactions with these niches can be challenging. This complexity makes it difficult to assess whether the current regime is being destabilised by external pressures or if innovations at the niche level possess the potential to disrupt and transform the regime. Recent scholarly work in challenge-oriented policies has called for innovation policies to consider the geographical dimension and spatial impact, with a significant emphasis on various types of regions (Hassink et al., 2022; Wanzenböck &

Frenken, 2020). While the MLP is criticised for being a heuristic concept that lacks operationalisation, for overemphasising technological niches and for neglecting the spatial dimension of transitions, the CoRIS approach recognises that regions vary in their capacity for transformative change and challenge-oriented innovation thus need place-specific innovation policies (Geels, 2011; Krätzig et al., 2019; Trippl et al., 2023a). It is pointing to a more purpose-driven directionality of innovation and encourages the mobilisation of existing and integration of new actors including civil society, thereby overcoming the MLP's critique of insufficient actor inclusivity and technological bias (Tödtling et al., 2021; Isaksen et al., 2022; Fastenrath, 2022). The CoRIS is considered to operate "at a regional scale, but it is interrelated with national, European, and global scales in terms flows of knowledge, resources, regulations and policies" (Tödtling et al., 2021, p. 2144).

For the objectives of this thesis, the CoRIS approach provides a more appropriate theoretical framework, which will be discussed in greater depth (Chapter 3.3 & 3.4).

3.2 Literature review

The main literature body consists of publications that directly or indirectly discuss the CoRIS approach (Tab. 2). First, a literature search in Elsevier's Scopus database was conducted to identify relevant articles by combining the terms ALL ("challenge oriented") and ALL ("regional innovation system,") resulting in a total of 21 documents (search date June 24th, 2024). The search input was modified to include all fields instead of being limited to the 'Article title, Abstract, Keywords'. This change was made since the latter search only yielded five articles in the results. It was crucial to authenticate the usage of these terms in other peer-reviewed literature. Out of the 21 papers, a thorough examination was conducted to determine their relevance to the research purpose. Eventually, the selection was limited down to 9 items (Tab. 2, IDs 1-9). The remaining 5 sources (IDs 10-14) were chosen based on their relevance to the CoRIS approach (IDs 10,11), understanding of the established scientific knowledge concerning the subject (IDs 12,13), or their indirect contribution to the advancement of the study (IDs 14). Table 2 displays the 15 main articles that examined for this study. All additional publications that were deemed relevant to the issue are mentioned in the text.

ID	Authors	Title	Year
1	Wanzenböck & Frenken	The subsidiarity principle in innovation policy for societal challenges	2020
2	Tödtling et al.	New directions for RIS studies and policies in the face of grand societal challenges	2021
3	Isaksen et al.	Regional innovation systems in an era of grand societal challenges: reorientation versus transformation	2022
4	Chaminade	Innovation for What? Unpacking the Role of Innovation for Weak and Strong Sustainability	2020
5	Trippl et al.	Rethinking regional economic resilience: Preconditions and processes shaping transformative resilience	2023b
6	Cappellano et al.	Where innovation meets directionality: an index to measure regional readiness to deal with societal challenges	2022
7	Hassink et al.	Exploring the scope of regions in challenge-oriented innovation policy: the case of Schleswig-Holstein, Germany	2022
8	Sovacool et al.	"Oh Yes! Net-Zero": Sociotechnical capabilities and regional innovation systems for British industrial decarbonization	2024
9	Trippl et al.	Regionale Innovations- und Wirtschaftspolitik in Zeiten transformativen Wandels: Der CORIS-Ansatz als Orientierungsrahmen	2023a
10	Fastenrath	Why we need more challenge-oriented innovation	2022
11	Trippl et al.	Challenge-oriented regional innovation systems: towards a research agenda	2024
12	Tödtling &Trippl	Regional innovation policies for new path development – beyond neo-liberal and traditional systemic views	2018
13	Asheim et al.	The Role of the Regional Innovation System Approach in Contemporary Regional Policy: Is it still relevant in a Globalised World?	2019
14	Mazzucato	Mission-oriented innovation policies: challenges and opportunities	2018

Table 2. *Primary documents in the CoRIS literature review (Scopus database)*

3.3 The emergence of CoRIS

Introduced in 2021, the CoRIS approach attempts to adopt a broader understanding of innovation in the field of economic geography. It builds on the regional innovation system (RIS) framework, which has been used since the 1990s across various regions, countries and at EU level to analyse positive or less favourable economic development but also to inform place-based innovation strategies and policies aiming at economic growth and competitiveness (Asheim et al., 2020; Isaksen et al., 2022; Trippl et al., 2024). The RIS approach has been instrumental in shaping the EU's regional policy agenda including the Constructing Regional Advantage (CRA) and later the Smart Specialisation Strategy (S3), which initially focused on the diverse landscape of European regions and subsequently extended beyond Europe (Asheim et al., 2020; Fastenrath, 2022).

The Regional Innovation System (RIS) approach is recognised as a theory that underpins competitive advantage through innovation, advocating for regional economic advancement via economic diversification and structural transformation, rather than merely through expansion. The framework attempts to explain geographical and temporal disparities in innovation distribution and helps designing policies that enhance the competitiveness of regional

economies (Isaksen et al., 2018a as cited in Asheim et al., 2019, p. 1). Fundamental to the RIS model are the interdependencies among the three main elements: actors, networks, and institutions. This synergy promotes interactive learning among firms, research bodies, and policy makers, encapsulated in the triple helix model (Asheim et al., 2020; Trippl et al., 2024). Scholarly research on RIS has highlighted the diverse nature of regional innovation capabilities, which stem from variations in RIS component endowments, internal connectivity, and external linkages. Moreover, the RIS framework has been associated with long-term regional economic restructuring, focusing on industrial specialisations, institutional support systems, and regional networks that facilitate the development of new industrial pathways and the revitalisation of existing ones (Trippl et al., 2024; Isaksen et al., 2022). Since RIS are per definition open systems, meaning that not only internal but also external factors like global production and innovation networks, supranational and national policy frameworks are influencing regional industrial development (Hassink et al., 2019, as cited in Trippl et al., 2024, p. 2, Asheim et al., 2015). By avoiding a one-size-fits-all approach and concentrating on regional dynamics and specific tools, the RIS framework provides a detailed and practical perspective on fostering innovation, renewal, and growth within industrial clusters and regional networks (Sovacool et al., 2024). However, the RIS approach has been criticised for prioritising the corporate sector with an emphasis on technological, marketing, and organisational innovation. In contrast, the CoRIS approach adopts a more critical and forward-thinking perspective on innovation being a response to societal needs instead of merely generating economic growth and competitiveness of the regional economy. Unlike numerous RIS studies, CoRIS assumes that innovation is not always positive but considers its potential unintended ecological and social consequences. This approach underscores a comprehensive understanding of innovation that encompasses solutions with positive social impacts while mitigating potential negative consequences, thus aligning regional strategies with broader societal needs and aspirations (Trippl et al., 2023a; Tödtling et al., 2021; Isaksen et al., 2022). CoRIS is an appropriate analytical tool for this paper because it promotes transformative change by incorporating diverse forms of innovation, a thought that will be further explained in Chapter 3.4. Given the persistence of societal challenges of global nature, such as climate change, environmental degradation, growing social injustice, and demographic shifts, we need to question our understanding and the function of innovation systems and the policies that result from them. The interconnectedness of these challenges requires a systemic view of innovation and innovation policies that pursue long-term oriented goals (Coenen & Morgan, 2020; Fastenrath, 2022; Tödtling et al., 2021; Trippl et al., 2024).

In the attempt of addressing these societal challenges through socio-technical change, a new paradigm has developed (Schot & Steinmueller, 2018). Alternative concepts reflecting this paradigm are mission-oriented (Mazzucato, 2018), transformative (Diercks et al., 2019; Schot and Steinmueller, 2018), and challenge-driven innovation policies (Calignano & Trippl, 2020) that take a different angle on innovation systems and processes (Cappellano et al., 2021; Fastenrath, 2022; Trippl et al., 2023a). These concepts put an emphasis on the trajectory and quality of innovation and aim to shift unsustainable socio-technical systems towards more sustainable and inclusive ones. Regional innovation policies therefore need to address existing locked-in socio-technical systems and networks while overcoming path dependencies that

might prevent these systems from responding to change (Chaminade, 2020; Hassink et al., 2022; Tödtling et al., 2021).

Mission-oriented innovation systems (MIS) and CoRIS are concerned with addressing societal challenges through innovation, however, MIS form around a specific mission or challenge, whereas CoRISs are broader, regional frameworks that can address multiple challenges and involve a wider range of actors and innovation types (Hekkert et al., 2020). According to Mazzucato (2018, p. 803), mission-oriented policies need to address the wicked nature of grand societal challenges, i.e., "complex, systemic, interconnected, and urgent [challenges], requiring insights from many perspectives". To succeed, mission-oriented policies need to build on ambitious missions with specific targets and timelines, providing a direction for innovation efforts, include a diversified portfolio of R&D or innovation projects, stimulate cross-sectoral and interdisciplinary collaboration and foster policy making at all levels of the public institutions involved (Mazzucato, 2018, p. 807). Moreover, these policies encourage experimentation, risk-taking, and a culture of learning from failure while advocating for sharing both risks and rewards between public and private sectors (Mazzucato, 2018, p. 809). Besides being bold and ambitious, research efforts and innovation activities should still remain realistic and socially relevant (Mazzucato, 2018, p. 811). While the definitions of MIS and CoRIS overlap to some degree, it is essential for CoRIS policies to account for the relationships among different regional challenges to ensure their effectiveness (Tödtling et al., 2021, p. 2145). The following subchapter will elaborate on this approach and its implications for policy practice.

3.4 CoRIS approach

The CoRIS approach challenges traditional RIS and can be seen as an extension to regional innovation policy and builds upon existing frameworks and approaches while addressing their limitations. It advocates for challenge-orientation and directionality of innovation (Hassink et al., 2022; Mazzucato et al., 2020; Mazzucato, 2018) but also addresses place-specific needs and problems to overcome universal one-size-fits-all policies. While mission-oriented, responsible research and innovation (RRI) and transformative innovation studies are criticised for lacking the sensitivity of considering the geographical context of innovation (Coenen & Morgan, 2020), CoRIS addresses this issue. Place-specificity emphasises that regional innovation strategies and efforts must be tailored to each region's unique characteristics and dynamics to be effective, while also considering the interconnection of national, European, and global scales (Tödtling et al., 2021). Since grand societal challenges are often global in nature, their solutions are thought to be global as well, without considering that regions have different capabilities, assets, and motivations in solving them. These challenges are often described as "wicked" - complex, unpredictable, open-ended, or intractable - making them unlikely to be solved on a global scale (Wanzenböck & Frenken, 2020; Head & Alford, 2015, p. 712). This "wicked" nature of societal challenges requires innovation policies to be coordinated and implemented at national and subnational (regions, municipalities) level. In transformative innovation policy literature, national governments are seen as critical agents, acting as catalysts, institutional entrepreneurs, and coordinators of network governance. They contribute to the formation of common visions, the establishment of targets, and the development of

regulations and incentives to direct market forces towards a long-term sustainability objective. Subnational governments are expected to develop challenge-oriented regional innovation policies that respond to place-specific needs, given the fact that regions are exposed differently to societal challenges. Moreover, they are ideal test beds or living labs to experiment with innovative solutions for sustainability transitions (Cappellano et al., 2021, pp. 1551-1552). Tödtling and colleagues (2021) suggested different elements to be considered for a reconfiguring of the conventional RIS approach (Tab. 3). These elements will be outlined in the following five sections.

A. CoRIS is extending the limited understanding of innovation as a market and technology-oriented practice to a more inclusive one, by incorporating civil society, public sector, organisations, and communities. This makes the RIS approach more dynamic and open for other types of innovation (social, user, and institutional innovation) to thrive (Asheim et al., 2019; Tödtling et al., 2021, p. 2143; Fastenrath, 2022).

B. Unlike other concepts, the CoRIS is not limited to a specific mission or challenge but rather reflects a region's ability to tackle interrelated challenges. Hence, the purpose of innovation should exceed the economic growth paradigm and serve as a response to societal needs (Tödtling et al., 2021, p. 2143).

C. A CoRIS considers the full spectrum of innovation effects, including both the "bright" and "dark" sides. This means that while innovations can lead to positive outcomes like new job creation and technological advancements, they can also have negative consequences, such as environmental degradation, social inequalities, or disruptive impacts on existing industries (Schot & Steinmueller, 2018). Ignored for decades, the consideration of harming effects allows RIS studies to concentrate on the most promising measures for a specific region to drive change and solve societal problems (Tödtling et al., 2021, p. 2143; Coad et al., 2020). A particular challenge can be tackled through different CoRIS initiatives such as reducing CO2 through energy efficient buildings, e-mobility, or optimised waste operations. While these initiatives are ideally complementary (e-mobility & renewable energies), they can be unrelated (e-mobility & energy-efficient buildings) or conflicting when competing for scarce resources (Tödtling et al., 2021, p. 2145).

D. The CoRIS approach significantly broadens the scope of actors, networks, and institutions involved in RIS by promoting inclusivity and participation across various stakeholder groups. This model goes beyond the traditional roles of funding and infrastructure provision, emphasising the importance of organising and coordinating an open innovation process. This involves establishing policy platforms and working groups that address technological, business, ecological, and social themes (Tödtling et al., 2021). Unlike traditional RIS, which typically operate within a triple-helix framework encompassing the private sector, public sector, and research institutions, CoRIS expands this to a quadruple-helix model. This includes integrating new actors from civil society and non-governmental organisations, thereby fostering a more diverse and inclusive innovation ecosystem (Asheim et al., 2020; Fastenrath, 2022). By engaging a wide array of actors, CoRIS amplifies the capacity to mobilise diverse

perspectives, knowledge bases, and resources crucial for the development of challenge-oriented innovations tailored to specific regional issues. These innovations can emerge organically and decentralised (bottom-up), with a focus on experimentation or be driven by policy actions (top-down). The EU's Smart Specialisation Strategy is an example for a top-down policy approach that builds on a region's strength and competitive advantage by supporting practice-based innovation (Asheim et al., 2020, p. 6). On the one hand, system-level agents play an essential role in reconfiguring regional assets and structures to support this inclusive approach. Change agents can be identified among local grassroots movements that develop from the bottom up or within policymakers who create extensive regulatory measures from the top down (Fastenrath, 2022, p. 62; Tödtling et al., 2021, p. 2146; Hassink et al., 2022). On the other hand, actors who support existing structures, referred to as reproductive agents may not only resist change but also play a crucial role in spreading challenge-oriented innovations within a region (Baekkelund, 2021).

While a CoRIS fosters inclusion by building on a multi-actor approach, one must not ignore the complexity of integrating various interests and promoting participation. Consequently, various socio-technical sectors experience "silo-thinking and a lack of collective action" (Fastenrath, 2022, p. 62). To avoid this, clear goals need to be set, a wide range of stakeholders need to be included into vision building, and potential conflicts of interest need to be managed through problem-based dialogue as well as effective communication and leadership (Tödtling et al, 2021, p. 14; Wanzenböck. & Frenken, 2020, p. 56) This applies to actors within and between CoRIS initiatives (Tödtling et al., 2021, p. 2152). Sovacool and colleagues (2024) emphasises this in their work on decarbonisation efforts across the United Kingdom and Fastenrath (2022) arrives to the same conclusion for the Gippsland Smart Specialisation Strategy in Australia. Actor networks and institutions cooperate on a regional scale but are influenced by policy motivations or constraints on the higher, supranational, or national level (Tödtling et al., 2021, p. 2146). Accordingly, a region's ability to tackle societal problems depends not just on regional dynamics but also on translocal networks and the region's embeddedness in national and supranational policy structures and regulations (Trippl et al., 2024, p. 3; Tödtling et al., 2021). A CoRIS initiative requires, as demonstrated by Vorarlberg's e-mobility project VLOTTE, the mobilisation of regional and extra-regional financial, human resources, assets, and inter-regional learning (Tödtling et al., 2021, p. 2153). Arguing that grand societal challenges need to be addressed on a regional level, challenge-oriented innovation policy is as difficult to implement on a subnational level than on any other level without being inherently "more democratic and context-specific" than national or supranational policies (Wanzenböck & Frenken, 2020, p. 57)

E. Moreover, the CoRIS framework advocates a shift from predominantly focusing on the supply side of innovation towards integrating the application side, i.e., how innovations developed to tackle concrete issues are applied in practice in specific regions. Innovation policies should therefore integrate demand-side instruments such as public procurement and not solely rely on supply-side instruments like financial subsidies to protect infant industries (Tödtling et al., 2021, p. 2143, Tödtling et al., 2018, p. 1784). Vorarlberg's VLOTTE initiative mentioned earlier, exemplifies how this could look like. Due to a lack of an automotive industry

and a reliance on e-vehicle imports, this challenge-oriented (regional energy autonomy) initiative focuses on the application side of innovation through social and institutional innovations (car leasing contracts, conversion to electric vehicle fleets…) (Tödtling et al., 2021, p. 2148). Considering the application side of innovation avoids that regions lose sight of their capacity to establish innovative solutions, which need to be upscaled in the region and beyond to actually solve place-based challenges. This capacity to diffuse challenge-oriented innovation refers to the earlier mentioned reproductive agency (Tödtling et al., 2021, p. 2143). Consequently, for CoRIS initiatives to be successful, arranging the cooperation with other policy fields becomes important (Diercks et al., 2019). Scholars assume that driving and hindering forces as well as the dynamics of actor networks and institutions will temporally and spatially shift, requiring CoRIS policies to remain adaptive and dynamic (Tödtling et al., 2021, p. 2146). But how can challenge-oriented innovation policies focus on solving grand societal challenges in this dynamic of system-level change?

	Conventional RIS approach	**Challenge-oriented** RIS approach
A. **Type** of innovation	Innovation in the regional corporate sector: technological, organisational, marketing innovation	Innovation in the regional corporate sector and in other realms (public sector, civil society, regional and urban communities: technological, user, social, institutional innovations)
B. **Purpose** of innovation	Economic growth and competitiveness of the regional economy	Grand societal challenges and problems faced by the region
C. **Effects** of innovation	Focus on positive effects (strong pro-innovation bias)	Focus on multi-dimensional effects of innovation: bright and dark sides
D. **Actors**, networks institutions	Firms, universities, state, intermediaries knit together in stable (local and non-local) networks and embedded in a static multiscalar institutional landscape	Conventional RIS actors and 'new' innovation agents (civil society, public sector actors, users, etc.) knit together in/influenced by dynamically developing networks and evolving institutional configurations at multiple scales
E. Production and **application** sides	Supply side (generation/production of innovation in the region)	Supply side and demand/application side (experimentation/diffusion/upscaling of innovation in the region)

Table 3. *Key differences between conventional RIS approach and CoRIS approach (adapted from Tödtling et al., 2021, p. 2144)*

While Table 3 demonstrates the key differences between conventional RIS and challenge-oriented RIS, the question of how this reconfiguration is happening remains. According to Isaksen and colleagues (2022) and Trippl (2023), a CoRIS can evolve along two different routes, through the reorientation of existing structures (reorientation strategies) or through the creation of new challenge-oriented structures (transformation strategies). The **reorientation** route involves leveraging the assets, actors, networks, and institutional structures of existing regional innovation systems (RIS) to address regional challenges and seize opportunities for green path development (Trippl et al., 2023b, p. 5). This approach enhances the challenge-

orientation of current RIS by redirecting established elements and functions towards new goals and recombining historically grown assets. However, innovation activities that address place-specific challenges might increase economic uncertainty, potentially leading to resistance from incumbents and lacking political and societal legitimacy. Therefore, mobilising established RIS actors and assets to tackle regional challenges with innovative solutions that also provide economic opportunities can be a suitable strategy in some contexts (Trippl et al., 2023a, p. 6; Trippl, 2023, p. 65). The **transformation** route involves integrating previously overlooked innovative actors, breaking up outdated networks, and fostering institutional changes. These new players have distinct objectives within the existing system compared to incumbent actors, who are motivated to maintain the status quo. Overcoming their resistance to change, as well as reducing support for 'business-as-usual' practices are essential elements of the transformation route, especially in regions specialised in polluting industries and unsustainable RIS (Kivimaa and Kern, 2016, p. 210; Trippl et al., 2023a, p. 6). Hence, strategic transformation involves building up a CoRIS by experimenting with, developing, and scaling challenge-oriented innovations while detecting unsustainable path dependencies and phasing out unsustainable practices. Public and private actors may avoid removing unsustainable practices and instead adopt a layering strategy, adding new procedures to existing ones, potentially resulting in the coexistence of old and new structures, and limiting transformative change (Trippl et al., 2023a, pp. 6-7; Trippl, 2023, pp. 65-66). However, reorientation and transformation strategies must be understood as two ideal types that represent both ends of a continuum, with many possible combinations in between. Sovacool and colleagues (2024, p. 18) showcase how the UK's green industrial restructuring can be seen as a "hybrid" between reorientation and transformation. By focusing on achieving a net-zero industry and building on past decarbonisation policy failures, it is implementing novel policy instruments like carbon taxes (transformation) but relying on existing markets for gas and carbon credits (reorientation). The decision on whether to pursue reorientation or transformation is influenced by two main factors. At first, a region's history and context which includes the existing RIS structures, established assets, industrial specialisations, and organisational support frameworks. Acknowledging these preconditions at different spatial scales allows regions to address potential path dependencies and overcome lock-ins. Secondly, the way in which grand societal challenges are understood by the region, i.e., with a predominantly local consequence or as a "system-wide" problem plays a role (Trippl, 2023, p. 67; Isaksen et al., 2022, p. 8; Hassink et al., 2022, p. 2307). Furthermore, choosing between reorientation or transformation might depend on the definition of the problem area. A well-defined problem area with supportive regional conditions calls for a RIS reorientation, whereas a complex problem area with extensive societal impact indicates a need for transformation, especially when essential assets are absent (Isaksen et al., 2022, p. 9). Given the urge to address grand societal challenges through sustainability transformations, the authors draw attention to potentially insufficient outcomes of reorientation strategies and the necessity of transformation strategies. The latter might involve questioning our social system and initiating change on a deeper level by developing new values, believes, skills, regulations, etc. (Isaksen et al., 2022, p. 10). Table 4 depicts both reconfiguration strategies for sustainability transitions.

	RIS reorientation strategies	RIS transformation strategies
Characteristics	Build on and reuse competences, actors, networks, and institutions in existing RISs. Fit into existing production and market system	Include several new types of actors, networks, and institutions. Require changes in production and market systems
Support for sustainable transition	Reusing & recombining existing assets	Creating (importing) new assets & destructing old assets
Policy strategies	Build on and adapt existing regional innovation policy for new sustainable goals	Create new policy for sustainable transitions

Table 4. *RIS reconfiguration strategies for sustainability transitions (edited from Isaksen et al., 2022)*

In their paper on rethinking regional economic resilience, Trippl and colleagues (2023b, pp. 9-10) have outlined four core processes as fields of action for a transformative regional innovation and economic policy. First, **identifying challenges and assets** involves addressing territorial sustainability issues rather than just incrementally enhancing regional strengths. This process includes determining significant regional problems, understanding their root causes, and identifying urgent needs. While leveraging existing economic and technological assets is important, driving innovation-based regional transformation often requires modifying the region's resource base, including natural resources, infrastructure, technologies, and competencies. The second process, **innovation development and diffusion**, focuses on creating, testing, and implementing innovative solutions for identified challenges. This process also involves scaling up these solutions within the region and spreading them to other regions facing similar issues. Innovations in this context can be technological, social, or institutional, and often require a combination of these types. **Unlocking and destabilisation**, the third process, emphasises not only supporting desirable innovations but also intentionally phasing out unsustainable industries, technologies, and practices. This exnovation process may face resistance from established actors but is crucial for transitioning to environmentally friendly solutions and uncovering new opportunities. Addressing resistance and facilitating this transition are central to regional innovation policies. Finally, **orchestration** involves coordinating various stakeholder groups with different motivations and capabilities. This process includes managing conflicts of interest and fostering open discussions about innovation goals. Effective orchestration requires both horizontal coordination across policy areas (such as labour, environment, spatial planning) and vertical coordination with national and supranational policy levels. While this can be complex, it is essential for aligning with broader policy frameworks like the European Green Deal. Depending on the RIS reconfiguration route or combination of strategies, these processes take a different course of action. When following a reorientation route, regional challenges and solutions emphasise technological innovation and economic value creation by strengthening the roles of existing actors. Conversely, if transformation strategies are primarily adopted, new actors become pivotal, and regional challenges and solutions focus on disrupting the current unsustainable RIS structure, making orchestration more complex.

3.5 Criticism and case relation

The central idea of the RIS framework is that a region's performance and capacity to innovate is mainly influenced by the interactions between three system elements: actors, networks, and institutions (Trippl et al., 2024, p. 3). This approach has been used as a tool to assess a region's strengths and weaknesses regarding economic development and for policy analysis. However, given the urgency of addressing grand societal challenges, scholars have encouraged rethinking of this approach, by introducing alternative concepts such as the CoRIS. While this approach has gained popularity in the last years, it is still in its infancy, thus requiring more conceptual research and empirical evidence on how RIS reconfiguration is translated into practice (Isaksen et al, 2022, Trippl et al, 2024). There exist a few papers analysing real-world cases in Schleswig-Holstein, Germany (Hassnik et al., 2021), Vorarlberg (Tödtling et al., 2021), Gippsland, Australia (Fastenrath, 2022), Italian regions (Cappellano et al., 2021), Lower Austria, Austria & Stavanger, Norway (Trippl et al., 2023b) and Great Britain (Sovacool et al., 2024). And by analysing Luxembourg's transition to a circular built environment through the CoRIS framework, this thesis aims to enhance the validity and applicability of this approach.

While traditional RIS continues to be an important tool for designing and implementing regional innovation policies, the framework has been facing critical voices. However, according to Phelps and colleagues (2018, p. 237), the RIS literature tends to concentrate on highly successful and innovative regions while neglecting less developed regions or uncompleted systems, creating the illusion that development is accessible for every territory. Moreover, many RIS analyses are criticised for focusing on a static landscape of actors and institutions rather than dynamic interactions, roles, and functions (Uyarra et al., 2019). Weber and Truffer (2017, p.111) question the use of predefined territorial borders to define systems, arguing that such boundaries do not reflect the increasingly globalised nature of innovation processes. Additionally, the emphasis on technological innovation within RIS, which has hindered a comprehensive understanding of new economic challenges related to radical, systemic, and value-oriented innovations (Jeannerat and Crevoisier, 2016). Concepts that are part of a RIS paradigm shift, are not without criticism either. Mazzucato's (2018) mission-oriented innovation policy is questioned for demanding a stronger implication of governments in the innovation process. Scholars worry that such policies favour certain sectors or technologies over others, potentially leading to inefficiencies. CoRISs bring together public and private parties to collaborate on addressing territorial sustainability problems through challenge-oriented innovation activities. Given that grand societal challenges do not stop at the border of a region, a more open perspective on innovation and systemic beyond-borders thinking help to better understand the emergence of transformative innovation. However, for concepts and theories like CoRIS to drive sustainability pathways, it needs to be translated into policy practice (Fastenrath, 2022, p.67). For this study, the CoRIS approach serves as theoretical lens through which Luxembourg's transition to a circular built environment is analysed. Kirchherr et al. (2017, p. 228), state that "trending concepts tend to diffuse in their meaning" and given its trending nature, the CE concept might fit into this category. The variety of prevailing definitions for CE makes it a less than ideal starting point for this study, which does not intend to establish an additional one. Instead of insisting on a clear and uniform

definition in the beginning, this study will embrace different perspective and examine how innovation operates in practice to gain insights into its nature. These insights can then enhance general innovation theories, like CoRIS, and provide clearer explanations of real-world issues to policymakers and other stakeholders in order to develop sustainable and effective innovation strategies that address grand societal challenges. In the following chapter, the methodological structure of this study will be defined.

4 Methodology

For this master's thesis, a qualitative empirical research approach will be applied. As research method, the case study design was chosen to investigate Luxembourg's transition towards a circular built environment. The collected data will be analysed using a qualitative content analysis.

4.1 Research Design

Main research question: How is Luxembourg's built environment influenced by the CE concept and what is necessary to ensure the transition towards a circular built environment?
Secondary questions:

1. How do actors involved in the transition to a circular built environment understand and address the CE?
2. How is governance of the CE approached in the built environment?
3. What barriers are hindering the transition to a circular built environment?
4. What driving forces could facilitate the transition to a circular built environment?

To address the main research question, it was determined that a single-case study design of exploratory nature would be suitable given that it offers the possibility to investigate a "contemporary set of events over which a researcher has little or no control" **(**Yin, 2018, p.44). Being widely used in qualitative research, this methodology is well-suited to understanding real-world situations (Yin, 2018), particularly in spatial and regional settings (Cox & Evenhuis, 2020). Since generalising findings from a case study to a broader level has been a concern, conclusions should be interpreted in consideration of the specific context (Harrison et al., 2017). It enables researchers to investigate the complexity, interdependencies, and dynamics of the circularity transition from many perspectives, resulting in a comprehensive knowledge of the subject (Yin, 2018, p. 24). Through the utilisation of interviews, documentation, and observations, this study endeavours to acquire a deeper understanding of stakeholder perspectives, policy dynamics and practical challenges related to CE initiatives. Figure 6 represents how the case is broken down into subunits that are embedded within the case and enable a comprehensive analysis of Luxembourg's construction sector throughout its transition towards a CE (Yin, 2018, p. 88).

For this thesis, the **context** provides the overarching environment within which the case study is conducted. The context is defined by Luxembourg's transition towards a CE. This context encompasses the economic, political, and regulatory framework that shapes the country's shift towards a CE. Additionally, it addresses the temporal scope, including both historical

developments and contemporary trends in CE practices. This contextual backdrop is essential for comprehending the specific dynamics and challenges associated with Luxembourg's efforts to embed CE principles across various sectors.

The **case** represents the central focus of the study, which is subject to in-depth examination. In this instance, the case is the building sector within Luxembourg. The research seeks to explore how CE principles are being implemented within this sector, including an investigation of current practices, strategies, and progress towards the adoption of CE principles in construction and building.

Embedded units of analysis refer to specific aspects or dimensions within the broader case that are examined in detail. For this study, the embedded units are:

1. **Understanding of CE:** This unit explores how various stakeholders contributing to a circular built environment understand and address the CE. It should be noted that this study analyses the concept from the perspective of actors who are familiar with and engaged in the topic.
2. **Governance of CE:** This unit examines governance practices in Luxembourg's building sector by analysing current initiatives that reflect the state of circularity within the built environment. Additionally, it discusses the importance of bottom-up initiatives in driving the transition towards a circular built environment.
3. **Barriers to transition:** This unit identifies and analyses the obstacles and resistances that impede the transition towards a circular built environment. These challenges are categorised in different barrier groups, based on the analysed material. Understanding these barriers is essential for formulating strategies to effectively address and overcome them.
4. **Drivers of transition:** This unit focuses on the factors that facilitate and accelerate the shift towards a circular built environment. These driving forces are grouped into categories based on the analysed data. Recognising and leveraging these drivers is essential for advancing the transition process.

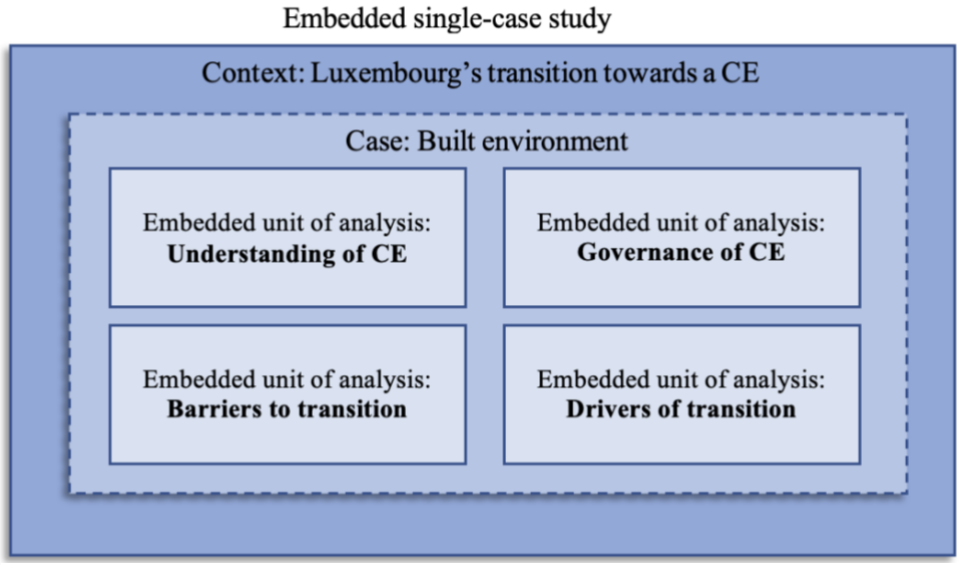

Figure 6. *The case study design for this study (based on Yin, 2018, p. 84, Fig. 2.4)*

4.2 Case selection

To justify the use of a single-case design, the case and its subunits were selected according to the following rationales (Yin, 2018, p. 90):

- a *critical* test of existing theory: The objective of this study is to examine Luxembourg's transition process towards a CE by consulting the CoRIS framework. Since research on the CoRIS approach is relatively new and only a handful articles have been published on this topic, empirical studies are critically needed. This study aims to link the CoRIS approach to CE in the construction sector. Luxembourg's unique economic, geographical, historical, and cultural context has not yet been analysed through the CoRIS framework, presenting an opportunity to test, refine, or expand the existing theory. This case study is poised to contribute to knowledge development and theoretical advancement by providing empirical insights into how the CoRIS framework aligns with CE principles in a distinct setting (Yin, 2018, p. 84).

- an extreme or *unusual* circumstance: Luxembourg's transition towards a CE presents an unusual case due to the country's unique geopolitical and economic context. For decades, the Grand Duchy of Luxembourg has encountered economic and demographic growth and had the highest commuter-influx in the EU, resulting in challenges such as housing scarcity or traffic congestions (Faller & Schulz, 2018). Besides these challenges, the combination of small scale and high wealth levels can present unique opportunities for implementing CE practices, which may differ significantly from larger, more populous countries.

- a *common* case*:* Despite Luxembourg's unique characteristics as a small, affluent nation, its construction sector shares similarities with other developed economies facing sustainability challenges. The selection of this case represents a common scenario encountered in various contexts globally, where efforts are underway to adopt circular practices in construction. Luxembourg's ecological footprint is among the highest in the world, substantially due to the contribution of a resource-intensive construction sector that is highly reliant on imports (OECD, 2020, p. 61). With the adoption of a national CE strategy (Schosseler et al., 2021), the reorientation of the ClechTech-Cluster towards CE, ecocities and urban resources management*,* or the implementation of the National Council for Sustainable Construction (CNCD), Luxembourg is heading towards a more sustainable future.

- a *longitudinal* purpose*:* Adopting a longitudinal approach allows for the examination of the evolution and impact of CE initiatives over time within Luxembourg's construction sector. This approach facilitates the analysis of policy changes, technological advancements, and shifts in stakeholder engagement dynamics, allowing for the identification of trends and patterns in the implementation of CE strategies and offering a comprehensive understanding of progress towards circularity.

4.3 Data collection

The necessary data for this research will be collected through a triangulation of methods, including interviews, document analysis, and direct observations to achieve a comprehensive understanding of the research problem (Yin. 2018, p. 173). Figure 7 represents the sources of evidence for this study.

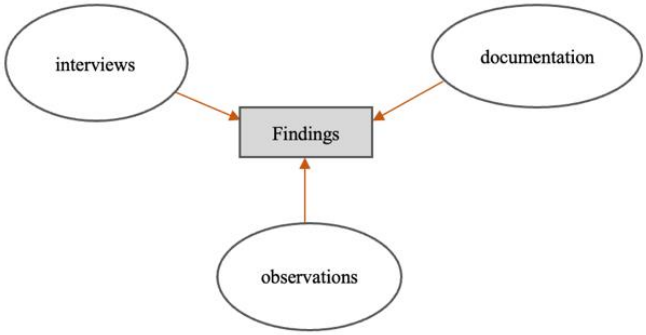

Figure 7. *Multiple sources of evidence (adapted from: Yin, 2018, p. 173, Fig. 4.2)*

Interviews are a pivotal method for collecting primary data, offering a direct line to the thoughts, experiences, and perceptions of individuals within a specific sector. In the context of Luxembourg's building sector, semi-structured interviews are particularly valuable. They allow for a standardised set of questions while providing flexibility to delve deeper into responses, fostering a rich exchange that can reveal nuanced insights (Gläser & Laudel, 2010, p. 40). This method is grounded in the principle of open-ended, neutral, and clear questioning, which encourages interviewees to share detailed and honest answers (DeJonckheere & Vaughn, 2019, p. 5). The individual interview setting was preferred over focus groups for its ability to provide a more personal and uninhibited conversation, which can be recorded for accurate transcription and subsequent analysis. The use of audio recording is a best practice for qualitative research, as it ensures that the depth and nuance of responses are preserved (Yin, 2018, p. 167).

The interview guide was structured in five thematic blocks, i) understanding of CE principles & innovation, ii) driving forces and key actors, iii) barriers and detractors iv) policy and regulatory support and v) future outlook. Given that two of the interviewees were directly involved in a particular CE initiative, an extra thematic section was included, vi) contributions to the CE transition. Once the guiding questions were developed, a pilot test of the interview was conducted to manage its timing, ensure a conversational tone, and make necessary adjustments to the questions (DeJonckheere & Vaughn, 2019, p. 5). Due to the diverse roles and expertise of the interviewees, the interview guide was slightly modified to gain relevant and insightful responses.

The interviewees were selected through desk research and based on recommendations from contacts made during the Circular Economy Day 2024. Except for the interview partner from the NGO sector, all interview partners had connections to the construction sector and were engaged in the CE. Each potential interviewee was sent a recruitment letter outlining the themes

to be discussed during the interview (see Appendix B). However, the specific interview questions were not shared beforehand to prevent participant bias and pre-formulated responses (Haukås & Tishakov, 2024, p.13). A total of 11 interviews with 12 people were completed, where two were conducted face-to-face and nine were taking place online. Participants included individuals from academia (university, research institute), the public sector (local authority, ministries, state co-funded agencies and institutions) private sector (engineering firm, architecture firm) and the non-profit sector. To maintain flexibility in the data collection phase (Yin, 2018, p. 120), the interview guide was refined, beginning with broader, open-ended questions to stimulate free-flowing responses before transitioning to more targeted questions. For the purpose of subsequent data analysis, all interviews were recorded and subsequently transcribed, utilising automatic speech recognition software. LUX-ASR was used for Luxembourgish interviews, while f4x was employed for those recorded in German and French.

Documentation serves as a critical source of secondary data, complementing the insights gained from interviews by providing a broader context and background information. This includes a wide range of materials such as policy documents, administrative records, websites, formal studies, scientific papers, books, conference recordings, and NeoMag, the Luxembourgish magazine for innovation and sustainable construction. These sources are invaluable for understanding the regulatory environment, industry trends, and the theoretical underpinnings of practices within the building sector. For instance, policy documents from governmental entities and institutions can shed light on the strategic direction and incentives shaping the sector, while scientific papers and books offer in-depth analysis and theoretical frameworks (Bowen, 2009, p. 27). The inclusion of such diverse materials ensures a well-rounded understanding supported by a stable, specific, broad, and unobtrusive source of evidence (Yin, 2018, p. 157, Fig. 4.1). Table 5 provides an overview of policy documents from Luxembourg related to the CE concept, which were analysed as part of this study.

Observation, as a method of data collection, offers a unique opportunity to witness and engage in the phenomena of interest in real-time. Attending the Circular Economy Day 2024 in Wiltz provided a valuable opportunity to network with professionals specialising in CE and to engage in discussions with individuals passionate about this domain. This event afforded the chance to witness the unveiling of innovative tools and to learn about the successful completion of projects, offering insights into both historical achievements and future prospects within the CE field. Engaging in a workshop and being present for presentations and discussion sessions throughout the day facilitated lively exchanges and casual talks with both attendees and speakers, enhancing the interactive and immersive experience of the event (Yin, 2018, pp. 165-167; Häder, 2019, pp. 234-236). Observation also allows for the collection of data that may not be captured through interviews or documentation, such as the tone and tenor of discussions, the level of engagement with certain topics, and the informal networks that exist. This method, when combined with interviews and documentation, enriches the research by adding a layer of experiential data.

ID	Title	Authors	Year of publication
1	Governmental Program 2014-2018	Luxembourg Government	2014
2	Third Industrial Revolution	The TIR Consulting Group	2016
3	Governmental Program 2018-2023	Luxembourg Government	2018
4	National Waste and Resource Management Plan	Environment Agency	2018
5	Zero Waste Strategy	Ministry of the Environment, Climate and Sustainable Development	2019
6	Data-Driven Innovation Strategy for the Development of a Trusted and Sustainable Economy in Luxembourg	Ministry of the Economy	2019
7	National Circular Economy Strategy	Ministry of Energy and Spatial Planning Ministry of the Economy Ministry of the Environment, Climate and Sustainable Development	2021
8	Revised Waste Framework Directive	Environment Agency	2022
9	Deconstruction guide	Environment Agency LIST	2022
10	Governmental Program 2023-2028	Luxembourg Government	2023
11	Roadmap for low-carbon construction	Ministry of Energy and Spatial Planning Ministry of the Environment, Climate and Sustainable Development	2023
12	Research and Innovation Smart Specialisation Strategy (RIS3)	Luxembourg Government	2024

Table 5. *Policy documents from Luxembourg related to the CE concept (own representation)*

4.4 Data analysis

A comprehensive qualitative content analysis guided by Kuckartz and Rädiker (2022) and the use of the computer assisted qualitative analysis software MAXQDA were selected to analyse the collected data. Accordingly, the qualitative content analysis is defined in the following words: "Qualitative content analysis is understood as the systematic and methodologically controlled scientific analysis of texts, images, films, and other content of communication. It involves analysing not only manifest but also latent content. The focus of qualitative analysis is on categories that are used to code all material relevant to the research question(s). Category formation can be deductive, inductive, or a combination of deductive and inductive. The analysis is primarily qualitative but can also incorporate quantitative-statistical evaluations; it can be either category-oriented or case-oriented." (Kuckartz & Rädiker, 2022, p. 39). The authors outline three methods, characterised by different approaches, that are frequently applied in research practice: the content structuring, the type building, and the scaling method

(Kuckartz & Rädiker, 2022, p. 104). In a content structuring qualitative content analysis, the material is categorised in a spectrum ranging from fully inductive category formation based on the material to largely deductive category formation, which is considered an appropriate method of this research project. Accordingly, the collected material was coded in several coding processes based on deductive-inductive category formation. This process begins with a small set of main categories that facilitate the identification and categorisation of relevant content, based on which subcategories are inductively derived. Figure 8 depicts the seven phases that serve as a framework for structuring this qualitative content analysis according to Kuckartz & Rädiker (2022, p. 132).

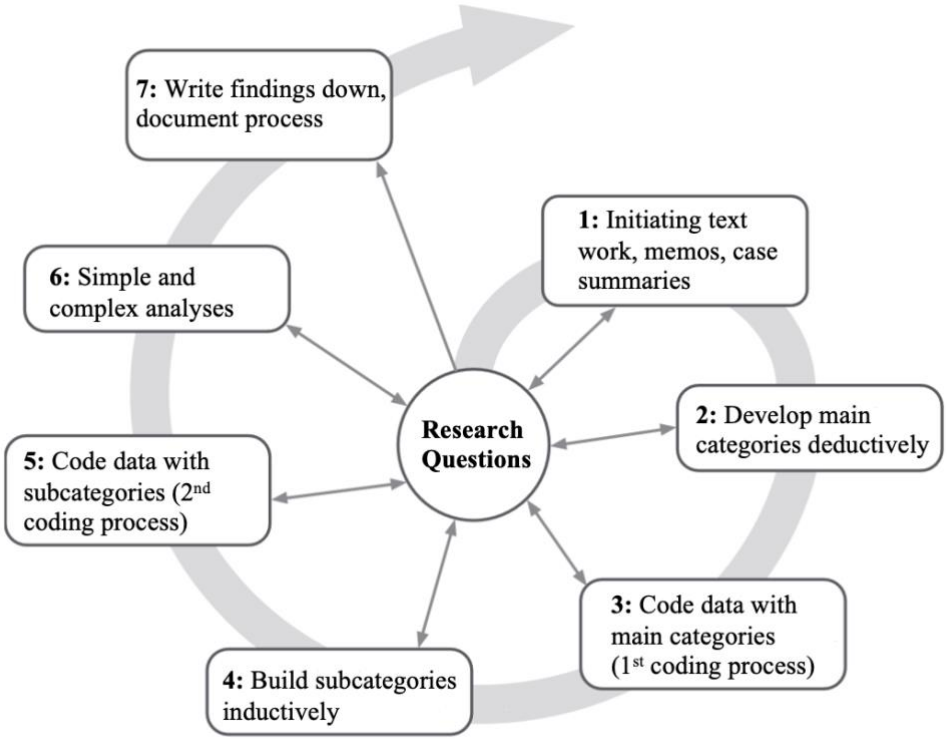

Figure 8. *Procedure of a structuring content analysis in seven phases (edited from Kuckartz & Rädiker, 2022, p. 132, Fig. 16)*

The initial steps of **Phase 1** (pp. 132-133) involved a meticulous examination of the documents collected during the data collection phase. This included highlighting key passages and annotating observations and emergent evaluation ideas in the margins. Notes were taken during the interviews and supplemented with observations from the transcription process. The transcripts were then verified against the audio recordings, translated into English, and subsequently uploaded into MAXQDA. Data from the Circular Economy Day 2024 were initially written down as bullet points on paper and later digitised. Phases 2 through 5 focus on the coding process using the MAXQDA software and are specifically applied to the interview transcripts. In contrast, the handling of documents and observations was performed manually, as detailed in Phases 6 and 7.

In **Phase 2** (pp. 133-134) a first draft of main categories was developed in a **deductive** way, inspired by the research questions and interview guides. For this study, eleven main categories were established, representing a compact yet manageable set. The different areas of focus hold a central position in the research project, are reflected in the description of the research questions, and represent a primary category in the analysis (Tab. 6). Subsequently, a trial run with a portion of the data was conducted to reassess the categories and their definitions, ensuring their practical applicability to the empirical material.

The initially established categories facilitated a seamless transition to **Phase 3** (pp. 134-137), the first coding process. This is where the interviews were manually encoded based on a search grid that included the eleven main categories. During this process, sections of text not pertinent to the research were excluded, and passages addressing several main categories were assigned multiple categories. It was ensured that each coded segment, whether consisting of a single sentence, multiple sentences, or an entire paragraph, was self-contained and comprehensible without reliance on the surrounding text.

In **Phase 4** (pp. 138-142), subcategories were **inductively** derived from the material assigned to the broader main categories. In line with the principles of frugality and clarity, the subcategories were developed to be as simple as possible while still providing the necessary level of detail. The coding system was meticulously aligned with empirical data and research questions to ensure relevance and coherence. Adjustments were made to refine the system, including evaluating the necessity of subcategories and integrating or modifying existing classifications from relevant literature on CE and CoRIS.

Phase 5 started with another trial run in MAXQDA, initiating the second coding process. Phases 4 and 5 are iteratively repeated: After subcategories are developed for one or more main categories, they are initially applied to the data material before proceeding to the next main category. If one text segment is associated with multiple main categories, this process helps to determine which main category is best suited after all.

After refining the main and subcategories categories, the data is analysed (simple & complex) in **Phase 6** (pp. 147-154). For this study, a category-based analysis along the main categories was applied and subsequently the segments within each main and subcategory were scrutinised to identify differences, similarities, noteworthy aspects, and interconnections between categories. This where the data from the other two sources of evidence, i.e., documentation and observation are included.

The concluding analysis in **Phase 7** (pp. 154-156) consists of documenting the findings, insights gained and answers to the research questions, presented in Chapter 5. Since phases 6 (analysis of data, which entails already drafts and finalised text sections) and 7 (final documentation of analysis where results are presented in an organised and systematic way) often require multiple iterations, they should be considered together. The theoretical framework, particularly the factors presented in Table 3 were guiding the drafting process.

ID	Main category	Subcategories
1	Regional context and embeddedness	**1.1** Spatial context; **1.2** Economic context; **1.3** Socio-cultural; **1.4** Political context; **1.5** Embeddedness in the EU
2	Understanding of the CE concept	**2.1** Definition; **2.2** Perceived importance; **2.3** Awareness; **2.4** Critical thinking; **2.5** Built environment
3	Actors & cooperations	**3.1** Actors in circular building; **3.2** Cooperation in the Greater Region; **3.3** National Cooperation; **3.4** International Cooperation
4	Barriers	**4.1** Regulatory barriers; **4.2** Cultural/behavioral barriers; **4.3** Financial barriers; **4.4** Knowledge barriers; **4.5** Market barriers; **4.6** Stakeholder barriers; **4.7** Supply chain barriers; **4.8** Technical barriers; **4.9** Organizational barriers; **4.10** Management barriers; **4.11** Technological barriers
5	Detractors	**5.1** Government bodies; **5.2** Industry; **5.3** Businesses
6	Driving forces	**6.1** Regulatory drivers; **6.2** Organizational drivers; **6.3** Knowledge drivers; **6.4** Supply chain drivers; **6.5** Business drivers; **6.6** Social drivers; **6.7** Technological drivers; **6.8** Evironmental drivers
7	Facilitators	**7.1** Government bodies; **7.2** Businesses; **7.3** NGOs & civil society; **7.4** Industry; **7.5** Research & educational institutions, **7.6** Architects & planners; **7.7** Customers
8	Innovation	**8.1** Innovation type; **8.2** Innovation purpose; **8.3** Innovation effects; **8.4** Actors, networks & institutions; **8.5** Production & application side
9	Role of bottom-up initiatives	no subcategories
10	Best-practice building initiatives	no subcategories
11	Future outlook	**11.1** Challenges; **11.2** Recommendations

Table 6. *Coding system for interview analysis in MAXQDA (own representation)*

4.5 Quality criteria

As a research design should logically reflect a collection of statements, its quality can be assessed through validity and reliability (Yin, 2018, p. 78). Validity can be addressed through different measures. **Construct validity** refers to the extent to which the operational measures in a study accurately reflect the theoretical concepts they are intended to represent. In case study research, construct validity is crucial as it ensures that the study accurately captures the nuances of the phenomena being examined. Yin (2018, p. 79) emphasises the importance of using multiple sources of evidence to enhance construct validity. For this thesis, construct validity was strengthened through data triangulation of multiple sources of evidence (interviews, documentation, and observations). Additionally, member checking was used, which allowed interviewees to evaluate and confirm the findings, lowering the probability of wrongfully reporting a situation or misrepresenting a relativist position (Yin, 2018, p. 300). **Internal validity** refers to the extent to which the results of a study can be attributed to the phenomena being studied rather than other factors (Yin, 2018, p. 80). In this thesis, internal validity was enhanced through pattern matching, explanation building, time-series analysis, logic models, and cross-case synthesis (Yin, 2018, p. 223). **External validity**, or generalisability concerns the extent to which the findings of a case study can be generalised to other settings or populations (Yin, 2018, p. 81). Yin (2018, p. 171) argues that external validity in case study research can be enhanced through theoretical generalisation rather than statistical generalisation. In this thesis, external validity is supported by providing a detailed context and

clear descriptions of the CoRIS framework and CE concept. This contextual information allows readers to assess the applicability of the findings to other similar settings. Kuckartz and Rädiker (2022) emphasise the role of case study replication in enhancing external validity. This approach not only strengthens the generalisability of the findings but might benefit other regions, or countries with a similar context. **Reliability** refers to the consistency and dependability of the study's findings (Yin, 2018, p. 82). This study adhered to these principles by systematically organising and documenting all aspects of the research process. To ensure reliability, a comprehensive digital database was established, encompassing detailed records of all documents, procedures, and methodologies used throughout the study. This database included meticulously organised folders that allowed for the precise tracking of literature sources relevant to different sections of the thesis. Excel spreadsheets were employed to manage interview protocols and literature reviews systematically. For document management, Zotero was utilised to aggregate and organise bibliographic sources, while Miro was employed to visualise and structure the development of the CE and to organise thoughts. Recordings were transcribed via Lux-ASR and f4x speech recognition tools and subsequently analysed with MAXQDA software to facilitate accurate data handling and analysis. This rigorous documentation and use of specialised software ensured that every step of the research process was traceable, thereby reinforcing the reliability of the study's findings.

4.6 Ethical considerations

In conducting this case study, several ethical considerations must be addressed to ensure the integrity and credibility of the research, particularly given the use of semi-structured interviews. First and foremost, the principle of informed consent is paramount. This involves providing clear and comprehensive information about the research objectives, methods, and the use of data, thereby ensuring that participants can make an informed decision about their involvement. According to Yin (2018, p. 126), obtaining informed consent is essential to respect the autonomy of participants and uphold ethical standards in case study research. Prior to the interviews, each participant was asked to sign an informed consent form (see Appendix A) including the study's objective as well as participant's benefits, risks, and rights. Additionally, issues of confidentiality and data protection are crucial. Given the sensitive nature of some of the information that may be disclosed during interviews and data collection, it is imperative to guarantee the anonymity and confidentiality of the participants. As highlighted by Yin (2018, p. 126), maintaining confidentiality not only protects participants but also enhances the trustworthiness and reliability of the research findings. The personal data collected during the interviews, was anonymised, and coded to maintain confidentiality throughout the research.

5 Results

In alignment with the central research question regarding Luxembourg's transition towards a built environment, Chapter 5 aims to examine the impact of the CE concept on the construction sector. Based on the CoRIS framework, and the secondary research questions, this chapter explores Luxembourg from a regional perspective in various contexts, analyses how the CE

concept is understood, identifies actor constellations and dynamics, and assesses the factors driving and hindering the transition.

5.1 The context of Luxembourg

The Grand Duchy of Luxembourg is a small, yet strategically located nation state in Western Europe with strong international but above all regional interdependence with its neighbouring countries (Fig. 9). Although these close relations have naturally developed due to the small size of the country, they play a significant role in shaping national identity and are reflected in societal structures, where Luxembourgish, German and French are all recognised as official languages.

> "And I think that typically, we are organised differently from our close European partners. Luxembourg has always been a country that had one foot in Germany, one foot in Belgium and one foot in France." (I5)

Despite its size and precisely because of its strategic geographical location, Luxembourg, as a founding member of the EU, is home of numerous EU institutions such as the Court of Justice, the Court of Auditors, and the European Investment Bank. The proximity to the EU, coupled with access to support, exchange with knowledgeable individuals, and the opportunity to participate in EU projects, attracts start-ups from around the world. These start-ups are focused on building expertise, which in turn enriches the country's innovation landscape. This aligns with the Ministry of the Economy (MECO)'s vision of fostering a robust economic ecosystem of companies, contributing to a more dynamic and integrated business environment (I7, I1).

> "In Luxembourg, the interaction and innovation are very, very strong, because the actors are also sitting much closer together, spatially and locally and you don't have so many different actors, because everything is much smaller on the scale." (I10)

Figure 9. *Zoom in Luxembourg (source: OECD, 2020)*

In contrast to its larger neighbouring states Germany and France, the relationship between the state and municipalities in Luxembourg is characterised by proximity, meaning the absence of intermediary levels such as federal states or departments. The 100 municipalities are autonomous local authorities with legal personality, meaning a significant portion of state responsibilities is delegated to them - duties that in other countries are typically managed by intermediate levels of governance (Lorig, 2008, p. 144). Given that numerous mayors also hold positions as members of parliament, they have the ability to advocate for citizens' interests at the national level, which facilitates close integration between local and national politics (Lorig, 2008, p. 108). However, the municipalities depend on national authorities to mobilise funds and private consultants like engineering firms to implement building projects. The state itself is viewed

as entrepreneurial and aims to drive innovation, a role that would typically be filled by private actors in larger countries. Moreover, as with other small nations, Luxembourg features proximity between political authorities and key stakeholders, such as businesses, NGOs, and research institutions. The existing personalisation, informality, and a less hierarchical society (Baldacchinoel & Wivel, 2020) can facilitate direct approaching of key figures and access to resources, thus influencing decision-making processes (I7, I1). However, when communication is lacking despite the short distances, it raises concerns about whether the limited circle of influential figures might hinder the realisation of new ideas (I4).

> "[…] everyone knows someone who knows a minister, so the pathways are extremely short, and regulations can be changed and updated much faster. That's what's good about us; we can be much more dynamic and move forward faster. This means, if we want to, we could implement things much faster." (I6)

With limited exploitable natural resources other than forests, Luxembourg depends on external markets for its energy and raw material supplies. While only 15% of the materials consumed in the country come from its natural resources, imports primarily consist of fossil fuels, building materials and metals (OECD, 2020, p. 61). While Luxembourg, like other small nations, faces challenges due to limited resource availability, it benefits from commercial neutrality in offering innovative solutions. This neutrality might position it as a valuable contributor in fostering cross-border relations. Unlike larger countries like Germany, France or the Netherlands, whose initiatives might be seen as attempts to benefit their own industries, Luxembourg is viewed as a neutral player whose efforts are met with appreciation rather than suspicion (I1).

> "Luxembourg is really small. […] in my opinion, it is not possible to try to create a local microcosm, where Luxembourg provides itself with all the materials it needs. This is relatively unrealistic. We would have to try to think about it regionally, be it the Greater Region or a little bigger." (I3)

Luxembourg's economy is driven by a strong financial sector, which represents 25.2% of the national GDP (Statec, 2023, p. 60). Services, largely financial services, generate 87% of value added, compared to 73% on average in OECD countries (OECD, 2020). While in the 1960s, the iron and steel industry accounted approximately for 30% of the country's economic output, labour shortage have triggered a decline in the industry (Casali, 2013). This structural change has enhanced a political diversification strategy focusing on the expansion of the financial sector (Hild, 2023). Today, the financial sector can be described as the backbone of the economy with international recognition. Regarding Luxembourg's economic structure, SMEs constitute 99.5% of all businesses, the majority of which are rooted in the financial, retail and construction sector (Chambre de Commerce, 2021).

The Grand Duchy has experienced exceptional demographic growth compared to other EU member states, with its population increasing substantially from 439,500 in 2001 to 660,800 in 2023 and is expected to continue growing in the coming years (Statec, 2023, p.12). Luxembourg's economic prosperity, which is not evenly distributed across the country, is a pole of attraction for employment in the Greater Region (Fig. 10). The country attracts more than 200,000 cross-border commuters every day, almost three times more than in 2001, representing 43% of the country's labour force (Statec, 2023, p.18). Besides a strong GDP, this demographic dynamic causes a dense transit road traffic in a country where the vast majority of personal journeys is already made my car (OECD, 2020). Luxembourg's demographic landscape is a diverse population composition, characterised by a significant proportion of foreign residents (52% of the population) and cross-border workers (45% of non-resident commuters, 3% of resident commuters) (Statec, 2023). This demographic profile has implications for housing demand, urban planning, and infrastructure development, necessitating innovative approaches to accommodate the evolving needs of the population. Over the past century, the country has notably neglected the development of social housing structures that could have provided an opportunity to intervene in the housing market with a downward effect on prices (Becker et al., 2019).

Figure 10. *The Greater Region (source: Saarland.de)*

Luxembourg has become one of the most expensive countries in the world due to increasing housing costs and expenditure on goods and services that surpassed the European average (Eurostat, 2023a). These developments have also manifested in societal concerns, with "housing" and "rising prices, inflation, costs of living" being identified as two of the most urgent issues confronting the country (EC, 2024b). The country's elevated standard of living, continuous economic growth supported by a significant daily influx of cross-border workers, and ongoing infrastructure development result in increased material consumption and waste production (OECD, 2020). In pursuit of addressing these challenges, the country has progressively engaged with the principles of the CE over the past decade.

5.2 Political efforts for a CE

The CE concept gained public attention in **2014**, when the MECO commissioned and funded a study to evaluate the country's potentials in transitioning from a linear towards a CE (see Hansen et al., 2014). At that time, the model was already viewed as an economic imperative and opportunity for Luxembourg to achieve economic diversification and resilience (Hansen et al., 2014). This study marked the beginning of a political vision that was manifested in numerous governmental documents: the governmental program for the legislation period 2014-2018 (GDL, 2014), for the legislation period 2018-2023 (GDL, 2018b), the coalition agreement for the election period 2023-2028 (GDL, 2023a), the Smart Specialisation Strategy (GDL, 2024b), and the Data-Driven Innovation Strategy (GDL, 2019). Luxembourg thereby indicates

its commitment to implementing the EU guidelines of the CEAP and proclaiming CE as the guiding principle of its innovation policy.

Moreover, since the MECO launched the strategic study "Third Industrial Revolution Strategy" in **2016**, conducted in close collaboration with economist Jeremy Rifkin, Luxembourg has followed the vision of becoming the first circular nation-state (TIR, 2016). This study already indicates that a holistic and cross-sectoral approach is necessary for a successful transition. After the "Circular Economy Hotspot" was held for the first time in the Netherlands, Luxembourg hosted the three-day event in **2017**, providing an opportunity to showcase circularity in action and enhance its presence in Europe and beyond.

Furthermore, Luxembourg has actively pursued a waste and materials management policy centred on prevention, the recovery of materials, and the integration of secondary raw materials into the economy. In **2018**, a comprehensive regulatory framework was adopted, the new National Waste and Resource Management Plan (PNGDR). According to the PNGDR, the CE is understood as a "profound structural transformation that reconciles economic and social development with the regenerative capacities of our planet" (GDL, 2018a, p. 8), where material flows are distinguished according to the butterfly diagram (EMAF, 2019). The expanded role of the strategy within the context of the CE included at first awareness-raising and informational activities regarding its fundamental principles, and later a focus on developing, promoting, and supporting these new economic and social models, going beyond traditional waste management concepts (GDL, 2018a, p. 9).

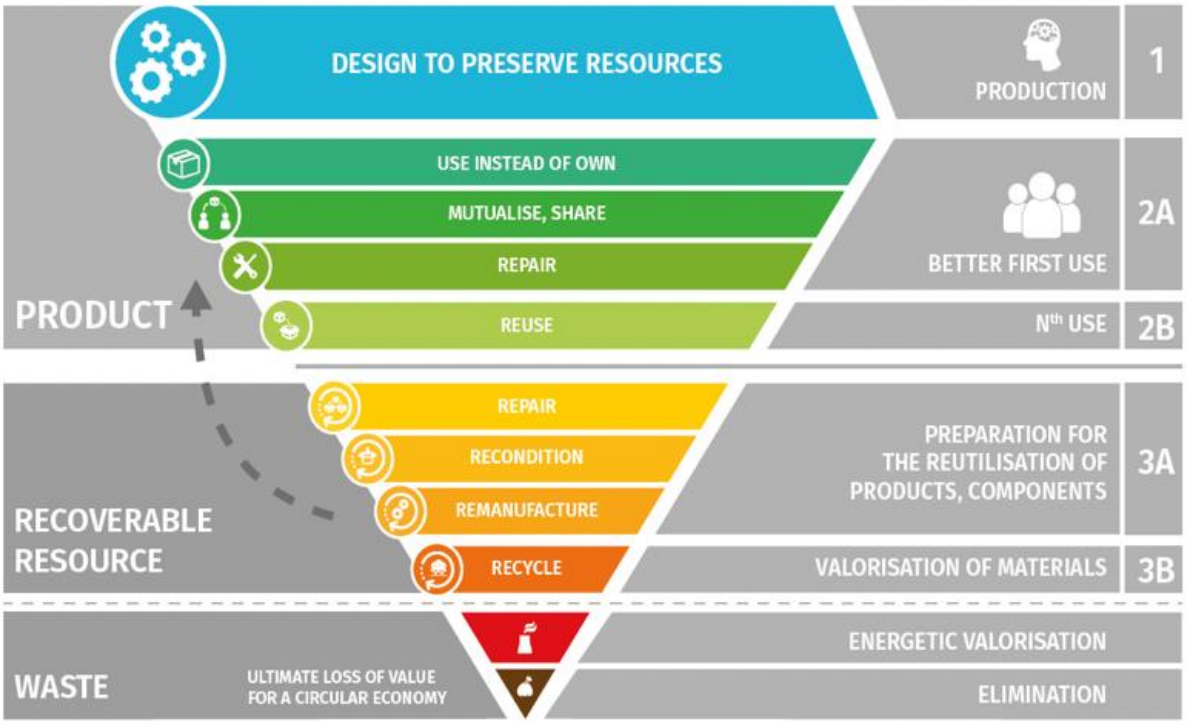

Figure 11. *Resource diamond for the technological cycle (source: Schosseler et al., 2021)*

One year later, in **2019**, a national Zero Waste strategy was published, stating that it neither aims nor has the capacity to completely eliminate the concept of "waste" as defined legislatively, or the waste itself. Guided by the principles of the CE, it instead seeks to outline the pathways to move closer to a vision of a "Zero Waste" world (Schosseler et al., 2020, p. 20). The understanding of CE is extended with the Value Hill business model, according to which objects are designed to extend their useful life and facilitate the recovery of components and materials at their highest value. Moreover, the butterfly diagram is refined into the resource diamond (Fig. 11) and resource leaf (Fig. 12), which are subsequently linked to the value hill model (create value = 1, maintain value = 2A, 2B, recover value = 3A, 3B). An analysis of these frameworks shows that resources and materials in CE debate are repeatedly associated with the term waste and waste management. Even the naming of the **waste** and **resource** management strategy itself indicates that these two concepts are intended to be considered together (Hild, 2023, p. 1977).

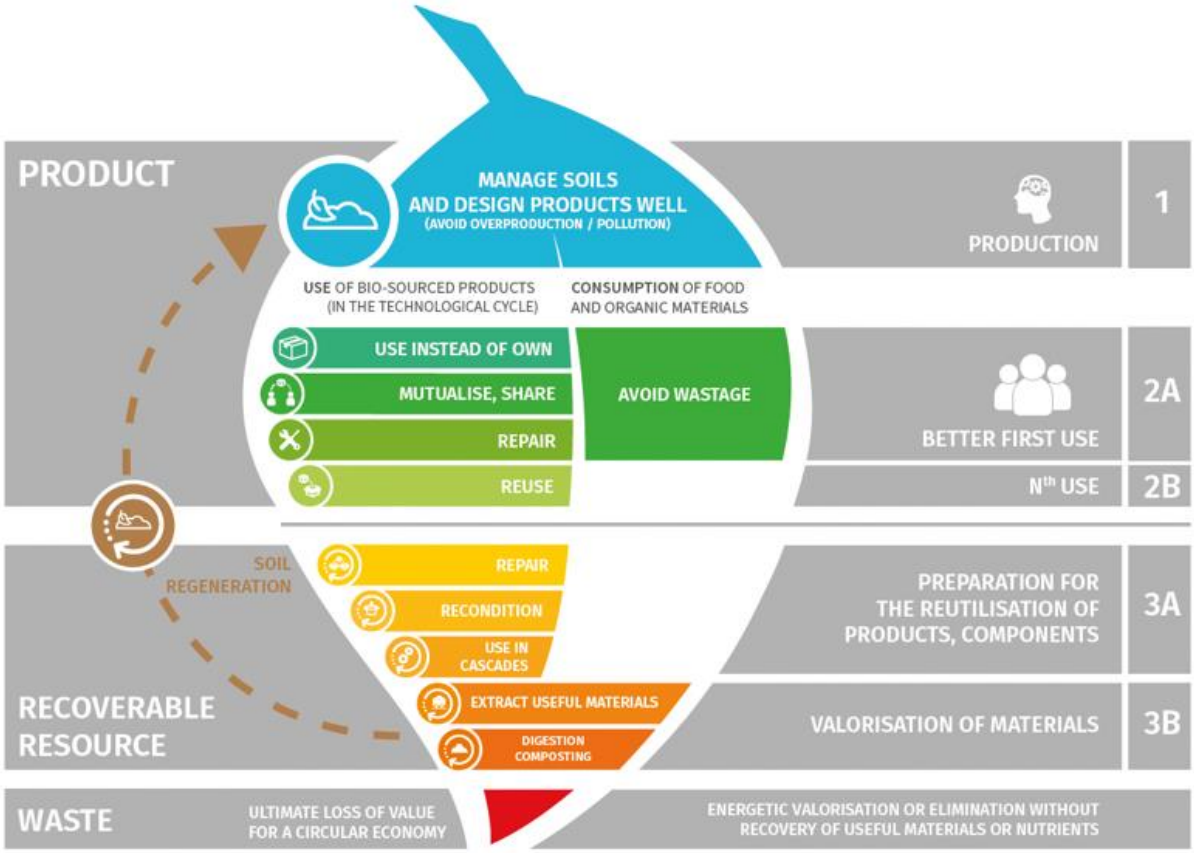

Figure 12. *Resource leaf for the biological cycle (source: Schosseler et al., 2021)*

As an effort to facilitate the transition to a CE, the Higher Council for Sustainable Development (CSDD) initiated a participatory process to define the principles of a CE in **2019/2020**. Participants in this process included representatives from the three primary helices, research community, private sector, and ministries (Schosseler et al., 2021), whereas stakeholders from civil society and NGOs were not mentioned raising questions about the participatory nature of the process.

The PNGDR and Zero Waste frameworks paved the way for Luxembourg's first CE Strategy, adopted in **2021**, a manifestation for the governmental willingness to take CE in Luxembourg "to the next level" in alignment with other national strategies such as the National Plan for Sustainable Development or the spatial sectoral development plans (Schosseler et al., 2021, p.7, I2). This strategy builds upon the holistic and cross-sectoral approach defined by Rifkin and colleagues (TIR, 2016) and by promising information exchange and collaboration within the value chain and across sectors. For the implementation of the CE concept in different sectors, regulatory, financial and knowledge creation/management tools are provided to create, maintain, and recover value. The implementation of a CE in Luxembourg is coordinated by a national unit comprising representatives from each ministry, who exchange knowledge every two weeks with various stakeholders, including ministries, administrations, and public agencies, depending on the specific topic. This unit also organises events to disseminate information on progress within Luxembourg and the Greater Region and to collect feedback from non-governmental organisations (Schosseler et al., 2021). The "Circular Economy Luxembourg Platform" aims to inform the national public and enhance international visibility. However, it seems to have received limited attention lately, with the most recent news entry dated November 15, 2023, and recent developments, such as the closure of the BENU village, a key citizen project, going unmentioned.[1] In September **2023**, a review which is yet to be published, was conducted in collaboration with representatives from different ministries to offer recommendations based on an evaluation of the status quo (I2).

The CE strategy aims at accelerating the implementation of the CE at national and regional levels while enhancing Luxembourg's profile as an international leader in CE practices. Recognising that CE efforts also need to be tackled across borders, the ministries are involved in international collaborations and networking, at various levels. Since **2022**, Luxembourg has co-chaired the CE sub-working group within the Environment working group of the Greater Region[2]. Members of the national CE coordination unit participated in the "Benelux Circular Economy Business Forum"[3], held in Luxembourg in October 2022, where they organised conferences on topics such as circularity in construction and infrastructure. Additionally, at the European level, members of the unit are involved with the European Environment Agency (EEA) and its partnership network the European Environment Information and Observation Network (EIONET)[4], where they concentrate on resource management and CE indicators.

Moreover, Luxembourg's government aims to improve citizen engagement in the CE by transposing the "Green Claims"[5] and "Right to Repair"[6] directives, recently adopted by the EC,

[1] URL of the CE platform: https://economie-circulaire.public.lu/en.html/
[2] URL The Greater Region: https://www.granderegion.net/Institutions/Le-Sommet-en-detail/Les-groupes-de-travail/GT-Environnement
[3] URL Benelux Circular Business Forum: https://www.granderegion.net/Evenements/2022/Benelux-Circular-Economy-Business-Forum
[4] URL Eionet: https://www.eionet.europa.eu/
[5] EU directive: https://environment.ec.europa.eu/topics/circular-economy/green-claims_en
[6] EU directive: https://ec.europa.eu/commission/presscorner/detail/en/ip_24_608

into national law. Businesses are ought to be engaged through the Ecodesign for Sustainable Products Regulation[7], also recently introduced by the European Commission.

One of the national key focus areas of Luxembourg's CE strategy is the resource-intensive and waste-producing construction sector, which also constitutes the research area of this thesis and will be analysed in greater detail in the next chapter.

5.3 Luxembourg's transition towards a circular built environment

The construction sector holds significant economic importance for Luxembourg. In 2023, it accounted for approximately 6.4% of the national GDP and, with over 52,500 employees, the majority of which work in SMEs, representing 10.5% of the workforce, was the fifth largest sector in the country (Statec, 2023, pp. 19&60). At the same time, the sector is primary contributor to resource consumption and waste generation, a phenomenon that is similarly observed in global waste production (Fig. 13, Fig. 3). Luxembourg's waste generated through construction activities, including deconstruction and demolition, has been steadily increasing, reaching 9 million tons in 2020, accounting for 14,400 kg per capita per year and contributing to 9% of its total emissions (GDL, 2022a). Most of the declared waste consists of excavated soils that result from infrastructure and development projects, mostly underground car parks (I2, l3).

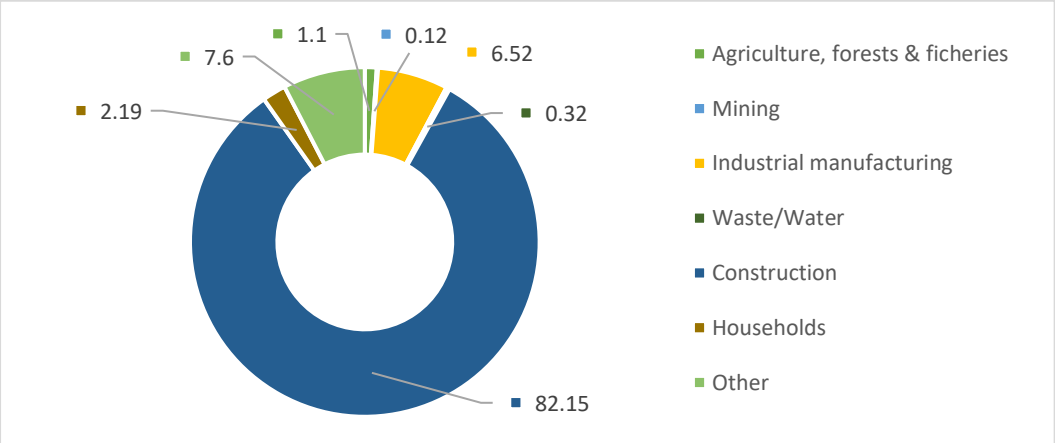

Figure 13. *Distribution (%) by sector of waste production per year in Luxembourg (2020) (edited from Interreg NWE, 2023, p.15)*

This development is driven by political measures aimed responding to population growth by creating new housing and offices spaces, which in turn puts pressure on the public property developers and construction firms who are facing a shortage of qualified workforce (Becker et al., 2019).

> "We need to build more schools, more housing, 40% more. And we already have problems; we can't even manage to build apartments. […] not only do we need to build more, and we can't even manage that with our current standards, […], but at the same time, we also need to completely rethink our economy and construction system.

[7] EU regulation : https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/ecodesign-sustainable-products-regulation_en

> And that is difficult. […] people say they lack time where people say they don't have the time. […] they lack the skills or capacities." (I6)

Given the limited availability of land in Luxembourg and the substantial land consumption associated with waste disposal, selective demolition of buildings is becoming increasingly important (Hild, 2023). This territorial restriction has led to multiple projects for the conversion of brownfields into residential and commercial areas. Large scale development projects include *Wunne mat der Wooltz* (Fig. 14) on a former tanning and leather industrial site in Wiltz, *Metzeschmelz* on a former steel mill site in Esch-Schifflange and *Plateau du Funiculaire* on a former steel mill landfill in Differdange. Additionally, the nation's dependence on imported building materials - primarily sand and gravel, which are growing scarce and expensive - makes the reuse and recycling of materials from existing structures viable alternatives to traditional construction methods (I2; GDL, 2022a). When examining the key methods and tools to promote circularity in the built environment, it becomes clear that establishing a physical and digital marketplace for construction and recycled deconstruction materials, supported by necessary regulatory frameworks and incentives, is a priority (Schosseler et al., 2021). Furthermore, the strategy adopts the Cradle-to-Cradle philosophy, which focuses on generating positive impacts rather than just minimising negative ones. This is achieved by promoting the use of wood and other bio-based materials in construction, as their production not only results in lower CO2 emissions but also sequesters carbon. One example is the e-Holzhaff platform, an initiative of Luxinnovation, which facilitates connections between local wood suppliers and businesses.[8]

Figure 14. *Wunne mat der Wooltz (source: virgule.lu)*

The PNGDR and Zero Waste strategy frameworks aim at advancing circularity in the building sector by providing strategies for managing construction and demolition waste (GDL, 2018a, pp. 103-111) and outlining plans to optimise the use of construction materials, reducing unnecessary excavation, extending building lifecycles, and promoting the reuse of materials from deconstruction (Schosseler et al., 2020). However, Luxembourg has yet to establish a market for demolition and deconstruction waste. In response, the Environment Agency, in partnership with the Luxembourg Institute of Science and Technology (LIST), introduced a

[8] URL of the E-Holzhaff platform: https://www.e-holzhaff.lu/de/e-holzhaff-plattform/

toolkit in 2018 to assist in the creation of material inventories for dismantling buildings, thereby supporting the implementation of the PNGDR. Four years later, they published a deconstruction guide to assist industry stakeholders and promote the adoption of best practices including technical clauses that intend to harmonise deconstruction and demolition projects within the context of public procurement (GDL, 2022a). Accordingly, old buildings should be regarded as stocks of raw materials at the end of their life, rather than merely as sources of waste. This is where the reuse of construction elements, preparation for reuse, and recycling of generated waste can serve as levers to reduce raw material consumption and CO2 emissions. Figure 15 shows the CE practices for Luxembourg's construction sector according to the LIST.

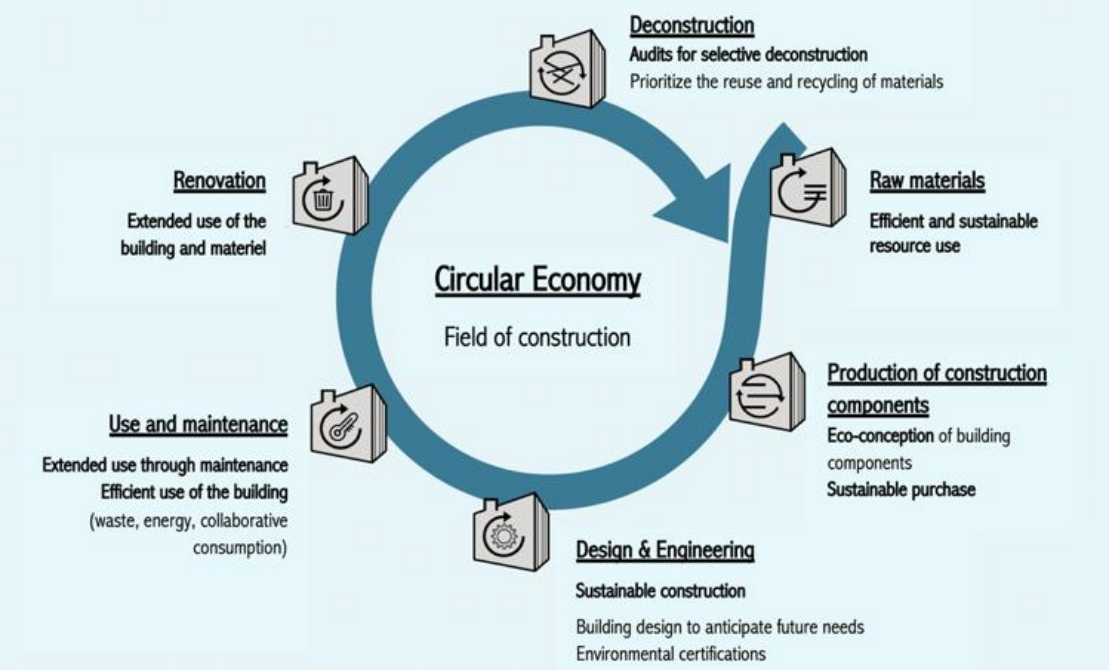

Figure 15. *CE principles in the construction sector developed by LIST (edited from Interreg NWE, 2023, p.12)*

With the passage of the law on June 9th, 2022, conducting a material inventory for the deconstruction of structures has become mandatory (GDL, 2022b). This further illustrates that the focus on implementing circularity is largely directed through the optimisation of waste management, a trend that is also evident in the interview analysis. With the exception of two interviewees, all discussed waste in the context of the CE, even though the topic was not explicitly addressed in the questions (I1-I9). The term "waste" was most commonly associated with "management".

In pursuit of carbon neutrality by 2050, the MECO in collaboration with the CNCD have recently developed a private-public roadmap for low-carbon construction outlining methods and tools to be developed in the coming years to implement the new provisions of the European Directive on the Energy Performance of Buildings (EPBD). It includes plans for a future building energy passport that will account for GHG emissions throughout the building's lifecycle, including emissions from the production of construction materials (embodied energy) and construction site emissions (GDL, 2023d). In this roadmap, circularity is addressed within

the contexts of "waste management" and "reuse," highlighting the political perspective of considering these terms together.

Actor networks

Implementing a CE necessitates systemic changes and required actions are not effective as standalone measures, as they affect the entire value chain and must be backed by various stakeholders. Besides the MECO, other ministries are involved in the transition towards a built environment, i.e., the Ministry of Housing and Spatial Planning (MLOGAT), the Ministry of the Environment, Climate and Biodiversity (MECB), the Ministry of Mobility and Public Works (MMTP), and the Ministry of Digitalisation (MinDigital).

Although the municipalities in Luxembourg are all integrated into CE practices through more centralised initiatives such as the Climate Pact 2.0 [9], and the SuperDrecksKëscht[10], there are considerable disparities in CE engagement, largely attributable to differences in size and financial resources. Municipalities that stand out for their commitment include Beckerich (I3, I9), Schifflange (I4, I6, I9), Esch-sur-Alzette (I4, I6, I7, I9), and especially Wiltz (I1, I2, I3, I5, I6, I7, I8, I9), which was officially announced Luxembourg's Circular Hotspot in 2015. With a population of 8,000 and situated in the North of the country, Wiltz is an essential player for regional dissemination of CE principles. Participation in the PREUSE NWE Interreg project[11], which focuses on reclaiming and reusing building materials, the annual organisation of the Circular Economy Day[12] (since 2021), the incorporation of CE criteria into communal building regulations[13], and the provision of training through the Circular Innovation Hub[14] collectively underscore the municipality's commitment to CE principles. The Masterplan "Wunne mat der Wooltz"[15], financed by the government, was the first large scale development project where the implementation of CE principles was considered. It is worth noting, that while the government has an interest in promoting Wiltz as CE hotspot, that should not lessen the importance of initiatives carried out by other municipalities.

> "The idea for the Wiltz hotspot was a national political birth, which was then gratefully received by the municipality." (I9)

Furthermore, the non-profit organisation CELL, Centre for Ecological Learning Luxembourg, plays a central role in supporting ecological transition efforts in Luxembourg. It unites various initiatives aimed at social, ecological, and economic change, with regional groups responsible for community-led initiatives such as Transition Minett, Transition Nord, Transition West, and

[9] Quality management system orchestrated by the Klima Agence, that supports municipalities in the areas of energy-efficient refurbishment of buildings and the circular economy. The communities are regularly evaluated and receive certifications based on their level of engagement.

[10] Organisation that supports municipalities and companies in resource conservation and waste management, including construction and demolition waste.

[11] URL Interreg North-West Europe **P**ublic **R**esponse to **E**nable the **U**se of **S**alvaged building **E**lements: https://preuse.nweurope.eu/

[12] URL Circular Economy Day: https://www.wiltz.lu/de/cap-2030-grosse-projekte/hotspot-der-circular-economy/tag-der-economie-circulaire

[13] URL Communal building regulations Wiltz: https://www.wiltz.lu/media/ee20848b-e78b-46b7-a8ab-c37a018c84e7/reglement-communal-sur-les-batisses-les-voies-et-les-sites-wiltz-weidingen-roullingen-2024.pdf

[14] URL Circular Innovation Hub Wiltz: https://imslux.lu/eng/news/633_circular-innovation-hub-upcoming-training-courses

[15] "Wunne mat der Wooltz" translates into "Living with the [river] Wiltz", URL: https://environnement.public.lu/dam-assets/documents/offall_a_ressourcen/offalldag/2017-hsa.pdf

Transition Stad. Besides its focus on collective intelligence workshops (e.g., Boost Lokal), the NGO organised a three-day festival in June 2024[16], where transition was addressed from different angles, offering workshops on district energy consumption and the creation of affordable, eco-friendly housing. Transition Minett is also working on establishing a Zero Waste Network for Luxembourg (I11). These organisations collaborate closely with networks in neighboring countries and at the European level, such as Ecolise[17].

The previously mentioned close collaboration between public and private sector actors is reflected in the building industry through a frequent exchange in semi-public organisations such as Luxinnovation or in the CNCD, a coalition of public and private sector representatives in construction offering continuing education to the sector, and creating links, both nationally and internationally (I2). As a result, influential figures are having considerable influence over political decisions and public opinion. Luxinnovation is the government's innovation agency, largely financed by the MECO, which is fostering innovation in eight key domains, amongst them wood and clean technologies[18]. In 2015, the institution launched a subsidy program called Fit4Circularity to support businesses in transitioning to a CE. This program included an assessment of innovation potential through CE practices, with several companies in the building and construction sector, such as Astron, Bamolux, and Contern, successfully completing the program (Economie Circulaire, 2023). Neobuild, another economic interest group serves as technological innovation center for the construction sector, with the goal of stimulating and facilitating innovation along the value chain; upstream, by promoting debate through research and information dissemination, and downstream, by establishing a network of experts and partners to support specific innovation projects (Infogreen, 2024). It releases the monthly magazine on innovation and construction NeoMag, which addresses promising projects in Luxembourg and the Greater Region (Fig. 16). It is closely linked to Infogreen, Luxembourg's first web magazine that provides daily information on the following sustainable development issues circular economy, eco-innovation, human rights and solidarity, sustainable mobility, social and solidarity economy, CSR, eco-construction, and energy transition[19].

Figure 16. *57th edition of the NeoMag (source: calameo.com)*

[16] URL Transition Days: https://www.transitiondays.lu/
[17] European Network for Community-Led Initiatives on Climate Change and Sustainability
[18] URL Luxinnovation: https://luxinnovation.lu/
[19] Infogreen is managed by the media agency Picto Communication Partners, which is also media partner of the NeoMag, URL Picto: https://www.picto.lu/infogreen

The Circular Innovation Hub, is not the only actor offering CE education and training programs. Semi-public actors such as the Chamber of Commerce (CC), the Chamber of Skilled Crafts (CdM) or the Ministry of Education, Children and Youth's agencies (CNFPC, INFPC, INAP), private actors such as the Construction Sector Training Institute (IFSB), House of Training, the Order of Architects and Consulting Engineers (OAI) or CNCD are dedicated to enhancing people's understanding of the CE. Education is advanced through various approaches, including meetings, conferences, and roundtable discussions, such as the Meet&Build events organised by the IFSB, as well as the incorporation of CE principles into the master craftsmen diploma by the CdM (I3). The Engineering firm LSC Engineering has even developed its own skill centre, where they offer training from internal specialists in spatial planning and construction. To further raise awareness about sustainability and educate future engineers on the key challenges in construction, they have been offering a course on CE at the University of Luxembourg for the past three years to shape the knowledge of future engineers (I6). The university's Department of Geography and Spatial Planning (projects: CIRCULUX, CIRCULAR) and Department for Engineering (project: Interreg NWW SeRaMCo[20]) have been involved in CE research projects. Moreover, the Environmental Research and Innovation (ERIN) department of the LIST has a separate Environmental Sustainability Assessment and Circularity (SUSTAIN) research unit which also participates in interregional cooperation (DDC[21] and its follow-up PREUSE[11], FCRBE[22]).

Figure 17 provides an overview of actors in the construction sector involved in CE practices, based on the document and interview analysis. The case of Noba (green box on the bottom left), a knowledge portal for sustainable construction developed through the collaboration of various stakeholders (indicated by black arrows), illustrates the intricate network of relationships among participants within Luxembourg's construction sector. Due to considerations of complexity, it was decided to exclude arrows that would typically illustrate relationships between actors. It is important to acknowledge that this diagram does not aim to provide a complete representation of all stakeholders and their interconnections.

[20] URL Interreg NWE **S**econdary **R**aw **M**aterial for **Co**ncrete Precast Products: https://vb.nweurope.eu/projects/project-search/seramco-secondary-raw-materials-for-concrete-precast-products/project-results/seramco-final-conference-booklet/
[21] URL Interreg NWE **D**igital **Dec**onstruction: https://www.list.lu/en/informatics/project/digitaldeconstruction/
[22] URL Interreg NWE **F**acilitating the **C**irculation of **R**eclaimed **B**uilding **E**lements in Northwestern Europe: https//rotordb.org/en/projects/interreg-nwe-fcrbe

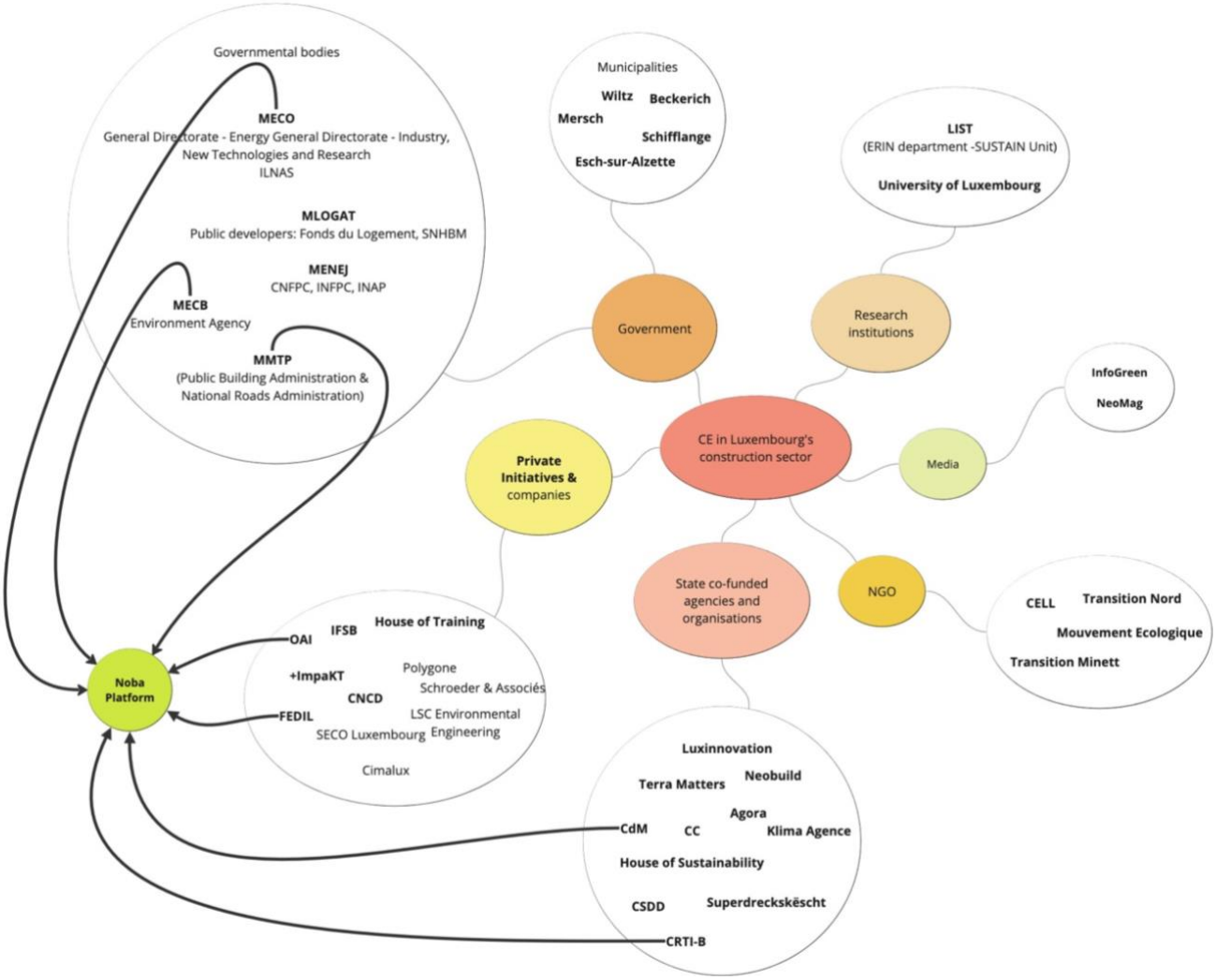

Figure 17. *Actors involved in the Luxembourg's transition to a circular built environment (own representation based on interviews)*

5.4 Understanding of the CE concept

This chapter examines how the CE concept is understood among stakeholders in Luxembourg's built environment. It explores how CE is defined within this context, the level of awareness among stakeholders, the perceived importance of adopting CE practices and expressed criticism.

5.4.1 Defining the CE

The CE concept is multifaceted and often interpreted differently across various sectors and stakeholders, as evidenced by the insights shared by the interviewees (I2, I6, I8, I10, I11). At its core, CE is understood as a way to minimise waste and maximise the reuse of materials, presenting an alternative to the traditional linear economy characterised by a "take, make, use, dispose" approach. However, the interviews reveal that while the overarching goals of CE are widely acknowledged, the specifics of its implementation and the relationship between CE and sustainability are subjects of ongoing debate and interpretation.

One key aspect of the CE, as highlighted by several interviewees, is its broad and sometimes ambiguous definition. One interviewee described it as a "fuzzy" concept that encompasses a wide range of interpretations and applications (I2). This lack of a clear, universally accepted definition complicates efforts to measure its effectiveness and to establish concrete guidelines for its implementation, leading to potential inconsistencies in its application:

> "[…] no one understands what it actually is. And when it comes to concrete things, like possibly taxing resources, then you're confronted with very different discussions. Nobody says no to the circular economy because […] we need to handle our resources differently. But no one understands what practical consequences it has for many aspects, including economic sectors, business models, tax models, and so on." (I2)

The relationship between CE and sustainability has also emerged in the interviews. While CE is often promoted as a pathway to sustainability, not all circular practices inherently lead to sustainable outcomes. As one interviewee noted, "not everything circular is necessarily sustainable," (I4) highlighting the need for a critical evaluation of circular practices to ensure they contribute meaningfully to broader sustainability goals. For example, while recycling and reusing materials like concrete can reduce GHG emissions, these actions alone may not fully address the environmental challenges associated with resource consumption and waste generation. While most interviewees mentioned circularity as a means for sustainable development, (I2, I3, I4, I6, I8, I9, I11), only one interviewee used the terms interchangeably (I10). Another interviewee pointed out that, in practice, the principles of circular construction more accurately reflect principles of sustainable construction.

> "I think that everyone is exploring how to best implement the principles of circularity, but in fact, they are principles of a more sustainable construction. " (I8)

While a sustainable future might be the indirect outcome of implementing CE practices, it might not be the primary goal. Hence, a company's CE strategy may prioritise boosting profitability and managing risks to satisfy investors, rather than demonstrating a genuine commitment to sustainability (I6). And while the CE is often discussed in terms of its business model aspects—such as new business opportunities and operational changes—it is essential to recognise that it operates at a different level compared to more comprehensive sustainability concepts. This distinction highlights that circularity, as a business model, may not fully address the broader, conceptual goals associated with sustainability and post-growth ideals:

> "I would think of another quote […] by Federico Savini, this is someone who is very concerned with post-growth in cities, someone who essentially said 'post-growth is a concept, degrowth is a strategy, doughnut is a tool and circular economy is a business model'. And that sums it up quite well. " (I9)

However, the CE is seen as a dynamic and evolving concept that requires collaboration across different sectors and stakeholders to be effectively implemented. The integration of CE principles is facilitated by strategic coordination between various ministries, such as those responsible for the environment, energy, and economy, ensuring that policies and initiatives are aligned with the overarching goals of sustainable development. Hence, CE is perceived as

a critical tool in implementing the 2030 Agenda of Sustainable Development, particularly by reducing GHG emissions and minimising the environmental impact of construction activities through the reuse and recycling of materials (I4, I7).

Additionally, several interviewees addressed the CE as a cross-sectoral phenomenon (I5, I7, I9). In Luxembourg, the concept seems to have spread across all sectors, with participation extending beyond ministries to include environmental organisations and the CC, thereby rendering it potentially less "elitist" compared to the Green Economy or Smart City debate (I9). This cross-sectoral approach has the potential to develop innovative tools and strategies, such as regulations, financial incentives, and knowledge management, that support the transition towards a more circular economy. However, this raises the question of whether sufficient cross-sector collaboration is actually being pursued in practice, or if each sector "in his corner is about to fiddle around a little" (I10).

Some interviewees mentioned that adopting a holistic approach to CE, one that goes beyond technical solutions to consider broader economic, political, and societal contexts would be necessary (I5, I9, I7, I11). One interviewee argued that CE cannot be effectively implemented solely through engineering or technical means, as these approaches often lack the broader perspective needed to address the complex challenges of resource management:

> "Indirectly, all these aspects must be connected within an industry that has not yet been created: the global industrialisation of the circular economy. So we must not only think about the construction itself but perhaps include other elements [such as storage facilities for reclaimed building material]." (I7)

This perspective suggests that achieving the goals of CE will require more than just isolated projects or technologies; it will necessitate a rethinking of production and consumption patterns on a global scale.

Practical challenges in implementing CE were also discussed, with some interviewees noting the significant work that remains to be done. One interviewee pointed out that while progress has been made, much more is needed to reach the point where new materials are no longer necessary, and only existing materials are reused (I8). This ambitious goal reflects the ongoing tension between the theoretical ideals of CE and the practical realities of its implementation.

5.4.2 Perceived importance and awareness

The importance of the CE in Luxembourg is generally acknowledged, though its practical implications and integration into existing frameworks face significant challenges. The CE is not only perceived as an environmental imperative but also as an opportunity for economic growth (I1, I4, I6, I7), especially given the surge in raw material prices (I11). However, the transition from a predominantly linear economy to a circular one is fraught with difficulties, particularly in ensuring economic continuity while adopting new models.

> "For this model to succeed, it must make economic sense, especially in an economy that predominantly follows linear principles. The significant challenge lies in transitioning while ensuring the continuity of economic activity." (I1)

Unlike post-growth and degrowth approaches that prioritise well-being over economic considerations (Vincent & Brandellero, 2023), the CE in this context is rather viewed as a means to tackle environmental issues while sustaining economic strength. Luxembourg's economic power and privilege are rooted in its current economic practices, which generate a broad network of indirect economic benefits. Instead of completely abandoning these practices, which could result in an immediate loss of economic value, a more balanced strategy is proposed (I7). This strategy involves continuing to work within the existing economic framework but with greater efficiency and resource-consciousness. Essentially, the aim is to preserve or adapt current services and economic activities while using fewer resources, thereby incorporating CE principles without compromising economic value. The growing sensitivity among consumers and the familiarity of households with waste sorting indicate a level of acceptance, which could be leveraged as a new marketing opportunity, however:

> "[…] as we have already said, it is not about accepting the concept, but about having an operational concept that can change the situation. "(I11).

There is a widespread agreement on the need for comprehensive engagement across all levels, from ministerial frameworks to grassroots initiatives, to ensure the successful implementation of the CE (I1, I3), which requires effective communication and awareness among all parties involved (I8). The awareness of the CE and its potential future impact in Luxembourg has been growing over the last decade (I1, I4) as one interviewee recounts from experience.

> "So, I asked them [employees of the public building administration] a specific question. What is your opinion? The answer choices were:
>
> a. Circular economy is a trend and will be gone in 5 years
> b. Circular economy and sustainability are the future and essential
> c. The world is doomed anyway, so we don't need to do anything
>
> Almost everyone, really 99% or 100% of the people said that circular economy and sustainability in construction are the future. […] I can now say that I conducted this non-scientific study with 120 people, including officials, who are not always the most receptive to change. […] It shows that people's minds are aligned with the idea that it is the future." (I6)

However, knowledge gaps seem to persist across all levels. Initially, public understanding of the CE was rudimentary, often conflated with recycling or viewed as impractical and consequently much effort was put in education and training (I1, I2) With a broad recognition of the need for a CE established, attention has now shifted towards concrete projects aimed at enhancing practical understanding and implementation. The development of eco-neighbourhoods (Elmen, Metzeschmelz or Rout Lëns) reflects an incremental but notable advancement in integrating CE initiatives into practice (I4, I2). Other initiatives, ranging from health-related initiatives to flexible building designs, illustrate an evolving engagement with circular principles, even if widespread implementation remains a work in progress.

> "[…] there are really initiatives that pop up and where we can easily see that this is multiplying, which is really positive. So my perception of the matter is that the interest in the subject is getting bigger and bigger, because actors like municipalities, are

> creating further demand. And then, people realise in which direction it is going and if they want to be interesting for their clients in five years, then they have to do trainings. This is really another huge step to get where we want to go […]." (I3)

Despite the increasing number of projects, progress appears to be inconsistent, with many projects continuing to follow conventional linear models (I4). The intricate nature and uncertain outcomes of applying CE principles to actionable policies and business models can impede effective adoption. It has been emphasised that such transformations require considerable time (I2, I3, I5, I9). Although the CE concept is frequently highlighted in political discussions (see GDL 2018; GDL 2023a), the lack of concrete actions following these discussions calls into question the actual advancement of this development.

Two interviewees highlighted the need to develop differentiated solutions that are tailored to specific contexts instead of applying one-size fits all solutions (I5, I9). Local sourcing of materials is not always the most sustainable solution if it causes other problems for local communities:

> "I think that the circular economy must be both, local but also very flexible and very agile in the sense that ideally, it is better to reuse locally, but for certain materials, where it is justified, why not consider moving them from a place where there are plenty of them to a place where there are not enough for example." (I5)

The implementation of CE principles varies across sectors, reflecting different levels of complexity and readiness. For example, the steel sector in Luxembourg has made strides in circularity by effectively recycling steel, which is less complex, i.e., it can be recycled with little loss by melting it down (I9). Other sectors with more complex product designs face greater challenges, especially in the beginning (I1). The implementation and awareness of CE practices also vary significantly between municipalities. One interviewee highlighted that larger municipalities like Esch-sur-Alzette and Bettembourg are more aware and proactive in integrating circularity into their practices, while smaller municipalities may lack the necessary tools and knowledge. This regional disparity suggests that targeted efforts to raise awareness and provide resources to smaller municipalities could enhance overall progress (I7).

5.4.3 Criticism

Criticism of the CE concept, particularly within the context of the construction industry in Luxembourg, reveals significant concerns about its current interpretation and implementation. A critical interviewee was suggesting that while CE provides useful strategies for sustainability - such as recycling, reusing, and reducing waste - it is ultimately limited in its effectiveness if economic growth continues (I11) Consequently, a circular system, where resources are endlessly reused without generating waste, is incompatible with an economy that is always expanding and consuming more resources. However, even if achieving a fully circular economy isn't possible, the CE model can still bring significant benefits by reducing environmental impact and improving efficiency.

A recurring theme among interviewees is the superficial understanding of CE, often reduced to advanced recycling rather than the broader goal of value retention and material reuse (I1, I2,

I6, I8, I9). This limited perspective is evident in practices like the reuse of construction waste for road fill, which, although technically considered recycling, does not align with the deeper principles of CE. As one interviewee pointed out:

> "Well, you can say we recycle over 80% of construction waste. Fine. But we dump it all under the roads. I don't think that has anything to do with value retention or the circular economy. That's waste management." (I2).

Another critical issue is the inconsistency in understanding and commitment among industry stakeholders. Some companies fail to critically assess the origins and lifecycle of the materials they use, while others have a more comprehensive grasp of their products. This discrepancy creates an uneven playing field, where those with a shallow understanding of CE may engage in greenwashing or ineffective practices, potentially setting back broader industry efforts (I3, I6, I11). The overabundance of discussions, workshops, and conferences on CE in Luxembourg further exacerbates this issue. While these events indicate a high level of interest, they often involve the same actors and lack the depth necessary to drive meaningful change.

> " The problem is that we also have many actors who think they understand what it [the CE concept] is, but they haven't truly grasped the challenge, and as a result, they communicate nonsense." (I3)

> "[a lot has been done in Luxembourg, from a regulatory and practical perspective] but that doesn't prevent certain actors from continuing to use the term more superficially, perhaps also exploit it politically or use it to address things with a green approach that are not that green after all." (I9)

This superficial engagement with the CE concept and the lack of considering the transition towards a CE as necessary, especially among the "backbones of construction - the construction operators" lead to misaligned efforts and wasted resources (I5). Moreover, Luxembourg's approach to CE is often criticised for its reactive rather than proactive nature. Despite having the financial resources to implement initiatives quickly when urgency arises, there is a lack of pioneering leadership in this field. The focus tends to be more on discussion than on substantive action and investment. As one interviewee noted:

> "We could move faster. In fact, we often wait until the last minute, and then, because we have a lot of money, we can implement things quickly. What I regret is that we are not pioneers in this field. We talk a lot, and […] I believe we could progress more swiftly and invest more resources in the circular economy here in the country." (I4)

To make significant strides, a more proactive and committed approach is needed to advance the CE and establish leadership in this area. In addition to the stakeholders' limited grasp of the concept, there were concerns that CE might simply represent a repackaged approach to maintaining existing business practices in a more sustainable guise. An interviewee highlighted that scepticism regarding the CE concept was based on two initial assumptions:

> "One [suspicion] was that, like smart city concepts etc., it could be a fine-sounding label for things that already exist or that still exist inadequately and which you want to increase the value of. And the second initial suspicion, which has indeed been

> confirmed, is that many actors in the field have a very shortened understanding of circularity and, in my opinion, large parts of the debate to this day deal with higher-quality recycling approaches and rely in a one-sided way much on technological solutions." (I9)

Even if a product adheres to CE principles, it may still contribute to unsustainable practices and societal issues, such as excessive resource consumption and environmental degradation (I9). The risk of such a rebound effect is a crucial part of circularity that needs to be considered, as it leads to unwanted consequences. One interviewee gives a concrete example:

> "Regarding copper, […] we injected 4 million tonnes of recycled copper into the system in 2015, which is roughly 60% of the 6 million tonnes that we produced forty years ago, in 1975. However, because of the continued growth in our demand, we now consume 16 million tonnes, and no longer 6; we therefore have to extract 12 million tonnes of copper again, despite the recycling that has allowed us to gain a little time, but we did not change the fundamental extractive logic of our economy." (I11)

Focusing solely on technical and technological solutions might cover the real issue: overproduction, overconsumption, and the promotion of unnecessary goods. As one interviewee stated, the creation of perfectly eco-friendly products is unnecessary when we can live without them, hence the most environmentally friendly energy is the energy we don't use (I11).

Furthermore, social, and ethical dimensions within the CE framework seem to have received limited attention. Only three interviewees have addressed this issue with respect to the implementation of CE practices in Luxembourg's built environment (I5, I6, I9), while others addressed it upon further inquiry or did not mention it at all. When social aspects are considered, they are often limited to the potential for job creation, neglecting the quality and conditions of these jobs. The recycling of demolition material in Luxembourg, for example, can create employment opportunities but often in hazardous and poorly paid roles. This reductionist view of social impacts fails to address the broader implications of CE practices such as the well-being of workers (stress factors, risk of accidents, payment, etc.) involved in those processes and is more akin to treating the symptoms rather than addressing the root causes (I9).

Lastly, the fragmented and unclear governance of CE in Luxembourg adds to the challenge of implementing a coherent and effective strategy. The lack of a clear line of responsibility among ministries and the shifting focus from energy efficiency to broader material considerations reflect a broader uncertainty about how to best integrate CE principles into national policy and practice (I10). This disjointed approach might hamper the ability to develop and enforce consistent standards and goals, further complicating the transition to a CE.

These findings set the stage for the following chapters, which will delve into the barriers hindering the transition to a CE in construction, as well as the driving forces that could propel this shift, providing a comprehensive view of the challenges and opportunities that lie ahead.

5.5 Barriers and detractors

The barriers to and detractors of the transition towards a circular built environment, that have been systematically identified and categorised, will be analysed in the following chapters. These obstacles, which range from regulatory and financial challenges to cultural and behavioural resistance, represent significant hurdles in Luxembourg's transition. Figure 18 illustrates how frequently these barriers were addressed by the interviewees, highlighting that regulatory barriers are a significant concern.

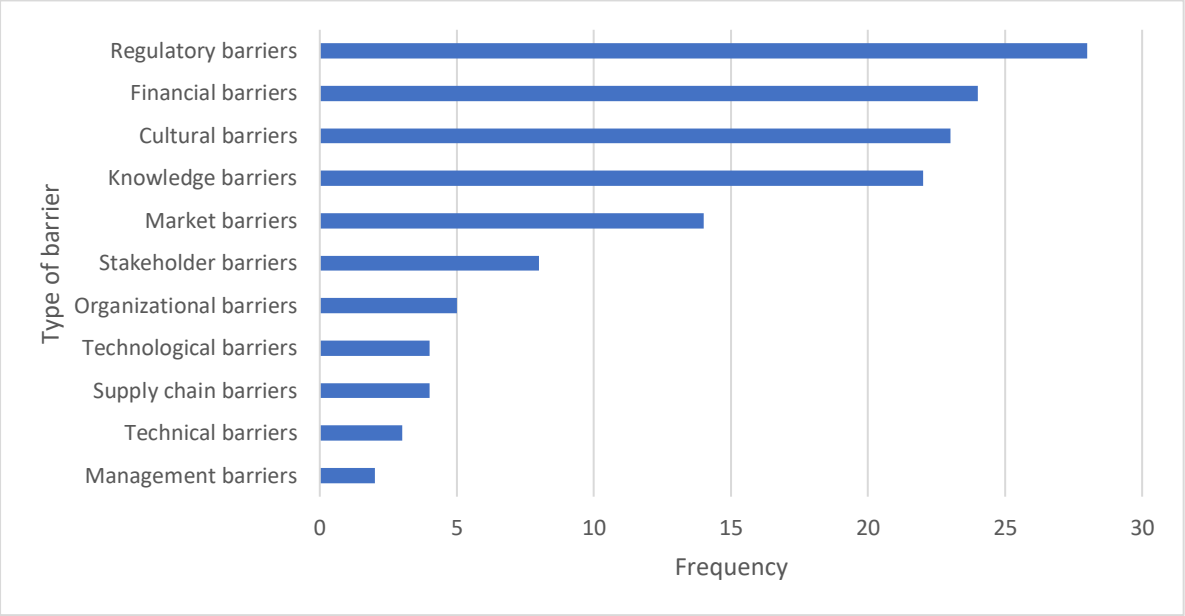

Figure 18. *Frequency of barriers based on interview data (own representation)*

5.5.1 Regulatory barriers

A significant regulatory barrier to the implementation of CE practices relates to the issue of waste status and its associated regulations (I1, I4, I9). Currently high-quality materials that derived from waste are not treated equally to raw materials. A clear and comprehensive framework for removing materials from waste status is missing. Despite European directives outlining general procedures for reclassifying materials, Luxembourg's national regulations remain ambiguous and are subject to the discretion of the responsible ministry, which has yet to establish a definitive position on this issue (I4). This uncertainty creates obstacles for reusing materials derived from selective deconstruction, as there is no formal agreement or clear guidelines on how these materials can be reintroduced into the construction cycle. Cross-border movement of waste is strictly regulated, which hinders the reuse of materials that are not clearly classified as waste (I5). However, the existence of these regulations can be justified by preventing illegal waste trafficking, a concern that was also addressed by the Environment Agency (GECT Alzette Belval, 2024). The fragmented and inconsistent application of waste legislation also complicates compliance and enforcement, particularly when coordinating with regulations from other jurisdictions (I8). Additionally, building regulations, standardisation, and material approval can create unwanted barriers for recycling and reuse of materials. Although the government supports renewable energy initiatives through subsidies for new

installations, such as solar modules, these subsidies do not extend to reused components, even when they have significant remaining lifespan:

> "These are little things that perhaps no one thought of when funding guidelines were written, […] when certain building standards and guidelines were established. [no one has questioned] what is waste and what is resource? What can be traded and what cannot? […] There is a great deal in the details, but this can be solved if the political will is there." (I9)

Furthermore, fragmentation and inconsistency of regulations across different municipalities can be an obstacle. With 100 municipalities, each possessing its own set of building regulations, navigating the regulatory landscape can become complex and inefficient. This decentralisation hampers uniformity in the implementation of CE practices, making it difficult for developers and contractors to align with a coherent set of standards (I6). Although a project may not solely depend on building regulations (I8), these regulations can serve as an effective lever, particularly when tied to specific obligations.

> "A building regulation could simply say that in new constructions, there would ultimately be an obligation to integrate […] a small percentage of reused materials. And in practice, it's quite simple to integrate reuse materials for functions that are barely visible and important. So, this could be the case for parking lots, it could be the case for technical rooms, and it could gradually be a way to finally demystify [make it easier to understand] reuse. " (I5)

Currently, the introduction of reused materials in the value chain lacks the standard warranties provided for new products, leading to reluctance among stakeholders to incorporate them in construction projects (I2, I8). Additionally, insurance and inspection agencies are not fully equipped to manage these materials, adding to the uncertainty as one interviewee explained:

> "Of course, when I get a new material from a factory, it comes with a warranty for several years. But when a material has been used, and it's been in place for six months, how do we provide a guarantee? That becomes a challenge." (I8)

Furthermore, regulations can have a contradictory nature. While there is a push towards sustainable construction practices, existing laws related to building safety, such as fireproofing requirements, can hinder the use of environmentally friendly materials like wood (I6).

One interviewee highlighted that the disconnect between theoretical frameworks and practical implementation often results in the creation of regulations that are both inappropriate and difficult to realise because the individuals responsible for these regulations lack practical expertise in the field.

> "There are indeed issues with the regulations; they need to be adjusted and made more favourable. There are always grey areas in policies related to making everything circular and sustainable as quickly as possible, including the national plans. When it comes to the implementation rules and laws, it often looks quite different. This is often a matter of lawyers and individuals who are not immediately familiar with the field—people who might not understand the matter deeply." (I8)

Moreover, regulatory frameworks seem to lack sufficient incentives for circular practices, particularly in the private sector. Although certain certifications and points systems exist, such as Lenoz certification or climate points, these measures are seen as insufficient to drive significant change. The lack of mandatory requirements for circular practices in public procurement means that cost considerations often overshadow sustainability, preventing the broader adoption of CE principles:

> "At the moment there is simply no step within the project where it would be taken into consideration what benefit exists of investing 2% more in a circular construction. It is simply not considered at all. And if you don't proactively ask that question yourself, no one will ask it." (I3)

5.5.2 Financial barriers

A key obstacle is the higher initial cost associated with circular construction practices compared to traditional methods (I1-I11). They involve substantial upfront investments due to the need for specialised materials, innovative technologies, and comprehensive long-term planning. This higher initial cost is a major deterrent for both private and public stakeholders operating under strict budget constraints.

> "Building sustainably costs 5% to 10% more. Just think of a house, with a heat pump on the facade, which will cost you a hundred [euros], a double facade, which you can always unscrew, will cost you four hundred [euros]. The customer says, I don't have that money. Of course, the cost for the private but also for the public builder is a restraint and slowing down the transition towards sustainability and circularity." (I10).

On a municipal level, budgets are generally oriented towards short-term investments. CE projects require a long-term perspective, considering the entire lifecycle of a building, including maintenance and decommissioning costs. However, municipal budgets in Luxembourg are focusing on immediate expenditures rather than long-term benefits. This mismatch creates challenges for integrating CE principles, as stakeholders struggle to reconcile short-term budgetary constraints with the long-term savings and benefits associated with circular construction .

> "Budgets are planned on an annual basis, or at most for five years. They focus on immediate investment costs without considering the long-term expenses for heating, maintenance, renovation, decommissioning, etc. We try to take these considerations into account, but the structure of a municipal budget is not adapted to this approach." (I3)

Risk aversion related to financial investments further complicates the adoption of CE practices. The perceived financial risks associated with these practices - such as uncertainties about material performance or future resale values - can deter stakeholders from investing in circular solutions. In Luxembourg, there is a prevalent tendency to prioritise immediate cost savings over potential long-term benefits. This risk aversion is amplified in a market where cost predictability is essential, leading to resistance against circular approaches that may initially appear more expensive (I2).

Moreover, the high cost of land in Luxembourg also poses a significant barrier (I3, I4, I6, I9). Affordable land is crucial for establishing the infrastructure necessary for circular building practices, such as recycling centers or reuse facilities. The scarcity of inexpensive land makes it difficult to set up necessary infrastructure, further limiting the feasibility of circular projects.

> "The other problem we have is the reclassification of certain materials because a material that is dismantled is not necessarily re-adaptable as such. So, we also have stock problems. Because using a material, storing it, involves setup costs and the associated economic expenses." (I7)

The high cost of land increases the overall financial burden of circular construction, making it less attractive to potential investors (I4).

Furthermore, SMEs tend to perceive CE as a concept that remains overly theoretical and one that is primarily accessible to their larger counterparts who possess adequate human and financial resources (Chambre de Commerce, 2021). They face considerable difficulties when it comes to adopting CE practices, including additional costs, and not having the infrastructure in place to deal with inherent complexities. The pressure to remain financially viable often leads these businesses to prioritise immediate cost savings over investing in circular solutions. This economic pressure is particularly acute in a sector experiencing financial strain, limiting the adoption of innovative but costly circular approaches (I9).

5.5.3 Cultural barriers

A major cultural challenge is the prevailing attitude towards waste and material reuse. Historically, the concept of waste as a separate category is relatively recent, and there remains a deep-seated habit of discarding items rather than reusing them (I1). This habitual reliance on waste disposal rather than material recovery seems to be rooted in society. The modern convenience of waste management systems, such as garbage cans, reinforces the notion that waste is simply something to be discarded, rather than a resource to be managed or reused.

In the construction sector, this mindset is particularly evident. For instance, in office buildings and other tertiary sector spaces, the common practice is to regularly replace interior elements every few years, driven by a culture of large turnover and frequent updates (I2, I11). This tendency reflects a broader preference for new over reused materials. The common perception is that new materials or products are inherently superior or more desirable than those that are reused. This is evident in the difficulty of integrating used items, such as sinks or toilets, into new projects, where there is often a strong preference for brand-new fixtures (I2, I7).

Moreover, there is a tendency to overlook locally available resources in favour of imported materials. For instance, despite having abundant local forests, Luxembourg often relies on imported wood, highlighting a disconnect between available resources and their utilisation (I3). Due to insufficient processing infrastructure, most of the wood is exported to neighbouring countries. In 2022, the volume of raw wood imported was more than twice the amount exported (Statec, 2023, p. 46). The society's mentality, driven by convenience and the perception of

higher quality or status seems to leave less room for local alternatives. One interviewee went even further stating:

> "I think that there are still a lot of psychological restraints to reuse in Luxembourg. It's considered cheap, not very pretty […]. And one of the problems is also when we look at the level of the most dynamic regions or among those which are dynamic in terms of reuse, […] regions which perhaps have fewer resources ultimately, when we have less resources, we are […]forced or inclined to reflect more and to find alternative solutions." (I5)

This perception is reinforced by a construction industry that has historically been marked by a culture of prosperity and abundant resources (I3, I4, I5, I6), leading to a reluctance to innovate or adopt more sustainable practices.

Implementing CE practices requires not only new knowledge but also a shift in mindset, which can be challenging. The complexity of implementing circularity in a rather "conservative world" can lead to internal resistance within municipalities and other organisations, where understanding and acceptance are still developing (I3). This resistance often stems from a lack of familiarity with the concepts and a reluctance to deviate from traditional practices. This resistance to change is compounded by societal expectations and standards, particularly in the context of public buildings and infrastructure. In Luxembourg, the focus on high-quality and new construction materials (I6, I7) hinders the market entry of reused or recycled materials. These alternatives are frequently perceived as inferior in quality, rather than being evaluated based on their functionality.

Generational perspectives also play a crucial role in the acceptance of reused materials. Individuals from older generations, who grew up during times of resource abundance and economic growth, often exhibit a lower receptiveness to material reuse. Conversely, younger generations, who are more attuned to sustainability concerns, generally demonstrate greater openness to such practices (I7). This generational disparity underscores the importance of sustained educational and awareness-raising efforts to facilitate a cultural transition towards embracing CE principles across diverse age groups.

Finally, societal structure and social norms in Luxembourg contribute to these barriers. In contrast to some neighbouring countries where second-hand and reused materials have gained greater visibility and acceptance, Luxembourg's social structure and cultural norms still favour high status, which limits the acceptance of reused materials (I9). Changing these deep-rooted cultural norms will require a concerted effort to shift public perceptions and promote the benefits of CE practices.

> "A change in mentality is necessary. But there can be many other things that come into play. So, I definitely wouldn't cite it as the sole reason […]." (I9)

5.5.4 Knowledge barriers

A fundamental issue in adopting CE practices is the lack of comprehensive information about circular products. When products designed for circularity reach the end of their life, they often

lack essential information about their circular features, which hampers effective management and reuse. The absence of a reliable system to ensure that this information accompanies the product throughout its lifecycle leads to inefficiencies and missed opportunities in recycling and reuse efforts:

> "[…] we produce circular products, design them to be circular, bring them to market, and then sell them. They eventually end up with a recycler or another company. However, we often lack information about the product and why it is circular, which means we are unable to effectively manage or utilise it. The information layer on the circularity of a product and a system that ensures that the data also travels around the world with the product, is missing." (I1)

Moreover, the sector is confronted with limitations in training and expertise. Although organisations such as the House of Training, OAI, and IFSB are involved in promoting CE principles, there is a notable shortage of experienced trainers and comprehensive training programs (I2). The field is characterised by a "learning by doing" approach, with many professionals still gaining hands-on experience in circular practices. This scarcity of seasoned experts hinders the dissemination of in-depth knowledge and limits the sector's ability to effectively train new practitioners.

Additionally, there seems to be a significant disparity in knowledge levels among various stakeholders within the building sector. While some professionals possess a high level of understanding of CE principles, others are less informed or resistant to these new practices (I3, I8). This uneven knowledge base creates challenges in achieving consensus and effectively collaborating across disciplines. The complexity of the CE concept can lead to insecurity, resistance, or misunderstanding, particularly in municipalities where the topic is not well-integrated into the existing knowledge framework (I3, I8).

Circular practices, such as demolition and deconstruction for material reuse, are perceived as more complex and costly, whereas traditional demolition methods are seen as quicker and cheaper, where project owners often lack visibility into the value of recoverable materials. This mindset, which does not necessarily align with reality, reinforced by outdated construction standards that prioritise large, heavy, and expensive buildings, can slow down the adoption of CE principles.

> "[…] an object without information is waste and therefore it is always this additional information that will cause an object to gain value. So, it's clear what we must focus on, but there are certain restraints […] what really slows down reuse and the circular economy is ultimately the current construction standards that we have. I think we build too big, too heavy, too thick, too expensive. Because these standards came from a period when energy had been abundant, and cheap. These were really years when we asked ourselves a lot fewer questions about sources." (I5)

Another challenge presents the scarcity of well-trained craftsmen who understand the materials and construction techniques that are essential for circular practices, especially in larger firms with a fluctuating workforce. The lack of detailed documentation for older buildings

exacerbates this issue, making it difficult to deconstruct and repurpose materials effectively (I8).

> "[…] the majority of the 100 municipalities are rather small an lack their own personnel with specialist knowledge in such specific areas. Unless […] the municipal engineer previously worked on circularity, these are new topics, and this also applies to other subject areas." (I9)

This gap in knowledge and training among craftsmen, coupled with the historical lack of documentation, complicates efforts to implement circular practices in deconstruction and material reuse.

Furthermore, the challenge of demonstrating sustainability poses a significant hurdle. Besides the lacking information on a product's circularity, limited availability of reliable sustainability certifications makes it difficult to assess and compare the environmental benefits of different approaches, such as renovating versus demolishing a building (I10). This knowledge gap hinders informed decision-making and the adoption of more sustainable practices in the built environment.

5.5.5 Market barriers

One major challenge is the inherent pressure within public property development to expedite construction projects. Entities such as the Fonds du Logement are under intense pressure to build quickly, which limits the feasibility of integrating CE principles that require careful planning and consideration (I2). This urgency often results in the prioritisation of speed over sustainability, perpetuating a cycle that undermines the adoption of more resource-efficient practices.

Additionally, the lack of a critical mass in the market poses a significant barrier. Luxembourg's relatively small size limits the scale at which CE principles can be effectively implemented and tested. This limitation affects both the market for reused materials and the ability to achieve a critical mass of projects necessary for meaningful change. For instance, the small market size restricts the development of a robust infrastructure for material reuse, as highlighted by some interviewees (I8, I5). This constraint makes it challenging to create a sustainable supply chain for circular materials and services, further impeding progress.

Luxembourg boasts the highest per capita "actual individual consumption" in the EU when measured in purchasing power standards (Eurostat, 2024). This significant purchasing power enables residents to frequently opt for new products rather than repairing or reusing existing ones. This financial comfort contributes to a lower demand for repair and reuse services, thereby reducing the economic incentive for businesses to engage in circular practices (I2, I9). While incentives like the Repair Bonus are effective in countries like Austria, in Luxembourg, the upfront cost of repairs often discourages individuals from opting for more sustainable solutions. This financial barrier further impedes the broader adoption of CE practices.

Moreover, the small scale of the Luxembourg market affects the willingness of stakeholders to invest in innovative circular solutions and restricts opportunities for piloting new ideas and

scaling successful innovations. This lack of experimentation and innovation is compounded by a market environment where unsustainable practices are often more cost-effective than circular alternatives.

> "The core point is that the market does not regulate the problem of sustainable transformation, because the transformation does not work according to market principles. That's why the legislator has to change or implement minimum requirements, which then really have to align with all actors, so that you get in the direction of transformation. Because this will never settle on the market alone, as long as it is cheaper to build unsustainably, you will always build unsustainably." (I10)

5.5.6 Stakeholder & supply chain barriers

A key barrier within the construction sector, is a notable lack of coordination between architects and engineers. These professionals frequently pursue their individual agendas without engaging in a unified approach, leading to inefficiencies, and missed opportunities for integrating circular practices (I7). Similarly, municipalities often work in isolation on their projects, which limits opportunities for shared learning and collective problem-solving. While there is some exchange of knowledge about specific implementations or issues encountered, this interaction tends to be reactive rather than proactive (I3). This lack of integrated collaboration hinders the development of cohesive strategies for implementing CE principles across different jurisdictions.

Communication challenges further exacerbate these issues. CE practices are mainly discussed within expert circles, with little attention given to the broader dialogue and the complex coordination needed across various sectors. While low-tech solutions may offer social viability, the debate surrounding them remains limited at political and business levels. Effective adoption of circular practices demands more than individual company efforts; it requires extensive matchmaking, coordination, and resource allocation to design products that facilitate circularity, as stated by one interviewee:

> "I think this requires a completely different type of moderation and support. […] probably the interaction of many actors, which also exists and is attempted to some extent, but would probably need a lot more resources." (I9)

If stakeholders work in isolation, it can result in duplicated efforts and missed opportunities for synergy (I8, I10). Despite the attractiveness of these ideas, practical cooperation between stakeholders remains rare, often occurring by chance, highlighting the need for structured support and improved communication channels to realise the full potential of CE initiatives (I9)

Supply chain inefficiencies also present significant barriers to achieving circularity in the built environment. Due to its geographical constraints, Luxembourg imports a large portion of the materials and energy it consumes. This likely makes it more challenging to monitor and assist suppliers in their efforts towards eco-circularity (I11). Furthermore, the reliance on multiple suppliers and customers complicates the implementation of circular practices. Without established systems for material recovery and reuse, companies struggle to integrate these

practices effectively into their operations (I1). Furthermore, limited cross-industry collaboration, where different trades within the construction sector - such as locksmiths, carpenters, and electricians - operate with minimal interaction. One interviewee has criticised:

> "And where the materials from one industry could possibly be reused by others or where an industry would have to structure its work in a way that the others can then engage according to a circular concept, this type of permeability is hardly present." (I9)

Logistical challenges further hinder progress. The synchronisation of processes and coordination of resources, such as transporting used windows or other materials, often presents significant obstacles. Even when there is a willingness to adopt circular practices, the logistical complexities can deter companies from pursuing these options. The difficulties associated with managing these logistics - such as waiting for appropriate transportation or handling new versus used materials - can undermine the feasibility of circular initiatives (I9).

5.5.7 Organisational & management barriers

The profitability and established efficiency of the current, predominantly linear, system reinforce the status quo, making it difficult for circular initiatives to gain traction. The complexity of existing buildings, with their various layers having different lifespans (foundations, structures, and beams) adds to the organisational challenges associated with deconstruction (I8). The resistance to change is exacerbated by external pressures such as rising energy prices and supply chain disruptions, which shift focus away from circular efforts (I1). Consequently, the inertia of established practices and the prioritisation of immediate economic concerns often overshadow long-term sustainability goals.

Another organisational challenge is highlighted by the reliance on municipal regulations for building-related obligations, such as inventories, audits, and the use of reusable materials. Municipalities are tasked with numerous responsibilities, including the Climate Pact and necessary transitional improvements in other areas than building, which often overwhelm their capacity (I5). Smaller municipalities, in particular, may struggle with the administrative burden of navigating complex regulatory frameworks while managing their existing responsibilities (I6).

From a management perspective, the existing frameworks are often not yet aligned with CE principles, making such initiatives financially unattractive:

> "Often the framework simply did not exist. To name an example, the pilot project of the circular parking lot, where we had the idea to buy parking as a service and not the parking lot […] in the private sector, you can deduct buying a parking from taxes, if you only buy the service of parking, you can't do it, so it's less profitable." (I1)

Many companies are hesitant to embrace circular practices due to the perceived lack of viable business models. The CE often involves long material cycles and significant upfront investment, which can be daunting in the face of economic uncertainties such as inflation and

deglobalisation (I4). As businesses grapple with these challenges, the shift towards circularity is often seen as a distant goal rather than an immediate priority.

5.5.8 Technological & technical barriers

Technologically, Luxembourg faces constraints due to the underdevelopment of its ecosystem for material reuse and circular practices. Compared to their neighboring countries[23], Luxembourg lacks comprehensive platforms and systems for the storage and reuse of construction materials, which limits the potential for circularity in the built environment (I5). The absence of such infrastructure not only hampers current efforts but also restricts the scalability of future initiatives. Additionally, even when technological solutions are available, their implementation is often hindered by the lack of necessary documentation and data. For instance, the inability to recover and reuse building components due to missing technical specifications highlights broader issues in data management and accessibility (I7). Circular products, although designed and marketed as sustainable, often reach recyclers or other companies without the critical information needed to manage or utilise them effectively (I1). This issue is not unique to Luxembourg but is rooted in global construction practices where thorough documentation was uncommon. The gap in data availability and quantification poses significant challenges to achieving systemic circularity.

Another significant technological barrier is the disparity in digitalisation across municipalities in Luxembourg. While some municipalities have adopted advanced systems, such as digital building permits, others still rely on outdated paper-based processes. As one interviewee stated:

> "[…] we are currently developing with CRTI-B, Luxembourg's competence centre for BIM, a digital building permit system. This works very well, but […] we realised that some municipalities still use paper plans and validate them in communal assemblies. So how do you implement something new, like circularity, if not all municipalities are equally equipped? " (I7)

This heterogeneity in technological adoption results in inconsistent practices and uneven progress across the country, thereby complicating the uniform implementation of new sustainable building initiatives.

From a technical perspective, the construction industry in Luxembourg is also characterised by adherence to traditional construction methods while innovative technologies such as 3D concrete printing remain marginal (I4). Many existing buildings in Luxembourg were not designed with future dismantling or material reuse in mind, making it difficult to repurpose these structures in line with CE principles. This is further complicated by the presence of hazardous materials, such as asbestos, which pose significant obstacles to safe and effective reuse.

[23] Examples for the reuse of construction materials in **Brussels**: http://www.reemploi-construction.brussels/ or in **Germany**: https://concular.de/

5.6 Driving forces and facilitators

The driving forces and facilitators of the transition towards a circular built environment that have been systematically identified and categorised, will be analysed in the following chapters. These catalysts, spanning from governmental support to widespread knowledge dissemination and education at all levels, present significant opportunities for Luxembourg's transition. Figure 19 illustrates how frequently these driving forces were mentioned by the interviewees, showing that regulatory factors appear to be significant drivers for the transition.

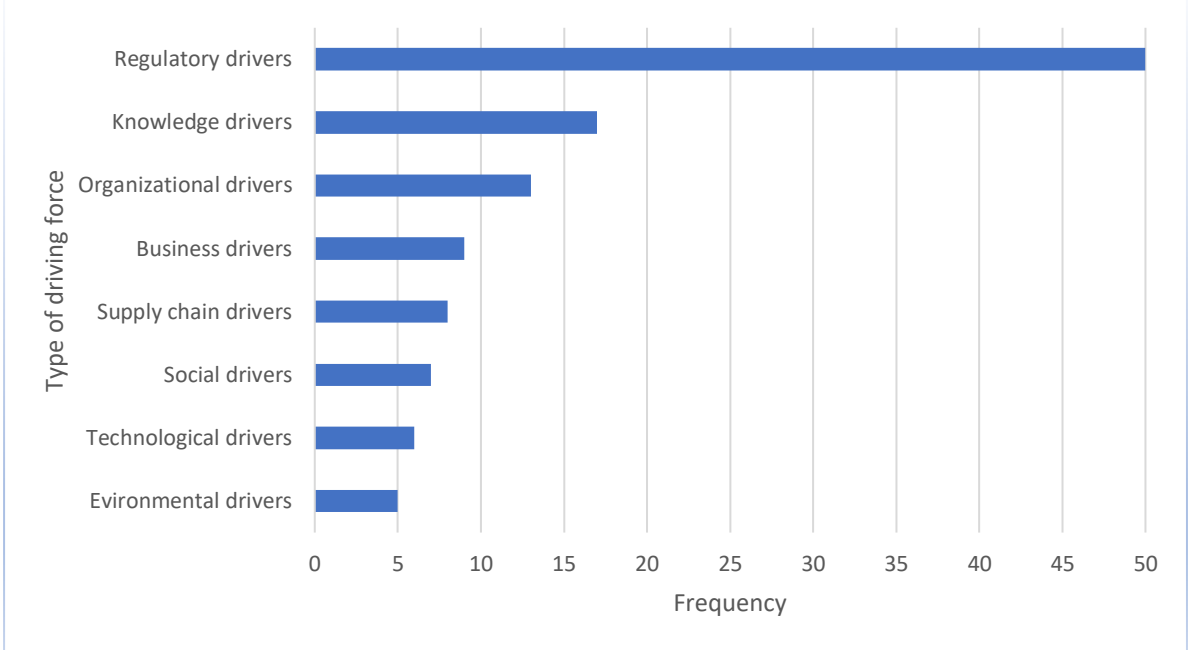

Figure 19. *Frequency of driving forces based on interview data (own representation)*

5.6.1 Regulatory drivers

A significant regulatory driver is public procurement, which has the potential to shape market behaviour by setting criteria that prioritise CE principles (I1, I2, I4, I10). As one interviewee highlighted, the public sector can play a critical role by requiring certain circular properties in tenders, thereby encouraging the adoption of sustainable practices. However, this approach is currently underutilised in Luxembourg, where the emphasis still often falls on cost rather than sustainability.

> "[…] the public sector can support such things. […] and one important one [instrument] that is always talked about but where we are not very advanced in Luxembourg, is the famous public procurement. Because there you could of course, instead of just taking the cheapest, set a number of criteria to operate differently." (I2)

One interviewee noted that adopting anti-greenwashing policies more widely - a relatively new approach - could help ensure the expression is used correctly and transparently, making CE practices more reliable for stakeholders and the public (I11).

Pilot and demonstration projects also emerge as a crucial mechanism for demonstrating the feasibility and benefits of circular construction practices (I1, I2, I3, I7, I8). Such initiatives not

only showcase what is possible but also help overcome the hesitation that often accompanies innovation. To disseminate the exemplary nature of these projects throughout society, the CE Platform (see Chapter 5.2) was established. One interviewee mentioned a concrete example of how pilot projects can drive progress by providing real-world proof of concept:

> "We have built the parking lot in Bissen […] where we had the idea to buy parking as a service and not the parking lot [the materials]. […]which is deconstructible and reconstructible and also the incubator that stands next to it has a number of circular elements in it." (I1)

Although this project succeeded in demonstrating potential outcomes due to close cooperation between the stakeholders (Trélat, 2023, p. 36), it was relatively costly, and the issue of scaling up remains unresolved.

Moreover, financial incentives, including subsidies and tax models, were identified as key drivers. Luxembourg offers subsidies to companies that invest in environmentally friendly practices, including those aligned with the CE. For instance, since 2024, businesses that engage in digital transformation projects through process or organisational innovation are eligible for an investment tax relief[24]. Additionally, the creation of financial models, such as sustainable loans that integrate value creation and maintenance, with favourable interest rates, could further incentivise the adoption of circular practices (I2). These financial tools are essential in making circular alternatives more attractive compared to traditional, linear approaches.

At the European level, the EU taxonomy represents a powerful regulatory driver by outlining the criteria for sustainable economic activities, including those in the construction sector (I2, I6, I7, I8). This taxonomy is increasingly influencing investment decisions, as banks and investors require proof of sustainability in order to provide financing. One interviewee noted:

> "And what's a significant lever is the EU taxonomy, the classification of what is sustainable and circular. That's a lever that no one really understood when the regulations came. But it's significant. Because if you're an investor, essentially a bank or a fund, you want a stamp on your portfolio of investments indicating sustainability […]." (I2)

The pressure from the EU taxonomy is forcing large developers in Luxembourg to consider circular practices, such as using recycled concrete, in their projects. This regulatory framework is accelerating the adoption of CE principles, even among actors who might otherwise be resistant to change.

Finally, standardisation is also mentioned as a driving force for the transition. Precisely, standardised building modules that can be adapted to living conditions, would facilitate easier reuse and adaptation of materials, reducing waste and promoting sustainability. Contrary to the

[24] URL Guichet.lu – the information portal that simplifies your interactions with the State: https://guichet.public.lu/en/entreprises/fiscalite/bonification-impot-investissement/bonification-transformation-digitale.html#accordionItem-accordionitem_services_en_ligne_et_formulaires

belief that standardisation would stifle creativity, it could actually open up new opportunities for creative design within a sustainable framework (I10).

5.6.2 Knowledge drivers

Although there seems to be ongoing resistance to incorporating the CE concept into school curricula (I1, I2), young people represent a critical, arguably the most significant target group. Rather than introducing an entirely new course on CE, the focus should be on embedding the principles within subjects like biology, chemistry, and geography. This approach fosters systemic thinking and helps students understand the broader implications of their education on sustainability (I2). Successful initiatives like the SuperDrecksKëscht, which promotes resource conservation and waste management, demonstrate the potential of early education in fostering environmentally responsible behaviours. Similar approaches could be used to teach the concept of circularity effectively. As one interviewee aptly summarises:

> "This understanding needs to be instilled at all educational levels, primary school, high school, and university. I believe every engineering student should learn about it. Once they grasp the concept, they won't need extensive further training; they can apply their engineering skills to create circular products. We have already implemented several initiatives with schools, and some schools are actively participating. However, there is still a significant need to integrate this understanding comprehensively across educational institutions." (I1)

Moreover, ongoing training and knowledge-sharing efforts are crucial for professionals in the construction sector and beyond. The House of Sustainability - an initiative from the CC and CdM - assists companies with sustainable development and offers solutions to integrate circularity into business models. It plays a vital role in ensuring that businesses are aware of and comply with new regulations. This is particularly important as companies may not always be proactive in seeking out information on their own (I6). Furthermore, higher education institutions such as the LIST and the University of Luxembourg serve as levers for creating a deeper understanding of these concepts. The completion and dissemination of research projects will be crucial in advancing the CE within Luxembourg and on a global scale (I7).

A significant challenge identified is the need for practical, on-the-ground understanding, as theoretical knowledge alone is insufficient. Real-world experience and the opportunity to learn from failures are essential for driving the CE forward. This hands-on approach is necessary to move beyond general interest and into actionable practices that can be implemented within the industry (I2). In addition, the importance of creating diverse knowledge-sharing platforms, such as conferences, round tables, and training sessions, is emphasised. These platforms allow for the exchange of ideas and experiences among different stakeholders, which is essential for building a comprehensive understanding of CE practices (I3). One interviewee highlighted the necessity of educating individuals across all societal segments, noting that it is crucial to persuade older generations of the advantages of circularity (I7), given their substantial representation within Luxembourg's population (Statec, 2023, p. 14).

Finally, the balance between internal and external knowledge inputs is crucial. Luxembourg benefits from its international connections and the influx of external expertise. However, without a strategic approach to integrating this knowledge, much of it risks being lost or underutilised. A balance must be struck between leveraging external insights and developing local solutions that are tailored to the specific needs and context of Luxembourg.

> "There are an incredible number of events […] where an incredible amount of prominent international expertise is brought to Luxembourg. And this expertise evaporates because there is no sensible follow-up, because there is no strategy as to how this knowledge can be integrated because certain fashionable topics disappear into the drawer when a minister changes […] one can also overemphasise external impulses, especially if these external impulses really have minimal resonance […]." (I9)

This balance will ensure that the CE is not just a theoretical concept but a practical, actionable strategy that can be implemented across sectors.

5.6.3 Organisational drivers

One crucial aspect that was mentioned several times is the role of communication in fostering circular practices (I1, I2, I7, I8, I10). Collaboration among ministries and other entities can facilitate the adoption of circular business models (I1). This involves not only sharing research and insights but also actively engaging with various actors to integrate circular principles across different stages of development (I3).

The collaborative nature of construction projects further underscores the importance of coordinated efforts.

> "[…] coordinating and proactively coordinating across all sectors, is, I believe, a very, very difficult undertaking that would have to be addressed with the same political emphasis as other steps that have already been taken." (I9)

A successful implementation of CE practices requires ongoing dialogue among all parties involved, from architects to end-users. This collaborative approach helps in aligning objectives and ensuring that sustainable practices are consistently applied throughout the project lifecycle (I8).

Moreover, the integration of circular practices demands a network of support and resources, including matchmaking and coordination between different sectors. This approach ensures that CE principles are embedded in product design and operational processes, thus enhancing overall effectiveness (I9). As Luxembourg is a relatively small country, leveraging regional partnerships and pooling resources can significantly boost the effectiveness of CE initiatives (I8).

Additionally, overcoming resistance to change is crucial to drive the transition. While some interviewees believe that "the real shift" in organisations, i.e., fundamentally changing the strategy, must originate from management level (I1), others argue that change management

requires involving people in the process of change rather than solely imposing top-down directives (I6). Intrinsic motivation can accelerate the adoption of sustainable practices:

> "We need to involve people and they need to be […] motivated to do it, so they don't feel forced to do something. And then it goes much faster when people are self-motivated." (I6)

5.6.4 Business drivers

Public tenders that prioritise circular solutions can provide a competitive advantage to companies that innovate in this space, creating a market environment where sustainability becomes a critical factor for economic viability. This incentivises businesses to adopt circular approaches, knowing that future market shifts could favour their more sustainable competitors (I1, I11).

Another business driver is the creation of an economic ecosystem that fosters innovation and attracts companies working within the CE. This strategic approach intends to position Luxembourg as a leader in CE practices and to strengthen the overall market for sustainable solutions (I1). The demand for circular practices is also being driven by municipalities and other local actors, who are increasingly recognising sustainability as a necessity. Consequently, businesses are compelled to adapt, realising that staying relevant in the market requires a commitment to sustainability (I3). This growing interest is prompting companies to invest in training and development to better align with emerging market demands.

However, the transition is not without challenges. The construction sector, must balance the need for circularity with economic considerations, especially in the face of multiple crises. Developers and builders are willing to take calculated risks, but not without a clear economic model that justifies the investment in circular practices (I4). This necessitates a closed-loop system where supply and demand for reused materials are synchronised, ensuring that materials can be recovered, reissued, and implemented effectively (I5).

Ultimately, businesses in Luxembourg are beginning to recognise that sustainability and profitability can go hand in hand. By demonstrating to clients that it is possible to build, live, and operate sustainably while also generating profit, companies can lead the market towards a CE (I6). The path forward involves continuous effort to educate and motivate companies to embrace this transition, ensuring that they are not left behind in a rapidly evolving market (I1, I7, I8).

> "If not everyone is on board, progress will be slow." (I2)

5.6.5 Supply chain drivers

Supply chain drivers have been considered essential to tackle global challenges. One of the primary factors pushing the transition towards circularity is the growing awareness of the vulnerabilities in traditional supply chains, exacerbated by events such as the COVID-19 pandemic or the Russia-Ukraine war. As one interviewee noted, CE practices can help reduce dependence on imports, making supply chains more resilient to external disruptions (I1). Accordingly, Luxembourg's logistic hubs, including the Findel airport and the Port of

Mertert[25], have the potential to become essential factors in the distribution and reception of construction materials throughout the Greater Region (I11).

A key element in this transition is the implementation of systems like Product Circular Data Sheets (PCDS), which allow companies to digitally manage their supply chains more effectively by providing detailed information about the lifecycle of materials (see Chapter 5.7). These systems track the residual value of materials, enabling reprocessing and reintegration into supply chains, which supports economic viability and helps companies align sustainability with operational efficiency (I1).

Another driver can be the strategic reintegration of materials into the value chain. This approach emphasises the need for dismantling installations with care and maintaining detailed records, such as updated maintenance logs, to ensure that components can be effectively reused or resold (I5). The willingness of all stakeholders in a supply chain to collaborate is crucial, as CE practices require precise information about the lifespan and condition of materials.

Furthermore, by repurposing items traditionally treated as waste, companies can inject new value into a supply chain, creating both economic and employment opportunities. Incremental innovations at smaller scales can also lay the foundation for larger, global value chains, making the CE not just a concept but a practical driver for supply chain resilience and sustainability (I7).

5.6.6 Social drivers

Critical social and cultural drivers that were identified, are the shift in mentality and awareness to overcome resistance to change. Transforming deep-rooted cultural attitudes towards sustainability requires comprehensive engagement from all stakeholders. Such an approach ensures that sustainability becomes integrated at every stage of development and operation.

> "And this is the shift in mentality that we must address, as it is deeply rooted in culture, this is indeed a significant challenge to make progress, but it is an important exercise to get the customer, the architects, the engineering offices, the companies involved and the end user […]. This must be done at all stages. […] on the one hand develop solutions and on the other hand change the mentality of the people." (I3)

For a successful transition, the societal understanding of consumption patterns and social needs should be reviewed, as a significant portion of consumption is driven by the desire for social distinction rather than genuine necessity. Consequently, marketing and its influence is an important lever in addressing "consumerist obesity" (I11).

Furthermore, the successful implementation of eco-neighbourhood projects, can demonstrate the tangible benefits of sustainable practices for residents, highlighting the importance of community awareness and involvement (I4). They do not only showcase the direct advantages of sustainability but also serve as practical examples that can foster broader societal acceptance.

[25] The river port Mertert is connected to a rail and motorway network, thus offering tri-modal transport logistics

The development of social and solidarity economy initiatives, such as reuse platforms in Switzerland and Belgium, underscores the potential for social innovation to drive sustainability. These platforms, supported by public authorities, illustrate how combining social objectives with practical solutions can create economic and environmental value. One interviewee highlighted a Belgian firm that focuses on energy renovation and uses reclaimed materials to enhance building insulation, thereby offering economic and social advantages through job creation and cost savings (I5). Developing a robust employment value chain around the reuse of materials and equipment creation through CE practices can be seen an opportunity to addressing the broader economic and societal impacts of sustainability (I7). However, if social considerations are limited to labour market potential, there is a significant risk of neglecting broader social inclusion (I9).

5.6.7 Technological drivers

One significant technological driver is the application of digital technologies and artificial intelligence (AI) in construction and deconstruction processes. Digital tools are expected to have great potential in the recognition, sorting, and recycling of building materials with greater precision (I2). This technological advancement facilitates more efficient material management and supports the broader goal of minimising waste and maximising resource reuse.

Additionally, the concept of adaptable and scalable building technologies was mentioned. The potential to design buildings with components that can be easily upgraded, dismantled, and reused highlights a shift towards more flexible and sustainable construction practices.

> "Technical equipment in a building could be designed to be adaptable and scalable and to be improved over time. […] the company would sell a service, for example air treatment or air conditioning like it is done for lighting, or even for slightly more complex techniques. And one would imagine that, at the time of deconstruction of the building, a lot of it could be salvaged and it could be reinstalled because it was designed to be able to be dismantled and reinstalled." (I5)

This approach not only promotes material efficiency but also aligns with evolving needs and technological advancements.

Digitalisation also plays a key role in this transition. The development of material passports and databases facilitates better information exchange and traceability of building materials. Such systems have the potential to support recycling efforts and ensuring that materials are efficiently reintegrated into new construction projects (I1, I2, I5). Nonetheless, excessive reliance on digital tools may increase the burden rather than ease the tasks. Several interviewees therefore mentioned the low-tech approach as a counter-narrative that emphasises minimal technological intervention while striving for innovative solutions. This approach seeks to achieve sustainability through simplicity, focusing on creating passive building designs that rely on minimal technology (I7). By reducing the reliance on complex and costly technologies, the low-tech approach aims to achieve economic efficiencies and environmental benefits.

Furthermore, the concept of flexible and modular building designs addresses the dynamic nature of modern living requirements. The use of container buildings and modular units allows

for easy adaptation to changing personal or family needs. This flexibility allows buildings to evolve with their occupants' lifestyles, promoting long-term sustainability and reducing the need for major renovations or new constructions (I10).

5.6.8 Environmental drivers

Central to the CE shift is the imperative to achieve climate neutrality by 2050, a goal that necessitates substantial reductions in the carbon footprint of buildings. As the construction sector is one of the largest contributors to GHG emissions (UNEP, 2023), addressing this issue is crucial for meeting broader climate objectives (I2). This urgency reflects a global awareness of the need to mitigate the environmental impact of building practices and the importance of adopting innovative solutions to reduce emissions (I4, I6).

A significant driver of this transition is the increasing scarcity and cost of building materials. The rise in material prices, coupled with limited availability, is pushing the construction industry towards more sustainable alternatives, such as the CE concept. As on interviewee expressed:

> "[…] the scarcity and especially the increase in prices of materials and products will, in my opinion, help the circular economy. That we will have to pay a high price for materials and products. We will be happy to find jobs, we will be happy to recycle, etc." (I4)

The CE emphasises the reuse and recycling of materials, which not only conserves resources but also minimises waste. This shift is not merely a reaction to economic pressures but also a strategic adaptation to ensure the longevity and resilience of building materials within a constrained market.

One interviewee highlighted that biodiversity, which is frequently regarded as an "externality" in conventional construction practices, is a crucial driver for change (I5). Recognising that biodiversity cannot be restored once lost underscores the importance of adopting sustainable practices to safeguard and maintain natural ecosystems. The implications of environmental degradation go beyond mere financial costs, encompassing significant long-term health risks associated with toxic materials and the substantial expenses of environmental remediation. This perspective reinforces the urgent need to incorporate sustainability into construction practices.

5.7 Circular initiatives in the construction sector

This chapter investigates selected CE initiatives within Luxembourg's construction sector to demonstrate how circularity is implemented in practice. Additionally, the perception of bottom-up initiatives and their role in this context will be addressed.

5.7.1 Product Circularity Data Sheet

Circularity

In 2019, the MECO, supported by the consulting company +ImpaKT, introduced the PCDS - a standardised data template that provides reliable information on the circular aspects of products to all stakeholders throughout the value chain, from buildings to packaging, textile, and consumer goods (GDL, 2024a). This tool enables a common language on product

circularity, facilitates traceability and transparency, making it easier to disassemble, reuse, and recycle products. By allowing each actor in the supply chain to add relevant data to the PCDS, this system helps maintain the circularity of products in a decentralised way.

> "At some point in a public procurement for example, one would always ask for the circular properties of a product and the PCDS is a way to deliver it. Of course, there would also be many other systems, but [the PCDS] is ready to be operated, therefore it has a lead and secondly it is also very practical, and the companies would adopt it and ideally if it isn't mandatory, sectors would see the added value and simply create the PCDS because they want to manage their supply chain, because they want to show that it is circular." (I1)

The data can be accessed as needed from the data exchange platform (still in creations), which reduces the need for redundant questionnaires and simplifies the verification process for circularity, a challenge in many standardisation efforts. The PCDS is designed to be practical, easy to implement, and capable of ensuring that essential information is available without compromising data confidentiality. In 2021, the PCDS was recognised an ISO/NP 59040 standard and is part of the 59000 series that aims to standardise the principles, implementation, and measurement of the CE. Since 2022, Terra Matters, an organisation co-founded by the MECO and CC has been tasked with developing, managing, and promoting the PCDS.

Scope

The entrepreneurial hands-on approach of Luxembourg's government, short communication channels and close cross-border relations have made Luxembourg a suitable testing ground for the PCDS (I1). Over 50 companies out of 12 European countries have already joined the initiative, divided in working groups and a stakeholder group for feedback and guidance (GDL, 2024a). The initiative began as a national effort, aimed at demonstrating the viability of circularity in pilot projects within Luxembourg. However, the project quickly expanded beyond the national level due to the inherently cross-border nature of supply chains in the Greater Region. For instance, materials like wood are imported from and exported to neighbouring regions, necessitating a broader application of the PCDS. Despite this regional involvement, the project's ambition extends to the European and even global levels, aiming to establish the PCDS as an international standard for circularity. Therefore, while the project is regionally embedded to the extent that it interacts with cross-border supply chains, its primary focus is on achieving broader European and global.

> "[…] we didn't want to give the matter a regional focus except to say Europe certainly, rather worldwide. The goal is to make it a world standard and use it." (I1)

Innovation

This PCDS represents a key example for Luxembourg's data-driven innovation strategy (GDL, 2019) that promotes circularity using big data solutions. It incorporates elements of technological innovation, organisational and institutional innovation; the integration of a standardised data exchange protocol and decentralised data storage system constitute technological advancements that support efficient and secure sharing of circularity data across supply chains. Additionally, it aims to transform stakeholder interactions and collaboration

within supply chains by standardising data exchange and verification processes. And finally, it encourages different entities, including corporations, public sectors, and other stakeholders to interact and collaborate in new ways, thus driving institutional change. While supporting the supply side by encouraging better product design, this solution also facilitates the demand side by making circularity information available to all stakeholders in the supply chain. This transparency aids in the diffusion and upscaling of CE practices across the region. The PCDS aims at economic growth and resilience by enhancing the competitiveness of firms through improved circular business models and contributes to the transition towards a CE by addressing critical issues such as resource efficiency, waste reduction, overcoming greenwashing and sustainable production and consumption. Since the initiative aims to combat greenwashing, a third-party verification scheme is applied to ensure the credibility and accuracy of the information presented in the PCDS.

In conclusion, the PCDS serves as a tool designed to promote circularity both in Luxembourg and on a global scale. From a systemic perspective, it should be regarded as a foundational element of CE, necessitating integration with complementary solutions, such as tracing systems, to ensure comprehensive circularity. The data exchange platform requires further refinement, and the template should undergo additional testing to ensure its user-friendliness across a diverse range of companies (Mulhall et al., 2022).

5.7.2 Circular Innovation Hub Wiltz

Circularity

Through a strategic political decision aimed at creating national and international visibility for CE practices, the municipality of Wiltz was designated national circular hotspot in 2015. This concept includes the top-down initiated building project *Wunne mat er Wooltz* and the creation of the Circular Innovation Hub to promote CE principles across diverse projects and encourage bottom-up engagement. The Hub engages in three primary focus areas, i.e., developing pilot projects as test laboratories, raising awareness on the CE, and ensuring that the knowledge gained from these projects is preserved and shared (Commune de Wiltz, n.d.). By offering a variety of formats, the HUB seeks to engage different target groups into CE activities. These include an annual conference initially aimed at municipalities but now open to the general public, the Circular Economy Day. Additionally, there are smaller events like movie debates, which are more accessible to citizens and involve discussions with experts. Through basic, and advanced training sessions on the CE, beginners and technically advanced participants are addressed. Furthermore, educational formats for school classes and roundtable discussions for B2B interactions are ensuring relevance and interest across various audiences (I3).

Scope

The Circular Innovation Hub is embedded at the regional level through its connections with local and regional actors, including municipalities, training institutions, and various stakeholders involved in CE projects. The Hub has established partnerships with organisations such as the Klima Agence, INAP, CNFPC, IFSB, and the CC to extend its reach and influence. However, the Hub struggles with gaining national recognition and broader regional integration.

> "The problem is […] that we don't have national recognition for what we are doing. This is why I am particularly pleased that we were able to develop the BauCheck [tool to support sustainable and circular building standards at municipal level] together with the Climate Agency, as the people who come to us are interested in what we are doing in Wiltz. However, for example, the connection with INAP is relatively recent. I believe it has been a year since we established that relationship, which helps us gain some national recognition, allowing municipalities to see that what Wiltz is doing is relevant." (I3)

While it has the potential to serve as a structure for uniting municipalities around CE initiatives, it currently lacks the authority or framework to impose its model on other regions. This limits its regional impact and highlights the need for a more cohesive structure to support broader adoption across municipalities.

Innovation

The Circular Innovation Hub aligns more with a modern approach to innovation that extends beyond traditional economic objectives. It not only engages in technological and organisational innovations but also addresses broader societal challenges by involving local communities and creating new governance frameworks. For grassroots initiatives, the municipality of Wiltz offers the space for interaction and support but intentionally refrains from active involvement, as doing so would contradict the essence of a bottom-up initiative.

> "They [citizens] need to take the initiative, so that it simply remains the concept of citizens for citizens. Because we also have our own initiatives as a municipality, where we try to propose what we think citizens need. That then balances itself." (I3)

While the Hub addresses the supply side of innovation by generating knowledge, it is equally important to focus on its dissemination to drive widespread change on the application side. To achieve this, the Circular Innovation Hub is working to gain national recognition through large-scale projects, which will help bridge the gap between experimentation and practical application.

5.7.3 Other initiatives

Another project that addressed CE in the construction sector is the grassroots initiative **Äerdschëff**[26], led by the non-profit organisation CELL. The Earthship itself was constructed with the help of local and international volunteers and in partnership with local companies and experts. It is a participatory construction site for learning, research, and teaching about low-tech approaches and the CE, that allows all interested professionals and private individuals at local and regional level, to contribute (Fig. 20). Funded by MECB and LEADER-CLLD. this project emphasises self-sufficiency in essential areas such as water, sanitation, food, heating, and electricity, aiming to address human needs in a manner that is both sustainable and resilient. The Earthship design is deliberately straightforward and single storey, enabling individuals with limited construction experience to build them with minimal dependence on public utilities and fossil fuels (ENRD, 2014). The pioneering project emphasises social inclusion and local

[26] Äerdschëff translates into Earthship, inspired by Mike Reynolds and Biotecture, URL: https://aerdscheff.lu/

development, actively collaborating with the secondary school in Redange and engaging with citizens through a participatory approach. In 2024, it was awarded the Bauhärepräis in the category *technical and energetic equipment*, highlighting its innovative richness and securing public recognition. However, the project has encountered significant obstacles in scaling up (Trapp, 2019), stemming from its niche appeal, complex methodologies, regulatory barriers, and limited market adoption (Booth et al., 2023).

Figure 20. *Äerdschëff in Redange (source: SGI Groupe, 2023)*

A different approach was taken in the reconversion of the **Campus Lycée Michel Lucius** (2018-2021), a pilot project of the Public Building Administration, focusing on the reuse of construction materials and the use of recycled concrete aggregates (GDL, 2023c). A life-cycle analysis of the existing structure determined that converting the current building, which housed classrooms, into a library (Fig. 21) was the most cost-effective and fastest option. In contrast to demolishing the old building and constructing a new modular library, this approach allowed for the preservation of functional spaces while generating less construction waste and CO2 emissions, amongst others by using recycled concrete. One of the key challenges was to execute an unprecedented approach, which considerably complicated the project. This included handling asbestos-contaminated building materials that could not be reused, as well as working with materials that were not designed to be dismantled (I8). This requires the recognition that not everything can be executed as originally envisioned, and that compromises must be made. Securing the New European Bauhaus Prize 2024 in the category of *shaping a circular industrial ecosystem and promoting life cycle thinking* has brought EU-wide recognition and provided a valuable platform for sharing experiences.

> "Since we did this project, we gained a lot of experience and that was also very important to communicate." (I8)

5.7.4 The role of bottom-up initiatives

Bottom-up initiatives and grassroots innovations have been identified as equally important to forward-thinking governmental policies in driving the transition towards a circular built environment (Pomponi & Moncaster, 2017, Charter & Keiller, 2014, Anantharaman, 2021). The interviewees underscore the importance of bottom-up efforts in complementing top-down approaches, highlighting their potential for innovation, community engagement, and practical implementation (I1-I8).

One of the key perceptions of bottom-up initiatives is their role in fostering learning and experimentation. They provide real-world examples and offer insights into "what has worked

and what not", which can be used to refine strategies and approaches to sustainability (I1, I11). It as it allows for the identification of best practices that can be scaled or adapted in other contexts.

Unlike top-down approaches, which are often constrained by rigid frameworks and regulations, bottom-up initiatives can operate more freely, exploring innovative solutions that may not be immediately viable at a larger scale. The example of the Äerdschëff project illustrates how bottom-up efforts can push the boundaries of what is possible, even if the solutions they develop are not universally applicable. These initiatives serve as experimental grounds for new solutions and approaches, also inspired by those of other countries, providing proof of concept for alternative ways of living and working that can inspire broader systemic change (I11).

> "Bottom-up initiatives are extremely important because, from the top down, you are in a relatively rigid framework, and not everything is possible. I think the Äerdschëff is fantastic. The energy they put into it is significant, although it's a bit extreme. It's not something that can be replicated 100 times here. But it's just to show people what's possible." (I2)

However, the success and sustainability of bottom-up initiatives are not without challenges. One significant issue is the reliance on subsidies and the lack of an economic model behind (I2, I4). Many bottom-up initiatives struggle to sustain themselves financially without external support, leading to the collapse of projects once subsidies run out. This highlights the importance of integrating economic considerations into the planning and execution of bottom-up initiatives to ensure their long-term viability, as one interviewee stated:

> "And they [projects like the BENU Village] collapsed because they relied on subsidies. There must be a business model behind it. And this business model in construction can be found among developers, construction firms. They need to see an interest so they can sell their apartments. "

One interviewee mentioned the COVID-19 pandemic as a significant challenge to the transition movement, disrupting its momentum and revealing the need to revitalise citizen engagement (I11). It highlighted the importance of developing more effective interaction methods and improving the movement's structure to adapt and continue making progress.

The relationship between top-down and bottom-up approaches is also a critical factor in the success of bottom-up initiatives. Interviewees noted that these two approaches must meet in the middle, creating a balanced and synergistic relationship. Top-down initiatives can provide the necessary support and resources, while bottom-up initiatives bring local knowledge, community engagement, and innovative solutions to the table (I1, I3). Furthermore, bottom-up initiatives serve as a signal to policymakers and the broader public that there is a grassroots desire for change (I11). They demonstrate a bottom-up demand for sustainability, which can influence political agendas and policy decisions (I5). However, despite their perceived importance, bottom-up initiatives often lack visibility and recognition. They are not always taken seriously by policymakers or the public, which can limit their impact and the resources available to them. This suggests a need for greater efforts to raise the profile of bottom-up initiatives and to integrate them more fully into the broader sustainability discourse.

> "To my knowledge, these initiatives suffer a little from perhaps a lack of structuring perhaps. And […] a lack of visibility because ultimately bottom-up initiatives are not always taken seriously enough or perhaps are not given enough effort or energy to. And so, in the public opinion, I think that it is still far from being a subject which ultimately has as much importance as that, and it is certainly not a priority anyway." (I5)

Consequently, the involvement of citizens in CE initiatives and triggering intrinsic motivation can be a strategy to overcome resistance to change. According to an interviewee, change management is more effective when people are involved and motivated rather than when solutions are imposed from above (I6). This approach can help to build a stronger societal commitment to sustainability, making the transition more resilient and enduring.

6. Discussion

The discussion initiates with an examination of the research questions posed in this study. Subsequently, the findings are evaluated through the lens of the CoRIS framework. Following this, the study's methodological strengths and weaknesses are assessed.

6.1 Addressing the research question

1. **How do actors involved in the transition to a circular built environment understand and address the CE?**

From the perspective of those actively involved with the concept, the CE is understood as a broad framework that suggest closing the loop of material and energy flows in production and consumption. It is acknowledged that the concept has gained significant recognition in the past decade, although significant knowledge gaps are perceived at all levels, and implementation remains in the early stages. This wide range of interpretations and applications across sectors and stakeholders is perceived as a challenge for the government to establish concrete guidelines for implementation and measuring the effectiveness of CE practices. Luxembourg's CE strategy seeks to address these challenges by offering targeted regulatory, financial, and knowledge-management tools for both sectoral and cross-sectoral implementation. In the construction sector, these tools are heavily focused on the reuse of recovered and recycled building materials, aligning the understanding of CE closely with resource and waste management optimisations. This alignment is largely due to the strategy's foundation in the Resource Diamond (Fig. 11) and Resource Leaf (Fig. 12) of the Zero-Waste Strategy.

At the micro level, within the construction industry, an increasing number of companies are incorporating CE principles into their projects, whether through modular design, leasing models, or viewing buildings as material stocks. Digital networking is increasingly recognised for its potential to enhance circularity. The government aims to harness this potential by promoting the adoption of BIM and PCDS. Both at the micro level, in the construction sector and at the macro level, CE is perceived primarily as a business model, with CE practices used as a means to achieve sustainable development. Within the government, as well as in semi-public organisations and private enterprises, economic viability, or at least economic stability, is considered essential for the successful implementation of CE practices. However, this

perspective on CE as an incremental approach, focused on environmentally friendly production, efficient resource, and waste management, supported by digitalisation, tends to address symptoms rather than causes. Critical voices argue that this shortened understanding of the concept poses a risk of perpetuating business-as-usual practices under the guise of sustainability. This group of sceptics that stem primarily from academia and the non-profit sector consider addressing root causes as necessary to tackle grand societal challenges and criticise the CE concept for inadequately addressing consumer behavior and the creation of needs as underlying issues. Consequently, CE should provide context-specific solutions that can differ from sector to sector and from material to material instead of a one-size fits all solution.

2. How is governance of the CE approached in the built environment?

Luxembourg's commitment to achieving a circular built environment is addressed across various levels of governance. The **government** is engaged in the CE by commissioning studies (e.g., Hansen et al., 2014; TIR, 2016), formulating strategies (e.g., CE Strategy, Zero Waste, PNGDR, Roadmap for Low-Carbon Construction), and engaging in initiatives and projects (e.g., Circular Hotspot Wiltz, Campus Lycée Michel Lucius). Furthermore, it supports and funds economic interest groups (e.g., Neobuild, Luxinnovation, Terra Matters, CRTI-B), initiatives led by non-profit organisations (e.g., Äerdschëff) and collaborates with actors from the private sector on solutions for the recycling of concrete aggregates (Schroeder&Associés, Beton Feidt for the Campus Lycée Michel Lucius) and bio-sourced wood (E-Holzhaff through Luxinnovation). The government's strong financial presence can enable project implementation, but it also creates dependencies and can blur the lines between public, private, and non-profit sectors.

On the local scale, the 100 **municipalities** are operating under strong state control and financial dependence which leaves a restricted room for experimental changes. Although the proximity between local and national governments provides an opportunity to amplify citizens' voices in the CE debate at the national level, participatory approaches remain limited. Currently, the municipal engagement in the CE is concentrated in a few municipalities. Some of them (e.g., Beckerich, Junglinster) have already engaged with alternative solutions such as regional currencies, energy cooperatives, and sustainable construction, launching projects aligned with the CE before the concept gained wider attention. Other municipalities are engaged in large-scale development projects for eco-districts like Esch-sur-Alzette and Schifflange (Metzeschmelz) or Wiltz (Wunne mat der Wooltz). The circularity efforts undertaken by the municipality of Wiltz illustrate how collaboration among diverse actors can catalyze both top-down and bottom-up initiatives. While the decision-making process to establish Wiltz as a national circular hotspot was a strategic political move, this decision was embraced by the local authorities. They seized the opportunity to establish the Circular Innovation Hub, aiming to engage civil society in the discourse on circularity through a series of events and discussion forums. Through the establishment of the CELL's regional group - Transition Nord, Wiltz became a fertile ground for community-led initiatives and a place for exchange to address sustainability and solidarity. Municipalities can serve as testing grounds and models for other

municipalities, potentially leading to a spillover effect. A good example is the Climate Pact 2.0, which was designed to engage municipalities in the country's climate and energy transition. Compared to its first version, this pact covers various CE criteria such as energy-efficient building refurbishment, shared spaces, or excavated soil treatment. Municipalities are incentivised to achieve the pact's criteria and outperform other municipalities with financial rewards and recognition, thus take part in the broader national strategy for sustainability. However, it is noteworthy, that the most engaged municipalities are often those with greater financial resources (e.g., Schuttrange, Niederanven) or human resources (e.g., Esch-sur-Alzette, Hesperange, Bettembourg, Schifflange). Since a successful transition requires collective effort, addressing the needs of smaller municipalities and finding place-specific solutions is also necessary. Increased intermunicipal cooperation could offer viable solutions by pooling the financial and human resources of smaller municipalities.

Besides top-down steering by the government, there is also some level of **bottom-up** organisation, though it remains relatively underdeveloped. As Taylor Aiken and colleagues (2020, p.222) noted regarding bottom-up initiatives in Luxembourg, "grassroots phenomena are only possible via influential individuals spearheading the project and heavy government funds channeled into these strategic aims". Pilot projects like the Äerdschëff, which continues to generate value through its educational programs after completion, is viewed by many stakeholders as just another initiative that failed to achieve large-scale impact. It seems that the challenge of governing is less about the availability of financial resources and more about stimulating bottom-up initiatives and scaling them up to generate large-scale benefits. Given Luxembourg's characteristic short pathways between stakeholders, **NGOs** have the potential to mediate by bringing together actors who have not previously collaborated. The reason why they fail is often their inability to navigate financial challenges, ineffectively collaborate with top-down approaches, or a lack of visibility and recognition required to drive broader systemic change.

Luxembourg's **research** institutions, the LIST and the University of Luxembourg are addressing the cross-border dimension of the CE by collaborating with other research institutes and industry stakeholders in the Greater Region. These interregional projects (e.g., PREUSE, SeRaMCo, FRCBE, CIRCULUX, CIRCULAR) demonstrate how place-specific challenges (e.g., cross-border import dependence and supply chains, limited demand for reused building material, etc.) can be tackled through regional embeddedness.

3. What barriers are hindering the transition to a circular built environment?

Although the CE has been addressed and implemented at political, corporate, and non-profit levels in Luxembourg, progress is slow. This study identified barriers that hinder the transition from a linear to a circular economy. These barriers, outlined in Figure 21, were identified through an analysis of Luxembourg's building sector. However, it is important to acknowledge that similar barriers may exist in other sectors and contexts.

Regulatory factors were the most frequently mentioned barriers hindering the implementation of CE in the built environment. The **classification** of waste-derived materials (refurbished,

recycled…) as **waste** is hindering their introduction in the value chain. Furthermore, the **fragmented and inconsistent** nature of **regulations** at different levels, the **lack** of **warranties** for reused building materials and missing **economic incentives** for circularity are slowing down the transition (see Chapter 5.5.1). Financial factors constituted the second most concerning barriers, encompassing higher **initial costs** for circular practices, the **short-term focus** of **municipal budgets**, stakeholder's **risk aversion**, elevated **land costs**, and **economic challenges**, especially for SMEs which have fewer resources available compared to larger corporations. This last factor has a great impact given that SMEs are the driving forces in Luxembourg's construction sector (see Chapter 5.5.2). Furthermore, **entrenched habits and perceptions** (e.g., design and status over functionality), **resistance to change**, and a general **reluctance to embrace reused or recycled materials** seem to be of major concern. Luxembourg's economic prosperity, though unevenly distributed across society, appears to increase the reluctance to adopt reused and recycled materials (see Chapter 5.5.3). A limited **understanding** of how to transform traditional operations into circular practices and the lack of acknowledging sustainable **benefits of CE practices,** can enhance resistance to change and slow down the transition. Using refurbished high-quality materials can be more sustainable compared to building with virgin raw materials. Given that CE is still at the beginning of its implementation, a **lack of expertise and training** becomes evident. It cannot be generally asserted that certain stakeholder groups have a better understanding of the concept than others; **knowledge gaps** appear to exist among planners, engineers, construction operators, policy makers and other actors (see Chapter 5.5.4). Luxembourg's socio-economic context is contributing to significant market barriers, hindering the transition, i.e., **pressure on public property development** to construct more in a limited time, due to population growth. Luxembourg's relatively **small** size limits the scale at which CE principles can be effectively implemented and tested, affecting both the **market** for reused materials and the ability to achieve a **critical mass** of projects necessary for meaningful change. Furthermore, a **high purchasing power** results in a preference for purchasing new products rather than repairing or reusing existing ones (see Chapter 5.5.5). Despite short information and knowledge exchange channels, **fragmented communication** and **limited cross-industry cooperation** are restraints to a successful implementation of CE practices. The country's reliance on imports due to limited access to resources is leading to **supply chain inefficiencies** that slow down the transition. The structure and coordination of these supply chains is complex and **reverse logistics networks** are not sufficiently developed (see Chapter 5.5.6). **Linear systems** and **resource-intensive traditional business models** are still **dominating** the market, which makes the access to circularity more difficult. Furthermore, businesses and municipalities are missing **organisational resources and capabilities** are missing to tackle increasingly complex circular processes. A **lack** of **successful frameworks** to implement circular construction projects complicate the adoption of circular alternatives (see Chapter 5.5.7). Technological and technical barriers that slow down the transition are primarily related **lacking information** on construction materials, products, and services, **limited data accessibility** and **insufficient technological infrastructure** (see Chapter 5.5.8).

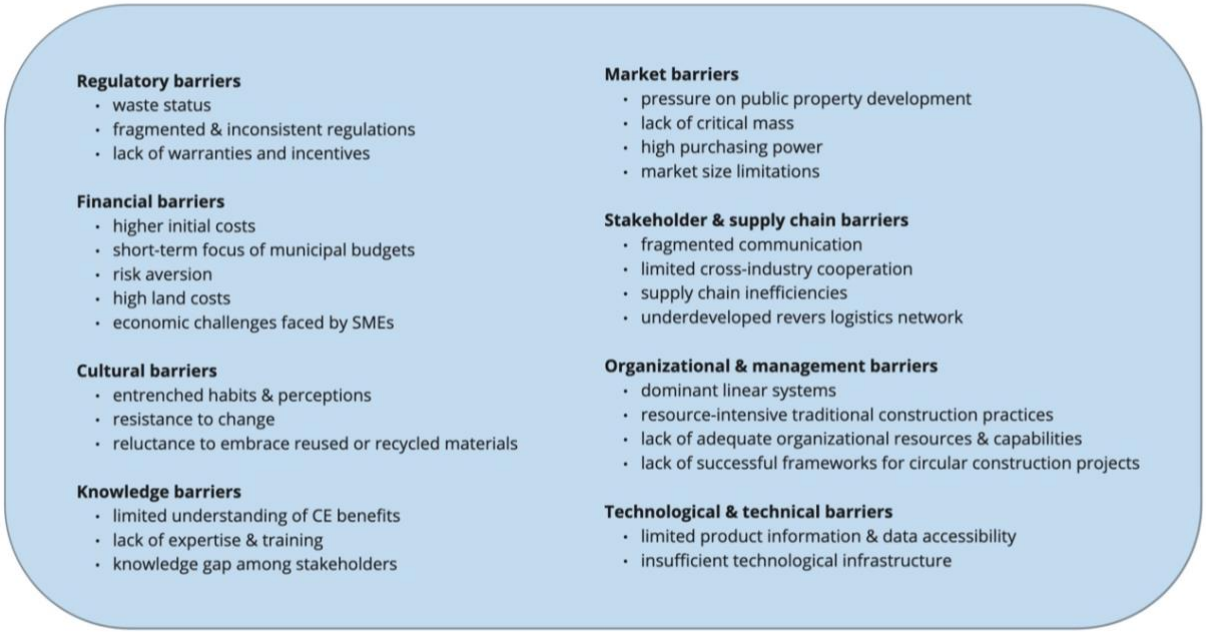

***Figure 21**. Barriers hindering the transition to a circular built environment (own representation)*

4. What driving forces could facilitate the transition to a circular built environment?

Based on the interviews conducted this study has identified potential driving forces that are intended to complement existing efforts towards achieving a circular environment. Figure 22 illustrates these factors.

Regulartory steering mechanisms and the government's role as a facilitator emerged as important levers for the transition. Although **circular procurement policies** have been addressed (e.g., technical clauses for deconstruction), circular and sustainable criteria need a greater appreciation in public tenders. Moreover, there is a need for additional **demonstration** and **large-scale projects** to facilitate learning, demonstrate the advantages of circular business models, and mitigate stakeholders' risk aversion. **Standardisation** procedures are another tool to facilitate the assessment of circular operating processes can accelerate the transition. A combination of national tax models and **financial support** systems, such as sustainable loans that integrate value creation and maintenance with favourable interest rates could further incentivise the adoption of circular practices. Besides national efforts, **European regulatory frameworks** seem to be a vital factor in accelerating the transition on national level (see Chapter 5.6.1). CE **knowledge dissemination** and **education** would need to expand **at all levels**, from primary schools to universities, ongoing **training,** and **knowledge-sharing efforts** for professionals in the construction sector and beyond through a **balanced** integration of **internal** and **external expertise** (see Chapter 5.6.2). For a successful implementation of CE projects and upscaling of innovative models, effective **communication** between stakeholders along the value chain are necessary. The case of Luxembourg illustrates that close proximity among stakeholders and short communication channels do not automatically result in improved communication and collaboration. The transition is a collective effort across all levels, sectors, and stakeholder groups, which is why **inclusive change management strategies** are essential

tools for building stronger societal commitment to sustainability, thereby making the transition more resilient and enduring. Moreover, As Luxembourg is a relatively small country, leveraging **regional partnerships and pooling resources** can significantly boost the effectiveness of CE initiatives (see Chapter 5.6.3). Demonstrating, that circularity provide **benefits** and **opportunities for competitive advantage** are perceived as crucial in changing supply and demand. The transition is heading for a closed-loop system where **supply** and **demand** for reused materials are **synchronised**. Given that companies are still primarily focusing on economic profitability, circular materials and practices need to become more **attractive.** Businesses can become driving forces in demonstrating how sustainability and profitability go hand in hand (see Chapter 5.6.4). Furthermore, the complexity of **supply chains necessitates** a more **effective management,** a **strategic reintegration** of **materials into the value chain**, as well as **incremental innovations** at **smaller scales** laying the foundation for global value chains. Technological drivers shaping the transition include **selective use of digital technologies** and **adaptive building design**. As Luxembourg increasingly relies on digital technologies to drive circularity, there is a risk of neglecting ecological, social, and participatory aspects. In this context, **low-tech solutions** may offer a promising alternative (see Chapter 5.6.5 & Chapter 5.6.7). Significant drivers that are often perceived as radical, are **shifting** deep-rooted **cultural attitudes** towards sustainability, **rethinking consumption patterns** and the way **social needs** are defined. Although the labour potential of a CE can be a social benefit, the quality of these jobs should also be considered to achieve a meaningful social impact. Initiatives for environmental protection and biodiversity preservation in relation to more sustainable and circular construction practices can **increase public awareness** about CE and help stakeholders and communities **to overcome resistance to change**. Environmental concerns like **GHG emissions, biodiversity** and **material scarcity** can also drive stakeholders to adopt circular practices. Although Luxembourg has explicitly addressed the reduction of GHG emissions in the construction sector and its consequences within its roadmap, the success of this roadmap remains to be seen (see Chapter 5.6.6 & Chapter 5.6.8).

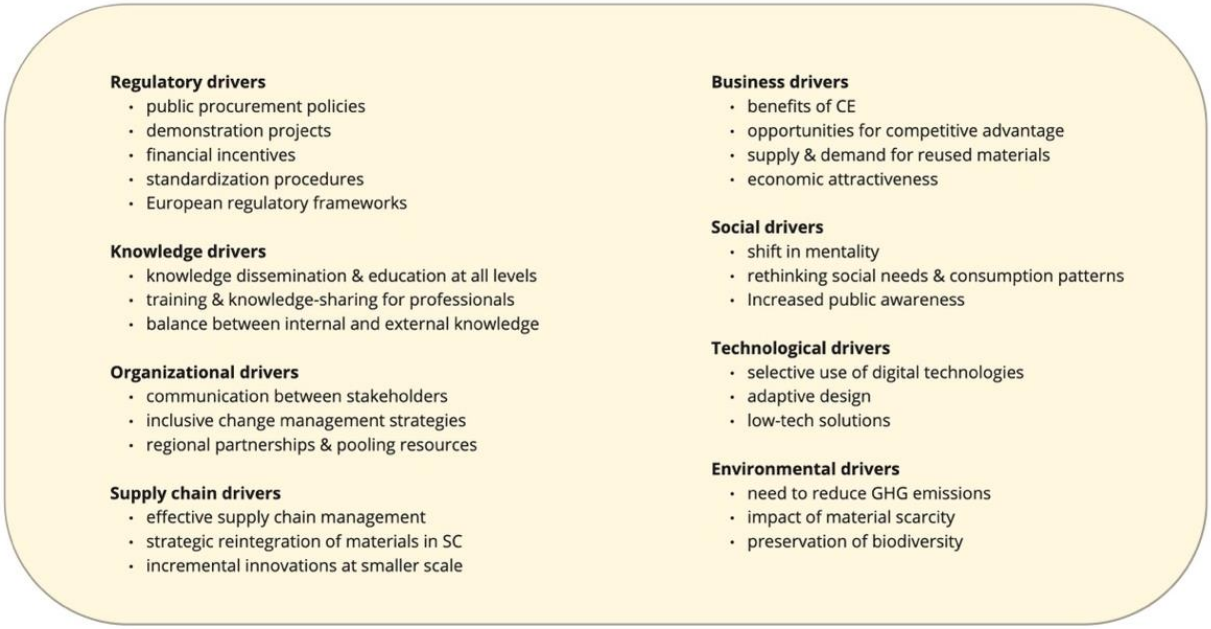

Figure 22. *Driving forces facilitating the transition to a circular built environment (own representation)*

5. How is Luxembourg's built environment influenced by the CE concept and what is necessary to ensure the transition towards a circular built environment?

Luxembourg's built environment is progressively being shaped by the CE principles, though the sector remains in the early stages of this transition. Currently, the construction sector continues to be dominated by traditional linear practices, with only limited integration into existing construction methods. While political support for CE practices becomes evident in policy documents, this support has often remained superficial, resulting in insufficient tangible actions and limited implementation of pilot projects. The gap between policy and practice highlights the need for more robust initiatives and effective enforcement mechanisms to drive substantial change. Currently CE implementations in Luxembourg are led by incremental changes that allow the existing economic system to stay viable, while radical changes are met with skepticism and resistance. The existence of fragmented regulations within a state-centered system makes a more inclusive incremental approach to the transition, more suitable than imposing radical changes.

Circularity in the built environment is largely driven by waste management optimisations, that focus on reusing and recycling construction material and relegates the principle of "reduce" and the critical examination of consumption patterns to a secondary concern. Although the CE seeks to minimise waste generation through closed-loop systems, it is crucial to recognise that this goal has not yet been fully realised. Therefore, waste prevention should be simultaneously promoted. By placing greater emphasis on waste reduction Luxembourg can achieve greater sustainability alongside the existing CE practices. Currently, CE development in Luxembourg is primarily primarily steered by a small, influential group of stakeholders, while there is growing interest among those with less comprehensive knowledge of CE. Promoting a more inclusive discourse on CE and facilitating the exchange of new ideas and alternative approaches might mitigate entrenched societal attitudes and resistance to change. Events like the Circular Economy Day illustrate this potential, demonstrating both the common interest in CE and the need for a more diverse range of perspectives. The current debate on CE might needs to shift towards an open and transparent dialogue, beyond expert circles, to address societal challenges.

Moreover, it is crucial to recognise the construction industry's dynamic nature and its potential for gradual transformation through public procurement and evolving customer demand. Shifting the focus from evaluating projects solely on delivery to considering their entire lifecycle in tendering processes is essential for fostering a CE approach. Moreover, while Luxembourg's focus on digitalisation in advancing the CE offers advantages (efficient management, resource tracking…), it should not be regarded as the only viable solution. A more comprehensive approach would integrate digital technologies where they are most beneficial (competitive advantage, training requirements, maintenance), complemented by low-tech solutions that are easier to implement and manage, yet remain effective and functional (questioning how much growth is needed to generate wealth). This balanced approach is likely to be more effective in achieving sustainable outcomes.

Luxembourg's embeddedness within the Greater Region, means that its regulations and the ecosystem cross borders, impacting a larger territory while being impacted by these external

forces. Existing collaborations are crucial for the country's development and represent potential for joint solutions. For instance, in the case of construction materials, establishing a regional system might be more successful than focusing on a national system (e.g., Interreg PREUSE). Close collaboration within the Greater Region, by pooling resources to develop solutions for specific regional problems, could significantly enhance the progress of a broader CE transition.

6.2 Analysis through the CoRIS lens

In this chapter, the elements of a CoRIS, (see Chapter 3.4, Tab. 3) are examined and applied to Luxembourg's construction sector, embedded in regional context.

A. Type of Innovation

In Luxembourg, the shift towards a circular built environment is primarily driven by technological innovations. This includes the adoption of circular business models supported by digitalisation, the development of circular data systems, modular construction methods, and advanced recycling technologies. Social innovations such as new cooperative models and community involvement do exist but are less emphasised by political action than technological solutions.

B. Purpose of Innovation

Circular building initiatives in Luxembourg extend beyond just promoting economic growth and competitiveness, as they tackle a range of broader challenges. For instance, the Äerdschëff project demonstrates a commitment to nature regeneration, social inclusion, food security and self-sufficiency. Furthermore, the Circular Innovation Hub contributes to a broader understanding of interconnectedness between resource consumption an environmental degradation through knowledge dissemination. The PCDS initiative tackles insufficient transparency regarding data on circular products, a challenge that is especially pronounced in a small country like Luxembourg, which depends significantly on cross-border trade. The initiative aims to enhance economic growth and resilience by improving firm competitiveness directed towards waste reduction and sustainable production of materials. This example illustrates that while generating economic viability of projects through circular business models, they are also perceived as a means to achieve wider societal benefits. Ultimately, while the subordinate purpose of innovation might be creating sustainable practices that contribute to broader societal well-being, companies are encouraged to adopt circular solutions that are economically viable, as those who do not may lose their competitive edge to more sustainable rivals.

C. Effects of Innovation

The extent to which innovation effects are addressed can only be determined to a limited degree, as this may vary depending on the specific context of each initiative. For example, the Äerdschëff initiative emphasises low-tech building solutions, questioning the necessity of more advanced technologies. There appears to be an understanding of existing negative outcomes associated with circular innovation, such as poor working conditions at recycling facilities (I9), challenges related to the transportation of recycled materials like concrete (I6), the risk of shifting impacts due to inadequate lifecycle thinking (I5), and the realisation that a solution

may be innovative on a micro level but not necessarily effective on a macro scale (I11). Even though the debate on phasing out existing unsustainable construction practices is ongoing, it seems to be confined to politically critical spheres, such as research institutions, political arenas, NGOs, and occasionally within businesses. A public and transparent discussion on exnovation strategies seems to be missing, as one interviewee noted:

> "I believe, the term exnovation at first sight triggers similar reflexes to terms such as sufficiency, degrowth or others, which are sometimes unintentionally, sometimes deliberately misinterpreted, and then also cited as a deterrent scenario in the media or in politics. "(I9)

D. Actors, Networks, Institutions

The CoRIS approach puts emphasis on a broader scope of actors, networks, and institutions by integrating actors from civil society and non-governmental organisations into traditional innovation ecosystems. The spatial context of Luxembourg has facilitated the emergence of a network of actors that collaborate closely not only at the national and municipal levels but also across borders. However, the entrepreneurial government plays a central role in promoting innovation across various sectors, such as the construction sector. This is exemplified by the numerous economic interest groups that are supported by the government (Luxinnovation, Neobuild, Terra Matters, etc.) which are instrumental in promoting innovation and driving sectoral transformation. A CoRIS can emerge organically, from the bottom-up or in a top-down manner through policy actions (Tödtling et al., 2021, p. 2146). The circularity efforts of the municipality of Wiltz illustrate how collaboration among diverse actors can catalyze both top-down and bottom-up initiatives. While the decision-making process to establish Wiltz as a national circular hotspot was a strategic political move, local authorities seized the opportunity to engage civil society in the discourse on circularity and to offer a ground for community-led initiatives that address sustainability and solidarity. Outside this circular environment, the integration of civil society and NGOs through participatory processes remains limited. Projects that did not succeed, such as the Benu Eco-Village, which ultimately collapsed due to financial inefficiencies, exacerbate the skepticism among other actor groups regarding the effectiveness of bottom-up initiatives that are funded top-down. The innovation ecosystem includes various actor groups, but traditional actors are strongly represented, leaving the citizen's perspective and collaboration with NGOs underrepresented. CE practices in construction are gaining recognition across stakeholder groups, however the wide range of interpretation and implementation inherent to the concept complicate the formulation of a shared vision. Luxembourg's policymakers, by developing frameworks for implementing circular models and providing financial support, along with non-profit organisations that act as a bridge between civil society and the government, have the potential to serve as change agents. However, this potential is currently restricted by insufficient cooperation and communication among actors.

E. Production and Application Sides

In a CoRIS, increasing emphasis is placed on the application side of innovations to address specific problems effectively (Tödtling et al, 2021, p. 2144). The Äerdschëff project shows a multi-purpose approach to innovation by offering solutions to a range of sustainability challenges. However, despite its contribution to circular and sustainable construction, the

project has encountered obstacles, hindering the transition from innovation production to a broader application, and preventing it from becoming a mainstream solution in the construction industry. The PCDS addresses the specific issue of information transparency regarding product circularity. By providing a standardised data template, the initiative aims to offer transparent and confidential information on product circularity. Although it has already been successfully tested, its potential for widespread adoption and upscaling remains to be seen. The three-year reconversion effort at Campus Lycée Michel Lucius received international recognition and highlighted the potential of innovative construction practices. However, the meticulous preparation required for the reuse of construction materials in existing buildings makes this approach difficult to apply for widespread application in Luxembourg's construction projects. These obstacles, coupled with the lack of mandatory requirements for circular practices in public procurement, contribute to the slow progress of the transition and hinder the actual solving of place-based challenges.

Considering the two RIS **reconfiguration strategies** for a sustainable transition (see Chapter 3.4, Tab. 4), I would argue that Luxembourg's innovation ecosystem in the built environment would need RIS reorientation regarding actor networks. A variety of actors are part of the CE debate through projects and strategies but communication and collaboration between these actors could be improved. The state will continue to be a significant actor in the innovation ecosystem, so RIS development should focus on how the state can use its position to promote sustainable solutions for the common good, rather than attempting to weaken the state. By placing greater emphasis on the competencies of existing actors, giving those who are underrepresented more room for innovation and including regional actors with a potential for synergies, the innovation ecosystem can be significantly enhanced.

The current governance and management system promotes innovative solutions that intend to fit in existing production and market systems. The general assumption is that these solutions need to emerge while the existing economic system continues turning. To tackle innovation in the built environment, more RIS transformation might be needed. This includes asking the question of "what we produce and why" rather than concentrating solely on "how we produce" and considering organisational and institutional innovations. However, it must be acknowledged, that radical change is perceived as unrealistic and unlikely to gain social acceptance. A fundamental overhaul of existing systems to address challenges a practical or effective approach.

6.3 Limitations and methodological considerations

To maintain transparency, it is essential to acknowledge the limitations inherent in the scope of this study as well as methodological considerations. For this analysis on Luxembourg's transition towards a circular built environment, literature reviews on the Circular Built Environment and the CoRIS framework, semi-structured interviews, desk research and direct observations were used as research methods.

The theoretical and conceptual framework for this study was primarily developed using articles retrieved from Scopus searches. Although Google Scholar and Research Gate were used to

gain an initial overview, the reliance on Scopus has introduced a degree of subjectivity, which is nevertheless a common aspect of empirical research (Häder, 2019). Regarding the single-case study research design, it is acknowledged that a multiple-case study might have offered more information and insights into Luxembourg's transition, providing stronger justification for the findings. To address this limitation, an embedded single-case study design with multiple units of analysis was used. While Luxembourg served as the central focus of this study, the country's deep interconnections with its neighbouring countries on many levels necessitated understanding it in a broader regional context.

My interest in the construction sector was prompted by its omnipresence in Luxembourg's daily life and its environmental impact, though it was a previously unfamiliar area of research for me. Hence, attending the Circular Economy Day 2024 proved instrumental in gaining insights into CE practices within Luxembourg. The event primarily served as an orientation, offering a glimpse into ongoing CE projects and the individuals engaged in these initiatives, and ultimately a possibility to identify potential interviewees. Although this event provided valuable observations, the study was constrained by the limited time available to explore the broader spectrum of conferences, workshops, and roundtables dedicated to sustainable and circular construction. Consequently, the findings offer an incomplete picture of the various stakeholder groups involved. Time constraints also impacted participant recruitment, as not everyone who received an invitation responded, despite a generally positive reception from those who did. The individuals who expressed interest responded promptly, showing considerable enthusiasm for the research topic. Although various stakeholder groups in the construction sector were interviewed, the number was limited by time constraints. Including perspectives from companies in waste treatment, training and civil society could have enriched the study, potentially altering or reinforcing the findings. Nevertheless, the broad representation of CE across multiple domains necessitated narrowing the study's focus to generate meaningful insights related to the research questions. To preserve the spontaneity and authenticity of responses, I opted not to share the interview questionnaire in advance. While this approach may have reduced transparency and missed opportunities for more detailed responses (Haukas & Tishakov, 2024), the recruitment letter provided interviewees with thematic blocks to outline the discussion topics. As this was my first experience conducting interviews, I gained confidence with each session. Although I adhered to my interview guide to avoid leading questions, the semi-structured format allowed discussions to evolve organically, helping me determine which aspects interviewees deemed important. It is important to acknowledge the inherent bias in interviews (Yin, 2018, p. 157). While some interviewees were cautious with political statements or comments on stakeholder groups, others were more forthright, fostering an open and honest dialogue. Responses to questions on innovation varied, with some interviewees providing superficial answers, while others demonstrated a deep understanding rooted in their professional experience.

The CoRIS framework has allowed for a more comprehensive perspective on innovation systems and the importance of considering Luxembourg within its regional context. The applicability of this framework to a real-world region demonstrates that actor groups and innovations are part of a dynamic system. This approach should not be seen as the sole truth

but rather as a means to understand and guide the transformation of innovation systems in relatively unexplored regions towards a more sustainable direction. Consequently, policies that build on this framework need to remain adaptive and dynamic.

7. Conclusion

This paper examines how the CE concept is understood and addressed in Luxembourg's built environment. The primary objective was to clarify the existing complexities, opportunities, and challenges that shape Luxembourg's shift from a linear to a circular economy. For this, barriers that hinder the transition and driving forces that have the potential to accelerate the transition were identified. For a more holistic understanding of these complexities and driven by the necessity of considering Luxembourg embedded in its regional context, the CoRIS framework was used in this study.

In Luxembourg's construction sector, CE is approached primarily as a business model, focused on resource and waste management optimisations that fit into existing consumption and production systems. Digitalisation is seen as a promising element to support the transition to a CE and is strongly endorsed politically, often through financial incentives or rewards. In the building sector, this includes digital material passports and the PCDS, increased use of digital building models, and connecting stakeholders on digital platforms. The CoRIS framework highlights that the government's approach to a circular built environment is driven by technological innovations, leaving social innovations a secondary concern.

While Luxembourg's policies support the CE through regulatory frameworks and funding initiatives, the implementation seems to be hampered by fragmented regulations, financial constraints, and resistance to change. This mirrors the CoRIS findings, which indicate that despite the presence of innovative projects and supportive policies, there is a lack of effective integration and collaboration among various actors. One of the most noticeable barriers hindering the transition is the lack of effective communication, showcasing that the proximity of stakeholders alone is not necessarily leading to better communication.

The government plays a central role in Luxembourg's network of closely linked actors. Through public-private partnerships and funding for CE projects led by municipalities, NGOs, or companies, the state maintains a strong position. RIS development should recognise the state's position and focus on how it can be leveraged to promote sustainable solutions for the common good, rather than attempting to undermine its influence.

To advance Luxembourg's circular transition, several recommendations emerge. Firstly, improving communication and collaboration among various actors, including civil society, NGOs, and government agencies, is crucial. This requires enhancing participatory processes and fostering greater inclusivity in innovation discussions. Additionally, leveraging Luxembourg's unique position within the Greater Region, regional partnerships should be strengthened to address cross-border challenges and pool resources effectively. Enhancing regulatory frameworks to provide clearer guidelines and incentives for CE practices is also

essential. This includes introducing mandatory circular criteria in public procurement and developing financial mechanisms that support circular business models.

Future research should focus on exploring the dynamics of actor networks within the context of CE, with a focus on enhancing the integration of diverse stakeholders into the innovation ecosystem. Investigating the impact of digital technologies on CE practices and their role in bridging gaps between innovation and application could provide valuable insights. Furthermore, studying the scalability of successful pilot projects and identifying the factors that contribute to their broader adoption can inform strategies for overcoming barriers to CE implementation.

While Luxembourg's ecosystem is making strides towards a circular built environment, a more integrated approach involving improved actor collaboration, enhanced regulatory support, and regional cooperation is necessary for a successful transition. Future research should aim to address these aspects, providing a foundation for more effective and widespread adoption of CE principles in Luxembourg and beyond.

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List of appendices

Appendix A: Declaration of consent & data protection information

Declaration of consent / data protection information

Thank you very much for being available as an expert for an interview, which will serve as the basis for a master's thesis at the University of Vienna.

According to the Austrian Data Protection Act (section 7, para. 2, sub-para. 2 of the Data Protection Act), you have to give your consent to this type of interview since your statements mentioning your name are used (quoted) in the academic master's thesis.

The contents of the interview are transcribed. You receive the transcription for approval before it is being used. The interview transcript will be attached to the thesis. An academic thesis must be published according to the Austrian Universities Act (by shelving it in the Austrian National Library and the Vienna University Library). It is usually also accessible online.

The data can be consulted by the lecturer or the supervisor (of the academic thesis) for the purpose of performance assessment.

In principle, it is permitted to store the collected data for an unlimited period of time according to article 89, para. 1 of the GDPR.

You can withdraw your consent to the use of this interview at any time. However, any statements used in the academic paper until this date are in accordance with statutory requirements and do not have to be removed from the paper.

You also have the right to be informed by the person responsible for this study about the personal data collected, the right to rectification, erasure, restriction of processing of data and the right to object to processing as well as the right to data portability.

If you have any questions regarding this survey, please contact the person responsible for this study: Gioia De Cillia (a11821758@unet.univie.ac.at) student in the degree programme Global Change and Sustainability at the University of Vienna.
For general legal questions regarding the GDPR/FOG and research conducted by students, please contact the Data Protection Officer of the University of Vienna, Daniel Stanonik (verarbeitungsverzeichnis@univie.ac.at). You also have the right to lodge a complaint with the Data Protection Authority (for example, via dsb@dsb.gv.at).

I hereby consent to the use of my personal data as part of the academic paper/thesis.

Place, date, name

Appendix B: Recruiting letter

Dear [name of interviewee],

I hope this message finds you well. My name is Gioia De Cillia, and I am currently pursuing my master's degree at the University of Vienna. I am in the process of conducting research for my thesis, which focuses on the **circular built environment in Luxembourg** under the supervision of Dr. Sebastian Fastenrath. Given your expertise and involvement in this field, I am writing to invite you to participate in an interview that will greatly contribute to my study.

My research aims to explore Luxembourg's transition to a circular economy, particularly within the construction sector. Your insights and experiences would be invaluable to understanding the current landscape and future potential of circular economy practices in Luxembourg. I believe you would be an ideal candidate for this discussion due to your significant role and knowledge in this area.

The interview is designed to be an informal conversation rather than a structured questionnaire, allowing for a more fluid and engaging exchange of ideas. It is expected to last between **30 to 45 minutes** and can be conducted in Luxembourgish, German, French or English.

The discussion will revolve around the following thematic blocks:

- Understanding of Circular Economy Principles
- Driving Forces and Key Actors
- Barriers and Detractors
- The Role of Innovation
- Existing Practices and Initiatives
- Policy and Regulatory Support

Your participation would not only contribute to the academic understanding of circular economy practices but also help identify practical steps and strategies for future developments in this sector.

Would you be available for an interview sometime next week? I am flexible with scheduling and can adjust to a time that suits your convenience. I would be pleased to come to your office for our conversation.

I greatly appreciate your time and attention and look forward to your positive response.

Yours sincerely,
Gioia De Cillia